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Zircaloy-2 Process Tube Activity - C Reactor

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Zircaloy-2 Process Tube Activity - C Reactor

August 26, 1964

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Zircaloy-2 Process Tube Activity - C ReactorI. Introduction

This report presents the dose rates which were observed during the removal of a zircaloy-2 process tube from C Reactor. The corresponding calculated activity is also presented for the purpose of correlation with the observed dose rate. The tube was removed on July 22, 1964, after having been irradiated by a neutron flux for 560 days (based on time operated efficiency).

II. Summary and Conclusions

The tube activity was monitored with a super high range TP (0-5000 R/hr) by suspending a probe through an access port in the floor of the "D" machinery room. As tube 3353 was pushed and cut into sections, the highest activity observed was 675 R/hr, which was seen in the center three-foot segment. The corresponding calculated activity was 650 R/hr. The neutron flux profile, as shown by tube activities along its length, was extremely peaked in the center; for example, the area under the activity curve was less than one-third of the area under a cosine curve of the same amplitude and cycle length.

III. DiscussionA. Observed Activity

On July 22, 1964, a zircaloy-2 process tube (2.25 inches outside diameter and 0.050 inch wall thickness) was removed from tube channel number 3353 in C reactor. The tube saw an effective neutron flux of 3.3×10^{13} nv for 560 days, or 1.6×10^{21} nvt. The reactor was shut down 13 days prior to the removal of the tube.

The tube was removed by use of a tube push pole from the front face. The tube was fed into the jaws of a guillotine which was mounted on adjacent rear face nozzles. After removal of the front and rear van stone flanges, the zircaloy cylinder was cut into specified lengths in the following order: 6 inches, 18 inches, 8 feet, 8 feet, 3 feet, 8 feet, with 5 feet of the tube remaining to be pushed.

The probe from the super high range TP instrument was suspended through an access port in the floor of the "D" machinery room by 33 feet of extension cable. The detector was positioned one foot above the tube and one foot in the downstream direction from the rear nozzle tip for all measurements. Measurements were also taken with a CP instrument to observe the gamma beam streaming through the access port. This beam activity was less than the activity one foot from the tube by a factor of approximately 2000.

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Presented below are the dose rates observed from tube number C-3353, with all measurements listed in R/hr at one foot:

<u>Section Number</u>	<u>Section Length (Feet)</u>	<u>Total Dose Rate</u>	<u>Residual* Dose Rate</u>	<u>Corrected Dose Rate</u>
1	2	-	-	-
2	8	80	14	66
3	8	480	25	455
4	3	700	25	675
5	8	600	18	582
6	8	150	13	137
7	5	-	-	-

*Dose rate from two-foot section of tube remaining in a "transition" pipe which was bolted to the rear gun barrel flange.

Figure I describes where the tube was cut and measured.

B. Calculated Activity

1. General Equations

Equations used for calculating activities were obtained from Overman and Clark.⁽¹⁾ These equations are:

$$A_1 = \frac{N\phi\sigma_{act}}{3.7 \times 10^{10}} (1 - e^{-\lambda_L t}) \quad (a)$$

$$A_m = \frac{N\phi\sigma_{act}}{3.7 \times 10^{10}} \left(1 + \frac{\lambda_L e^{-\lambda_m t} - \lambda_m e^{-\lambda_L t}}{\lambda_m - \lambda_L} \right) \quad (b)$$

where A_1 and A_m = activities of the (n, γ) product and its daughter, respectively, in curies

N = number of target atoms

σ_{act} = activation cross section, in barns

ϕ = thermal neutron flux, in $n/cm^2 - sec$

λ_L and λ_m = decay constants of the (n, γ) product and its daughter, respectively

t = irradiation time (units consistent with decay constants)

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2. Reactions of interest

The reactions of interest are based on zircaloy-2 compositions listed in Nucleonics Data Sheet No. 30:

Element	Weight Fraction
Sn	0.015
Fe	0.0012
Cr	0.0010
Co	0.00002
Zr	0.982+

3. Calculation of Source Strength

The Zr^{95} - Nb^{95} activity represented ~97% of the total activity present in the tube at the time of removal.

A sample calculation of the Zr^{95} - Nb^{95} activity in a three-foot section in the center of the tube is described herein.

First, equations (a) and (b) were reduced to a more applicable form, using $\phi_{th} = 3.3 \times 10^{13} \text{ n/cm}^2 \cdot \text{sec}(2)$:

$$A_l = 890 N \sigma_{act} (1 - e^{-0.693t/t_l}) \quad (a')$$

$$A_m = 890 N \sigma_{act} \left[\frac{T_l}{T_l - T_m} (1 - e^{-0.693t/T_l}) - \frac{T_m}{T_l - T_m} (1 - e^{-0.693t/T_m}) \right] \quad (b')$$

where T_l and T_m are the respective half lives of the (n, γ) product and its daughter.

For Zr^{95} - Nb^{95} ,

$$N_{\text{Zr}^{94}} = 1.43 \times 10^{24} \text{ atoms}$$

$$T_{\text{Zr}^{95}} = 63.3 \text{ days and } T_{\text{Nb}^{95}} = 35 \text{ days}$$

$$(\sigma_{act})_{\text{Zr}^{94}} = 0.09 \text{ barn}$$

$$t = 560 \text{ days}$$

Equations (a') and (b') yield a Zr^{95} - Nb^{95} source strength of 229 curies. A correction for the 13 day decay after reactor shutdown yields 209 curies. Using a similar method, one obtains the total activity present in the three-foot center section of the zircaloy-2 process tube at the time of measurement:

$$A_{total} = 216 \text{ curies}$$

4. Calculation of dose rate

The process tube was viewed as a live source for calculational purposes. Self-shielding was neglected, as it was within the errors in cross section and distance measurements. The equation used to calculate the dose rate, R_{γ} , is cited in reference 3:

$$R_{\gamma} = \frac{\Gamma q}{ah} \left[\text{Arctan}\left(\frac{a-b}{h}\right) + \text{Arctan}\left(\frac{b}{h}\right) \right] \quad (c)$$

where Γ = gamma ray dose rate constant in $\frac{\text{cm}^2 - R}{\text{mc} - \text{hr}}$

q = source strength, in mc

and a , b , h = distances (in cm) specified in the following sketch:

The gamma ray dose rate constant, Γ , was determined as follows⁽³⁾:

$$\Gamma = 1.50 \times 10^5 \mu_a E_{\gamma}$$

where μ_a = absorption coefficient in air

E_{γ} = effective weighted gamma ray energy, in Mev

substituting, $\Gamma = (1.50 \times 10^5) (3.9 \times 10^{-5}) (0.76)$

$$\Gamma = 4.44 \frac{\text{cm}^2 - R}{\text{mc} - \text{hr}}$$

Now using equation (c) and substituting know values,

$$\begin{aligned} R_{\gamma} &= \frac{\Gamma q}{ah} \left[\text{Arctan}\left(\frac{a-b}{h}\right) + \text{Arctan}\left(\frac{b}{h}\right) \right] \\ &= \frac{(4.44) (2.16 \times 10^5)}{(91.5) (32.5)} \left[\text{Arctan} 2 + \text{Arctan} 1 \right] \end{aligned}$$

or, $R_{\gamma} = 650 \text{ R/hr}$ at 1 foot from the 3 foot center section of process tube 3353-C.

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