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**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
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FINAL REPORT - PRODUCTION TEST 200-2
PROCESSING OF SPECIAL IRRADIATED PLUTONIUM

AUTHOR

R. A. Pugh

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Atomic Weapon Data

FINAL REPORT - PRODUCTION TEST 200-2
PROCESSING OF SPECIAL IRRADIATED PLUTONIUM

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DECLASSIFIEDINTRODUCTION

One of the specifications for the final plutonium product is a maximum neutron emissivity (neutrons per gram-second). The major source of neutrons in plutonium is the spontaneous fission of the ^{240}Pu isotopes.⁽¹⁾ The concentration of the ^{240}Pu isotope is a function principally of the total pile exposure^(2,3) and, to a lesser extent, of pile operating parameters; in particular, the moderator temperature.⁽⁴⁾

The objectives of this production test^(5,6) were:

1. To establish with greater accuracy and precision, empirical relationships between the neutron emissivity, the plutonium isotope ^{240}Pu concentration, and the pile exposure.
2. To determine if the isolated plutonium nitrate solution could be used as a control point for neutron emissivity prior to final fabrication.

Accomplishment of these objectives would permit setting of pile exposure goals at the maximum possible level for greatest economy while still maintaining product quality within specifications.

SUMMARY AND CONCLUSIONS

The following relations between the neutron emissivity, the plutonium ^{240}Pu isotope concentration, and the pile exposure were obtained with a precision of about one per cent:

200 MWD/T

Neutrons per gram second = $0.0933 \times \text{megawatt days per ton}^*$
Per cent ^{240}Pu = $0.0090 \times \text{megawatt days per ton}$

*Weighted average of a pile push. See reference 10.

300 MWD/T

Neutrons per gram second = $0.0960 \times \text{megawatt days per ton}$
Per cent ^{240}Pu = $0.0092 \times \text{megawatt days per ton}$

These values are somewhat higher than would be predicted from earlier data or from extrapolation of data at higher exposure levels (see Figure 1), and indicate a maximum ratio in the neighborhood of 300 MWD/T.

The precision of the neutron count of plutonium nitrate solution was found to be inadequate for predicting or controlling the neutron emissivity of the plutonium metal derived from such solution.

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DISCUSSION

The cost of producing plutonium is highly dependent on the pile exposure level. For a given quantity of plutonium produced, the quantity of uranium it is necessary to process is inversely related to the exposure. On the other hand, the quality of the plutonium produced, as measured by the concentration of the undesirable 240 isotope, is a direct function of the exposure.

Up to the advent of the low neutron emissivity (or low 240 isotope) plutonium program, pile exposure was not limited by quality specifications but by pile operation, notably slug ruptures. The specification of a neutron emissivity of less than 20 or 25 neutrons per gram second, however, definitely limited uranium pile exposure and made it mandatory that precise relationships between emissivity, 240 content, and exposure be determined if highest permissible exposures were to be maintained.

Early studies ^(2,3,8) of the relationship between the plutonium isotope 240 content, the neutron emissivity, and the pile exposure level, assumed linear or constant ratios to zero MWD/T, weighted by data at the higher exposure levels (>400 MWD/T). Later routine measurements of neutron emissivity at final inspection indicated somewhat higher values for the ratio with respect to exposure, especially in the 200 to 300 MWD/T range. The apparent discrepancy is due in part to changes in pile moderator temperature, which has a significant effect on the 240 concentration, ⁽⁴⁾ and in part to the fact that the ratio is not constant but dependent on second order effects during exposure.

To achieve maximum exposure levels, it was also desirable to institute a blending operation prior to final fabrication. Fluctuations in emissivity for a given nominal average exposure of up to five per cent had been noted. Such fluctuations are inherent because of wide variations in the slug or tube exposures making up a push, and the difficulty in determining the average exposure of a push. An efficient blending operation could, therefore, permit an increase in average pile exposure of up to five per cent. The most convenient point for measuring the emissivity and for blending is the plutonium nitrate solution feed to the purification and fabrication process.

PROCEDURE

Two uranium metal batches of carefully controlled exposures were pushed from C pile and processed via the bismuth phosphate separations process and the plutonium purification and fabrication process. Special cleanouts of all equipment were made prior to processing to prevent contamination. Approximately 19 tons of uranium metal exposed to 200 MWD/T and 24 tons exposed to 300 MWD/T were processed.

Neutron emissivities (neutrons per gram second, n/g-s) of the plutonium metal were measured in a "Bertha geometry" neutron counter using standard techniques and distributed multiplication constants as supplied by the Los Alamos Scientific Laboratory. ⁽⁷⁾

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To measure the emissivities of the plutonium nitrate solution, standard loads were placed in shipping containers (sample cans) and the container inserted in the counter geometry. Since geometry and other counting effects were unknown, the following empirical formula was used as a measure of the emissivity:

$$\text{Count ratio per gram (CR/G)} = \frac{\text{sample can counts per minute} - \text{background}}{(\text{source counts per minute} - \text{background}) \times \text{plutonium weight}}$$

The plutonium isotope ^{240}Pu content was determined by the Chemistry Unit, Applied Research Section, using a fission counter. Samples for fission counting were taken at the isolated plutonium nitrate solution step.

RESULTS

Pertinent data from the production test are presented in Tables I and II. In Figure I, the relation between neutron emissivity is also presented graphically. For comparison over a wider range, the results of this test are extended to 900 MWD/T exposure levels by supplementary data compiled by the Product Inspection Unit.

As shown by Figure I, the ratio of neutron emissivity to pile exposure is not quite linear, with a maximum in the 300 MWD/T range, and is, in general, higher for low exposures. The results of this test have been confirmed subsequently by production data, and led to a lowering of pile exposure goals for low exposure production. (9)

It must be pointed out that the data of this test are applicable only for a particular set of pile operating parameters. Variations of up to five per cent have been noted between different piles and for the same pile under varying operating conditions. Studies along this line are being continued by the Product Inspection Unit.

The precision of neutron counting of gross quantities of plutonium nitrate solution was found to be inadequate for controlling the neutron emissivity of plutonium metal derived from such solutions. Although the data from this production test did indicate sufficient precision for detecting such differences as might result from gross contamination of 200 MWD/T plutonium with 600 MWD/T plutonium, subsequent data have shown only a loose correlation. The apparent reason for the failure of solution neutron counting lies in the significant and varying contribution of light element α -n reactions to the total neutron flux.

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TABLE I

PRODUCTION TEST DATA - 200 MWD/T

<u>Sample Can Emissivity CR/G*</u>	<u>Neutron Emissivity n/g-s*</u>	<u>Assembly Emissivity n/g-s*</u>	<u>Average Isotope 240 Content Per Cent</u>
4.288	18.98)	18.65	1.80
4.392	18.38)		

* CR/G: count ratio per gram ($\times 10^3$)
n/g-s: neutrons per gram-second

TABLE II

PRODUCTION TEST DATA - 300 MWD/T

<u>Fabrication Step</u>	<u>Neutron Emissivity n/g-s</u>	<u>Average Isotope 240 Content Per Cent</u>
Direct Machining	29.47)	2.755
First Recast	28.83)	
Second Recast	28.81)	

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