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PT IP-200-A, TEMPERATURE MEASUREMENT OF URANIUM SWELLING CAPSULE

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August 11, 1958

PT IP-200-A, TEMPERATURE MEASUREMENT OF URANIUM SWELLING CAPSULE

OBJECTIVE

The objective of this production test is to measure the temperature obtained in a uranium swelling capsule at known flux conditions.

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SUMMARY

A NaK-filled uranium swelling capsule and the associated thermocouple train will be irradiated in DR Reactor for one operating period. An adjacent tube will be charged with numbered standard fuel elements to measure the front-to-rear flux distribution.

BASIS AND JUSTIFICATION

In the development of fuel elements for the NPR, one potentially serious fuel element problem - high temperature uranium swelling - has not been experimentally investigated. A series of experiments⁽¹⁾ has been proposed in which uranium fuel rod with different amounts of Zircaloy-2 cladding will be irradiated to high exposure at temperatures equivalent to those expected in an NPR. These experiments should show the importance of high temperature uranium swelling as a limiting factor in NPR fuel element behavior.

To obtain sample rod temperatures of 250 to 300°C on the surface and 500 to 650°C at the center, the rods will be irradiated in aluminum capsules loaded in standard reactor process tubes. The high temperatures will be obtained by restricting the heat flow from the uranium sample to the coolant. The purpose of this test is to determine the validity of the heat transfer calculations used in predicting the temperature drops within the capsule by irradiating one capsule at known flux conditions and measuring the temperature attained by the uranium rod sample. The data obtained from this test will be used in determining the irradiation conditions required for the full scale uranium swelling tests.

TEST DETAILS

1. Test Charge

The test capsule consists of a 1.6% enriched Zircaloy-2 jacketed uranium rod 0.630 inches OD and 4.0 inches long in a 1.440 inch OD aluminum capsule 10.4 inches long with 0.282 inch wall. The 0.123 inch space between the rod and the capsule wall is filled with an alloy of sodium and potassium ("NaK") which is molten at room temperature. An expansion chamber is provided for thermal expansion of the NaK and any volumetric increase of the uranium. The complete design of the capsule is given in Reference 1.

A stainless steel jacketed thermocouple extends through the rear cap of the capsule into a Zircaloy-2 thimble in the uranium rod. Coolant water is excluded from the capsule by two Swagelok fittings. The complete capsule and thermocouple arrangement is shown in HW-56589.⁽²⁾

- (1) HW-56132, "In-Reactor Retained Swelling Experiments"; Weber, J. W., May 20, 1958.
- (2) HW-56589, "Proposal for Irradiation of Uranium Swelling Capsule", Weber, J. W., June 30, 1958.

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The test capsule is the upstream element of a thermocouple train about 21 feet long. The only other material charged in the process tube will be two stainless steel dummies upstream of the thermocouple train which are included to prevent chattering of the capsule.

One process tube adjacent to the tube containing the thermocouple train will be loaded with numbered standard fuel elements to measure the front-to-rear flux distribution.

2. Irradiation Facility

The test capsule and flux monitoring column will be loaded in DR Reactor in two adjacent process tubes in such a location as to provide a normal equilibrium adjacent tube power of 900 ± 50 kw. The tubes selected should be in the third lattice unit away from a control rod.

3. Charge Procedure

If possible, two tubes scheduled for discharge during the outage in which this production test will be charged should be selected for the production test loading. If none are available that satisfy the requirements of the test, the discharge of green metal is authorized. The flux monitor column should be charged with numbered normal fuel elements. Two steel dummies and the thermocouple train with capsule will be charged from the rear face. The thermocouple wires extending from the modified rear cap will be attached to a junction box from which thermocouple lead wires will be run across the rear face to the recording instrument.

4. Operating Limits

Appropriate Panellit trip and outlet temperature limits will be provided by representatives of Research and Engineering Operation.

5. Expected Temperature Conditions

With the process water flow and adjacent tube power expected for the test, the capsule will heat the coolant no more than 2°C . The maximum surface temperature of the capsule will not exceed 55°C .

The calculated maximum uranium temperature is about 725°C at the requested adjacent tube power. It is conceivable, with the inaccuracies inherent in power generation and heat transfer calculations, that the maximum uranium temperature could be as high as 965°C .

6. Exposure

The test column and adjacent flux monitoring column will be irradiated for a minimum time of one week of equilibrium reactor operation. Both of the columns will be discharged at the first convenient outage after completion of the one week of equilibrium operation.

