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July 1, 1954

PRODUCTION TEST 105-576-A
IRRADIATION OF POWDER METAL COMPACT SLUGS

OBJECTIVE

To evaluate by pile irradiation the stability and resistance to rupture of powdered metal compacts.

BASIS AND JUSTIFICATION

Powder metallurgy techniques produce slugs of near theoretical density, randomly oriented grain structures, grain sizes of less than one-tenth existing in production material, high yield strength, but extremely low ductility. Although preliminary irradiations of this material have been performed, (5) a more thorough pile evaluation is required. It is proposed that the evaluation be accomplished by irradiating one tube of regular control slugs and one tube of powder metal compact slugs to rupture at C Pile. Additional slugs will be irradiated to normal concentrations at lower powers.

To serve as pilot irradiations for the remaining slugs, two tubes of mixed derby and ingot compact slugs will be irradiated at C Pile, two of which will be discharged and inspected before the remaining powder metal compact slugs are charged.

The remaining powder metal compact slugs will be charged at F Pile. Preliminary in-pile testing of powder metal compact slugs has revealed some distortion of the slugs. Evi-

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dence indicates that large grain size is probably the cause of the distortion. All of the metal under this proposed irradiation will be ultrasonically tested and all large grain size pieces rejected. To test the uniformity of ultrasonically examined metal it is proposed to examine eight tubes of the metal after irradiation.

Although fine grain size and random orientation are achieved with powdered metal compacts, some of the pre-irradiation testing data have not appeared too promising. (See Appendix) One outstanding and possibly very important exception, is the higher bursting strength under biaxial stress of the powder metal compact slugs, (97,500-104,000 psi internal pressure) as compared to as-rolled material (79,000-80,000 psi internal pressure). What effect the pre-irradiation physical properties of uranium may infer, as far as pile survival is concerned, is not known. Since irradiated uranium has drastically different properties from non-irradiated material, some pre-irradiation physical tests may not be pertinent to pile stability.

SCHEDULE

1. Starting date - July 1954.
2. Duration of test - Approximately one year.
3. Area - C and F.

PRIORITY

This test authorizes the irradiation of two tubes until they rupture. This will entail the discharge of two ruptures, which may be stuck.

COSTS

Cost Code - XXXX-5270-5909. (5909 code is to be used to distribute costs evenly to codes 253.61-66)

Reactivity Loss Involved - Negligible.

Man-Hours Required - Reactor Section, Operations, Power and Maintenance Unit.
Two ruptures requiring possibly 16 man-hours.
Charge-discharge of Specials, 4 man-hours.
Metal Preparation Section, Operations Unit, 400 man-hours.

Elevator Time Required - Discharge of two ruptures requiring possibly 8 hours of elevator time. Charge-discharge of twelve tubes requiring possibly 30 minutes per tube for a total of 6 hours.

DESCRIPTIVE DETAILS

Description of Slugs in Pile - Sylvania currently uses cast ingots, scrap, and uranium derbies as starting materials for powder metal compact slugs. The derby material eliminates the recasting step in production and yields a compact lower in carbon, nitrogen and iron than the compacts prepared from ingot uranium.(7) The derby compacts are comparable in physical properties and reactivity to ingot metal compacts. It is requested that the following types of slugs be canned in accordance with "F" Process Specifications and charged under P.T. 105-576-A. The slugs to be charged are:

Type A - Four -inch Sylvania derby powder metal compact slugs, lead dip canned. These slugs are to be pickled eight seconds maximum. These slugs will be identified by production test number, tube number, and position in tube.

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Type B - Four-inch Sylvania ingot powder metal compact slugs, lead dip canned. These slugs are to be pickled eight seconds maximum. They will be identified by production test number, tube number, and position in the tube.

Type C - Four-inch Z pieces that have undergone only one transformation. These slugs will be identified by production test number, tube number, and position in the tube.

Type D - Four-inch Sylvania ingot powder metal compact slugs, lead dip canned. These slugs will be pickled eight seconds maximum. They will be identified by production test number and will be charged into F Pile utilizing the lot charging system, except for 8 tubes which will be identified by production test number, tube number, and position number.

Type E - Four-inch alpha rolled salt-bath, heat-treated, lead-dip canned material to act as control pieces. These slugs will be identified by production test number, tube number, and position in the tube.

