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IRRADIATION SUMMARY REPORT - PT-IP-247-A-FP
IRRADIATION OF 1.47 ENRICHED SELF-SUPPORTED
I&E FUEL ELEMENTS IN RIBLESS PROCESS TUBES

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IRRADIATION SUMMARY REPORT - PT-IP-247-A-FP
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HANFORD ATOMIC PRODUCTS OPERATION
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IRRADIATION SUMMARY REPORT - PT-IP-247-A-FP
IRRADIATION OF 1.47% ENRICHED SELF-SUPPORTED
I&E FUEL ELEMENTS IN RIBLESS PROCESS TUBES

INTRODUCTION

The objective of this test was to irradiate self-supported fuel elements under conditions of severity comparable to those expected for future loadings of this geometry. From this irradiation an attempt was made to determine the resistance to corrosion of cooled cladding, the effect of supports on cladding corrosion and coolant flow patterns, resistance of "hot-spot" type of attack, and rupture resistance of projection fuel elements. These results are compared to rib supported control elements in a relative manner.

To accomplish this comparison, four shortened columns of 1.47% enriched self-supported fuel were charged into B Reactor on 11-27-59, along with four columns of 1.47% enriched, current geometry fuel under authority of reference 1. As authorized⁽¹⁾, operating conditions were balanced as closely as possible within equipment and calculational limitations to minimize any "built-in" differences between the two materials being compared in order that exposure could be used as the basis for the rupture and corrosion comparisons.

SUMMARY OF RESULTS

Operating conditions attained for both the test and control material were in the desired range, i.e., maximum specific powers up to 110 kw/ft.* and tube flows of 46 to 51 gpm. On 12-23-59 and again on 12-30-59, failures were sustained in the control material. On 12-30-59 the remaining control columns were discharged. The test elements were discharged without failure on 2-9-60 at which time they had demonstrated a reduction in "hot-spot" failure probability of at least a factor of 30 at the 95% confidence level.

Examination of the control elements indicated thirteen "hot-spot" flow patterns, one side hot-spot failure and one side-other failure. No hot-spots were observed on the self-supported columns. Evaluation of measured weight losses for the self-supported fuel elements indicated good agreement with calculated weight losses, even in the region of 8-10 grams weight loss per piece. Calculated weight losses were within a factor of two of measured losses, which is well within the accuracy of the measurements, and the measured values were in a majority of the cases less than the calculated losses expected.

DISCUSSION

Daily operating data, calculations performed during the tests execution, post-irradiation examination forms, and analysis of results are contained in HWN-2461, "Data Calculations - Personal Notebook - PT-IP-247-A", RE Hall. Figures 1-8 attached, present the flux distribution, maximum, realistic typical tube power for each of the columns and include notations relative to rupture location and specific power*, and tube maximum specific power*. As can be observed, the flux patterns are quite similar for both the test and control material and correspond quite closely (except for the central dip caused by the continued presence of 8 rod) to the chopped cosine curve assumed in the test design. Calculations

*All specific powers are in KW per foot of uranium core.

1. HW-59756, "PT-IP-247-A-8-FP, Irradiation of 1.47% Enriched Self-Supported I&E Fuel Elements in Ribless Process Tubes", RE Hall, 7-29-59.

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of relative annular failure probability as calculated from Bloomstrand's model⁽²⁾ while assuming cosine flux distribution and using the IBM-709 programmed "Slug Design Analysis" program, indicated less than a factor of 4 difference between the least and most severe columns in the test, with the self-supported columns typically slightly more severe.

On 12-23-59, column 1770-B containing control material failed. Forces up to 4500 pounds were required to discharge the failure piece, which was classed as a side-hot-spot failure. On 12-30-59, the second authorized failure in control material occurred in tube 1764-B. Again forces in the range 4800 to 5000 pounds were required to discharge the failure which due to discharge damage was impossible to classify as anything except a side-other failure. The remaining two columns of control material were likewise discharged on 12-30-59. Examination of the control elements in the 105-C Metal Examination Facility indicated one additional "near-failure" was present in column 1764-B and another in 1882-B. Both of these elements are being examined in the Radiometallurgy laboratory and will be discussed in the laboratory inspection report when issued. Exposure for the control elements are tabulated below along with typical flow and "maximum-typical" power conditions.

