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CALCULATION OF RESIDUAL ACTIVITY IN A P R-1
SHIELDING RINGS AFTER SHUTDOWN

Contract No. DA-44-009 Eng.2864

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CALCULATION OF RESIDUAL ACTIVITY IN APPR-1SHIELDING RINGS AFTER SHUTDOWN

In AP Memo No. 31, calculations of residual activity were made for various APPR-1 components. The purpose of this memo is to extend these calculations to the eight concentric shielding rings which surround the pressure vessel and thermal shield. The rings are hollow steel cylinders, with a two-inch wall thickness. The following numerical designations have been used for purposes of simplification:

<u>Ring Number</u>	<u>Outside Diameter in Inches</u>
1	68
2	74
3	80
4	86
5	92
6	98
7	104
8	110

Calculations were made for time after shutdown of 1 day, 10 days, 30 days, and 1 year. Irradiation times (i.e. operation times) of .3 year, .75 year, and 1.5 years were used; these correspond to 3 megawatt years, 7.5 megawatt years, and 15 megawatt years, respectively, for continuous full-power operation. Activities were calculated for a single ring, isolated from the other rings. The method of calculation is outlined below.

The thermal flux distribution given in Reference 1 was used to find the thermal neutron flux to which each ring would be subjected

during reactor operation. The following results were obtained:

<u>Ring Number</u>	<u>Thermal neutron flux in cm⁻²sec⁻¹</u>
1	9.68×10^{10}
2	2.88×10^{10}
3	8.60×10^9
4	2.56×10^9
5	7.64×10^8
6	2.27×10^8
7	6.79×10^7
8	2.02×10^7

Source strengths were calculated by the following formula:

$$S_v = \phi \Sigma_a E_x (1 - e^{-\lambda t_i}) e^{-\lambda t_r}$$

where: S_v = source strength (Mev/cm³-sec)

ϕ = thermal neutron flux (neutrons/cm²-sec)

Σ_a = macroscopic cross section (cm⁻¹)

E_x = gamma energy (Mev)

λ = $.693/t_{1/2}$ (sec⁻¹)

$t_{1/2}$ = gamma half life (sec)

t_i = irradiation time (sec)

t_r = time after shutdown (sec)

Values of $\Sigma_a E_x$ and λ for the various gamma groups emitted by 1065 steel were taken from data presented by Bopp and Sisman in Reference 2. The source strengths of the different gamma groups were added, and their average energy was taken as 1.2 Mev.

Gamma fluxes were calculated with the formulas presented by Foderaro and Obenshain in Reference 3. Some difficulty was encountered in calculating the effect of the radial source strength gradient, since there are no formulas for cylinders which take this into account. The difficulty was overcome by making two flux calculations for a two-inch

thick infinite slab, the first taking into account the non-uniform source strength distribution, the second assuming uniform source strength. The ratio of the results for these two calculations was then used to correct a uniform source strength calculation based on a three-foot diameter truncated cone approximation for the shield rings. The truncated cone was used because the range of the self-shielding data for cylinders did not cover our case; the three-foot diameter took into account the axial decrease in source strength at the ends of the rings. Since there is little shielding, the build-up factor was taken as unity throughout the calculations. Fluxes were calculated at a distance of four feet from the ring, in the radial direction.

For a gamma energy of 1.2 Mev., Reference 4 gives the following relation between gamma flux and dose rate:

$$D = \frac{\phi_{\gamma}}{5.6 \times 10^2}$$

where: D = dose rate (mr/hour)

ϕ_{γ} = gamma flux (Mev/cm²-sec)

The activity of each of the eight shield rings, in terms of dose rate, with irradiation time and time after shutdown as parameter, is presented in a chart below. Note that the numerical designations of the rings given on page 1 have been used in the chart.

The results are based on several assumptions, of which the most uncertain is the magnitude of the thermal flux in the shield rings. Also, operating conditions will probably be different from those calculated. These may result in the actual activity differing from the calculated values, possibly as much as a factor of ten lower.

If selective salvage of the shield rings is proposed, dose rate measurements of the actual activity would be desirable at the time of removal.

INDUCED ACTIVITY IN SHIELDING RINGS

<u>t_i</u>	<u>t_r</u>	Dose rate from ring in mr/hour							
		<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>	<u>#5</u>	<u>#6</u>	<u>#7</u>	<u>#8</u>
.3 year	1 day	6890.	2050.	612.	182.	54.3	16.2	4.83	1.44
	10 days	5710.	1700.	508.	151.	45.0	13.4	4.01	1.19
	30 days	4370.	1300.	388.	116.	34.4	10.3	3.06	.912
	1 year	621.	185.	55.3	16.4	4.90	1.46	.436	.1300
.75 year	1 day	9070.	2700.	806.	240.	71.5	21.3	6.36	1.89
	10 days	7720.	2300.	687.	205.	60.9	18.1	5.42	1.61
	30 days	6080.	1810.	541.	161.	47.9	14.3	4.26	1.27
	1 year	1480.	442.	132.	39.3	11.7	3.49	1.88	.310
1.5 year	1 day	10700.	3180.	951.	283.	84.1	25.1	7.49	2.23
	10 days	9340.	2780.	830.	247.	73.6	21.9	6.54	1.95
	30 days	7630.	2270.	678.	202.	60.1	17.9	5.34	1.59
	1 year	2780.	828.	247.	73.5	21.9	6.52	1.95	.581

t_i = irradiation time

t_r = time after shutdown

Numerical designation of rings as given previously.

REFERENCES

1. Richards, Preliminary Design Study for a 20 MW Army Package Power Reactor, APAE No. 9, page 48, June, 1956.
2. Bopp and Sisman, "How to Calculate Gamma Radiation Induced in Reactor Materials," Nucleonics, 1, 14, January, 1956.
3. Foderaro and Obenshain, Fluxes from Regular Geometric Sources, WAPD-TN-508, June, 1955.
4. Reactor Handbook, volume 1, RH-1, page 946.

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