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TITLE

PRODUCTION TEST IP-314-A
MEASUREMENT OF FUEL ELEMENT TEMPERATURE CHANGE
AS THE RESULT OF FILM DEPOSITION

AUTHOR

W. K. KRATZER

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PRODUCTION TEST IP-314-A
MEASUREMENT OF FUEL ELEMENT TEMPERATURE CHANGES
AS THE RESULT OF FILM DEPOSITION

OBJECTIVE

The objective of this production test is to measure the effect of crud film deposition on fuel element temperatures during irradiation in high pH water.

SUMMARY

A Zircaloy-2 jacketed natural uranium solid cylindrical fuel element with thermocouples located at various positions in the element and adjacent coolant channel will be irradiated in the KER Loops to measure the effect of crud film buildup on fuel temperature. Two 1.82 by 1.45 inch enriched 36 inch long tubular elements will be used to provide enough heat to permit operation of the loops at temperature. Duration of the test will depend upon the results obtained; however, the maximum exposure of any of the uranium in the loading will not exceed 1000 MWD/T.

BASIS AND JUSTIFICATION

Crud film deposition on fuel element heat generating surfaces has been observed in the KER Loops and at other sites. The effect of such film is to increase the fuel element surface and fuel temperatures by impairing heat transfer from the fuel element jacket surface to the coolant. Although, in the KER Loops, visually detectable film has occurred only on elements irradiated in low pH water, experience at Chalk River^(1,2) has shown that significant crud film can form on elements in high pH coolant, particularly with high fuel element surface heat fluxes.

This test is intended to measure the temperature effect of crud film deposition on a fuel element surface at a surface heat flux and coolant composition approximating those anticipated in the NPR. These data will be used for estimating the severity of crud film induced temperature effects in the NPR fuel elements.

TEST DETAILS

1. Fuel Elements

The thermocouple element consists of a 1.000 inch diameter 0.020 inch Zircaloy-2 jacketed natural uranium rod mounted in a 1.820 inch o.d., 1.450 inch i.d. stainless steel sleeve. The rod is twelve inches long and the sleeve sixteen inches long. Five thermocouples are mounted in the rod-sleeve assembly; three in the uranium rod to measure center and edge temperature and two in the coolant annulus around the rod. The stainless steel protecting tubes of the thermocouples are attached to the Zircaloy-2 fuel element cap by a eutectic braze junction developed by R. G. Wheeler, Fuels Development Operation, ELO. The two tubular heater elements are 1.820 inches o.d., 1.450 inches i.d.,

1. Minor, J. E. and E. A. Evans. Trip Report - Westinghouse, Pittsburg, Feb. 11, 12, 1960 - ANL, Chicago, Feb. 13, 1960. (CONFIDENTIAL-UNDOCUMENTED)
2. Fillnow, R. H. Trip Report, WAPD-TR-9063. Feb. 5, 1960. (UNCLASSIFIED)

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and thirty-six inches long. The tubes have 0.020 inch Zircaloy-2 jackets and contain 1.47% enriched unalloyed uranium. A 1.000 inch diameter stainless steel rod is mounted concentrically in the tubes to provide a more balanced flow distribution through the coolant channels and to hold the thermocouple wires. All of the uranium components of the thermocouple train have been non-destructively tested for jacket thickness and bond condition and have been autoclaved for 48 hours at 400°C in 1000-1500 psig steam. Details of the elements and thermocouple train are given in SK-1-22749.

2. Loading

The loading will consist of the assembled thermocouple train only. The train is made up of the nozzle insert downstream, twenty-one eight inch perfs or spacers, one thirty-six inch tubular heater element, two perfs, one thirty-six inch tubular heater element, two perfs, and the twelve-inch thermocouple element upstream.

3. Irradiation Facility

The thermocouple element will be irradiated in KER loop 1. If sufficient incentive exists to perform the test in one of the other KER loops, this may be done provided operating conditions appropriate to the other loops are provided by Process and Reactor Development Operation and approved by Process Technology Operation prior to charging.

