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INTERIM REPORT NO. 1 — BT 105-577-A — IRRADIATION OF SOLID
AND CORED HOT PRESSED FUEL ELEMENTS

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HW-36752

INTRODUCTION:

In order to evaluate the performance of uranium slugs canned by the hot press method, several tubes of this metal were charged at C Pile and scheduled for irradiation until a specified number of ruptures had occurred. At the present time, all scheduled ruptures of hot-pressed slugs have been obtained. This report summarizes the irradiation experience under this test and the results obtained to the present time, and presents conclusions which are drawn from this experience.

SUMMARY AND CONCLUSIONS:

Under the authority of this test nine tubes of hot press canned eight-inch slugs and three tubes of lead-dip canned standard production eight-inch slugs were charged at C Pile in order to determine the relative rupture resistances. Three tubes each of three types of hot pressed fuel elements were irradiated under this test.

1. Solid slugs with the diffusion type closure obtained in hot pressing.
2. Solid slugs with the diffusion type closure backed by a fusion weld.
3. Cored slugs with the diffusion closure backed by a fusion weld.

The three tubes of each slug type were scheduled for irradiation until one rupture occurred, at which time the rupture and the two remaining tubes were to be discharged. Three failures occurred, one in each type of hot pressed slug. The two failures of solid pieces were side failures; the cored piece failed by uranium cleavage. These failures occurred at exposures between 550 and 610 MWD/T. Because statistically significant results had been obtained, the three lead-dip canned control charges were discharged after having reached exposures between 900 and 990 MWD/T without failure.

A post irradiation examination of the pieces, and a statistical evaluation of the exposures at failure revealed that:

1. The bond between the jacket and core may deteriorate during irradiation.
2. The side failures were caused by a penetration of the jacket wall rather than by water leaking down from a defective closure.
3. The cored piece which failed by uranium cleavage showed no evidence of jacket penetration prior to the splitting. The appearance of this piece indicates that stresses in the regions of the end-plugs were responsible for the failure.
4. The fact that no side failures occurred in the cored, hot-pressed pieces does not indicate that their resistance to this type of failure was superior to that of the solid, hot-pressed pieces.
5. The three failures, as compared with the successful irradiation of the control tubes to 900 MWD/T indicate with 98% confidence that the test slugs were inferior to the control slugs.

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Three charges of mixed types of slugs were irradiated to specified goal exposures for post irradiation examination. An inspection of the metal from these tubes and from some of the "to rupture" tubes disclosed:

1. Several pieces had elliptical patches on the sides, with the area inside the patch having different filming characteristics than the rest of the slug. These areas were presumed due to overheating of the slug, probably from a flow disturbance in the region. It is possible, however, that the markings were caused by uneven heating of the jacket around areas which had become unbonded. This possibility is to be investigated by a metallurgical examination of some of the marked slugs.
2. Several pieces were badly pitted, and there was evidence of intergranular corrosion of the jacket. This may have been the mechanism of failure, with water entering the slug through a "point penetration" of the jacket.

DISCUSSION:

Under the authority of PT 105-577-A fifteen tubes of eight-inch uranium slugs were charged in C File in September, 1954. These charges consisted of three tubes each of: (1) solid, hot-press-canned pieces with a diffusion closure; (2) solid, hot-press canned pieces with a diffusion closure backed up by a fusion weld; (3) cored, hot-press canned, pieces with a diffusion closure backed up by a fusion weld; (4) solid, lead-dip canned, regular production metal; (5) alternated pieces of the four types. The mixed charges were scheduled for irradiation of one tube to an exposure of 300 MWD/T and the other two tubes to 600 MWD/T. Post irradiation examinations and measurements of these pieces were to be made to discover any differences in the effects of irradiation on the various types of slug. The other twelve tubes operated under a "to rupture" test, the three tubes of each metal type being scheduled for irradiation until one rupture occurred.

At the present time the pieces charged under this test have all been discharged. Table 1 presents a summary of their irradiation experience. Table 2 presents operating data concerning the pieces which failed.

The two failures which occurred in the solid, hot-pressed slug charges were both side failures. One of these, shown in Figure 1, was badly swollen and had a long crack and several smaller ones in the jacket wall. An examination by the Radiometallurgy unit disclosed that:

1. Swelling was caused by the buildup of corrosion products. This swelling was the probable cause of the jacket splitting.
2. The uranium core was not split.
3. There was no evidence of water penetration at the closure.
4. Intergranular corrosion of the jacket had occurred in the swollen area.⁽¹⁾ Penetrations of as much as 2/3 of the jacket wall thickness were observed. It is possible that such corrosion, resulting in a penetration through the jacket wall at a point, initiated the failure.

(1) Personal communication, H. Harty to J. K. Anderson.

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FIGURE 1a.

Photograph of Ruptured, Hot-Press Bonded Piece from Tube 3283-C, Showing the Break in the Can Wall.

FIGURE 1b.

Photograph of Ruptured, Hot-Press Bonded Piece from Tube 3283-C.

