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Subject Final Rept. - Prod. Test #305-9-P
Poisoning Effectiveness and Uniformity of
Myrmalloy Slugs

To File

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APRIL 2, 1946

FINAL REPORT

PRODUCTION TEST NO. 305-9-P

POISONING EFFECTIVENESS AND UNIFORMITY OF MYRNALLOY SLUGS

Introduction

The poisoning effectiveness and uniformity of the first production batch of 33 myrnalloy slugs was tested in the 305 Test Pile on February 26, 1946, prior to charging into the D Pile in accordance with Production Test No. 105-49-P, Supplement A.

Summary

On the basis of data reported below, a full column of myrnalloy slugs located in an unshadowed position at the center of an unflattened 2004-tube pile is estimated to absorb 39 inhours. A high degree of uniformity was demonstrated by tests in which the slugs were handled in batches of four.

Experimental Details

Two heavy metal slugs at the center of the 305 test stringer were replaced in turn by (a) a 16" column of lead slugs, (b) a 16" column of lead-cadmium slugs, and (c) by various sets of myrnalloy slugs, each set containing four four-inch pieces. For each arrangement, the pile reactivity was measured by taking duplicate rising periods with all rods out. Periods were converted to reactivities in inhours by means of the table of Document No. 3-1283.

The test configurations and associated reactivities are described in the following table. Numerals indicate the number of the particular myrnalloy slug.

Configuration	Pile Reactivity (1h)	Configuration	Pile Reactivity (1h)
Heavy metal only	81.4	1-3-4-5 (check)	41.85
Lead	76.45	21-22-23-24	41.85
Lead-cadmium	10.3	25-26-27-28	41.85
1-3-4-5	41.9	29-30-31-32	41.85
7-8-11-12	42.1	33-34-35-36	41.85
13-14-15-16	41.85	1-3-4-37	42.0
17-18-19-20	41.95	1-3-4-5	41.9

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The pile reactivity with the four-slug myrnalloy batches in place varied from 41.85 ih to 42.1 ih. This small variation is of no practical significance; the uniformity of the 33-slug batch is considered satisfactory.

An approximate and non-rigorous estimate of the reactivity loss produced by a column of myrnalloy slugs at the center of an unflattened 2004-tube pile may be based on the following data for the reactivity loss produced by the given substitution in a similar column:

<u>Substitution</u>	<u>Reactivity Loss</u>
<u>In 105 Pile</u>	
(a) Lead for heavy metal	7 ih
(b) Lead-cadmium for heavy metal	68 ih
(c) Lead-cadmium for lead	61 ih
<u>In 305 Pile (from table)</u>	
(d) Lead for heavy metal	4.95 ih
(e) Lead-cadmium for heavy metal	71.1 ih
(f) Myrnalloy for heavy metal	39.5 ih
(g) Lead-cadmium for lead	66.15 ih
(h) Myrnalloy for lead	34.55 ih

By simple proportion, using the heavy metal-filled column as reference standard, one finds the reactivity loss produced by substitution of myrnalloy for heavy metal in a 105 Pile as $(bf/e) = (68 \times 39.5/71.1) = 38$ ih; using the lead-filled column as reference standard, $(ch/g) + a = (61 \times 34.55/66.15) + 7 = 39$ ih. A figure of roughly 39 ih is therefore indicated.

A more detailed treatment, provided by one of us (R.L.M.), leads to the same answer. The first step is to find the poisoning power of a full column of lead-cadmium slugs and one of thorium slugs in the 305 Pile. From considerable experience with control rods in the 105 Piles, it is known that a segment of a column of poisoning material has a poison value proportional to the square of the neutron density. Longitudinally, the neutron density is represented by a cosine curve. The effective pile length is 571 cm (Ref. 1); the length of the test column is 16 inches = 40.7 cm. The value of a full lead-cadmium column is then:

$$\frac{2}{\pi} \frac{571 \text{ cm.}}{40.7 \text{ cm.}} (81.4 \text{ ih} - 10.3 \text{ ih}) \int_0^{\pi/2} \cos^2 x \, dx = 500 \text{ ih.} \quad (1)$$

$$\text{or,} \quad 7.03 (81.4 \text{ ih} - 10.3 \text{ ih}) = 500 \text{ ih.}$$

For a full column of myrnalloy, the constant 7.03 is unchanged, and the value of the full column is:

$$7.03 (81.4 \text{ ih} - 41.9 \text{ ih}) = 278 \text{ ih.} \quad (2)$$

The second step is to convert inhours in the 305 Pile to inhours in the 105 piles. This conversion is helped by the fact that the effective radius of a poison column is constant, regardless of the size of the unit, provided that the lattices of the units are similar. It was assumed for purposes of calculation that the lattices are similar in the present case. A full column of slugs is known to have an effective radius of 0.05 cm. (Ref. 2). This is the radius of the cylinder on which the neutron density extrapolates to zero in a homogeneous pile having only thermal neutrons in it.

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The problem then resolves itself into finding the effective radius of a thorium column. This can be done by first finding the constant in the relationship between buckling and total poisoning in the 305 Pile.

$$\text{Radial buckling} = (2.405)^2 / (\text{radius})^2 \text{ plus a constant times the reactivity absorbed by poison.} \quad (3)$$

For this we have available the observation that the reactivity of the 305 Pile, of 257 cm. effective radius, is lowered 500 ih by a lead-cadmium column of 0.05 cm. effective radius. The radial buckling is found from the known boundary conditions and the implicit equation:

$$\frac{N_0(bR)}{J_0(bR)} = \frac{N_0(257b)}{J_0(257b)} = \frac{N_0(br_0)}{J_0(br_0)} \quad (4)$$

where b^2 is the radial buckling and r_0 is the effective radius of the poison column, 0.05 cm. Then b is 0.01013 cm^{-1} when 500 ih of poison is in the center of the small pile, and Equation (3) is evaluated as

$$10^4 b^2 = 0.8757 + 0.000301 F \quad (5)$$

where F is the value of the poison in inhours. From Equation (5), b for the thorium column in the 305 pile is 0.009795. The value of r_0 is found to be 0.00013 cm. from Equation (4). From Ref. 2, the poisoning power is found to be 39 ih. The accuracy of this figure is limited by the approximate theory used to convert from the small unit to the large unit. A theoretical value of 47 ih was obtained by the nomograph of Ref. 3.

References

- (1) Final Report, Production Test 305-4-P, "Determination of the Effectiveness of a Poison Column", Document No. 3-2087; (2) "Estimation of Temperature Distribution in Poisoned Unit", Menegus to Jordan, 4/30/45, Doc. No. 3-2297, Fig. 6; (3) "Pile Poison - Procedure for Calculating Effect of Various Materials on Pile Reactivity", Menegus to Jordan, 5/19/46, Doc. No. 7-3721.

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