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TITLE

PRODUCTION TEST IP-402-A, IRRADIATION OF
ZR-2 CLADDING STUDIES CAPSULES

AUTHOR

W. K. Kratzer

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March 24, 1961

PRODUCTION TEST IP-402-A, IRRADIATION OF Zr-2 CLADDING STUDIES CAPSULES

OBJECTIVE

The objective of this production test is to evaluate the effects of Zr-2 jacket uniformity, thickness, and temperature on non-uniform clad straining.

SUMMARY

Twenty-one aluminum capsules, eighteen containing three Zr-2 jacketed uranium specimens and three containing one uranium specimen instrumented with a thermocouple to measure the uranium temperature, will be irradiated in three process tubes in DR Reactor to exposures up to 2000 MWD/T. Each test channel will contain seven capsules, one of which will be instrumented with a thermocouple. A full column of numbered normal fuel elements will be irradiated in columns adjacent to each of the test columns to determine the front-to-rear flux distribution.

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Approximately 100 days of equilibrium operation will be required to complete the test and special pick-up will be required for the three test and three control columns.

BASIS AND JUSTIFICATION

Several recent high temperature test irradiations of Zircaloy-2 jacketed fuel elements have resulted in jacket failure by a mechanism which appears to involve localized straining of the fuel element jacket. The jacket would neck down and separate along a line without indications of uniform straining, necking, or thinning in the rest of the jacket. Some of the factors which may affect the straining mechanism are the jacket-thickness, uniformity, and temperature. In order to determine the relative effect of these variables, and to apply this knowledge to NPR fuel, a test program⁽¹⁾ has been set up to irradiate Zr-2 jacketed rod samples incorporating these variables. Since testing involves jacket failure of the rod samples, the samples are sealed in aluminum capsules filled with NaK. In addition to containing the uranium and fission products, the aluminum capsules provide temperature control through variation of the thickness of the capsule wall and the NaK annulus.

TEST DETAILS

1. Fuel Elements

The Zr-2 jacketed rod specimens are three inch long sections of 0.593 inch O.D. Zr-2 jacketed coextruded rod containing 1.47% enriched uranium. Unbonded Zr-2 end caps are welded to the rod specimens. The thermocouple specimen differs from the other specimens by having an axial hole drilled into the uranium into which is inserted a 1/16 inch stainless steel jacketed chromel-alumel thermocouple. The thermocouple passes out of the specimen and the capsule through a series of Swage-lok fittings.

Two types of aluminum capsules will be used. One type contains three specimen rods and the other type contains one specimen rod instrumented with a thermocouple. Both types of capsule are 0.8 to 0.9 inch O.D. and are contained in a 1.44 inch O.D. sleeve with a 1/16 inch wall to position the capsule in the process tube. The thermocouple capsules are 10 inches long and the others 14 inches long. Each capsule consists of a cylindrical chamber containing the centered rod specimens surrounded by NaK and a separate NaK expansion chamber at one end. The capsule design is illustrated in Figure 1. A detailed description and drawing are given in HW-67263⁽²⁾ and H-3-9599.

The aluminum capsules containing a single rod specimen instrumented with a thermocouple are the upstream elements of thermocouple trains used to check the specimen operating conditions by measuring the specimen uranium temperature. The thermocouple trains are similar to the standard thermocouple probes except that the probe head is replaced by the instrumented capsule and the train contains one thermocouple instead of six.

(1) Weber, J. W. Proposal for the Irradiation of Cladding Studies Capsules, HW-67264, November 1, 1960 (SECRET)

(2) Weber, J. W. Cladding Studies Capsule Design, HW-67263, November 1, 1960.

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A column of fuel adjacent to each test channel will contain normal fuel elements that have been numbered and whose position in the process tube is known.

2. Loading

The process tubes containing the capsules will be loaded with seven capsules, six containing three rod specimens each and one in the downstream position containing one rod specimen instrumented with a thermocouple. The column of capsules will be positioned at the midpoint of the process tube by the thermocouple train terminating in the instrumented capsule. The number and type of upstream dummies and spacers have been specified by the Reactor Engineer to provide appropriate flow control and Panellit protection. The detailed test column loading is given in Table 1.

