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INTERIM REPORT - OPERATIONAL PHYSICS ASPECTS OF SUPPLEMENT A - PRODUCTION TEST IP-14-AC USE OF E METAL IN SHIELD PROTECTION

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INTERIM REPORT - OPERATIONAL PHYSICS ASPECTS OF SUPPLEMENT A
PRODUCTION TEST IP-14-AC USE OF E METAL IN SHIELD PROTECTION

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INTERIM REPORT - OPERATIONAL PHYSICS ASPECTS OF SUPPLEMENT A,
PRODUCTION TEST IP-14-AC - USE OF E METAL IN SHIELD PROTECTION

INTRODUCTION

The masonite in the old pile shields is deteriorating because of the temperature conditions to which it is subjected. One method of mitigating this deterioration is to reduce neutron leakage to the shields by utilizing the fringe tubes for target material. One possible target material is depleted uranium, i.e., uranium from which the bulk of the isotope 235 has been removed. The purpose of this test supplement⁽¹⁾ has been to irradiate a fringe depleted pattern (1) to establish the enrichment loading of E metal necessary to maintain reactor production, (2) to determine the depression in shield temperature which could be obtained by such a loading, and (3) to establish the operational economics of this method of production. The latter of these goals is to be the subject of a later report.

SUMMARY

With full length depleted uranium charges in the outermost fringe process tubes the heat generation rate in the adjacent shields is reduced to approximately 75 per cent of the value for a natural uranium loading under comparable reactor conditions. The reactivity compensation can be achieved by the use of one and one-half full length E columns for each depleted column where the E charges are placed in the second and third tube rows from the reflector. These results substantiate calculational techniques developed earlier.⁽²⁾⁽³⁾

DISCUSSION

The placement of target material in the outermost ring of tubes in the reactor reduces the leakage of neutrons from the pile and thereby reduces the generation of heat in the shield. If enrichment were not used to compensate for the target material, the size of the reactor effectively would be reduced. However, when compensating enrichment is employed in the rings of tubes adjacent to the target material it is possible to maintain reactor production rates.

A. Flux Distribution

Depleted charges, consisting of 33 eight-inch pieces of uranium depleted to approximately 0.20 per cent U-235 content, were placed in tubes 1996B through 2896B inclusive with the exception of problem tube 2496B. Compensating enrichment columns consisting of 43 six-inch pieces of solid 0.947 per cent E metal were placed in tubes 1995B through 2895B inclusive and 2094B, 2294B, 2494B, 2694B and 2894B. Several full pile temperature maps were obtained prior to and subsequent

- 1) HW-50316 - Production Test IP-14-AC-Use of E Metal in Shield Protection, Supplement A - W. L. Bunch and L. W. Lang - 6-23-57.
- 2) HW-46165 Rev - PT-IP-14-AC - Use of E Metal in Shield Protection - W. L. Bunch and L. W. Lang - 3-6-57
- 3) HW-51723 - Interim Report, Operational Physics Aspects of PT-IP-14-AC - Use of E Metal in Shield Protection - W. L. Bunch - 9-18-57.

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to the installation of this load so that comparative power distributions could be obtained. The normalized thermal neutron flux distribution through the test loading, based on the temperature maps, is shown in Figures 1 and 2. It can be seen that the flux distribution away from the test load has been unperturbed. The cosine curve used to fit the flux distribution prior to the test loading yields a value of 21 microbucks for the lateral component. This is significantly less than the value obtained from the DR reactor and apparently indicates the effect of differences due to exposure, temperature, graphite purity, and other operating and reactor variables.

