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DESIGN OF PRODUCTION TEST IP-280-A-FP, IRRADIATION OF ALLOYED DINGOT URANIUM FUEL ELEMENTS

INTRODUCTION

Under the provision of the previous low hydrogen dingot production test design¹, up to 25 tons/month of low hydrogen dingot fuel elements were to be fabricated for irradiation to normal variable discharge goals in C and DR Reactors. Results of this test indicated canning yields of low hydrogen dingot solid and I & E fuel elements were comparable to typical production cores fabricated from uranium ingots. However, irradiation experience has shown that both solid² and I & E low hydrogen dingot cores³ were less dimensionally stable than their ingot counterparts.

Since startup of the Weldon Spring facility, MCW has experienced difficulty in producing low hydrogen dingot uranium of satisfactory quality. It appears now that sufficient process improvements have been made to control hydrogen content and refine the grain size of dingot metal. Hydrogen content has been reduced by the pre-heating of the UF_4 charges at high temperature before triggering the bomb reduction reaction. Grain size has been reduced by alloying additions of iron and silicon.

Receipt of the alloyed, low hydrogen dingot uranium is scheduled to be initiated at the rate of 25 tons/month; provided this dingot metal meets all requirements as to grain size orientation, hydrogen content and, upon successful demonstration of the stability of this material the schedule may be increased stepwise up to 150 tons/month over a twelve-month period.

This report presents the design of a test to permit irradiation of alloyed, low hydrogen dingot uranium fuel elements, and to provide for monitoring of their performance.

OBJECTIVE

The objective of this test is to authorize irradiation of alloyed, low hydrogen dingot uranium fuel elements on a pilot scale, and to monitor their performance.

SUMMARY OF TEST

Initially, 25 tons per month of alloyed, low hydrogen dingot material will be charged for two months. Measured charges will be loaded with the initial 25 tons to monitor the stability of this material. Following a two-month delay in the monitor charging, and if the dingot meets all specifications referenced herein, routine charging of quantities up to 60 tons/month may proceed for six months and, assuming continued favorable performance, up to 150 tons/month may be accepted to complete large scale evaluation of dingot uranium, and on a continuing basis thereafter.

1. HW-48750 E, "Supplement A to PT-IP-56-A-86-MT, Evaluation of Low Hydrogen Dingot Uranium Fuel Elements", R. E. Hall. 2-11-58.
2. HW-53358 RD, "Analysis of Dimensional Distortion Data from Production Test IP-56-A", J. L. Jaech. 10-25-57, Secret.
3. HW-59944 RD, "Analysis of Data from IP-56-A-86-MT; Evaluation of Dimensional Stability Characteristics of Low Hydrogen Uranium I&E Fuel Elements", K. B. Stewart. 4-9-59, Secret.

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BASIS

Although purer and more dense than standard ingot uranium, the dingot uranium produced in the past by MCW has demonstrated poorer dimensional stability during irradiation. The instability has been manifest as warp, nearly double that of ingot which was irradiated in the same charge and by surface bumping up to 5 mils in height. Both the bumping and the warp are normally associated with large grain size, non-uniform orientation and/or residual stresses.

To improve the stability, primarily by grain size reduction, additions in the range of 150 ppm iron and 100 ppm silicon are being made to the green salt prior to reduction. The hydrogen content of the metal has been reduced by pre-heating the green salt at high temperature prior to triggering the metal reduction. Further refinements to the process include heat treatment in chloride salt bath to suppress hydrogen build-up, followed by delayed, hot-quench to improve grain structure.

The cause of extrusion defects seen in dingot metal received earlier this year⁴ has been located and eliminated by reducing the diameter of the follower block to prevent the billet surface from extruding on the surface of the bar. The alloyed, low hydrogen dingot cores are expected to demonstrate equivalent or better dimensional stability than the standard ingot cores. Receipt of up to 25 tons/month has been scheduled for the initial two months of this evaluation. After a two-month lead time, provided the dingot metal meets all specifications as recorded herein, receipts will be increased to 60 tons/month for six months and further as previously scheduled⁵. The scope of this design is to extend the irradiation of alloyed, low hydrogen dingot I & E fuel elements up to 150 tons/month. Receipts in excess of 150 tons/month will depend on satisfactory performance of metal irradiated in this test.

FABRICATION OF TEST MATERIAL

1. Components

Caps and cans are for eight-inch natural uranium OIIN size I & E cores. Component code M-1 or M-2. The components are to meet all requirements of "F" Process Specifications.

2. Cores

Cores will be eight-inch natural OIIN I & E fabricated from extruded dingot bar prepared in accordance with Material Specifications⁶ with the exception of Specification 100.2 where the iron and silicon impurities may not exceed 185 ppm and 140 ppm respectively. All dingot cores shall be beta heat treated in blank form in chloride salt.

4. J. W. Talbott, "Utilization of Dingot Uranium", Undocumented Letter to A. T. Gifford. 3-4-59, Unclassified.
5. HW-47029, "Process Specifications, Fuel Element Manufacturing Processes", Fuels Preparation Department. (Confidential)
6. HW-48444, "Material Specifications, Fuel Target and Cladding Materials", Fuels Preparation Department. (Confidential)

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3. Assembly

All fuel elements shall be fabricated in accordance with the "F" Process Specifications⁵.

4. Quality of Material

All standard quality control measures will be applied in fabrication of fuel elements.