TABLE I
SUMMARY OF IRRADIATIONS

Type Charge	Area	Number of Tubes	Exposure	Type of Slugs			
				Derby (A)	Ingot (B&D)	Z (C)	Type (E)
Rupture	C	1	To rupture				64
Rupture	C)	1	To rupture	64			
Rupture	C)	1	To rupture		64		
Control	C	1	200	21 (or less)	22	21 (or more)	
Control	C	1	400	21 (or less)	22	21 (or more)	
Control	F	8	600		512		
Lot Charged	F	44 (Approx)	600		2944		
Reserve (2)		4			256		
Total		61		106	3820	42	64

- (1) One of these tubes will be discharged at 600 MWD. Only the type metal which shows up best in the control tube inspection will be irradiated to rupture.
- (2) These slugs are to be non-recanned and are to be held for further testing, if results warrant.

Charging Details - The first charges will be two central tubes at C Pile. The charging pattern for these tubes will be as follows: Standard rear dummy pattern, BACBAC---BACB. If derby material is short in supply, normal uranium may be substituted as necessary. One tube will be discharged at 200 MWD/Ton and one at 400 MWD/Ton.

After the C Pile central charges have been irradiated for approximately six weeks, ten central charges and the lot charged slugs will be charged at F Pile. The control

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tubes at F Pile will be charged in known order and will be picked up special and held for examination. Only the tube numbers of the lot charged material need be known. All F Pile charges will be scheduled for 600 MWD/Ton exposure.

Four-inch slugs, Type E, will be canned upon the receipt of suitable rod for fabrication. As soon as possible thereafter the three charges designated for "testing to rupture" will be charged. After the inspection of the irradiated control tubes at C Pile, one of the powder metal compact charges earmarked as being "tested to rupture" will be discharged at approximately 600 MWD/Ton. The one remaining will be that containing metal of apparent highest quality. The charging pattern for these tubes will be as follows:

Derby Material

Standard rear dummy pattern - AAA----AAAA

Ingot Material

Standard rear dummy pattern - BBB---BBB

Central Tube

Standard rear dummy pattern - EEE---EEE

Pile Facilities Required - A total of five central zone tubes at C Pile and fifty-five central zone tubes in F Pile.

PROCEDURE

Metal Preparation - Uranium Development Sub-Unit will furnish the derby and ingot powder metal compact slugs to be lead-dip canned. 3608 acceptable powder metal compact slugs are desired. The rejects are to be recanned only once. Two hundred and fifty-six of the non-reject powder metal compact slugs are to be set aside for testing at a later date. Metal Preparation will furnish the 127 alpha-rolled, salt-bath, heat-treated four-inch control pieces for lead-dip canning. All slugs will be lead-dip canned, finished, and inspected according to F Process Specifications. (300 Area Specifications.) Ingot and derby slugs are to retain their respective identities. After Fuel Technology has made up the charges for the control tubes and rupture test tubes they will specify which of the remaining slugs may be made up as a lot and processed by the lot charging system.

Fuel Technology - Uranium Development Sub-Unit will furnish the powder metal compact slugs to Metal Preparations. After canning, Fuel Technology personnel will make up the pile charges and number the slugs for the control tubes, and rupture tubes.

SPECIAL INSTRUCTIONS

Abnormal Hazards - Only such hazards as are incident to ruptured slugs. (Possibly stuck.) Should the high exposure pieces charged under this test limit pile powers, the "to rupture" tubes will be allowed to exceed limiting tube powers by 5 percent.

Special Adjustments to Canning Equipment - None

Data Desired - Ultrasonic grain size determinations on all powder metal compact slugs will be obtained before irradiation. Length, warp, and diameter measurements, and the weight of all slugs in control and rupture tubes are required. Post-irradiation measurements will be made on a selected number of slugs from each discharged control tube prior to the charging of lot charged material. Visual examination of all type A, B, and C material will be made. As much other data as seems feasible in view of

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the facilities available will be obtained. All results are to be reported to R. W. Reid, Pile Technology Sub-Section, and M. A. Ryan, Fuel Technology Sub-Section. Hourly readings of tube operating data will be taken by Reactor Section personnel on data sheets, furnished by Pile Technology, for those tubes being irradiated to rupture.

RESPONSIBILITY

Metal Preparation Section - The Metal Preparation Section will furnish and be responsible for lead-dip canning of all slugs, for normal quality control and for normal numbering of each slug.