Three process tubes, one adjacent to each of the three test columns, will be loaded with a normal charge of numbered fuel elements. The adjacent, or control, tubes will be charged and discharged at the same time as the test columns. If a control tube must be discharged before its companion test column, a new charge of numbered elements will be loaded in the tube and discharged at the same time as the test column. Discharge of green metal is authorized to make available the six tubes needed for this test. Discharge of green control columns is also authorized. Discharge of up to one ton of green metal may be required.

3. Irradiation Facility

The test capsules will be irradiated in DR reactor in process tubes selected by the Reactor Physicist and the Reactor Engineer.

4. Charge, Discharge, and Special Pickup

Process tubes containing the test capsules will be loaded by hand, the capsules and thermocouple train from the rear face and the upstream dummies from the front. The adjacent control tubes of numbered normal elements may be charged by any desired means as long as identity of the elements is retained. A detailed charge and discharge procedure will be provided by the test author prior to charging. Both test and control tubes will require special pickup. Test and control elements from each pair of tubes may be stored in one bucket, however, elements from different tube pairs should not be mixed.

5. Operating Conditions

The process tubes containing the test capsules will produce about 100-110 kw and will operate with a 14-15°C coolant ΔT .

Orifice size and upstream dummy configuration will be selected by the Reactor Engineer to provide the appropriate Panellit pressure.

The expected power and temperature conditions for the uranium specimens in each capsule are given in Table 2 based on the arrangement of the capsules in each test column shown in Figure 2.

6. Compliance with Process Standards

This test does not authorize deviation from any operating process standards.

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7. Process Tube Selection

The process tube location for the test and control columns will be selected by the Reactor Physicist to provide an adjacent tube power as near 750 kw as possible.

8. Exposure

One of the test columns will be irradiated to a specimen exposure of about 1000 MWD/T and the other two test columns to a specimen exposure of about 2000 MWD/T. These exposures will take about 50 and 100 operating days to attain.

9. Special Procedures

The special procedures required for this test include:

- a. Probing the test columns with a 1.44 inch diameter, 16 inch long probe prior to charging.
- b. Manual charging of the test columns, the capsules and thermocouple trains from the rear and the upstream dummies from the front.
- c. Maintaining identity of numbered elements in control columns.
- d. Special pickup of both test and control columns.
- e. Reporting daily data on form provided by the test author.

10. Costs

- a. Cost code for incremental costs: XXXX-5R24-XXX.73
- b. Time for each column:

	<u>Elevator time, hours</u>		<u>Manhours</u>
	<u>Front</u>	<u>Rear</u>	
Charge test column	1/2	1	4
Discharge test column	1/4	1/2	2
Charge control column	1/4	-	1/2
Special pickup	-	-	1/2

- c. Reactivity loss: Reactivity of each test column will be about the same as a column of dummies. There is no loss associated with the control columns.

11. Data Desired

Operating data from the test and control columns and from certain surrounding tubes will be supplied on forms provided by the test author. Elements discharged from the control columns will be weaseled to obtain the front-to-rear flux distribution.

12. Test Duration

This production test will be terminated one year from the date of initial charging or on December 31, 1962, whichever occurs earlier, unless extended

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by a properly approved supplement.

13. Hazards

The greatest hazard associated with this test is that of an unscheduled reactor shutdown in case of capsule failure. Out-of-reactor tests of deliberately failed capsules have shown that the small quantity of NaK in a capsule will react with the process water and be washed downstream without damage to the capsule or process tube. Fission products from the specimen escaping from the failed capsule will give normal rupture indications. The aluminum sleeve around each capsule, Figure 1, provides additional protection against process tube damage.

RESPONSIBILITIES

Hanford Laboratories Operation

Reactor and Fuels Research and Development Operation

Fuels Development Operation

Fuel Element Design Operation is responsible for fabricating the test capsules, pre-irradiation inspection and testing, analyzing test data, and reporting test results.

Irradiation Processing Department

Research and Engineering Section

Process and Reactor Development Subsection

Reactor Fuels is responsible for coordination and conduct of the production test and all technical aspects of the test relating to the capsules and fuel specimens.

Process Technology Subsection

Process Engineering is responsible for selection of process tubes for the test in conjunction with the reactor physicist, establishing the dummy pattern, orifice sizes, and operating conditions for the test columns, assistance in charging the test columns, and liaison with the Processing Operation in obtaining test data.

Operational Physics Subsection

File Physics is responsible for selection of the process tubes for the test in conjunction with the reactor engineer.