5. Quantity of Material

Approximately 216 acceptable test elements will be required for measured charges to accompany the initial loading. These will be made up as 12 alternated test control charges for irradiation. Subsequently, one measured charge per dingot lot, composed preferably of the pieces measured under the Quality Grading Program⁷ will be required to monitor the irradiation of the bulk of the dingot metal. Approximately 25 tons per month of alloyed low hydrogen dingot will be received for two months initially. Provided the quality of this material is equivalent to that of the ingot uranium currently received, the quantity of alloyed low hydrogen dingot will be increased to 60 tons per month for a period of six months and then to 150 tons per month for a second six-month period and an acceptance thereafter, based on experience obtained during the first year of alloyed low hydrogen dingot use⁸.

COMPARISON STANDARDS

Standard control elements are required for the initial measured charges only. They will have OIIN I & E ingot uranium cores heat treated in core blank form in chloride salt. Approximately 216 acceptable standard controls are required for this test.

TESTING

Pre-Irradiation Testing and Measurements

1. All fuel elements for the initial eight measured charges and subsequent monitor charges will have warp and diameter measurements of all pieces and weight measurement of downstream 1-17 pieces recorded.
2. Identity and position of measured fuel elements will be recorded by a "series" and position number stamped on the male end of each fuel element.

IRRADIATION

Initially up to 25 tons per month for a two-month period accompanied by measured charges to monitor stability will be charged for exposure to normal variable discharge

5. HW-47029, op. cit.

7. HW-59939 A, "Design of Production Test IP-216-A-7FP, The 300 Area Program for Quality of Normal I & E Fuel Elements", W. H. Hodgson & R. E. Hall. 4-24-59. (Confidential).

8. J. W. Talbott, op. cit.

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goal. Provided the dingot cores meet all specifications referenced herein, the routine charging of alloyed dingot material in quantities up to sixty tons per month will proceed, when ready, for six months and thereafter, provided the specified quality is maintained, increase to 150 tons for an additional six months for the evaluation of the acceptability of alloyed dingot uranium as standard process material. The initial loading will be composed of approximately 400 tubes, twelve of which will consist of alternated dingot and ingot fuel elements. These twelve charges will contain pre-measured and weighed fuel elements and will be irradiated four to 400 MWD/T and eight to 800 MWD/T exposures in an old reactor. The remaining group of up to 400 charges will be charged during a two-month period to normal variable discharge goals. The subsequent irradiation of sixty tons per month will probably be performed in several old reactors. A measured charge will accompany each lot of dingot material irradiated as outlined in FT-IP-216-A⁹.

POST EXPOSURE MEASUREMENTS

1. Post exposure measurements of diameter, warp and weight changes for all pre-measured elements are required.
2. All fuel elements will be visually examined for surface conditions.
3. All measured fuel elements will be weighed to permit calculation of specific power and specific exposure.

TEST AUDIT

Notebook HW-61619 will be needed to record all laboratory data pertaining to the test. The extended duration of the test makes it impractical to attempt the use of one notebook for the entire test. Therefore, identity of the notebook containing 100 Area data will be given in the final report for this test. Any unusual incidents, whether or not they seem important at the time, are to be recorded in the notebook.

The appendix of this report contains a list of items to be used as a guide for preparation of the notebook.

TEST LIMITATIONS AND HAZARDS

No unusual test limitations or hazards are anticipated.

Reactor Fuels
Process and Reactor Development
Irradiation Processing Department

Process Engineering
Engineering Section
Fuels Preparation Department

9. HW-58271, "Production Test IP-216-A, Evaluation of Performance of Normal Production I & E Fuel Elements", R. E. Hall & R. R. Bloomstrand. 1-6-59, Secret.

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APPENDIX

DATA TO BE RECORDED IN PRODUCTION TEST NOTEBOOK

I. Fuel Element Core

A. Chemical Composition

B. Casting Data

1. Site
2. DIngot or ingot
3. Mold Size
4. Mold type (temperature distribution)
5. Mold liner
6. Pickled or unpickled derbies

C. Fabrication Data

1. Site
2. Type of fabrication (rolled, extruded, etc.)
3. Attendant conditions

D. Heat Treatment

1. Site
2. Form of material when treated
3. Attendant conditions

E. Finishing Data (Machined or Centerless Ground)

F. Finished Dimensions (Pre-assembly)

G. Properties

1. Orientation data
2. Tensile data
3. Other significant properties

H. Pre-assembly Treatment (Including Inspection)

II. Can

A. Chemical Composition

B. Fabrication Data

1. Site
2. Type of fabrication
3. Attendant conditions

C. Heat Treatment

D. Finished Dimensions (Pre-assembly)

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E. Properties

1. Hardness
2. Tensile data
3. Other

F. Pre-assembly Treatment (Including Inspection)

III. Assembly Process

- A. Process Used
- B. Brief Explanation of Process
- C. Attendant Conditions

IV. Post Assembly Treatment

- A. Protective Coating
- B. Autoclaving
- C. Other Treatment
- D. Inspection

V. Pre-irradiation Examination

- A. Dimensions
- B. Warp

VI. Irradiation

- A. Coolant Temperature
 1. Inlet
 2. Outlet
- B. Panellit and Crossheader Pressures
- C. Number of Shutdowns (Controlled and Scram)
- D. Other

VII. Post Irradiation Examination

- A. Visual
- B. Warp (And Other Profilometer Data)
- C. Fracture Data
- D. Other

VIII. Log. Running account with dates recording the progress of the PT, unusual incidents (such as a slight change in process during assembly), and other deviations whether

**DATE
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8/12/94

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