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PRODUCTION TEST IF-247-A-8-FP
IRRADIATION OF 1.47% ENRICHED SELF-SUPPORTED I & E FUEL ELEMENTS IN RIBBLESS PROCESS TUBES

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July 29, 1959

PRODUCTION TEST IP-247-A-8-FP
IRRADIATION OF 1.47% ENRICHED SELF-SUPPORTED I AND E
FUEL ELEMENTS IN RIBLESS PROCESS TUBES

OBJECTIVE

The objective of this test is to irradiate self-supported fuel elements under conditions of severity comparable to those expected for future loadings of this geometry, to attempt to determine the resistance to corrosion of cooled cladding, the effect of supports on cladding corrosion and coolant flow patterns, and the relative resistance to "hot-spot" type attack and rupture of "projection" fuel elements and rib supported elements.

TEST SUMMARY

This test will authorize irradiation of four columns of self-supported and four columns of rib-supported I and E, 1.47% enriched fuel elements until two ruptures are sustained in each group or until one type demonstrates a significant factor of improvement in rupture resistance over the other.

BASIS AND JUSTIFICATION

Preliminary testing⁽¹⁾ of both solid and OIIN I and E self-supported fuel elements in the self-supported fuel element demonstration facility in 105-B has indicated that the concept of a self-supported fuel element in a ribless process tube is feasible under current operating conditions. Specifically, it has shown that the bridge-rail ribs provide adequate support, do not severely obstruct flow channels, and do not of themselves create an area of rapid corrosion. Nine columns of solid self-supported and thirteen of I and E self-supported fuel elements have been discharged to date without a single area of evident rapid corrosion. In summary, nothing has been found as yet to indicate that the self-supported fuel element is not feasible.

Prior to removal of the ribless process tubes, it is desirable to attempt to pilot the same factors IP-84-A⁽¹⁾ did except at conditions under which I and E fuel will probably operate in the future. It is necessary that this pilot loading be accomplished on as rapid a schedule as possible in order that this program may be adequately integrated with the zirconium tube replacement schedule for which tubes are currently being procured.

The method chosen to pilot these conditions involves the irradiation of enriched (1.47% U-235) fuel elements to attain high specific power, oversize fuel elements to attain high annular coolant temperatures with respect to the interior coolant channel, and short charging to control the maximum corrosion rate on the test material, to compare with fuel elements having surface conditions as similar as possible in a ribbed process tube. The control elements will also be enriched to 1.47% U-235 and will also be short charged but will be of current OIIN geometries. Irradiation must be until two ruptures are sustained in the control material and thereafter until sufficient exposures have been accumulated on the test material to demonstrate a significant factor of improvement.

1) HW-50991-A, "Production Test IP-84-A, Evaluation of Slugs Having Projections For Use In Ribless Process Tubes", R. E. Hall, March 12, 1958.

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TEST DETAILS

1. A) Fuel Elements - Test

- a) Cores - All cores for this test shall be 1.47% enriched and shall meet all HAP0 specifications as to purity and fabrication. Core dimensions shall be 1.370" x 0.481" x 7.00".
- b) Cladding - Can and spire components shall be X-8001 alloy aluminum of the CIIN (1.460 x 0.375) dimension reduced in length so as to fit a 7" length core. Canned fuel dimensions shall be 1.460" x 0.375" x 7.640" nominally.
- c) Supports - The bridge rail supports shall be of the same type used previously⁽¹⁾ except that the height shall be reduced so as to retain the effective rib outside diameter of 1.600 inch. Eight ribs shall be attached, four to each end at 90° spacing, using spot welding techniques.

B) Fuel Elements - Control

- a) Cores - All cores for the control material shall be 1.47% enriched and shall meet all HAP0 specifications as to purity and fabrication. Core dimensions shall be 1.356" and 0.416" x 7.000" nominally.
- b) Cladding - Can and spire components shall be X-8001 alloy aluminum of the OIIN (1.445 x 0.310) dimension reduced in length so as to fit a 7 inch length core. Canned fuel dimensions shall be 1.445" x 0.310" x 7.640" nominally.
- C) Testing - All elements accepted for reactor charging must pass the normal quality control specifications for CIIN and OIIN fuel elements in process at the time this test is prepared.
- D) Measurements - Preirradiation measurements of weight, diameter and warp shall be recorded for all pieces in this test. In addition interior probolog measurements of canwall thickness shall also be made.
- E) Quantity - Four charges of 20 pieces each plus 8 spares (total 88 pieces) will be required for each of the test and control groups.