4. Deviations from Process Standards

Since replacement of the KER-1 process tube on April 9, 1960, some of the Standards⁽³⁾ no longer apply. Deviations from Process Standards authorized by this production test are listed below:

K-010

10.01 - System Integrity Requirements

KER Loop 1 will be cold hydrostatically pressure tested at 4000 psig before operation.

10.02 - Operating Pressure and Temperature Limitations

- A. Maximum coolant pressure at outlet of in-pile assemblies will be 1600 psig.
- B. Maximum coolant temperature at tube outlet will be 293°C.
- D. Maximum pressure setting for the pressurizer relief valve and rupture disc will be 1720 psig.

3. Process Standards Reactor, HW-4600 K. (SECRET)

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10.03 - In-Pile Pressure Test Requirements for High Pressure Loop Operation

The hydrostatic test pressure shall be 4000 psig at an estimated tube wall temperature of 20°C, 3650 psig at 60°C, and 3250 psig at 100°C.

K-040

40.01 - Water Supply Requirements

The production test shall specify operating conditions that, during normal operation, will limit the maximum internal fuel element temperature to 660°C or less.

40.02 - Safety Circuit Requirements

A. Process Tube Outlet Water Temperature: The maximum operating temperature alarm setting shall be 293°C and the high temperature trip setting shall be 303°C.

K. Process tube exit pressure alarm shall be set at 1600 psig.

5. Operating Conditions

The coolant shall be pressurized water with the pH adjusted to 10 ± 0.5 by the addition of LiOH. The desired operating flow is 50 gpm with the low flow trip set at 40 gpm. The desired operating outlet temperature, high outlet temperature trip, and boiling point suppression trip are given in figure 1 as functions of the observed tube ΔT .

Dashed lines indicating the desired operating temperatures and trip settings needed to maintain the maximum uranium temperature below 660°C are also included in figure 1. In the absence of other information, the dashed lines will guide the selection of operating conditions. One of the thermocouples in the thermocouple element, however, indicates the maximum uranium temperature directly. Based on the thermocouple readings, the outlet temperature and trip settings may be set to exceed or fall short of the values designated by the dashed lines provided:

a. The temperatures do not exceed the limitations set by the solid lines; which are based on the requirements that boiling will not occur on the fuel elements during normal operation and burnout will not occur at the limiting trip conditions.

b. The maximum uranium temperature shall not exceed 660°C.

6. Exposure

Duration of the test will depend upon the results obtained, however, the exposure of any of the elements in the loading shall not exceed 1000 MWD/T.

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7. Special Procedures

Discharge of the thermocouple train into a special tray will not be required. The thermocouple train will be loaded from the rear face of the reactor and thermocouple leads will be strung across the rear face and out to recorders on the X-2 level.

8. Priority

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

9. Costs

a. Cost Code - XXX.5320-XXX.54

b. Time

	Elevator Time, Hours		Manhours
	Front	Rear	
Charge	1	3	10
Discharge	1	1	4
	2	4	14

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

The probability of failure of the elements included in the thermocouple train should not be appreciably greater than that of normal tubular or cluster loadings. The stainless steel - Zircaloy-2 junction between the thermocouples and the thermocouple element end cap may increase the risk of water entry to the element, however the assembly has withstood autoclave testing and similar junctions have been successfully used for other in-reactor high pressure applications.

RESPONSIBILITIES

Hanford Laboratories Operation

Reactor and Fuels Research and Development Operation

Fuels Development Operation

Fuel Element Design Operation is responsible for fabrication of the thermocouple element assembly and the tubular elements analysis of data, and issuance of technical reports.

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Materials Development Operation

Coolant System Development Operation is responsible for assembly of the thermocouple train, providing and maintaining the thermocouple leads, junctions, and temperature recorders, 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.
- d. Reactor safety and production continuity as they are affected by loop operation.

Process and Reactor Development Operation is responsible for:

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

KE-KW Reactor Operation

KE Processing Operation is responsible for:

- a. Operational safety.
- b. Production continuity, except where inconsistent with provisions of this test.

Reactor Fuels Unit
Process and Reactor Development Subsection
IRRADIATION PROCESSING DEPARTMENT

WK Kratzer/km

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FIGURE I

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

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