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February 6, 1963

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PRODUCTION TEST IP-572-A
EFFECT OF ECCENTRICITY ON THE IRRADI-
ATION BEHAVIOR OF KVNS FUEL ELEMENTS

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PRODUCTION TEST IP-572-A
EFFECT OF ECCENTRICITY ON THE IRRADIATION BEHAVIOR
OF KVNS FUEL ELEMENTS

OBJECTIVES

The objectives of this production test are to (1) confirm the KVNS fuel element design, (2) determine the effect of support height on annulus coolant temperature distribution (R Value),* and (3) evaluate the effect of eccentricity on KVNS fuel element irradiation behavior.

TEST SUMMARY

This production test authorizes the charging of ten monitor fuel columns, and the use of thermocouple probes in ten smooth-bore Zircaloy process tubes in the KW Reactor as follows:

1. Three tubes to be machine charged with KVNS fuel elements fabricated according to current specifications. The nominal R Value expected in these tubes is 1.15.
2. Three tubes to be hand charged with KVNS fuel elements with 0.080 inch support height and two tubes with fuel elements with 0.070 inch supports. The nominal expected R Values are 1.35 and 1.50 respectively.
3. One tube to be hand charged with KVNS fuel elements with 0.070 inch supports with a mixer located at fuel position six, to evaluate the mixer efficiency in smooth-bore tubes.
4. One tube to be hand charged with 35 normal KVNS fuel elements and three KVNS fuel elements with 0.050 inch supports. The latter three fuel elements to be located at fuel element positions nine, ten, and eleven. Data from this tube will indicate the adequacy of specifying a minimum support tab of 0.050 inch.

BASIS AND JUSTIFICATION

The general stability and operability of self-supported fuel elements has been demonstrated in Zircaloy tubes at the C Reactor. The KVNS fuel element design, which was based on this experience, has been shown by laboratory flow tests and preliminary in-reactor tests (2 tubes at KW) to provide the design heat transfer characteristics.

Additional testing is required to confirm the adequacy of the KVNS design and to evaluate its irradiation behavior. This testing cannot be accomplished until Zircaloy tubes are in place at the K Reactors.

The self-support feature of the KVNS fuel element is the most probable source of future operating problems. The primary function of the supporting member is to center the fuel elements in the process tube so as to obtain adequate heat transfer. It is not possible to obtain perfect centering because of necessary tolerances in

* The terms "R Value" and "eccentricity" are defined in Appendix 1.

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fuel manufacturing and the need to provide charge-discharge facility. In general, lower support height means easier charge-discharge operations and lower fuel element manufacturing costs. It also means higher annulus coolant temperatures because of eccentric fuel element alignment. Excessive eccentric alignment can result in local boiling in the annulus which reduces the ability of the Panellit gauge to respond to certain types of flow-loss accidents, increases the probability for fuel element cladding corrosion failure, and, in the worst case, may result in fuel element burnout.

The currently specified minimum support height of 0.092 inch, based on laboratory data and limited in-reactor exposure, provides for a maximum R Value of 1.20, assuming charging operations will not decrease the support height by more than 0.003 inch. This specification complicates both fuel manufacturing and reactor charge-discharge operations. This production test, then, will concentrate on this problem, to provide data to permit the minimum support height to be more precisely determined, and perhaps, reveal unnecessary conservatism in the current specification.

HAZARDS

1. The primary hazard associated with this test is that higher than normal corrosion rates increases the probability for fuel failure. Exposures will be limited according to corrosion rates calculated on the basis of coolant temperature measurements to minimize this probability. Tubes will be discharged at scheduled goal or upon accumulating 20 mils of calculated corrosion.
2. A possible hazard exists if local annulus boiling occurs because this reduces the ability of the Panellit gauges to respond to certain flow-loss incidents. Operation within the annulus boiling limit will be obtained by selecting tubes with sufficient rear header pressure to suppress boiling. This will be verified by comparison of coolant outlet temperature measurements with end-of-active zone saturation pressures.
3. Laboratory data show that eccentric alignment of the fuel element reduces the heat flux at which burnout occurs. These experiments show that at the maximum eccentricity authorized by this test (60%), the ratio of burnout heat flux to operating heat flux is greater than 2.0. A ratio of 1.4 is considered acceptable for reactor operation.

TEST DETAILS

1. Reactor

This test will be conducted at KW Reactor.

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2. Materials

a. Process Tubes

Ten smooth-bore Zircaloy-2 process tubes will be utilized in this test. Assuming a more or less random installation location of the smooth-bore tubes will be effected, the tubes for this test will be selected by the test authors with the concurrence of the Manager, KW Processing. All tubes selected for use in this test will be bore-gauged after installation and the results transmitted to the test authors. Tubes with 50 psig or higher rear header pressure will be required for fuel elements with 0.070 inch supports.

b. Fuel Elements

1) General

All fuel elements used in this test will contain natural uranium cores and be fabricated by the "F" canning process as presently specified for the KVN fuel elements.

2) Quantity

A total of approximately 400 fuel elements will be used in this test. One water-mix piece will be required. This water-mix element will consist of a normal KVN piece with a water-mix spool of special dimensions attached to the element.

