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POLONIUM PRODUCTION

NEUTRON FLUX IN BISMUTH COLUMNS

SUMMARY

The best available estimate for the thermal neutron flux in columns of bismuth slugs is:

$$\frac{(\text{nv in bismuth columns})}{(\text{nv in adjacent heavy metal})} = 3.2$$

Discussion

On the basis of polonium assays by the customer, an improved equation for the prediction of the polonium content of a bismuth tube has been developed (Marshall to File, 11/9/45 Doc No. 7-2853). At the end of 1/2 days of steady irradiation during which the temperature rise in adjacent heavy metal tubes had been T °C., this equation gives as the number of curies of polonium per tube:

$$C = 0.855 T (36.31 + 1.39 \exp(-t/7.2) + 37.7 \exp(-t/196)) \quad (1)$$

$$= 0.855 T F(t) \quad (2)$$

The growth of Radium E and polonium follows the equations:

$$\frac{dr}{dt} = (\text{nv})_b b - rR \quad (3)$$

$$\frac{dp}{dt} = rR - pP \quad (4)$$

where

- b = the number of bismuth atoms per column
- s = the capture cross-section of bismuth, 0.015 barns
- r = the number of RaE atoms per column
- p = the number of polonium atoms per column
- R = the decay constant of RaE, 1/7.2 days
- P = the decay constant of Po, 1/196 days
- t = the time of irradiation
- (nv)_b = the average nv in the bismuth

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For $r = 0$ and $p = 0$ at $t = 0$, these equations have the solutions:

$$\begin{aligned} r &= (nv)_{bsb}/K (1 - \exp(-Rt)) \\ p &= (nv)_{bsb} \left\{ \frac{1}{P} - \frac{\exp(-Rt)}{P-R} + \left\{ \frac{1}{P-R} - \frac{1}{P} \right\} \exp(-Pt) \right\} \end{aligned} \quad \begin{matrix} (5) \\ (6) \end{matrix}$$

$$= 4.66 (nv)_{bsb} F(t) \times 10^5 \quad (7)$$

The number of curies of polonium per tube is $pP/(3.7 \times 10^{10})$; b is 1.63×10^{26} bismuth atoms per 62-slug column of 916-gm. slugs. Using these constants and representing the exponential function by $F(t)$ as in Equation (2), one can express the number of curies per column in the form:

$$C = 1.82 (nv)_b F(t) \times 10^{-12} \quad (8)$$

The nv in an adjacent heavy metal column, $(nv)_u$, is related to the temperature rise in the 20 gpm cooling water stream as follows:

484 gram-atoms of uranium per 32-slug column
 0.6×10^{24} atoms per gram atom
 3.9×10^{-24} cm² fission cross section of uranium. The product so far is the fission cross section per column.
 $(nv)_u$ average nv in uranium. Product is fissions/sec.
 3.2×10^{-11} watt-seconds per fission
0.239 calories per watt-second
0.00079 °C temperature rise per cal/sec added to a 20 gpm stream of water, 1/1264 cc/sec

$6.86 (nv)_u \times 10^{-12} = T$ degrees temperature rise in a 32-slug heavy metal column.

Inserting this value for T in Equation (2), one obtains:

$$C = 5.86 (nv)_u F(t) \times 10^{-12} \quad (9)$$

and comparing this result with Equation (8), one arrives at the result:

$$\frac{(nv)_b}{(nv)_u} = \frac{5.86 \times 10^{-12}}{1.82 \times 10^{-12}} = 3.2$$

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