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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

[redacted]

DATE June 29, 1959

[redacted]

TITLE

DESIGN OF PRODUCTION TEST IP-262-A-11-FP, EVALUATION OF PROJECTION FUEL ELEMENTS FOR USE IN RIBBED PROCESS TUBES - DEMONSTRATION LOADING

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DESIGN OF PRODUCTION TEST IP-262-A-11-FP, EVALUATION OF PROJECTION FUEL ELEMENTS FOR USE IN RIBBED PROCESS TUBES - DEMONSTRATION LOADING

June 29, 1959

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DESIGN OF PRODUCTION TEST IP-262-A-11-FP, EVALUATION OF PROJECTION FUEL ELEMENTS FOR USE IN RIBBED PROCESS TUBES - DEMONSTRATION LOADING

INTRODUCTION

For several years, a major category of fuel element failures has been the side corrosion type, characterized by localized accelerated fuel element jacket corrosion. Since it has been demonstrated[1] that misalignment of fuel elements in a process tube will produce flow patterns and accelerated corrosion, termed "hot-spots", failure to align the fuel elements in process tubes is considered a contributing factor in the production of side corrosion failures.[2] Attempts have been made to prevent misalignment by use of tru-line features on the ends of the elements. These have been only partially successful. Concurrently, testing of X-8001 nickel aluminum alloy for fuel element jacket material has shown that this alloy is not completely successful in preventing corrosion failures. Since misalignment is apparently a "primary" cause of hot-spot corrosion, the proposal has been made to attach projections to the side of fuel elements to assure alignment during irradiation.

Preliminary testing of both self-supporting and "bumper"* fuel elements is underway. Data on the self-supporting fuel elements have demonstrated that the bridge-rail projections have sufficient support strength, do not of themselves create a corrosion problem and in actuality probably eliminate any hot-spot areas. Although one tube of bumper fuel elements in KW Reactor[3] has been discharged, data are not as yet available.

Potentially, the most severe corrosion conditions exist during the summer months when reactor inlet temperatures are high. It is desirable then, provided bumper fuel elements limit hot-spot corrosion, to evaluate the bumper concept for large scale use possibly by the summer of 1960. To accomplish this, a demonstration loading of the bumper type fuel elements must be underway by about July, 1959. The purpose of this report is to present the design of a test to evaluate the fabrication process and irradiation performance of fuel elements having projections, which may prevent misalignment in ribbed process tubes and meet the aforementioned goals.

OBJECTIVE

The objective of this test is to demonstrate the feasibility of projection fuel elements for use in existing ribbed process tubes and to demonstrate the reduction in rupture rates or hot-spot incidence so achieved.

TEST SUMMARY

To demonstrate the bumper fuel element concept, this test will incorporate two parts; a) irradiation of 20 columns of bumper fuel elements and 20 columns of controls per reactor in B,D,DR,F, and H Reactors to ~150 per cent of the normal exposure goals, and

1. HW-55789, "Final Report on PT-105-634-A, In-File Cocked Slug Tests," P. B. McCarthy and F. W. VanWormer, 6-2-58. (Secret)

2. HW-59168, "A Postulated Hot-Spot Failure Mechanism," E. C. Wood, 2-9-59. (Secret)

3. HW-56525 C, "Production Test IP-183-A-98-FP, Evaluation Of Projection Fuel Elements For Use In K Process Tubes," R. E. Hall, 11-5-58. (Secret)

*Bumper fuel elements have bridge-rail type ribs attached to prevent misalignment in tubes having standard height ribs.

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b) irradiation of four columns each of enriched (0.94% U-235) I & E fuel elements with bumpers and four columns of enriched (0.94% U-235) I & E fuel elements without bumpers until two ruptures are sustained in each or until one type demonstrates a significant improvement.

BASIS

One of the three major categories of HAPO fuel element failures is the side-corrosion type of failure. Past experience has indicated that uniform corrosion, as calculated with existing techniques, could not account for the majority of these failures; but rather, some rapid corrosive mechanism must be assumed. It has been demonstrated previously[4] that misalignment of fuel elements in a process tube will produce a hot-spot type flow pattern and area of heavy corrosion. Calculations by Wood[5] indicate that temperatures sufficiently high to produce a steam jacket on the fuel element can be obtained with local annulus clearance reductions to a value of less than 15 mils. Steam jacketing of an area of a fuel element surface could permit further surface temperature increases, sufficient to initiate accelerated attack with relatively short incubation periods, and presumably failure, if imperfect Al-Si bonds are exposed. Even without encountering the steam jacketing condition, sufficiently high surface temperatures may be reached to give more rapid than predicted corrosion rates, however, this effect is expected to be small unless several elements are misaligned as a group.

It has been proposed that projections be attached to the side of the fuel element to assure alignment. It is possible to prepare, on a production scale, a projection element which will guarantee an annular clearance of more than 15 mils. This element, termed a "bumper" fuel element, is designed to be supported on the ribs of the process tube, oriented such that the projections reduce the possibility of misalignment.

Testing to date has been confined to the self-supported type of fuel element primarily; wherein it has been demonstrated that the supports have sufficient strength, do not of themselves create a corrosion problem and in actuality, most likely eliminate any hot-spot areas. Currently, a preliminary test loading of bumper fuel elements is under irradiation in KW Reactor. This test is designed to indicate any potential process or discharge problems. It also is designed to prove under current operating conditions, the incidence of hot-spots is, in fact, reduced or eliminated. This test is scheduled for discharge about July, 1959.