2. Irradiation

- A) Charging - Four charges of 20 pieces each shall be charged in order into ribless process channels chosen by the assigned process engineer and physicist as specified in the appendix. Sufficient solid dummies shall be inserted in the downstream dummy train to adjust the tube flow to 50 gpm. At least two perforated dummies shall separate the solid and I and E portions of this tube loading. (See appendix).

The four charges of control material shall be charged into 4 tubes having corrosion index less than 5 (MR 55 or greater), located identically with the test material with respect to the reactor centerline. Locations in the reactor should be such as to have all control material at least 4 lattice units from any other enriched columns.

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TEST DETAILS (cont'd)

- B) Irradiation - During irradiation, daily temperature and flow data shall be recorded for each column. Based on these data, the loading pattern may be modified to either produce a higher power or surface temperature by adding one to three pieces upstream or lower surface conditions by removing downstream solids in order that the desired operating conditions may be achieved. These data shall also be utilized to calculate uniform corrosion.
- C) Discharge - Each column shall be discharged and picked up special for post irradiation examination. (See Process Standard H-020).

This test may be discharged when any of the following criteria have been met:

- 1) Two ruptures have been sustained in the control material and sufficient exposure has been accumulated on the test material to indicate a factor of improved rupture resistance of 20 with a 95% confidence.
  - 2) Should one failure occur in the test material prior to the second failure in the control material, the test may be discharged.
  - 3) After two failures in either group, the remaining two columns from that group may be discharged.
  - 4) When calculated uniform corrosion is sufficient to remove the aluminum cladding, exposing AlSi, as calculated without the normal conservatism, the individual column may be discharged. This is indicated in the appendix as an upper limit to the test.
- D) Operating Conditions - Predicted and maximum operating conditions calculated for the eight columns of this test are tabulated in the appendix along with the detailed loading pattern and target exposure.
- E) Rupture Potential (2)(3) Rupture potential for the test columns has been calculated to be 8 - 40 times that of normal OIIN operating under current conditions. Based on this, failure is predicted in one of these columns in from 30 to 70 operating days. The uncertainty in these calculations is large, however, and factors of improvement based on comparison of actual and "predicted" rupture performance are not accurate enough for purposes of fuel evaluation. This test will therefore be evaluated by use of control material.

3. Post Irradiation Examination

- A) All fuel elements irradiated as part of this test shall be visually examined and weaseled; and shall have weight losses, diameter growth and warp recorded. Ribs shall then be removed from a few chosen elements and canwall thickness determined non-destructively. Two chosen elements shall be examined destructively in the radiometallurgy laboratory to check canwall profiles. Internal canwall reduction shall also be measured.

- 2) "Enriched Self-Supported Test - B Reactor", R. R. Bloomstrand, April 15, 1959. Confidential-Undocumented.
- 3) "Enriched Self-Supported Test - B Reactor (II)", R. R. Bloomstrand, May 4, 1959, Confidential-Undocumented.

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4. Costs

- A) All incremental costs incurred as a direct result of this test may be charged to XXXX-532C-XXX.04.
- B) Outage time losses due to this test will be primarily associated with rupture removal. Should all four ruptures authorized by this test be sustained, outage time losses could be as high as 100 hours of production (assumed 25 hours/rupture), however both the test and the control material are significantly more rupture prone in the interior coolant channel (as are all I and E fuel elements) and if failure occurs there, the rupture removal time could be materially reduced. Should only a portion of the authorized ruptures occur prior to discharge of the test, a proportionate reduction in outage costs would probably result.
- C) To decrease these costs, several steps are being taken to facilitate rupture removal, these include:
- 1) A transfer cask capable of transferring self-supported elements is being designed.
  - 2) A water-cooled push-pole is being adapted so that it will be unnecessary to remove coolant even during pushing operations. Should water flow be removed inadvertently or should the tube rupture, this push-pole will be capable of supplying helium gas as a coolant.
  - 3) A stronger rear face dummy gunbarrel is being fabricated to assure breakage of the stronger ribless 62-S alloy tubes.
  - 4) Some production loss may also occur as a result of these columns causing surrounding columns to approach their operating limits. If this occurs the surrounding columns may be discharged at a lower goal or replaced with short columns at the discretion of the assigned engineer.