Four types of elements will be used in addition to the water-mix element. The quantities of each type are listed below:

<u>Element Type</u>	<u>Quantity Required (including spares)</u>
A	157
B	120
C	120
D	3

3) Geometry

All of the fuel elements used in this test will be of the KVN geometry. Listed below are the dimensional requirements for these elements:

<u>Nominal Dimensions (inches)</u>	
Core O.D.	1.431
Core I.D.	0.533
Core Length	8.325
Finished Fuel O.D.	1.520
Finished Fuel I.D.	0.420
Finished Fuel Length	8.865

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The allowable tolerance on outside diameter for fuel elements used in this test is ± 0.002 inch.

	Element Type			
	A	B	C	D
Nominal Support Height	0.092	0.080	0.070	0.050

All support rails will be fabricated from 0.050 inch aluminum stock in accordance with Drawing H-3-7948, and are to be attached to the fuel element by ultrasonic welding techniques. Placement of the supports on the fuel element will be as specified on Drawing H-3-7950.

The dimensions of the water-mix spool to be used for this test are as follows:

Body Diameter	1.20 inch
Protruding Lip Diameter	1.51 inch
Hole Diameters	0.45 inch
Length	2.0 inches

The end contours shall conform with the end contours of the KVN fuel elements. Material and finish for the spool shall be as specified on Print H-3-7597.

4) Measurements and Tests

All normal quality measurements and tests used for regular production fuel elements will be given to all of the elements of this test. In addition to these routine measurements, each finished fuel element of this test will have O.D. and I.D. at the three standard locations, length and warp-ellipticity measurements taken. The weight of the downstream 15 pieces in each fuel column will be required.

Special diameter measurements will be obtained on 32 of the fuel elements. Two inside and outside diameters, 90° apart, of these special pieces will be measured every one inch along the length of the element. In addition, bore core measurements will be obtained to permit characterization of can wall thickness of these elements. The weight of each of these pieces will also be taken and recorded. Three of the elements will be made into type D pieces (0.050 inch supports). The remaining pieces will be made into eleven type A, nine type B, and nine type C elements.

All elements for this test will have support height measurements taken and recorded. The records will be maintained to permit identification of each support height measurement with the corresponding support.

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5) Column Make-up

For convenience, each fuel column type described below will be assigned an arbitrary code letter. This code letter need not appear on any fuel elements.

Three fuel columns of 38 elements each will be formed of elements with the 0.092 inch minimum support height. Column Code - E.

Three fuel columns of 33 elements each will be formed of elements with the nominal 0.080 inch supports. Column Code - F.

Two fuel columns of 33 elements each will be formed of elements with the nominal 0.070 inch supports. Column Code - G.

One fuel column of 33 elements will be formed of 32 elements with 0.070 inch nominal supports and one water-mix element, also with 0.070 inch nominal supports, placed in the number six position from the downstream end. Column Code - H.

One fuel column will be formed of 35 elements with 0.092 inch minimum supports and three elements with nominal 0.050 inch supports, the latter elements to be placed in element positions 10, 11, and 12 from the downstream end of the column. Column Code - J.

The specially measured fuel elements will be placed into the appropriate columns, located in the 10, 11, and 12 positions from the downstream end.

Each column will be assigned a series number and this series number, as well as the individual element position number within the column, will be stamped on the base end of the element, number one piece being downstream. Each fuel column will be supplied with two spare pieces. One spare water-mix element will be supplied.

c. Thermocouple Probes

Each tube utilized in this test will be equipped with a downstream thermocouple probe. The installation of each thermocouple probe will be monitored by the fuels representative of Research and Engineering.

This test authorizes a maximum of ten downstream thermocouple probes to be installed.

3. Irradiation

a. Charging

The three "E" fuel columns of this test will be machine charged and the remaining seven columns of elements will be hand charged. The hand

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charging will be accomplished without the front nozzle assemblies attached to the tubes. All columns will be charged in numerical sequence, number one piece being downstream. The charging of these elements will be followed by the fuels representative of Research and Engineering. After charging, each column will be seated against the downstream thermocouple probe. Each fuel column series number will be recorded as to tube into which it was charged and the location of any spare pieces which are used will also be recorded.

b. Data

Daily temperature and flow data during operation for each of the tubes charged in this test will be recorded on data sheets provided by the test authors. The thermocouple temperature data will be recorded daily at approximately the same time on the data sheets. For convenience, it is suggested that all data be recorded during the day shift. The assigned Process Engineer, KW Reactor, will assume the responsibility for collection of the completed data sheets.

c. Operating Conditions and Limits

This test authorizes operation with high process tube R values and, therefore, higher local annulus coolant temperatures and fuel element surface temperatures than normal. Boiling of the annulus coolant will be prevented by selecting process tubes with sufficient rear header pressure to maintain the end-of-charge coolant temperatures below the coolant saturation temperature. This will be verified by thermocouple probe data. Exposures will be limited to a calculated cladding corrosion loss of 20 mils or normal goal, whichever is less. Jacket corrosion losses will be calculated weekly, based on measured outlet coolant temperatures. TAI limits will be the same as those which are specified for KVN process tubes by PT IP-565-AM.*

d. Goal Exposure

The goal exposure for each of the columns of this test will be specified by the test authors after accumulation of no more than 14 days of operating data. The goal exposure of each column will be determined by the maximum corrosion rate for that tube, with the thermocouple probes supplying the temperature information. The goal exposure which is specified will provide reasonable certainty for non-rupture performance. In the event of malfunction of a thermocouple probe, the goal exposure for that tube will be based upon conservative estimates of the corrosion rates for that column of fuel.

