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DESIGN OF PRODUCTION TEST IP-272-A-FP, PILOT TEST OF SELF-SUPPORTED FUEL ELEMENTS IN RIBLESS ZIRCONIUM PROCESS TUBES

W. H. Hodgson

and

R. E. Hall

[redacted]

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DESIGN OF PRODUCTION TEST IP-272-A-FP, PILOT TEST OF SELF-SUPPORTED FUEL ELEMENTS IN RIBLESS ZIRCONIUM PROCESS TUBES

INTRODUCTION

Development of projections for self-supported fuel elements has indicated that it is feasible to attach collapsible supports of the bridge-rail type either by resistance spot welding or ultrasonic welding techniques. Irradiation testing of both solid and I & E fuel elements in the B Reactor ribless process tube facility (13 tubes) has progressed without incidence of hot spots. Comparison of 12 tubes of self-supported I & E fuel elements discharged at a variable goal of 800 MWD/T with standard I & E fuel elements chosen at random from metal that was irradiated in B Reactor at the same time, shows the incidence of hot spots was reduced by a factor of 13 at the 95% confidence level.

Utilization of zircalloy tubes is expected to eliminate tube replacement problems and permit the use of larger diameter fuel elements or greater coolant flow since the greater strength of zircalloy will permit the use of thinner tubes. It appears expedient on the basis of the reduced incidence of hot spot type corrosion and the potential advantages of the larger fuel core size or the alternate greater coolant flow as a result of larger tube I.D., to evaluate these concepts on a pilot scale. This report presents the design of a pilot test for this evaluation.

OBJECTIVE

The objective of this test is to authorize irradiation of pilot-scale quantities of self-supported fuel elements in ribless zirconium process tubes to confirm fuel geometry, to test on a pilot scale the self-supported fuel element and the zirconium process tube concepts, and to permit development of reactor equipment capable of handling self-supported fuel elements.

SUMMARY OF TESTS

Up to one hundred ribless zirconium process tubes are to be installed in C Reactor, and necessary reactor equipment modifications will be made to permit routine charging of these tubes with self-supported natural uranium fuel elements. This test authorizes continued loading of these tubes until authorized by reactor process standards or until it is deemed impractical to convert C Reactor to this geometry.

DISCUSSION

Previous testing in support of this test has been accomplished under two programs; a) Projection Fuel Testing, and b) Zirconium Tube Development. These are summarized

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below: (Economics aspects are discussed in references.[1-4])

a) Projection Fuel Testing[1,2]

Development of projections for self-supported fuel elements has indicated that it is feasible to attach a collapsible support of the bridge-rail type either by electrically spot welding or by ultrasonically bonding the support to the fuel element after fabrication. Irradiation testing[1] of solid fuel elements in the B Reactor ribless tube facility at annular specific powers up to approximately 60 KW/ft (equivalent to approximately 85 KW/ft for I & E elements having an annular heat flux of 60 KW/ft) has indicated that within the test limitations a reduction in hot spot incidence did occur, even though the incidence on the control material was also lower than predicted (one observed). No hot-spot flow patterns were observed on the self-supported elements.

During the first quarter of CY 1959, irradiations in the test facility were converted to I & E fuel elements to be compatible with the remainder of the reactor and testing has continued. To date, nineteen columns of self-supported I & F material have been discharged from the ribless tubes at exposures up to 870 MWD/T. Visual examination of these elements has revealed no hot-spot flow patterns or areas of excessive corrosion.

To establish the incidence of hot spots on the fuel elements irradiated in production columns, three buckets, approximately 750 elements, were chosen at random for visual examination. They exhibited a hot-spot incidence of about 7.5%. A comparison of these data with the self-supported fuel data has indicated that for both the solid and I & E fuel element testing, hot-spot incidence is reduced by a factor of about four with a 99% confidence level. This factor of reduction is 13 for the I & E fuel and 7 for the solid fuel at the 95% levels. (The differences being in sample size.) Based on these data, it is concluded that further testing is justified on a pilot scale to observe these differences in actual fuel performance.

b) Zirconium Tube Testing

Justification for the use of the more expensive zirconium process tube lies in the high strength and corrosion resistance of the metal itself. For all practical purposes, the zirconium or zircalloy tube has an infinite life expectancy.

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1. HW-50991 A, "PT-IP-84-A, Evaluation of Slugs Having Projections for Use in Ribless Process Tubes." R. E. Hall, 3-12-58.

2. HW-50991 B, "PT-IP-84-A, Supplement A, Evaluation of Slugs Having Projections for Use in Ribless Process Tubes." R. E. Hall, 9-29-58.

3. HW-59756 C, "PT-IP-247-A-8-FP, Irradiation of 1.47% Enriched Self-Supported I & E Fuel Elements in Ribless Process Tubes." R. E. Hall, to be issued.