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7. Authorization for Special Procedures and Costs

This test authorizes additional downtime if the charging or discharging of the test and monitor columns cannot be accomplished during normal outages. The discharge of green metal to obtain appropriate tube locations and the discharge of the monitor column after one week's operation is also authorized.

Special pick-up of the normal fuel elements in the monitor column and the test capsule is required.

8. Costs

Cost code: XXXX-5320-XXX.14

	<u>Elevator Time</u>		<u>Manhours</u>
	<u>Front</u>	<u>Rear</u>	
Charge and discharge monitor column	1/2	1/2	4
Charge and discharge thermocouple train	<u>1/2</u>	<u>2</u>	<u>8</u>
	1	2-1/2	12

Reactivity Loss: 9 in-hours.

DATA DESIRED

1. Activity measurements will be made on the normal fuel elements from the monitor columns.
2. The test capsule will be sent to the Radiometallurgy Operation for examination.
3. Inlet and outlet water temperatures and Panellit and header pressures will be recorded daily for the test and monitor columns and for selected surrounding columns. Data sheets will be provided.
4. Temperature readings from the thermocouple in the test capsule will be taken at the same time as the tube temperatures.

HAZARDS

The hazards to the reactor resulting from the irradiation of the test capsule cannot be completely evaluated, although out-of-pile tests and an analysis of the probable sequence of events if the capsule should fail indicate that the hazards should be negligible. As shown in HW 56589, the pre-irradiation testing and the capsule design should preclude a capsule failure from water entry or from expansion of the NaK.

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If a hole should occur in the jacket, out-of-pile simulated failure tests⁽³⁾ have shown that the NaK-water reaction will have no serious effect on the capsule. Eight NaK filled capsules were deliberately failed in 98°C water in the 314 Building flow tubes. After running for two hours the NaK had been completely flushed from the capsules. There was no distortion and no serious corrosion on any of the capsules. Escape of NaK to the coolant should cause no hazard from the NaK-water reaction.

If a jacket failure should occur, however, and some of the escaping NaK be replaced by water in the capsule, the resulting mixture of Na, K, NaOH, KOH, water, and steam in the NaK annulus would have a much lower thermal conductivity than the original NaK, causing an immediate overheating of the uranium rod and probable failure of the Zircaloy-2 rod jacket. The probable series of detectable events if the capsule should fail would be:

- a) Activity indicated on the gamma monitor as a result of the Na 24 in the coolant. Analysis of a water sample would show no fission products.
- b) An increase in the uranium rod temperature of several hundred degrees C, as indicated on the temperature recorder.
- c) Activity on the gamma monitor and confirming fission products in the water sample when the rod jacket fails.

It is doubtful that the capsule would swell enough during the sequence of failure events to cause an indication on the Panellit gauge. The initial NaK-water reaction would cause no swelling, and there is enough room in the NaK chamber to accommodate a doubling in volume of the uranium rod as a result of the uranium-water reaction. By the same reasoning it is improbable that a failed capsule would stick in the process tube.

DISCHARGE IN THE EVENT OF A FAILURE

The reactor should be shut down and the test discharged if a confirmed rupture occurs in the tube containing the sample. In addition, the test will be discharged if activity is indicated on the gamma monitor, without confirming fission products in the coolant water, and the sample rod temperature recorded from the inpile thermocouple increases more than 100°C over its stable value.

RESPONSIBILITIES

Hanford Laboratories Operation

Reactor and Fuels Research and Development Operation

Fuels Development Operation

Fuel Element Design Operation is responsible for preparation of the test capsule, pre-irradiation testing, analysis of the data and issuing technical reports.

(3) HW-56588, "Results of NaK Capsule Failures in Hot Water Flow Tube",
Wesley T. W., June 30, 1958.

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Irradiation Processing Department

Research and Engineering Operation

Irradiation Testing Operation will be responsible for installing the thermocouple train and associated equipment.

Process Technology Operation will be responsible for providing assistance in pre-shutdown scheduling, preparation for charging, and collection of data.

Process and Reactor Development Operation will be responsible for technical aspects of the irradiation, analysis of data, termination of the production test, and issuance of the final report.

Component Testing Operation will be responsible for taking activity measurements of the monitor elements if this cannot be done at the reactor.

D and DR Reactor Operation

DR Processing Operation will be responsible for scheduling, operational safety and production continuity, and collection of routine operating data.

Reactor Fuels Operation
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

WK Kratzer:dgm

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