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WANL-TME-660
January, 1964

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RADIATION LEVELS
IN
THE ACTUATOR
(TITLE UNCLASSIFIED)

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ATOMIC ENERGY ACT
OF 1954

Westinghouse Electric Corporation

Astronuclear Laboratory

Box 10864, Pittsburgh 36, Pa
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January 30, 1964

* Mr. R. W. Schroeder, Chief
Space Nuclear Propulsion Office
NASA Lewis Research Center
21000 Brookpark Road
Cleveland 35, Ohio

Subject: WANL-TME-660, "Radiation Levels in the Actuator", dated
January, 1964

Dear Mr. Schroeder:

Transmitted herewith are three (3) copies of the subject report.

This report is transmitted for your information.

Respectfully,

H. F. Faught
Program Manager
NERVA Nuclear Subsystem

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cc: SNPO-C Pittsburgh Office

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1.0 PROBLEM

To determine the nuclear heating rate, neutron flux and gamma dose rate in the flight type General Electric (Model AG20) control drum actuators.

The actuator geometry is described in Reference 1, Addendum 2.

The data are to be computed for the actuators when used with the lithium hydride-steel (flight type) shield and the aluminum (test mockup) shield.

2.0 RESULTS AND CONCLUSIONS

Presented in Figure 1 is a sketch of the actuator used in this analysis. This figure along with Table 1 shows the material distribution in the actuator and its location with respect to the reactor shield assembly. The actuator weighs approximately 15 pounds.

Figure 2 shows the locations in the actuator at which the radiation levels and heating rates were computed. This figure is of the plane which contains the actuator axial centerline and the axial centerline of the reactor core. All data were prepared for this plane.

The heating rates and radiation levels corresponding to the data point locations in Figure 2 are given in Tables 2 and 3. Table 2 contains data for the actuator as when used with the lithium hydride-steel (flight type) shield. Table 3 presents similar data for the aluminum mockup shield when it replaces the lithium hydride-steel shield. Detailed descriptions of both shields are in Reference 1. Addendum 2 to Reference 1 gives a detailed description of the actuator. Since the bulk of the actuator is aluminum, the heating rates are given in units of watts per gram of aluminum. For other materials in the region the heating rate will be essentially the same as in aluminum on a "per gram" basis. More specifically a gram of steel or other material will absorb practically the same amount of heat as a gram of aluminum at the same location. This is only true where most of the heating is due to gamma rays which is the case for the actuator.

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From this analysis it can be noted that: 1) the heating rate for the case of aluminum mockup shield is in general 10% higher than for the flight shield condition and, 2) the total neutron flux is as much as a factor of 50 higher for the case of the aluminum shield.

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3.0 METHOD OF ANALYSIS

Heating rates and gamma ray dose rates were computed using program 14-0 (see Reference 2). Only the sources for the gamma rays born in the active core were run for all data points. To determine the effect of secondary gamma rays (those generated outside the active core) on the actuator heating rates, one point for each shield was run using all the secondary sources outside the reactor core. For the lithium hydride-steel shield, 37 extra-core source regions were run. For the aluminum mockup shield, 19 extra-core source regions were run. The ratio of total gamma dose to the core gamma dose at the point in question was computed to be 2.1 for the lithium hydride-steel shield case and 2.5 for the aluminum shield mockup case. These factors were then used at all the data points throughout the actuator to account for the increase in heating rate and gamma dose rate due to extra-core gamma ray sources. Therefore the data in Tables 2 and 3 include extra core gammas. The source terms for both the core gamma rays and for gamma rays born outside the core are to be found in Reference 3.

Neutron fluxes for energy greater than 1.0 mev were computed at all data points in the actuator. These data were normalized to the neutron flux for energy greater than 1.0 mev computed by program CURE⁴ at the shield surface. It was computed by program CURE at the shield surface that the energy distributions for the three neutron groups were in the following proportions as given in the table below.

Neutron Energy Distribution (Relative Units)

Configuration	$E < 1.86 \text{ ev}$	$1.86 \text{ ev} < E < 1.0 \text{ Mev}$	$E > 1.0 \text{ Mev}$	Total
LiH-SS Shield	.029	.816	.155	1.000
Al Shield	.178	.740	.082	1.000

The neutron fluxes then in Tables 2 and 3 for energy groups other than ($E > 1.0 \text{ Mev}$) were obtained by normalizing to the energy distribution proportionalities given in the above table.

