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PT IP-205-A
IRRADIATION OF ZIRCALOY-2 JACKETED ROD AND TUBE
ELEMENTS IN THE KER LOOPS

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PT IP-205-A
IRRADIATION OF ZIRCALOY-2 JACKETED ROD-AND-TUBE
ELEMENTS IN THE KER LOOPS

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OBJECTIVE

The objective of this production test is to obtain information about the behavior of Zircaloy-2 jacketed rod-and-tube fuel elements during irradiation at high coolant temperatures. Specifically, this test should provide information about fuel element dimensional stability, suitability of the rod and tube support system, and behavior of the uranium-Zircaloy-2 bond.

SUMMARY

Four co-extruded Zircaloy-2 jacketed rod-and-tube elements, two with welded tube end closures and two with integrally extruded tube end closures, will be irradiated to 2500 MWD/T at jacket surface temperatures up to 270° C in the KER loops. One Zircaloy-2 jacketed seven-rod cluster UO₂ element will also be irradiated.

BASIS AND JUSTIFICATION

Three types of extended surface fuel elements are being considered for high temperature use in an NPR - seven-rod cluster elements, rod-and-tube elements, and tube-and-tube elements. Development work is proceeding on all three types. One phase of the development program includes high temperature irradiation testing of sample fuel elements of each type to observe fuel element distortion, behavior of the support system, and changes in the jacket-uranium bond. This test provides the initial high temperature irradiation of Zircaloy-2 jacketed rod-and-tube elements.

TEST DETAILS

1. Fuel Elements

The four rod-and-tube fuel elements in this test loading will consist of a 1.000-inch diameter natural uranium rod with a 0.020-inch thick co-extruded Zircaloy-2 jacket mounted concentrically in a 1.785-inch O.D., 1.375-inch I.D. natural uranium tube with a 0.030-inch thick co-extruded Zircaloy-2 jacket. Two of the fuel elements will have welded Zircaloy-2 end caps on both the tube and rod, as shown in Figure 1. The over-all length of these elements is thirty-six inches. The remaining two elements have tubes with integrally extruded Zircaloy-2 end closures. Each of the integral end caps is about one and three-quarters inches long, producing a fuel element thirty-nine and one-half inches long with effectively the same amount of uranium as the thirty-six inch element.

The rod is supported in the uranium tube and the uranium tube in the process tube, by "suitcase handle" supports at four positions along the length of the fuel element. The rod is held in the tube by the rod end cap projection welded to the tube end spider as shown in Figure 1. The other end of the rod is not restrained longitudinally to permit differential linear expansion of the rod and tube.

All of the fuel elements have been visually examined, ultrasonically tested for jacket-uranium bonding, and in the case of the integral tube end closures, jacket-end cap bonding, and autoclaved for forty-eight hours in 300° water. In addition, the integral end closures have been X-rayed to verify the jacket thickness at the uranium-end cap junction and to insure that the end closure is free of uranium stringers. After final assembly and testing, the fuel elements will not be modified without the concurrence of Process and Reactor Development Operation.

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The UO_2 fuel element consists of seven Zircaloy-2 jacketed rods assembled in a cluster with a 0.072-inch spacing between the rods. The rods are separated by Zircaloy-2 wire wrapped on a ten-inch pitch around the rods and the element is supported in the tube by 0.115-inch Zircaloy-2 wire wrapped around the cluster on a ten-inch pitch. Each rod is eighteen inches long with sixteen inches of fuel--swaged UO_2 of 85 to 87% theoretical density made from natural uranium. The clad rod is 0.560-inch O.D. with a 0.030-inch Zircaloy-2 jacket. The rods were X-rayed for weld integrity and autoclaved for seventy-two hours in 400° C, 1300 psi water.

2. Loading

The tube charge, listed from the downstream end of the process tube, is given in Table 1. All of the spacers and perfs will be made of stainless steel.

Table 1

Tube Loading

<u>Position</u>	<u>Description</u>
1-14	8" triangular spacer
15	18" UO_2 cluster
16	8" triangular perf
17*	39 1/2 rod-and-tube element
18	8" triangular perf
19	8" solid cylindrical spacer
20	8" triangular perf
21*	36" rod-and-tube element
22	8" triangular perf
23	8" solid cylindrical spacer
24	8" triangular perf
25*	36" rod-and-tube element
26	8" triangular perf
27	8" solid cylindrical spacer
28	8" triangular perf
29*	39 1/2" rod-and-tube element
30	8" triangular perf
31-34	8" triangular spacers

* The exact piece designation and positioning of the rod-and-tube elements will be provided before charging.

The solid cylindrical spacers used for flow mixing between the rod-and-tube elements will be provided by Process and Reactor Development Operation. Stainless steel coupon holders may be substituted for any of the downstream triangular spacers in positions 1 to 14 or for any of the upstream triangular spacers in position 31 on to the front of the tube.

If, for some reason, such as lack of one of the fuel elements, the loading must be modified, Process and Reactor Development Operation will provide a revised loading pattern and set of operating conditions prior to charging. If a revised loading pattern cannot be obtained, the position specified for the missing fuel element will be filled with spacer material and the loop operated at low temperature until a new set of operating conditions has been provided.