This photograph was taken with the slug rotated 180° from its position in Figure 1 a.

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IRRADIATION EXPERIENCE OF METAL CHARGED UNDER PT-105-517-A

Tube Number	Type* Metal	Charge Date	Discharge Date	Goal Exposure	Discharge** Exposure	Average Tube Power	Peak Tube Power	Type of Failure
1576-C	SBI	9-3-54	11-9-54	300 MMD/T	278 MMD/T			
1675-C	SBI	9-3-54	1-19-55	600 MMD/T	568 MMD/T			
1583-C	USI	9-26-54	1-19-55	600 MMD/T	523 MMD/T			
3172-C	1	9-3-54	4-12-55		987	800 KW	1080	
3274-C	1	9-3-54	4-12-55	1 Rupture	906	742	943	
3281-C	1	9-3-54	4-12-55		959	776	1060	
3272-C	B	9-3-54	1-19-55		560	752	566	
3282-C	B	9-3-54	1-19-55	1 Rupture	553	731	900	Slide
3374-C	B	9-3-54	1-19-55		598	796	936	
3273-C	S	9-3-54	1-23-55		630	820	1070	
3275-C	S	9-3-54	1-23-55	1 Rupture	612	796	1042	Slide
3283-C	S	9-3-54	1-23-55		568	737	900	
1382-C	U	9-26-54	2-27-55		607	743	952	Split
1482-C	U	9-26-54	2-27-55	1 Rupture	601	739	943	
1582-C	U	9-26-54	2-27-55		584	731	949	

* B: Hot-pressed, solid, with diffusion weld.
 S: Hot-pressed, solid, with diffusion plus fusion weld.
 U: Hot-pressed, cored, with diffusion plus fusion weld.
 I: Standard, lead-dip canned.

** As calculated from daily operating data received from 105-C Operations.

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TABLE II

OPERATING DATA FOR RUPTURED HOT-PRESSED SLUGS UNDER PT-105-577-A

Tube No.	Days of Operation	Tube Exposure	Piece No.	Position*	Slug** Power	Local** H ₂ O Temp.	Type of Failure
3374-C	102	598 MWD/T	5-B B-109	5	30.2 Kw/ft	89.7° C	Side
3283-C	102	568 MWD/T	9-B S-473	10	44.4 Kw/ft	69.0° C	Side
1382-C	111	607 MWD/T	3-U U-750	16	57.2 Kw/ft	53.3° C	Split

* Pieces numbered from downstream end of column.

** Calculated from tube power and water temperatures under equilibrium conditions shortly before failure.

The other side failure was stuck in the tube and was badly damaged in being removed from a section of tubing. The pounding on one end of the piece pushed the core partially out of the jacket at the other end, forcing off the cap. The fact that the core could be pushed out of the jacket indicates that bonding was almost non-existent at this time.

The third rupture was the uranium cleavage failure of a cored piece. This piece was split longitudinally along a diameter, and was also split transversely at the base of each end plug. The occurrence of this failure at an exposure of 607 MWD/T is anomalous to the results of a previous test, which indicated a high resistance to cleavage for cored slugs. The difference in performance of the metal irradiated under the two tests may be due to differences in the methods of fabricating the two groups of cored slugs. The fact that the hot-pressed, cored, slug broke at the base of each end plug shows that there were high stresses at these positions. Such stresses might be the results of the method of inserting the end plugs. The plugs were hot-press bonded into the uranium "tube" with forces of ten to twelve tons per square inch being applied. This pressing would induce stresses at the time of fabrication, and should there be a tendency for the plugs to grow and/or the uranium cylinder to expand into the void, such stresses might be increased to a point where the uranium would fracture.

The cored, enriched uranium, pieces irradiated under the previous test had the end plugs threaded and screwed into the hole. This method of plugging would give a "looser" fit, inducing little, if any, stress at the time of canning, and would give some room for any expansion of the uranium.

A metallurgical examination of the hot-pressed, cored, piece which failed, and of two similar pieces which did not fail is planned. The results of these examinations may reveal the reason for the failure.

The fact that the hot-pressed cored slugs did not fail by side failure cannot be considered significant. When these pieces were discharged as a result of the cleavage failure, their exposures were comparable to those at which side failures occurred in the solid pieces. If the cleavage failure had not occurred, the cored pieces would have

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had to continue under irradiation until their exposures increased 200 to 300 MWD/T, without a side failure, to demonstrate that their performance in this respect was significantly different from that of the hot-pressed solid pieces.

At the conclusion of the test the exposures at which failures occurred were to be analyzed statistically to determine the relative rupture resistances of the three types of hot pressed slugs and the lead-dip canned control slugs. With the three control tubes having reached an exposure of 900 MWD/T there is a 95% probability that the control metal has a lower failure rate than any of the three types of hot pressed slugs. Considering the hot pressed metal as a whole, the three failures incurred indicate with a 98% probability that this metal is inferior to the control.

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