4. HW-59621 A RD, "K Pile Production Expansion and Fuel Element Limitations." L. W. Lang, 3-20-59.

   HW-59621 A RD, "OII Pile Production Expansion and Fuel Element Limitations." L. W. Lang, 3-20-59.

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Thus, once installed, the tube need not be replaced for the remaining life of the reactor except to replace tubes damaged by ruptured fuel elements or mechanical damage to end fittings.

To date, only a limited number of zircalloy tubes have been installed in HAPO reactors. Production Test IP-143-A, Supplement A[5] authorized limited installations of ribbed zircalloy tubes in C Reactor. Under this test, 3 tubes were installed. One tube was removed after a short service due to a cracked Vanstone flange. Subsequent investigation[6] indicated that the Vanstone flange had not been adequately formed upon installation, although all testing had indicated a sound flange. The two remaining tubes performed satisfactorily until one was removed subsequent to a fuel failure.

The initial study by Lang[7] discussed the ecomonic incentives for conversion to zircalloy process tubes. The prime incentives are 1) elimination of tube replacement and associated lost production, and 2) an increase in either conversion ratio (by using larger fuel elements) or power level (by increase in coolant flow) which would be possible with the larger I.D. zircalloy tube. The original study postulated gradual replacement on a normal replacement schedule. Subsequent studies by Lang have indicated a greater desirability of replacement on "single-shot" basis. In either case, the payback period is of the order of 1.5 to 2.5 years on a 50-3 analysis basis.

However, because the zircalloy tube has essentially an infinite life, a number of possible methods of increased production must be integrated into one expansion program. As part of the overall program, this test is to be conducted to provide information as to the feasibility and advisability of the smooth bore tube self-supported fuel element concept.

TEST DETAILS

1. Preparation of Fuel Elements

a) Components - The components for the original two columns will be prepared under the direction of engineering personnel, FPD, from KIN I & E cans and KIIN I & E spires. Subsequent charges will utilize CIVN components (1.500" O.D. x .380" I.D.). Component Code: U-2

b) Cores - For the initial columns, the cores will be standard eight-inch

5. HW-54964, "PT-143-A, Evaluation of In-Reactor Performance of Zircalloy Process Tubes." D. H. Curtiss and D. F. Bolender, 5-5-58.

6. HW-54866, "PT-IP-143-A, Supplement A, Evaluation of In-Reactor Performance of Zircalloy Process Tubes." D. H. Curtiss and D. F. Bolender, 5-5-58.

   Letter, "Zirconium Tube Program - Zircalloy-3 Process Tube 3681-C - Flange Leak." W. M. Harty from R. M. Smithers, 3-16-59. (Unclassified)

7. HW-59092, "The Economics of Zirconium Process Tubes." L. W. Lang, 12-20-57.

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KIIN I & E size. Thereafter, cores will be CIVN I & E (8.325 x 1.410 O.D. x .485 I.D.). Core Code: T

c) Assembly - All fuel elements shall be fabricated in accordance with the Fuels Preparation Process Specifications.[8]

Each of the self-supported elements shall have eight X-8001 alloy colapsible-type bridge-rail supports attached to the jacket, four approximately one-inch from each end and spaced at 90° intervals around the element. The ribs will be attached either by electrical resistance spot-welds or by ultrasonically formed bonds, and shall be in accordance with drawing H-3-7950. All fuel elements will have the following nominal dimensions:

	Finished	Core
Outside Diameter	1.500"	1.410"
Inside Diameter	0.380"	0.485"
Length	8.965"	8.325"
Effective Rib Diameter	1.670"	

d) 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 and technical assistance for the welding process will be supplied by Process Engineering, FPD.

e) Quantity of Material - Approximately 368 acceptable, revised self-supported KIIN I & E cores (8.965" x 1.500" x 0.380) will be required for the initial two measured charges. Approximately one month later, 272 acceptable self-supported fuel elements will be required for 8 measured charges. Subsequently, 170 acceptable measured and 800 unmeasured acceptable self-supported CIVN fuel elements are required for the 30-tube charge scheduled for November. In December and January, up to 970 acceptable self-supported CIVN fuel elements will be required per month to charge the ribless tubes scheduled for installation during that period. Thereafter, approximately 970 acceptable self-supported fuel elements, including 170 measured pieces will be required per month as replacements as long as the zircalloy tubes are in use or until the test is terminated.

f) Comparison Standards - When required, adjacent columns in ribbed process tubes will be utilized for comparison standards.

g) Dummy Pieces - Downstream dummies may be either expendable perforated dummies with attached supports similar to those on the fuel elements or

8. HW-50991 A, "PT-IP-84-A, Evaluation of Slugs Having Projections for Use in Ribless Process Tubes." R. E. Hall, 3-12-58.