It may be desirable to know the neutron flux for $E > 2.9 \text{ Mev}$ or $E > 0.1 \text{ Mev}$. Hence for the case of the lithium hydride shield, the total flux data in Table 2 should be multiplied by .025 and .31 to obtain the flux greater than 2.9 Mev and 0.1 Mev respectively. For the aluminum shield case the total flux data in Table 3 should be multiplied by 0.44 and .12 to obtain the flux greater than 2.9 Mev and 0.1 Mev respectively.

4.0 REFERENCES

1. WANL-TME-291, and Addendums 1 and 2, "NRX-A Configuration for Radiation Analysis", Westinghouse Electric Astronuclear Laboratory, M. A. Capo, R. N. Nassano, R. G. Soltesz.
2. XDC-59-2-16, "Shielding Computer Program 14-0 and 14-1 Reactor Shield Analysis", General Electric Company ANPD, J. T. Martin, J. P. Yalch, W. E. Edwards, January 1959.
3. WANL-TNR-128, "Reactor Analysis of the NRX-A, Vol. 2, Radiation Analysis", Westinghouse Electric Astronuclear Laboratory, September 1963.
4. APEX-452, "CURE-A Two-Space Dimension, Multigroup Code for the IBM 704", General Electric Company ANPD, F. M. Tranthum Jr., August 1958.

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TABLE 1

Actuator Volume Fractions

<u>Material</u>	<u>Volume Fraction</u>
<u>Region 1 *</u>	
Aluminum	0.333
Steel	0.574
Void**	0.093
<u>Region 2</u>	
Aluminum	0.363
Carbon	0.036
Chromium	0.004
Iron	0.018
Nickel	0.001
Void	0.578
<u>Region 3</u>	
Aluminum	0.406
Steel	0.020
Void	0.574
<u>Region 4</u>	
Aluminum	0.199
Iron	0.001
Nickel	0.008
Steel	0.026
Void	0.761
<u>Region 5</u>	
Aluminum	0.702
Steel	0.053
Void	0.245

* See Figure 1 for Region Description

** Hydrogen has not been included in this table because it has a negligible effect on the radiation levels presented.

TABLE 2 - RADIATION LEVELS IN THE ACTUATOR
WITH LiH-SS₂ SHIELD

	Heating Rate watts/gm-Al	Gamma Ray Dose Rate (Rad-c/Hr)	Neutron Flux ($\frac{N}{CM^2 - SEC}$)			TOTAL
			E < 1.86 ev	1.86 ev < E < 1MEV	E > 1MEV	
1	5.71 (-2)	2.29 (7)	8.2 (9)	2.07 (11)	3.88 (10)	2.54 (11)
2	5.90 (-2)	2.38 (7)	8.8 (9)	2.42 (11)	4.52 (10)	2.96 (11)
3	2.86 (-2)	1.14 (7)	5.2 (9)	1.49 (11)	2.78 (10)	1.82 (11)
4	2.50 (-2)	9.93 (6)	5.1 (9)	1.44 (11)	2.69 (10)	1.76 (11)
5	2.25 (-2)	8.97 (6)	5.0 (9)	1.42 (11)	2.66 (10)	1.74 (11)
6	2.05 (-2)	8.13 (6)	6.0 (9)	1.71 (11)	3.20 (10)	2.09 (11)
7	3.41 (-2)	1.36 (7)	1.5 (10)	3.80 (11)	7.14 (10)	4.66 (11)
8	5.02 (-2)	2.02 (7)	6.8 (9)	1.77 (11)	3.32 (10)	2.17 (11)
9	3.66 (-2)	1.47 (7)	5.3 (9)	1.42 (11)	2.67 (10)	1.74 (11)
10	2.90 (-2)	1.16 (7)	5.1 (9)	1.27 (11)	2.39 (10)	1.56 (11)
11	1.52 (-2)	6.03 (6)	3.2 (9)	8.10 (10)	1.52 (10)	9.94 (10)
12	9.42 (-3)	3.72 (6)	2.3 (9)	6.08 (10)	1.14 (10)	7.45 (10)
13	1.23 (-2)	4.88 (6)	2.9 (9)	7.74 (10)	1.45 (10)	9.48 (10)
14	1.60 (-2)	6.36 (6)	4.1 (9)	1.12 (11)	2.09 (10)	1.37 (11)
15	1.40 (-2)	5.54 (6)	5.9 (9)	1.39 (11)	2.61 (10)	1.71 (11)
16	4.52 (-2)	1.81 (7)	6.3 (9)	1.58 (11)	2.97 (10)	1.94 (11)
17	2.93 (-2)	1.17 (7)	4.5 (9)	1.09 (11)	2.05 (10)	1.34 (11)
18	2.29 (-2)	9.14 (6)	3.8 (9)	9.70 (10)	1.82 (10)	1.19 (11)
19	1.22 (-2)	4.86 (6)	2.4 (9)	6.29 (10)	1.18 (10)	7.71 (10)
20	7.65 (-3)	3.04 (6)	1.7 (9)	4.58 (10)	8.59 (9)	5.61 (10)
21	1.37 (-2)	5.43 (6)	3.3 (9)	8.40 (10)	1.57 (10)	1.03 (11)
22	1.16 (-2)	4.58 (6)	3.8 (9)	9.45 (10)	1.77 (10)	1.16 (11)