Testing Subsection

Irradiation Testing is responsible for assistance in assembly, charging, and maintenance of the thermocouple trains.

Component Testing is responsible for weaseling the control elements and examination of test and control elements after discharge if this should be necessary.

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RESPONSIBILITIES (cont'd)

Manufacturing Section

D and DR Reactor Subsection

DR Processing Operation is responsible for scheduling the test, operational safety and production continuity of the reactor, and collection of operating data.

W. K. Kratzer
Reactor Fuels
Process and Reactor Development
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

WKK:gb

FIGURE 1

CLADDING STUDIES CAPSULE

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TABLE 1

Test Column Loading

<u>Position from the Downstream End</u>	<u>Number</u>	<u>Description</u>
1 - 26	26	8 inch perfs
27	1	10 inch thermocouple capsule
28 - 33	6	14 inch capsules
34 - 35	2	8 inch perfs
36 - 55	20	8 inch solid aluminum dummies
56 - 57	2	8 inch solid stainless steel dummies

TABLE 2
EXPERIMENTAL CONDITIONS

Capsule Designation	Fuel	Zr-2 Cladding Thickness, Inches	Temperature - C		Zr-2 Cladding Surface	Desired Exposure MWD/T	Specimen Power, kw/ft
			Uranium Axial	Uranium Surface			
A3U11	1.47% E, Unalloyed	0.030	477	318	240	1000	20
A3U21	" "	0.030	513	358	280	1000	20
A3U22	" "	0.030	513	358	280	1000	20
A3U31	" "	0.030	548	398	320	1000	20
A3A21	1.47% E, 2 w/o Zr	0.030	454	337	280	1000	14.6
A4U21	1.47% E, Unalloyed	0.040	537	391	288	1000	19.2
B3U11	1.47% E, Unalloyed	0.030	477	318	240	2000	20
B3U12	" "	0.030	477	318	240	2000	20
B3U21	" "	0.030	513	358	280	2000	20
B3U22	" "	0.030	513	358	280	2000	20
B3U23	" "	0.030	513	358	280	2000	20
B3U24	" "	0.030	513	358	280	2000	20
B3U31	" "	0.030	548	398	320	2000	20
B3A21	1.47% E, 2 w/o Zr	0.030	454	337	280	2000	14.6
B3A22	" "	0.030	454	337	280	2000	14.6
B4U11	1.47% E, Unalloyed	0.040	503	350	247	2000	19.2
B4U21	" "	0.040	537	391	288	2000	19.2
B4U22	" "	0.040	537	341	288	2000	19.2
A4U2TC1	1.47% E, Unalloyed	0.040	537	319	288	1000	19.2
B4U2TC1	" "	0.040	537	391	288	2000	19.2
B4U2TC2	" "	0.040	537	391	288	2000	19.2

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A4U2TC1	A4U21	A3U21	A3A21	A3U22	A3U11	A3U31
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Tube 1 Exposure 1000 MWD/T

B4U2TC1	B4U21	B3U21	B3U31	B4U11	B4U22	B3U22
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Tube 2 Exposure 2000 MWD/T

B4U2TC2	B3U23	B3A21	B3U11	B3U12	B3U24	B3A22
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Tube 3 Exposure 2000 MWD/T

← Downstream

Figure 2

PROPOSED CHARGING PATTERN

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APPROVALS

J. H. Brown

J. H. Brown, Manager
Process and Reactor Development Subsection
RESEARCH AND ENGINEERING SECTION

R. W. Reid

R. W. Reid, Manager
Process Technology Subsection
RESEARCH AND ENGINEERING SECTION

L. G. Lewis for

C. G. Lewis, Manager
Testing Subsection
RESEARCH AND ENGINEERING SECTION

G. C. Fullmer

G. C. Fullmer, Manager
Operational Physics Subsection
RESEARCH AND ENGINEERING SECTION

O. H. Greager

O. H. Greager, Manager
RESEARCH AND ENGINEERING SECTION

D. S. Lewis

D. S. Lewis, Manager
DR Processing Operation
D-DR Reactor Operation
MANUFACTURING SECTION

W. D. Richmond

W. D. Richmond, Manager
D-DR Reactor Operation
MANUFACTURING SECTION

E. R. Astley

E. R. Astley, Manager
Applied Reactor Engineering
MANUFACTURING SECTION

O. C. Schroeder

O. C. Schroeder, Manager
MANUFACTURING SECTION

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