HAZARDS

Should a rupture occur in the fuel operating under these conditions, difficulties may be similar to those experienced with the first I and E fuel failure at C Reactor. (4) In this case the element could not be removed from the process piping, and higher than normal rear face readings were encountered. Notwithstanding this potential, incentives for the self-supported fuel program are so great as to far outweigh these problems. It will be absolutely necessary to determine failure type and operating problems expected under forecasted conditions.

Calculations (5) indicate that the test is safe from heat transfer and hydraulic aspects, including sub-cooled burnout, under the maximum (worst case) operating conditions predicted.

4) HW-430 78 C, "Production Test IP-I A Evaluation of I and E Slugs Operating at High Specific Powers", F. W. Van Worman, September 13, 1956.

5) Personal Communication, P. A. Carlson, May 30, 1959.

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RESPONSIBILITIES

Fuels Preparation Department

Manufacturing Operation

The Manufacturing Operation shall be responsible for canning all pieces by the "F" Process, for normal quality control, and for pre-irradiation measurements and marking.

Engineering Operation

The Engineering Operation shall be responsible for liaison in the 300 Area portion of this test and for providing technical assistance.

Irradiation Processing Department

Research and Engineering Operation

Process Technology Operation shall be responsible for assistance in scheduling, assistance in charging of the test, assistance in choice of the test channels, and for forwarding of operating data to the author, and for specification of operating limits.

Process and Reactor Development Operation shall be responsible for coordination of the test, data analysis, reporting of irradiation experiences, and for recommending column modifications and discharge.

Operational Physics Operation shall be responsible for assistance in choice of test channels and for modification of surrounding charges.

Component Testing Operation shall be responsible for obtaining post-irradiation examination data, and interior channel cladding thickness.

B-C Reactor Operation

B Processing Operation will be responsible for planning, scheduling, the operational safety, and production continuity of the reactor, and for collection of routine operating data for the test.

Reactor Fuels Unit
Process and Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

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APPENDIX

1. Operating Conditions*

	TEST		CONTROL	
	Maximum	Probable	Maximum	Probable
a) Surrounding Tube Power	1100 KW	1000 KW	1100 KW	1000 KW
b) Test Tube Power	1145 KW	1040 KW	1145 KW	1040 KW
c) Maximum Specific Power	100 KW/ft	91 KW/ft	100 KW/ft	91 KW/ft
d) Tube Flow (Adjusted)	50 gpm	50 gpm	50 gpm	50 gpm
e) Assumed Inlet Temperature	15° C	15° C	15° C	15° C
f) Heat Split to Annulus	0.68	0.68	0.712	0.712
g) Flow Split to Annulus	0.57	0.57	0.734	0.734
h) Maximum Surface Temperature				
Annulus	150° C	139° C	148° C	139° C
Hole	110° C	104° C	138° C	123° C
i) Maximum Corrosion Rate -				
Annulus	18 mil/yr	9 mil/yr	17 mil/yr	9 mil/yr
Hole	5 mil/yr	4 mil/yr	21 mil/yr	12 mil/yr
j) Assumed R Annulus	1.20	1.30	1.29	1.29

2. Loading Pattern - Rear to Front

- 14 - 8" Aluminum Perforated Dummies
- 6 - 8" Solid Aluminum Dummies
- 3 - 8" Perforated Aluminum Dummies (Expendables)
- 20 - Enriched Pieces (Enriched 7" HM)

3. Desired conditions are between probable and maximum cases indicated above. If conditions are near maximum, or above, flow will be increased during the next reactor outage. If conditions are below "probable" flow will be decreased to attain sufficiently severe conditions.

4. Reamed venturi will be required to maintain pinellit pressures within process standards limitations.

1463
3064
3065
3066

* Assume cosine flux distribution in downcomer

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note: For flow other than 50 rpm, adjust inlet temperature by $0.06(X)(1.5)$
 where: $X = 50 - \text{flow in rpm}$
 $T = \text{at 50 rpm and operating power}$

FIGURE 1--PREDICTED ALSO EXPOSURE IRRADIATION PERIOD

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