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those fabricated by extrusion as shown in drawing SK-1-3688. The latter will be used if they are available in time. The former will be fabricated by FPD if required.

2. Schedule

For planning and scheduling purposes, the below outlined tentative schedule is provided; however, it is understood that other factors such as associated equipment schedules, reactor outage dates, and fuel element availability may modify the program appreciably. (This assumes tube delivery during August or September.)

Approximate Date	Test	Remarks
Nov. 1, 1959	Charge two short charges into two ribless zirconium process tubes to check hydraulics. Columns to be equipped with thermocouple trains.	Columns to be hand charged since charge machine will not be ready.
Jan. 1, 1959	Install and charge eight additional ribless zirconium tubes with full length charge of CIVN elements with thermocouple probe trains to obtain basis for operating limits for demonstration loading.	Columns will require hand charging.
Feb. 1, 1959	Install and charge thirty ribless zirconium process tubes as first portion of demonstration test.	
Mar. 1, 1960	Install and charge the remaining ribless zirconium tubes as the final portion of the ribless tube demonstration.	
Apr. 1, 1960 and thereafter	Provide for replacement charging of the facility at a rate approximating 30 columns per month as long as the zirconium tubes are in use or until the test is terminated.	

3. Duration

This test shall continue until full-scale reactor use of this material is initiated or until the test results indicate that insufficient justification for this program exists, and thereafter until the ribless tubes have been removed from the reactor. Periodic status reports reflecting the progress of the program will be prepared when necessary.

4. Monitor Columns

a) The preliminary loading of 10 columns shall be weighed and measured to premit evaluation of corrosion and dimensional stability of the CIVN geometry elements.

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These columns shall be thirty-two pieces in length and shall each have two additional pieces for use as spares. Each piece shall be numbered by piece and column in the normal order. Two of these columns shall be used as shortened columns for the initial testing and will be fabricated from old KIN-size cans and KIIN-size spires. The remainder will be fabricated from components obtained for this test.

b) Five monitor columns per month shall be charged for corrosion rate determinations and at the discretion of the test author and the concurrence of the Manager C Processing Sub-Section, may be equipped with thermocouple probes for refinement of operating limits and investigations into currently unforeseen problem areas.

5. Discharging

a) All monitor columns charged as part of this test shall be discharged and picked up separately and held for examination in the C Metal Examination Facility.

b) The remainder of the columns may be discharged with the normal discharge and handled as regular metal, or separately as dictated by experiences.

c) After irradiation all monitor charges shall be visually examined, weighed, and measured to observe irradiation changes. Hot-spot flow patterns and areas around the supports shall be examined in detail. If necessary, destructive examination of several pieces will be scheduled in the radio-metallurgical laboratory.

TEST HAZARDS

Hazards peculiar to this test fall into two categories, i.e., failures of fuel element cores and failure of the concept. Since this is a fairly new concept which has only been tried in B Reactor with roughly 25-50 charges of metal, and since the geometry of the elements was chosen as a result of calculations which were extrapolations of empirical data, there is a finite probability of encountering fuel failure difficulties. Every attempt is to be made to avoid these, however, through laboratory checks of the hydraulics, and through a cautious loading schedule. Since this element will be slightly larger (0.040") than any previously used, it is possible, but not likely, that a threshold has been crossed and failures will be encountered. This is not deemed likely however.

The other possibility is that the entire concept may be deemed not feasible. This could arise either from a cancellation of the zirconium tube program due to lack of sufficient economic justification and subsequent decisions to use ribbed aluminum tubes of the current type, or if metal handling procedures become sufficiently complex as to make self-supported elements unattractive. Previous economic studies indicate sufficiently short payout periods to make the zirconium tube program attractive and use of the cheaper tube (ribless) makes the payout period even shorter. As in any such study, the choice of assumptions could affect the result; however, it is unlikely that other reasonable assumptions will change the result in this study. If it should be decided to use ribless aluminum tubes rather than zirconium, preliminary tube wear and corrosion data are being obtained at B Reactor where the columns were charged into 63S aluminum tubes.

It would, therefore, appear that no extreme risk is involved in this testing program with regards to safety; and no production losses other than those normally involved in any fuel development program can be expected.

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TEST AUDIT

Notebook HW-61669 will be used to record all fabrication 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.

Reactor Fuels
Process and Reactor Development
Irradiation Processing Department

Process Engineering
Engineering Section
Fuels Preparation Department

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APPENDIX

DATA TO BE RECORDED IN PRODUCTION TEST NOTEBOOK

I. Fuel Element Core

A. Lot Numbers
B. Finished Dimensions (Pre-Assembly)

II. Can

A. Alloy Type and 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. Process For Attaching Projections
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 or not they seem pertinent at the time of occurrence.

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