The power distribution data in Figure 2 has been described by the following equations for the five reactor zones covered (see References 2 and 3 for method):

- 1) Flattened zone $\phi_1 = 1$
- 2) Natural uranium zone $\phi_2 = \cos 0.0046 x$
- 3) Enriched zone $\phi_3 = 0.615 \cos (.015x - 2.76)$
- 4) Depleted zone $\phi_4 = 0.228 \cosh (6.97 - .024x)$
- 5) Reflector $\phi_5 = 0.789 \cos 0.0046 x$

where x is in centimeters. From these equations the buckling of the various zones is as follows:

- 1) 0
- 2) 21 μb
- 3) 225 μb
- 4) -576 μb
- 5) 21 μb

These values should be of value in estimating other loadings utilizing these materials; that is, double layers of depleted, triple layers of depleted, etc. One important value which can be obtained from this curve is the reduction of flux in the reflector. The coefficient of the reflector cosine curve is 0.789-- indicating that the flux leakage to the shield is 78.9 per cent of the unperturbed value.

B. Shield Temperature

Shield thermocouples were located in both the far side and top biological shields as part of the water plant expansion project. These thermocouples record the temperature of each of the seven layers of steel which sandwich the six cycles of masonite in the shield. The innermost steel is adjacent to the thermal shield; the temperature of this steel should be closely related to the heat generation rate in the shield. However, many perturbing influences make it difficult to evaluate heat generation in the shield based on the shield temperature at any given time.

It has been postulated that the temperature of the shield (above local water temperature) should be related to the flux leakage to the shield at that point by the equation:

$$T_{SW} = \frac{a \phi}{k}$$

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relative
flux
(tube power)

Tube Row
Figure 1

FLUX DISTRIBUTION IN FAR SIDE OF B REACTOR
PRIOR TO DEPLETED LOADING

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- A $\cos 0.0046 \pi$
- B $0.615 \cos (0.015 - 2.76)$
- C $0.228 \cosh (6.97 - 0.0244)$
- D $0.789 \cos 0.0046 \pi$

--- π
in cm

Tube Row
Figure 2

FLUX DISTRIBUTION FAR SIDE OF B REACTOR
AFTER LOADING DEPLETED MATERIAL
IN FRINGE TUBES

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where k is a gross thermal conductivity coefficient between the shield and the water and a is a proportionality constant. More realistically the relation should be

$$TSW = \phi \left(\frac{a_1}{k_1} + \frac{a_2}{k_2} + \dots + \frac{a_m}{k_m} \right)$$

where a_1 and k_1 are geometrical proportionality constants and thermal conductivity coefficients for the regions between the shield thermocouple and the water (layers include steel, lead, pipe, contact resistances and film resistances). Many of these factors are subject to change because of gas composition and mechanical deformation; hence, it has been impossible to determine accurately the heat generation in the shield on the basis of shield temperature alone. Qualitatively it is readily apparent that the depleted material reduced the heat generation rate significantly.

The following data indicate that the heat generation in the shield was reduced by the depleted material to approximately 75 per cent of the unperturbed value. As indicated above the evaluation is limited. The data presented are from "best" equilibrium conditions existing within the two months prior to and after the loading changes. These data indicate somewhere between a 15 and 35 per cent decrease due to the depleted uranium.

TABLE I

SHIELD TEMPERATURE REDUCTION
DUE TO DEPLETED LOADING

Date	Cond.	Maximum Δ Temp		Relative, Adj. Tube Power		Gas Comp.	
		Side	Top	Side	Top	CO ₂	He
1-20-58	Before	96	60	.965	.828	50	50
3-24-58	After	82	55	.960	.757	48	51
	% Change	-15%	-7%	-1/2%	-8%		
2-17-58	Before	98	51	1.000	.811	39	61
3-18-58	After	86	59	.941	.738	58	41
	% Change	-12%	+ 16%	-6%			

The temperature distribution through the side shield before and after the depleted loading is shown in Figure 3.

C. Conclusions

It has been established that a small though significant reduction in shield temperature can be achieved by using depleted target material loadings in the outermost fringe tubes and that no operational problems are created from a re-activity and control standpoint. Therefore, the practical use of depleted uranium in the outermost fringe tube depends upon the economics of such a loading.

W. L. Bunch

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Irradiation Testing Operation

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Figure 3

TEMPERATURE DISTRIBUTION THROUGH THE B REACTOR
SIDE SHIELD BEFORE AND AFTER DEPLETED LOAD

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