In order that fuel elements of the bumper type may be available by the summer of 1960, a demonstration loading of significant numbers of columns of these elements must be initiated by about July, 1959. Even though the test in KW Reactor will not be out at this time, preliminary discharging will have been accomplished and if unforeseen problems are evidenced, this test may be cancelled. The bulk of the bumper test in KW will be discharged during August, 1959 (or possibly the end of July) and negative results from this test may be the basis for discharge of the individual reactor demonstration loads, as well as the high exposure test.

To insure that a significant number of columns for the demonstration loading will be irradiated, and since charge machines will not be available, it is desirable to put a portion of this loading into each of the older reactors. The high exposure test is scheduled to be irradiated in F Reactor, since equivalent outage time losses are

4. Op. Cit. HW-55789.

5. Op. Cit. HW-59168.

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currently scheduled under other testing programs for the other older reactors.

PROCEDURE

A. Fabrication of Test Material

1. Fuel Element - Fuel elements for this test will be eight-inch natural OIIN cores clad in X-8001 alloy components (lot code LD)[6], and six-inch enriched (0.94% U-235) OIIE cores clad in C-64 alloy components (lot code HC).[6]

2. Assembly - All fuel elements shall be fabricated in accordance with the 300 Area Process Specifications.[7] Each of the bumper elements shall have eight collapsible-type bridge-rail supports spot welded to the jacket, four approximately one-inch from each end and spaced at 90° intervals around the element. The ribs will be in-line to facilitate charging between the ribs. Rib heights and effective diameters are listed below:

	Fuel Element OD	Rib Height	Effective OD
Natural U Bumper Element	1.445"	0.040"	1.525"
Enriched U Bumper Element	1.440"	0.0425"	1.525"

3. Quality of Material - All standard quality control measures will be applied in the fabrication of fuel elements. Specifications for grading the quality of projection welds will be established by Process Engineering.

4. Quantity of Material - Approximately 3550 acceptable OIIN I & E fuel elements with bumpers attached are required for this test. These 3550 fuel elements will be divided equally among the 5 older reactors to make up the 20 charges of test elements for each reactor.

   In addition, a total of 320 acceptable OIIE I & E fuel elements are required for the high exposure test. Half of this total (160) are to have bumpers attached.

COMPARISON STANDARDS

A total of 3550 OIIN I & E control fuel elements will be required for the 100 tube demonstration loading, and 160 OIIE controls for the enriched portion of the test. All of these controls will be standard production I & E fuel elements assembled wihtout bumpers.

6. LD designates an 8" x 1.356" x 0.416" core clad in X-8001 alloy components with an 0.040" thick can wall.

   HC designates a 6" x 1.351" x 0.416" core clad in C-64 alloy components with an 0.040" thick can wall.

7. HW-47029, "Process Specifications, Fuel Element Manufacturing Processes, Fuels Preparation Department." (Confidential)

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TESTING

Pre-Irradiation Testing and Measurements

1. Pre-exposure measurements of warp and external diameter are required for all fuel elements to be utilized in the high exposure test.

2. Weight shall be measured and recorded for alternate pieces 1-17 in all charges, test and control.

3. All fuel elements for this test will be assembled in charges and stamped with series and sequence numbers.

IRRADIATION

The high exposure test which includes four columns of OIIE, I & E enriched (0.94% U-235) fuel elements with bumpers and four columns of OIIE, I & E enriched (0.94% U-235) fuel elements without bumpers, is scheduled to be irradiated in F Reactor until two ruptures are sustained in the control material and thereafter until a factor of improvement of ~20 is demonstrated. The entire high exposure test is to be discharged if two ruptures occur in the bumper columns charged under the high exposure portion of this test, or if one occurs prior to both control failures.

POST EXPOSURE MEASUREMENTS

1. All fuel elements from the high exposure test and 10 columns of test and control pieces in the demonstration loading from each reactor will be visually inspected for surface conditions.

2. Post exposure measurements of weight, warp and diameter are required from all fuel elements from the high exposure test. Warp measurements are required from 10 columns each of test and control pieces in the demonstration loading from each reactor.

3. All measured fuel elements will be weaseled to determine specific exposure and specific power.

4. Selected elements may be examined further in the radiometallurgy laboratory.

TEST AUDIT

Notebook HW-60444 is to be used to record all data pertaining to this production test. Any unusual incidents, whether or not they seem important at the time, are to be recorded in the notebook. The appendix to this report is a guide for preparation of the notebook.

TEST LIMITATIONS AND HAZARDS

Hazards peculiar to this test are primarily associated with the presence of the bumpers on the fuel surface. These arise from the fact that the bumpers do restrict fuel element displacement in the process tube so that it is conceivable that these elements could

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stick tighter after rupture than do smooth elements, although rib collapsibility should reduce the problems associated with this. They also could jam during charging or discharging; however, laboratory testing to evaluate this problem indicated no problems. Should the results of the KW Reactor test prove this concept to not be feasible, this test will be cancelled.

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APPENDIX

DATA TO BE RECORDED IN PRODUCTION TEST NOTEBOOK

I. A. Fuel Element Core Lot Numbers

B. Finished Dimensions (Pre-assembly)

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

D. Pre-assembly treatment (including inspection)

II. A. Can - Lot Numbers

B. Finished Dimensions (Pre-assembly)

C. 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
C. Weight

VI. Irradiation

A. Coolant Temperature
1. Inlet
2. Outlet

B. Panellit and crossheader pressures
C. Number of shutdowns (controlled and scram)
D. Other

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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 or not they seem pertinent at the time of occurrence.

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