The anticipated goal exposure plan for these columns is listed below:

* HW-76254, "Production Test IP-565-AM, Installation of Zirconium Process Tubes, 105-KW Reactor," D. H. Curtiss, M. H. Schack, January 16, 1963, Unclassified.

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<u>Column Type</u>	<u>Average Tube Discharge Exposures</u>	<u>Anticipated Residence Time</u>
E	800 MWD/T	3 months
F	500 MWD/T	2 months
G	500 MWD/T	2 months
H	500 MWD/T	2 months
J	500 MWD/T	2 months

Changes in the scheduled goal exposure of these elements may be made with the concurrence of the Manager, KW Processing and the test authors.

e. Discharge

Special pickup after discharge will be required for each of the fuel columns of this test. Up to three tubes of elements may be stacked in a single bucket as long as identification of the elements contained in each bucket as to tube number can be maintained.

In the event of discharge under unusual circumstances, i.e., after occurrence of a rupture in one of the columns, elements from each tube may be requested to be put in individual buckets to facilitate post-irradiation handling.

Although no ruptures are authorized by test, the occurrence of a failure in one of the tubes will not be sufficient cause for discharge of additional columns. The decision to discharge other columns will be based in part upon results of the examination of the rupture element and other elements from the failure column. Discharge of any other fuel elements as the result of a rupture will require the consent of the test authors.

4. General

a. Postirradiation Examination

All fuel columns used in this test will be examined after discharge at the Metal Examination Facility, 105-C. A comprehensive visual examination of both the outside and inside surfaces will be made. Inside and outside diameters, warp-ellipticity and length measurements will be made on all elements. Specially designated elements will also be weighed. Additional measurements as deemed necessary by the test authors may also be requested.

After analysis of the examination data, specific elements will be sent to the Radiometallurgy Laboratory for destructive examination.

b. Costs

The costs associated with this test are estimated to be as follows:

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			<u>Total Man Hours</u>
1) Bore-gauging ten tubes	15 min/tube	2-1/2 hours - front elevator time	7-1/2
2) Installation of ten thermocouple probes	20 min/probe	3-1/3 hours - rear elevator time	10
3) Special charging of ten monitor columns of fuel	15 min/tube	2-1/2 hours - front elevator time	5
4) Special pickup of ten fuel columns	15 min/tube	2-1/2 hours - front elevator time and pickup chutes time	2-1/2

The cost incurred as a direct result of this production test may be charged to the following cost code XXXX-5R23-XXX-.71.

c. Schedule

The present schedule calls for installation of approximately 100 smooth-bore Zircaloy-2 tubes in KW Reactor during February, 1963. It is the intent to charge all of the elements of this test during that outage. Should this schedule prove to be impractical, the test will be charged at the first outage mutually agreed upon by the affected personnel.

RESPONSIBILITIES

Production Fuels Section will be responsible for the canning, finishing, testing, quality control, and preirradiation measurements of fuel elements used in this test.

Research and Engineering Section

Process and Reactor Development Subsection shall be responsible for over-all coordination of the test, provision of bases for operating limits, analysis of operating data, provision of technical support, and reporting of the test results.

Process Technology Subsection shall be responsible for providing assistance to both the Processing Operation and the Process and Reactor Development Subsection in preshutdown scheduling, in selection of test channel locations, specification of operating limits, and for forwarding operating data to the authors.

Testing Subsection shall be responsible for process tube measurements and postirradiation fuel element examination and measurements.

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Manufacturing Section

KE-KW Reactor Operation will be responsible for scheduling, for operational safety and production continuity of the reactor, and for charging the test material.

Production Scheduling shall be responsible for scheduling the discharge of the test material and for maintaining accurate records for the material charged under this program.

K. L. Hladek

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Process and Reactor Development
Research and Engineering Section

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APPENDIX I DEFINITIONS

The terms "R Value" and "eccentricity" used throughout this document are defined as follows:

1. The temperature variations around the annulus are expressed mathematically as "R values". R is defined as:

$$R_x = \frac{\Delta t_x}{\Delta t_b}$$

Where: R = R value, unitless

Δt = Temperature rise, any temperature units

Subscripts:

x = A particular point on the tube circumference.

b = Bulk coolant conditions.

2. Eccentricity is defined as the amount the fuel element is displaced from perfect centering in the process tube as shown in the following sketch.

$$E = \frac{a}{r_{\text{tube}} - r_{\text{fuel}}} \quad (100)$$

E = eccentricity (%)

r = radius, inches

a = amount of displacement as shown in sketch, inches

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