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MACRO-EXAMINATION OF ENRICHED URANIUM SLUG RUPTURES

INTRODUCTION

This report covers the preliminary data obtained in a metallurgical study of the three enriched uranium slugs which ruptured in the 100-C Pile. The three slugs were from PT-105-532-A2, "Irradiation of Enriched Uranium Slugs," (1) a test conducted by Pile Technology for the purpose of studying the effects of high specific powers in uranium slugs. The uranium used in this test was enriched to 1.75

- (1) Lang, L. W., Production Test 105-532-A2, Irradiation of Enriched Uranium Slugs, HW-27146, February 16, 1953 (SECRET).

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percent U-235. Slug powers for the enriched metal were expected to be roughly double that of ordinary uranium operating in the same flux.

The laboratory work which has been done to date has consisted of a close inspection of the slug fragments as they were received and after electrolytic cleaning. Evidence of major defects and changes in the metal can be detected in this type of examination, but the cause of abnormalities involving metallurgical or chemical anomalies cannot be conclusively determined without further analysis. By comparison with the split type ruptures of natural uranium, "abnormal" features for a rupture could be identified. For such comparison there was available the observations obtained on four recent split failures of natural uranium which were examined under identical conditions of preparation and inspection.

SUMMARY

The three Ike failures had split longitudinally and transversely. A large void at the center of one slug resembled voids produced in alpha-rolled uranium by thermal cycling across the alpha-beta transformation temperature. (2) In all the slugs, a well-defined core of metal terminating about 1/4" from each surface was delineated by electrolytic cleaning. The "core" was more pronounced than a similar effect seen on natural uranium ruptures. The difference in the metal at the center and periphery of the slugs and the void at the center appeared to have been the results of in-pile thermal treatment.

DETAILS

The following three enriched uranium slug failures were examined by Radiometallurgy in December, 1953:

TABLE I (3)

<u>Failure No.</u>	<u>Tube No.</u>	<u>Discharge Date</u>	<u>Exposure</u>
Ike 1	1463-C	9-5-53	Comparable to that of the central slug in a normal U column exposed to 700 MWD/T.
Ike 2	1463-C	9-5-53	
Ike 3	3766-C	9-5-53	

Figures 1, 5, and 7 show the slugs as received. The gross appearance of the failures was similar to that of many split type failures of natural uranium slugs. The uranium split into two or more pieces with very little evidence of corrosion of the uranium having taken place during the process of failure.

The fragments of the slugs were separated and the fracture surfaces cleaned electrolytically in a 10 percent by volume HNO₃ solution. This treatment quickly removed most of the uranium corrosion product and left the central portion of

(2) Hayward, H. R., Peak Temperature Limit for Uranium Metal Slugs, AER-54T-445, 2-5-54, (SECRET)

(3) Anderson, J. K., Enriched Slug Data and Comparative Rupture Rates - July through September, 1953, HW-39027, 10-1-54, (SECRET).

the slug slightly discolored. (Figures 3, 4, 6, and 8). In addition to the etching effect there was a slight difference in the fracture pattern at the center and periphery. This was most pronounced on the transverse sections (Figure 4). The core effect stopped short of the ends of the slugs, which precludes an inclusion distribution from rolling as being the cause. Similar cores have been seen in some of the recent split slugs of natural uranium, but those seen in the Ike were better defined, particularly in Ike 3 (Figure 9) where the core was partially outlined by multiple fine cracks in the uranium.

The section shown in Figure 9 is of particular interest because of the large void at the center of the slug. The metal surrounding the void contained numerous cracks to the extent that it looked friable. The void itself did not appear to be a manufacturing defect. On the other hand it did resemble the voids observed in alpha-rolled uranium cycled 40 times between 20 C and 730 C in a salt bath. (4) Similar voids have been produced in alpha-rolled uranium by cycling at North American Aviation, Inc. (2) The cycling experiments which produced the voids in the metal involved application of the heat from the outside of the slug. The difference in application of heat does not invalidate the comparison with the thermal treatment slugs receive during pile exposure because, in both cases, the void is probably produced during the quenching part of the cycle when cold alpha phase uranium exists in the periphery of the slug while the central core of uranium is transforming from the beta to alpha phase.

The comparison with the results of cycling unirradiated uranium are pointed out mainly because of the striking similarity in the appearance of the voids in the Ike slug and the cycled samples. This similarity, per se, does not allow the conclusion that the void was produced by cycling with the upper limit above 660 C. Existing information on the probable temperature attained by this slug indicates that it operated well below a core temperature of 660 C, but the piece does appear worthy of further detailed work to determine, if possible, the treatment which the metal at the center has received.

The only evidence of manufacturing defect on any of the slugs was seen on Ike 1 where the underside of the cap appeared to have been incompletely bonded to the slug. In Figure 2 the central portion of the Al-Si on the cap can be seen to be darkened. This appeared to be a thin film of dark brown oxide, which may be an indication that the cap was incompletely bonded to the slug.

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(4) Levenick, L. E., Report on Thermal Cycling of Hanford Uranium Slugs Across the Alpha-Beta Transformation Temperature, HW-28305, 6-1-53, (SECRET)

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Figure 1

Ike

Magnification 1.4X

Figure 2

Ike

Mag. 2.2X

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Figure 3

Ike 1

Magnification 1.6X

Figure 4

Ike 1

Mag. 2.2X

• Figure 5

Ike 2

Magnification 1.5X

Figure 6

Ike 2

Magnification 1.4X

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Figure 7

Ike 3

• Magnification 1.2X

Fig. 8

Ike 3

• Mag. 1.8X

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Fig. 9

Ike 3

Mag. 1.9X

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