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3. Irradiation Facility

The fuel elements may be irradiated in any one of KER Loops 2, 3, or 4, tubes 2864, 3565, or 4268 KE. The loops consist of 2.100-inch I.D. Zircaloy-2 process tubes through which coolant of controlled composition, pressure, and temperature is recirculated. The fuel elements may not be irradiated in KER Loop 1 because of the smaller process tube size.

4. Operating Conditions

The coolant will be pressurized water with a pH of 4.0 to 11.0. The operating conditions are:

- a. Desired operating flow - 60 GPM.
- b. Low flow trip - 48 GPM.
- c. Low pressure trip - 785 psig.
- d. High outlet temperature trip - as shown in figure 2.
- e. Desired operating outlet temperature - as shown in figure 2.
- f. Boiling point suppression trip - as shown in figure 3.

If recirculation with system pressures less than 785 psig is required, the outlet temperature should be reduced and maintained at least 100° C below the system saturation temperature.

5. Power and Temperature Relationships

The high outlet temperature trip, desired operating outlet temperature, and boiling point suppression trip have been set as functions of the observed tube ΔT so that, regardless of the power produced by the fuel elements, the fuel element surface temperature will not exceed the system saturation temperature during normal operation; the fuel elements will not burn out at the limiting trip conditions¹; and bulk boiling will not occur in the tube. The maximum uranium temperature, as calculated, should not exceed the alpha-beta transformation temperature during operation. The anticipated specific power of the rod-and-tube elements (Kw/ft of uranium) is 1.0-1.1 times the specific power of an adjacent standard element. The UO₂ cluster element should produce 2.4 per cent of the observed charge power with the rod-and-tube elements supplying the balance of the power.

6. Exposure

The goal exposure of the rod-and-tube elements is 2500 MWD/T average exposure.

7. Special Discharge Procedure

The fuel elements from this production test will be discharged into a special tray and lowered to the basin to prevent fuel element damage which might obscure fuel element distortion occurring during irradiation. A detailed discharge procedure approved by Process and Reactor Development Operation, Coolant Testing Operation, and KE Processing Operation will be issued prior to the time of discharge. If the approved discharge procedure has not been issued, the fuel elements will be discharged normally.

1. F. W. Van Wormer, "Burnout Limits in KER Loops, Rod-and-Tube and Seven-Rod Cluster Fuel Elements, Sept. 18, 1958.

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8. Priority

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

9. Costs

a. Cost Code - XXXX-5320-XXX.14

b. Time

	<u>Elevator Time, hours</u>		<u>Manhours</u>
	<u>Front</u>	<u>Rear</u>	
Charge	3	2	4
Discharge	$\frac{1}{4}$	$\frac{4}{6}$	$\frac{24}{28}$

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.

10. Data Desired

Routine operating data, including coolant flow, inlet and outlet temperature and pressure, system pressure, and operating time at temperature, will be taken during irradiation.

11. Hazards

Failure of the rod-and-tube elements is improbable. The corrosion resistance of the Zircaloy-2 jackets, the high operating temperature, and the extended surface geometry should preclude either a jacket or a core failure. If a failure should occur, there is sufficient volume in the outer and inner coolant channels to accommodate the uranium-water reaction products from a failure in both the rod and the tube without process tube splitting. The stability of UO_2 in high temperature water will prevent fuel element swelling or tube splitting if the UO_2 cluster element should fail. Prior to charging, the distortion of the Loop 2 process tube will be measured by horizontal and vertical traverses and a rod-and-tube dummy of the same dimensions as the fuel elements will be pushed through the tube to verify that the fuel elements can be charged and discharged readily.

DEVIATION FROM PROCESS STANDARDS

This production test authorizes deviation from Process Standard K-040 Section 40.01, which limits the maximum uranium temperature to 600°C . This production test authorizes maximum uranium temperatures above 660°C - the alpha-beta transformation temperature. Although the production test design calculations indicate that the maximum uranium temperature should not exceed 660°C , the possibility always exists that the temperatures may actually go higher. For this reason, deviation from the Process Standard is authorized.

Maximum fuel temperatures of the UO_2 elements may exceed 2000°C at the center. Operation with oxide at these temperatures in both the MTR and the KER loops has given no difficulty.

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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 rod-and-tube elements, analysis of data, and issuance of technical reports.

Ceramic Fuels Development Operation is responsible for fabrication of the UO₂ cluster element, analysis of data, and issuance of technical reports.

Irradiation Processing Department

Research and Engineering Operation

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

Coolant Testing Operation 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.

Process and Reactor Development Operation is responsible for:

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

KE and KW Reactor Operation

KE Processing Operation is responsible for:

- a. Operational safety.
- b. Special discharge procedure.
- c. Production continuity, except where inconsistent with the provisions of this test.

Reactor Fuels Operation
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

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Figure 1
Zircaloy - 2 Jacketed Rod And Tube Element

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