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TITLE

PRODUCTION TEST IP-292-A, IRRADIATION OF
EIGHTEEN-INCH ZR-2 JACKETED TUBE-AND-TUBE
ELEMENTS IN THE KER LOOPS.

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HW-62814

Page 1

D I S T R I B U T I O N

1-2. AEC-HOO: Att: AT Gifford	29. ME Jackson
3. AEC-HOO: ATT: FM Midkiff	30. PC Jerman
4. FW Albaugh	31. WK Kratzer
5. WK Alexander	32. GA Last
6. JA Ayres	33. EE Leitz
7. DE Baderstadt	34. CG Lewis
8. RS Bell	35. NR Miller
9. WA Blanton	36. JE Minor
10. RW Bown	37. JF Music
11. JH Brown	38. WI Neef
12. SH Bush	39. SL Nelson
13. JJ Cadwell	40. R Nilson
14. RL Call	41. GF Owsley
15. AC Callen	42. CA Priode/WG Albert
16. TL Deobald	43. T Prudich/RE McGrath
17. RL Dickeman	44. RW Reid
18. DR Dickinson	45. RJ Shields
19. RV Dulin	46. HG Spencer
20. JM Fouts	47. JT Stringer
21. FC Franklin	48. WL Swanson
22. GC Pullmer	49. JW Talbott
23. GT Geering	50. P Thompson
24. SM Gill	51. RE Trumble
25. OH Greager	52. LD Turner
26. RE Hall	53. FW Van Wormer
27. TM Hall	54. FW Woodfield
28. WR Hamilton	55. 300 Files
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PRODUCTION TEST IP-292-A, IRRADIATION OF EIGHTEEN-INCH
ZR-2 JACKETED TUBE-AND-TUBE ELEMENTS
IN THE KER LOOPS

COPY 1 OF 1, SERIES 100

OBJECTIVE

The objective of this production test is to evaluate the performance characteristics of tube-and-tube elements, particularly the dimensional changes in the elements, degree of irradiation damage to the uranium and the clad-core bond, and the corrosive attack, if any, in pH 10 water.

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SUMMARY

Five eighteen-inch enriched tube-and tube-elements will be irradiated in the KER Loops in pH 10 water to an exposure of 3500 MWD/T.

BASIS AND JUSTIFICATION

A charge of three Zircaloy-2 jacketed enriched tube-and-tube elements irradiated in KER Loop 3 under PT-IP-250-A, Supplement B, (1,2,3,4) failed by pitting corrosion of the Zircaloy-2 jackets after 19 operating days in the reactor. The cause of the pitting corrosion is not known, but abnormally high jacket surface temperatures resulting from a heavy crud film associated with the pH 4.5 water in which the elements were irradiated may have been a necessary requirement for the corrosion to occur. This hypothesis is supported by the observation of similar pitting corrosion of much less severity on a rod from a tube-and-rod charge (5,6,7) which was also irradiated in pH 4.5 water with the concomitant heavy crud film. These elements had been irradiated for 200 days at a coolant temperature 60°C lower than the tube-and-tube elements and were discharged at 1900 MWD/T without failure.

Observation of Zircaloy-2 pitting corrosion in low pH water raises the question of whether similar corrosion may also occur in pH 10 water with Li OH addition, which is the coolant planned for use in the NPR. This test authorizes the irradiation of five enriched tube-and-tube elements to a goal of 3500 MWD/T in pH 10 coolant to see if a pitting corrosion problem exists under irradiation conditions as near to NPR conditions as can be obtained in the KER Loops. KER Loop operating experience has shown that crud film formation is considerably less in high pH coolant than in low pH coolant. Consequently pitting corrosion should not occur if it is dependent upon high jacket surface temperatures induced by a heavy crud film. Corrosion has not been observed in high pH water but the test conditions were not as severe as for the Loop 3 test. Corrosive attack, however, is not anticipated in this test.

The behavior of tube-and-tube elements during irradiation to intermediate goals at high temperature must be determined as part of the program for developing fuel elements for high temperature service in the NPR. Successful irradiation of the tubular elements under the conditions of this test will provide a basis for future testing at higher powers and heat fluxes.

TEST DETAILS

1. Fuel Elements

The five tube-and-tube fuel elements consist of a 1.050 inch OD, 0.500 inch ID inner tube mounted concentrically in a 1.820 inch OD, 1.450 inch ID outer tube. Both tubes have 0.020 inch co-extruded Zircaloy-2 jackets. The tubes are 18 inches long with 1/4 inch end caps. Both tubes are supported at the ends by welded Zircaloy-2 semi-flexible supports. Details of the elements are the same as shown in SK-2-8782, Revision 1, except for the shorter length and the elimination of the midpoint support.

Both unalloyed and U-2W/O Zr alloyed fuel elements will be irradiated. The unalloyed elements are enriched to 1.47% and the alloyed elements to 1.6%.