Reactor Section - The Reactor Section will be responsible for scheduling, charge-discharge operations, operational safety, and production continuity of the piles. In addition, the Reactor Section will be responsible for maintenance of records of tubes containing test material.

Technical Section - A. C. Callen, Canning Process Sub-Unit, will be responsible for technical assistance and liaison between Technical and Metal Preparation.

J. W. Riches, Uranium Development Sub-Unit will be responsible for preparation of the final report.

H. L. Henry, Pile Engineering, will be responsible for the technical aspects of the pile irradiation and following 105 Building operations. An interim report covering pile operation may be issued by Pile Engineering, if facts warrant.

J. M. Fouts, Fuel Examination Sub-Unit, will be responsible for identification of slugs and for obtaining and recording the desired data, and will forward all data to M. A. Ryan, Uranium Development Sub-Unit, and R. W. Reid, Pile Engineering.

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APPENDIX

Slug Quality Considerations

It is believed that the most desirable fuel element for pile irradiation is one that possesses a fine grain size, randomly oriented grain structure to avoid growth and surface distortion, (1,2,3,4) and good mechanical properties to inhibit slug rupture. Recent experience with alpha-rolled and beta heat treated uranium at long exposures and high specific power levels, wherein a large number of slugs have failed in fatigue induced by cyclic strain, indicates that the mechanical properties of the fuel core may be of primary importance and fine grain size of secondary importance. With powder metallurgical methods it is possible to produce uranium slugs of near theoretical density, randomly oriented grain structures, and grain sizes of .005 mm to .015 mm in diameter, corresponding to grain sizes of less than one-tenth that existing in current production material.

The tensile strength of uranium powder metal compact slugs averages 90,000 psi, which is equivalent to beta heat treated material. The ductility as measured by the per cent elongation is poor for the powder compacts, ranging from 0 to 2 per cent, while beta heat treated material averages eight per cent elongation. Uranium powder metal compact slugs annealed at 600 C in argon exhibited decrease in tensile strength and an increase in ductility in 50 per cent of the samples tested, and no change in mechanical properties from the as-received material in the other 50 per cent of specimens tested. Powder metal compacts tested under cyclic strain split transversely after a few cycles, while heavily striated natural uranium lasted about 100 cycles and split longitudinally. Annealed (600 C in argon) powder metal compacts withstood 50 cycles without splitting, while others lasted 23 and 12 cycles before splitting transversely. Stripped lead dip canned powder metal pieces lasted 48, 7, 2, and 3 cycles before splitting transversely. This test is intended to simulate the radial temperature distribution on a slug under pile irradiation. The test curve of temperature distribution versus stress fits the pile curve rather well except in one portion where the stress on the outer circumferential fibers has been estimated to be about four times that occurring in the pile. Under biaxial stress as-rolled material burst at 79,000 to 80,000 psi internal pressure and metal compacts burst at 97,500 psi to 104,000 psi internal pressure. Annealed (600 C) powder metal compacts burst at 80,000 psi to 95,000 psi internal pressure.

In-pile testing of 45 powder metal compact slugs, manufactured by Sylvania electric Products Inc. using laboratory equipment, was conducted under PT 313-105-4-M⁽⁵⁾. Of the 45 slugs irradiated, one slug discharged at 424 MWD/T and one at 572 MWD/T were distorted. The distortion observed was not of the surface type as found frequently on normal triple-dip material but was a gross change of the slug cross-section similar to that observed on gamma extruded metal. The cross-section had become elliptical in shape as opposed to its original round cross-section. Ultrasonic examination⁽⁶⁾ (unavailable at the inception of this test of 45 slugs) of the distorted slug discharged at 424 MWD/T showed a large grain size at the distorted end and a fine grain size at the undistorted end of the slug. All of the material under this proposed irradiation will be ultrasonically tested for grain size, and no large grain size pieces will be charged, as probably happened in the case of PT 313-105-4-M material.

The present Sylvania pilot plant utilizes cast uranium ingots as a starting material for the powder metal compact slugs. The overall cost of producing these fuel cores can be decreased substantially by the use of uranium derbies in the place of ingots as starting material by eliminating vacuum casting of uranium from the derbies. In addition to the economic gains possible through this substitution, a compact of higher purity results from the use of derbies.⁽⁷⁾

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