TABLE 2 - RADIATION LEVELS IN THE ACTUATOR
WITH LIH-SS† SHIELD (CONT'D.)

	Heating Rate watts/gm-Al	Gamma Ray Dose Rate (Rad-c/Hr)	Neutron Flux ($\frac{N}{CM^2 - SEC}$)			TOTAL
			E < 1.86ev	1.86 ev < E < 1MEV	E > 1 MEV	
23	2.68 (-2)	1.07 (7)	4.0 (9)	1.07 (11)	2.00 (10)	1.31 (11)
24	1.14 (-2)	4.49 (6)	2.3 (9)	5.80 (10)	1.09 (10)	7.12 (10)
25	1.08 (-2)	4.30 (6)	2.1 (9)	5.87 (10)	1.10 (10)	7.19 (10)
26	1.47 (-2)	5.84 (6)	2.5 (9)	6.61 (10)	1.24 (10)	8.10 (10)
27	2.99 (-2)	1.19 (7)	3.9 (9)	1.13 (11)	2.11 (10)	1.38 (11)
28	1.78 (-2)	7.10 (6)	2.8 (9)	7.30 (10)	1.37 (10)	8.95 (10)
29	1.09 (-2)	4.34 (6)	2.1 (9)	5.32 (10)	9.99 (9)	6.53 (10)
30	8.05 (-2)	3.23 (7)	1.3 (10)	3.99 (11)	7.49 (10)	4.89 (11)
31	9.01 (-2)	3.64 (7)	2.6 (10)	6.55 (11)	1.23 (11)	8.04 (11)
32	7.47 (-2)	3.00 (7)	3.2 (10)	8.40 (11)	1.58 (11)	1.03 (12)
33	6.89 (-2)	2.76 (7)	1.2 (10)	2.99 (11)	5.62 (10)	3.67 (11)
34	4.09 (-2)	1.63 (7)	1.1 (10)	2.84 (11)	5.32 (10)	3.48 (11)
35	3.72 (-2)	1.49 (7)	1.5 (10)	3.82 (11)	7.18 (10)	4.69 (11)
36	1.90 (-2)	7.55 (6)	7.2 (9)	1.91 (11)	3.58 (10)	2.34 (11)