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The steps involved in preparing the fuel elements from the as-received rod are given below:

- a) Cut to length.
- b) Vertically salt bath heat treat at 730°C for six minutes, quench to 600°C for six minutes, air cool, water wash to remove salt.
- c) Machine to length, machine end cap recesses.
- d) Vapor blast surfaces, pickle in 1 to 1 HNO₃ to remove copper, and water rinse. Repeat vapor blasting, pickling and rinsing to insure complete copper removal.
- e) HCl pickle followed by light HNO₃-HF pickle of tube ends to remove residual uranium from cladding surfaces in preparation for closure.
- f) Insert end caps and weld in vacuum using electron beam.
- g) Ultrasonic bond and wall thickness test.
- h) Fluorescent dye penetrant test.
- i) Light HNO₃-HF etch followed by welding on supports.
- j) HNO₃-HF pre-autoclave pickle.
- k) Autoclave in 400°C, 1500 psi steam for 72 hours.
- l) Visual inspection of elements.
- m) Dimensional measurements including ID, OD, length and warp. Straighten elements if necessary.
- n) Assemble elements.

The preparation procedure for some of the elements will be varied by removing the copper extrusion coating before the heat treating step.

2. Loading

The loading will consist of 23 eight-inch spacers down stream, 1 eight-inch stainless steel triangular perf, 5 enriched tubular elements, 1 eight-inch stainless steel triangular perf, and up to 15 eight-inch spacers upstream. The spacers may be carbon steel perfs, (8) normal stainless-steel triangular spacers, or coupon holders approved by Process and Reactor Development Operation and Coolant Testing Operation.

Replacement of the spacer material downstream of the fuel elements with a thermocouple train to measure flow channel temperatures is also authorized, provided the thermocouple train meets the requirements specified in Supplement B to PT-IP-250-A.

3. Irradiation Facility

The test may be irradiated in KER high temperature recirculating loops 2, 3, or 4, however, present plans call for irradiating the test in KER Loop 4.

4. Operating Conditions

The coolant will be pressurized water with the pH at 10.0 + 0.5. The desired operating flow is 60 gpm with a low flow trip of 48 gpm. The low pressure trip will be set at 1500 psig. The desired operating outlet temperature, high outlet temperature trip, and boiling point suppression trip are given in figure 1.

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If recirculation with system pressures less than 1500 psig is required, the outlet temperature will be reduced and maintained at least 100°C below the system saturation temperature.

5. Exposure

The goal exposure for the tubular elements is 3500 MWD/T.

6. Costs

a. Cost Code: XXX-5320 - XXX.09

b. Time per charge:

	<u>Elevator Time Hours</u>		<u>Manhours</u>
	<u>Front</u>	<u>Rear</u>	
Charging	1	2	10
Discharging	1	4	15
Total	2	6	25

c. Reactivity change: The test loading will have a reactivity intermediate between that of a dummy charge and a standard charge of normal fuel elements.

7. Priority

Additional down time is authorized if charging or discharging cannot be accomplished during a normal outage.

8. Special Procedures

The fuel elements will be discharged into a tray according to procedures developed by the KE Maintenance Operation.

9. Hazards

There is a definite possibility that this test will result in a fuel element failure. If pitting corrosion should occur at the test conditions it would probably cause jacket failure before the elements have reached goal. In addition there is always the possibility of failure occurring by some mechanism not associated with pitting corrosion. If a failure should occur, and the failed area contacted the process tube in such a manner as to promote tube hydriding, the process tube would have to be replaced. The four Zircaloy-2 jacketed fuel element failures that have occurred in the KER Loops have demonstrated, however, that the delayed neutron monitor is capable of detecting failures and shutting down the reactor with a minimum distortion of the fuel element and without process tube distortion. The worst result of a fuel element failure should be an unscheduled reactor outage and replacement of the loop process tube.

10. Disposition of the Fuel Elements

The fuel elements from this production test will be retained in the 105 KE storage basin after discharge until such time as other storage locations have been found.

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RESPONSIBILITIES

Hanford Laboratories Operation

Reactor and Fuels Research and Development Operation

Fuels Development Operation

Fuels Design is responsible for the fabrication of the tube-and-tube elements, analysis of data, and issuance of technical reports.

Irradiation Processing Department

Research and Engineering Section

Component Testing Unit is responsible for post-irradiation examination and testing of components in the test charge.

Coolant Testing Unit is responsible for:

- a. Operation of the KER Loops.
- b. Taking basic operating data.
- c. Scheduling the loop charge with the concurrence of KE Processing Operation.
- d. Reactor Safety and production continuity as they are affected by loop operation.

Process and Reactor Development Sub-Section is responsible for:

- a. Technical aspects of the fuel element irradiation.
- b. Termination of the production test and issuance of the final report.

KW-KW Reactor Operation

KE Processing Operation is responsible for:

- a. Operational Safety
- b. Production continuity, except where inconsistent with the provisions of this test.
- c. Special discharges.

W X Kratzer

Reactor Fuels Unit
Process & Reactor Development Sub-Section
IRRADIATION PROCESSING DEPARTMENT

WK Kratzer:klm

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Figure 1

Operating Temperatures and trip settings
as a function of the observed tube ΔT .

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