TABLE I

<u>Tube</u>	<u>Flow</u>	<u>Power</u>	<u>Exposure*</u>	<u>Failure</u>
1764-B	50 gpm	950 KW/Tube	20.5 MWD/Tube	Side-Other
1770-B	48	1080	17.0	Side-Hot-Spot
1866-B	49	1100	22.7	None
1882-B	49	1125	23.8	Incipient

No failures were sustained in the self-support columns which were irradiated to the exposures shown in Table II. Statistical evaluation of these exposures indicated factors of relative failure resistance improvement shown in Table III.

TABLE II

<u>Tube</u>	<u>Flow</u>	<u>Power</u>	<u>Exposure**</u>
1768-B	47 gpm	1050 KW/Tube	53.1
1862-B	47	1100	53.0
1872-B	48	1025	52.8
1880-B	50	1200	58.8

*Exposures are in MWD/Tube. There were 16.1 charges per ton for these loadings. Equivalent exposures may be obtained by multiplying the exposure in MWD/ton by a factor of 0.80.

**Exposures are in MWD/Tube. There were 16.3 charges per ton for these loadings. Equivalent exposures again may be obtained as for Table I.

2. HW-55377, "Analysis and Correlations of HAP0 Rupture Experience with Natural Uranium Material", RR Bloomstrand, et. al., 4-23-58.

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TABLE III

<u>Demonstrated Factor of Improvement*</u>	<u>Confidence Level</u>
11	99%
30	95%
100	50%

Visual examination of the control elements indicated 13 hot-spot flow patterns in addition to the two failures, while none were observed on the projection elements. The probability of this 13-0 split occurring due to chance alone is extremely slight (approximately 1 in 10,000).(3) Since surface conditions were comparable, it is concluded that alignment does appreciably reduce, and probably eliminates, hot-spot formation. For this reason, it is probable that the above listed factors of improvement are if anything conservative estimates.

Corrosion data from the four self-supported columns have been analyzed.(4) The expected corrosion rates of the annular and spire surfaces of each element were calculated, and these rates together with irradiation time were used to obtain the total weight loss expected for each element. These expected weight losses were obtained from pre- and post-irradiation measurements. The agreement between the expected and observed weight losses was reasonably close. The observed weight losses were on the average about 80% of those calculated and except for a few scattered points, ranged between 55% and 130% of the expected values. This degree of "scatter" is not considered excessive based on previous corrosion test results. The implications of this agreement in the corrosion rate regions tested are important since plant expansion studies require operating conditions similar to the test conditions, and divergence between predicted and actual corrosion rates would have been significant from an operational standpoint.

Examination of the aluminum process tube 1880-B which was installed in May, 1958, and removed after this test was performed by D. E. Strege.(5) It appears from these data that repetitive recharging of aluminum process tubes probably shortens the useful life due to abrasion of the bottom portion of the tube. Twenty months use and eight cycles of fuel, including one charge of 1.47% enriched fuel, had reduced the tube wall to a minimum measured thickness of 42 mils from the original 62 mils. A difference of 2 mils was observed at the upstream end, 14 mils at the maximum difference, and 8-10 mils for the downstream end of the tube. It is probable that a major portion of the tube damage was due principally to corrosion incurred during the final cycle; however, a second tube is scheduled for removal later this year to confirm this hypothesis and verify the tube abrasion effect.

*Assumes a fifth power exposure dependency.

3. Personal Communication, J. L. Jaech

4. Analyzed by N. R. Miller but reported here for completeness.

5. Letter, "Results of Actual Tube Wall Thickness Measurement - B Reactor", D. E. Strege, 2-24-60.

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CONCLUSIONS

1. Rupture resistance was different by a factor of at least 30 between the test and control fuel at the 95% confidence level.
2. Under operating conditions typical of those forecasted, self-supported fuel elements relieve hot-spot problems and do not introduce localized corrosion problems of their own.
3. Extrapolated corrosion curves appear accurate and possibly conservative for X-8001 alloy in the region tested.
4. Further testing to evaluate tube abrasion effects in aluminum and zirconium tubes, and temperature unbalance in high flux regions is indicated by the results of this test.

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N. R. Miller	Technical assistance relative to aluminum corrosion.

Reactor Fuels Unit
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FIGURE 1 -- Flux Profile

FIGURE 2 -- Flux Profile

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FIGURE 3 -- Flux Profile

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FIGURE 4 -- Flux Profile

FIGURE 5 -- Flux Profile

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FIGURE 6 -- Flux Profile

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FIGURE 8 -- Flux Profile

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