TABLE 3 - RADIATION LEVELS IN THE ACTUATOR
WITH ALUMINUM SHIELD

	Heating Rate watts/gm-Al	Gamma Ray Dose Rate (Rad-c/Hr)	Neutron Flux ($\frac{N}{CM^2 - SEC}$)			TOTAL
			E < 1.86 ev	1.86 ev < E < 1 MEV	E > 1 MEV	
1	6.82 (-2)	2.73 (7)	1.97 (12)	8.22 (12)	9.06 (11)	1.11 (13)
2	6.95 (-2)	2.75 (7)	1.97 (12)	8.22 (12)	9.08 (11)	1.11 (13)
3	3.36 (-2)	1.33 (7)	1.05 (12)	4.40 (12)	4.85 (11)	5.94 (12)
4	2.92 (-2)	1.16 (7)	9.28 (11)	3.88 (12)	4.27 (11)	5.23 (12)
5	2.64 (-2)	1.05 (7)	8.47 (11)	3.53 (12)	3.89 (11)	4.77 (12)
6	2.30 (-2)	9.10 (6)	7.44 (11)	3.10 (12)	3.42 (11)	4.19 (12)
7	3.95 (-2)	1.57 (7)	1.13 (12)	4.72 (12)	5.20 (11)	6.37 (12)
8	6.03 (-2)	2.41 (7)	1.74 (12)	7.28 (12)	8.02 (11)	9.82 (12)
9	4.31 (-2)	1.72 (7)	1.28 (12)	5.33 (12)	5.88 (11)	7.20 (12)
10	3.42 (-2)	1.36 (7)	1.04 (12)	4.35 (12)	4.79 (11)	5.87 (12)
11	1.81 (-2)	7.15 (6)	6.66 (11)	2.78 (12)	3.06 (11)	3.75 (12)
12	1.13 (-2)	4.45 (6)	4.74 (11)	1.98 (12)	2.18 (11)	2.67 (12)
13	1.44 (-2)	5.67 (6)	5.40 (11)	2.25 (12)	2.48 (11)	3.04 (12)
14	1.83 (-2)	7.25 (6)	6.02 (11)	2.51 (12)	2.77 (11)	3.39 (12)
15	1.62 (-2)	6.40 (6)	5.13 (11)	2.14 (12)	2.36 (11)	2.89 (12)
16	5.45 (-2)	2.18 (7)	1.58 (12)	6.59 (12)	7.26 (11)	8.89 (12)
17	3.48 (-2)	1.39 (7)	1.05 (12)	4.36 (12)	4.81 (11)	5.89 (12)
18	2.71 (-2)	1.08 (7)	8.29 (11)	3.46 (12)	3.81 (11)	4.67 (12)
19	1.47 (-2)	5.80 (6)	5.48 (11)	2.29 (12)	2.52 (11)	3.09 (12)
20	9.23 (-3)	3.65 (6)	3.96 (11)	1.65 (12)	1.82 (11)	2.23 (12)
21	1.61 (-2)	6.35 (6)	5.38 (11)	2.24 (12)	2.47 (11)	3.03 (12)
22	1.33 (-2)	5.23 (6)	4.38 (11)	1.83 (12)	2.02 (11)	2.47 (12)

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TABLE 3 - RADIATION LEVELS IN THE ACTUATOR
WITH ALUMINUM SHIELD (CONT'D.)

	Heating Rate watts/gm-Al	Gamma Ray Dose Rate (Rad-c/Hr)	Neutron Flux ($\frac{N}{CM^2 - SEC}$)			TOTAL
			E < 1.86ev	1.86 ev < E < 1 MEV	E > 1MEV	
23	3.16 (-2)	1.26 (7)	9.50 (11)	3.96 (12)	4.37 (11)	5.35 (12)
24	1.37 (-2)	5.40 (6)	5.13 (11)	2.14 (12)	2.36 (11)	2.89 (12)
25	1.28 (-2)	5.05 (6)	4.63 (11)	1.93 (12)	2.13 (11)	2.61 (12)
26	1.77 (-2)	7.00 (6)	5.96 (11)	2.49 (12)	2.74 (11)	3.36 (12)
27	3.50 (-2)	1.40 (7)	1.04 (12)	4.35 (12)	4.79 (11)	5.87 (12)
28	2.12 (-2)	8.38 (6)	6.59 (11)	2.75 (12)	3.03 (11)	3.71 (12)
29	1.31 (-2)	5.18 (6)	4.70 (11)	1.96 (12)	2.16 (11)	2.65 (12)
30	9.35 (-2)	3.75 (7)	2.63 (12)	1.09 (13)	1.21 (12)	1.48 (13)
31	9.98 (-2)	4.00 (7)	2.77 (12)	1.16 (13)	1.27 (12)	1.56 (13)
32	8.40 (-2)	3.35 (7)	2.34 (12)	9.78 (12)	1.08 (12)	1.32 (13)
33	7.98 (-2)	3.20 (7)	2.25 (12)	9.41 (12)	1.04 (12)	1.27 (13)
34	4.58 (-2)	1.83 (7)	1.37 (12)	4.68 (12)	6.31 (11)	7.73 (12)
35	4.13 (-2)	1.64 (7)	1.25 (12)	5.20 (12)	5.73 (11)	7.02 (12)
36	2.14 (-2)	8.55 (6)	6.96 (11)	2.90 (12)	3.20 (11)	3.92 (12)

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SECTION A-A

Figure 1
 ACTUATOR GEOMETRICAL MOCKUP FOR RADIATION LEVELS
 (All Dimensions are in Centimeters)
 (Axial Dimensions are Measured from the Cookie-Core Interface)

Figure 2
LOCATION OF DATA POINTS FOR RADIATION LEVELS
(See Tables 2 and 3)