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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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SUPPLEMENT A TO PT-IP-183-A-98-FP:
EVALUATION OF PROJECTION FUEL ELEMENTS
FOR USE IN K PROCESS TUBES

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By DK Hanson - 12-17-93
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SUPPLEMENT A TO PT-IP-183-A-98-FP:
EVALUATION OF PROJECTION FUEL ELEMENTS FOR USE IN K PROCESS TUBES

OBJECTIVE

The objective of this supplement⁽¹⁾ is to authorize charging of ten tubes of "bumper" fuel elements and controls into each K Reactor. The test is designed to reevaluate the reduction in hot-spot incidence associated with fuel alignment within K Reactor ribbed process tubes for both natural and enriched uranium I&E fuel elements of the KIV geometry.

TEST SUMMARY

Ten columns of bumpered test elements and ten columns of non-bumpered control elements are to be charged into the high flux region of each K Reactor. All fuel elements will be fabricated from KIV size components and will be irradiated to 1200 MWD/T. All columns, both test and control, are to be picked up special and sent to the 105-C-MEF for examination. KW Reactor will test enriched I&E bumpers and KE Reactor will test natural I&E bumpers.

BASIS AND JUSTIFICATION

Fuel misalignment within the process tube has long been hypothesized as one of the major causes of hot-spot flow and corrosion patterns and hence hot-spot ruptures. A bumper fuel element was developed to alleviate this type of fuel failure. Testing of the bumper fuel geometry in the old reactors^(2,3&4), specifically D Reactor, has demonstrated an ability to markedly increase resistance to side failures and to reduce hot-spot frequency:

- A. A test utilizing 1.47% enriched bumper and non-bumper control I&E fuel elements was conducted at D Reactor⁽⁴⁾ to determine the relative rupture resistance of the bumpered fuel. The test data indicated a factor of at least 38 improvement in rupture resistance at the 95% confidence level for the bumper fuel⁽⁵⁾.
- B. While the test⁽³⁾ to evaluate the reduction in hot-spot incidence associated with the bumper fuel did not reveal as dramatic a result as the relative rupture resistance test, it did demonstrate that the bumper fuel element can be effective in alleviating hot-spots. In essence, thirteen columns of bumpered elements were compared to fourteen columns of non-bumpered controls with the following results⁽⁶⁾:

- (1) HW-56525-C, "PT-IP-183-A-98-FP, Evaluation of Projection Fuel Elements for Use in K Process Tubes", R. E. Hall, 11/5/58.
- (2) HW-60444-C, "PT-IP-262-A-11-FP, Evaluation of Projection Fuel Elements for Use in Ribbed Process Tubes - Demonstration Loadings", R. E. Hall, 5/25/59.
- (3) HW-60444-D, Supplement A to IP-262-A, R. E. Hall, 10/7/59. - - - Authorized 20 tubes in D Reactor.
- (4) HW-60444-E, Supplement B to IP-262-A, M. A. Clinton, 6/20/60. - - - Authorized 4 tube run-to-rupture test and 100 tube demonstration load at D Reactor.
- (5) HW-32687 Rev, "Statistical Distribution Theory Underlying the Reactor Fuel Element Failure Problem", J. L. Jaech, 1/18/55.
- (6) Test was conducted with collapsible bumpers which were fabricated from 20 mil stock. The reasons why some bumpers were ineffective is under investigation.

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<u>Item</u>	<u>Effective Bumpers</u>	<u>Ineffective Bumpers</u>	<u>Non-bumper Control</u>	<u>Significance</u>
Number of tubes	5	8	14	No
Hot-Spots Observed	7	66	162	Yes
% Hot-Spots	4.2	24.7	34.4	Yes

Previous testing of bumper fuel elements in KW Reactor⁽¹⁾ (ten tubes charged on 3/24/59 and discharged on 7/26/59) indicated that the concept and geometry were feasible in that fuel distortion did not yield discharge problems and that the presence of the supports did not create localized areas of rapid corrosion. However, one of the major objectives of the test - to provide data to indicate a statistically significant difference in hot-spot incidence - was not achieved⁽⁷⁾ and further testing was authorized for the older reactors. The justifications for further testing of the bumper fuel in K Plant are as follows:

1. The currently observed hot-spot incidence for normal production over that experienced from the control material from the earlier test appears to be larger⁽⁸⁾. When the previous test was run, mid 1959, the hot-spot incidence in the control material was low⁽⁹⁾ - so low in fact, that even if bumper fuel had been better the test data could not have supported such a conclusion.
2. The I&E fuel element geometry has changed from KIII to KIV and the bumper fuel currently being tested is termed a 3-rail element whereas previous testing was done with a 4-rail bumpered element.
3. A larger guaranteed annulus can be obtained in a K process tube and thus data to aid in establishing necessary annular clearances to eliminate hot-spots obtained.
4. Since the inlet nozzle will have been internally broached to accommodate the bumpered fuel, charging the fuel through these modified nozzles with an old reactor prototype bumper charging machine will provide an opportunity to evaluate the adequacy of the nozzle design. The earlier test performed at KW required the inlet nozzles to be removed and the fuel elements to be hand charged.

TEST DETAILS

1. Reactor

- A. KE Reactor has been chosen for the test involving natural uranium I&E bumper fuel.
- B. KW Reactor has been chosen to run the enriched uranium I&E bumper fuel test.

(1) Op. cit., HW-56525-C, p. 2.

(7) HW-65717, "Status Report - Projection Fuel Testing Program, July 1960", M. A. Clinton, D. W. Peacock, 7/15/60.

(8) Eighty-two tubes of fuel examined from PT-IP-216-A from both K Reactors indicated an over-all average hot-spot frequency of about 12% or 5 hot spots/tube. The hot spots observed varied from 0 to 15 per tube.

(9) One hot spot in the control material and none on the test fuel.

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2. Material

A. Fuel Elements

- 1) Cores - Core material for the enriched charges shall be 0.947% enriched uranium of the KIV-E size. Cores for the natural uranium charges will be of the KIV-N size.
- 2) Cladding - Can and spire components shall be X-8001 alloy aluminum furnished by Alcoa in the KIV sizes.
- 3) Projections - The bumper rails will be fabricated from X-8001 aluminum alloy and attached to the fuel element by ultrasonic welding techniques. Six collapsible type rails will be attached, three on each end on 90° centers inline.
- 4) Nominal Dimensions - The finished fuel elements will have the following nominal dimensions:

<u>Dimension (inches)</u>	<u>KIV-N</u>	<u>KIV-E</u>
Core OD	1.370	1.370
Core ID	0.498	0.513
Core Length	8.325	6.000
Canned OD	1.459	1.459
Canned ID	0.385	0.400
Effective Element Length	8.865	6.540
Bumper Height	0.060	0.060
Bumper Length	2.312	2.132
Bumper Width	0.188	0.188
Bumper Thickness	0.032	0.032
Maximum Bumper Diameter	1.585	1.585
Distance Bumper from End of FE	1.250	0.500

All components will meet requirements set forth in fuel element process specifications⁽¹⁰⁾ and all finished dimensions will be within normal fuel tolerances⁽¹¹⁾.

- 5) Water-Mixers - Water-mixer elements will not be required for this test.
- 6) Quality - All elements, both test and control, accepted for reactor charging must pass the normal quality control specifications in effect at the time this test material is prepared. All material representing each metal type, both the bumpered test elements and non-bumpered control elements, will be selected from the same parent lot and will be canned under similar conditions.
- 7) Quantity - Twenty tubes of natural uranium and twenty tubes of 0.947% enriched I&E fuel will be required by this test. Half of each metal type will be fabricated with 60 mil high collapsible bumpers.

(10) HW-47029, "Process Specifications, Fuel Element Manufacturing Processes", PPD.
(11) H-3-7350 Rev 9, "Canned Uranium Fuel Elements", 8/4/60.

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<u>Columns</u>	<u>Type</u>	<u>Pieces/Charge</u>	<u>Spares</u>	<u>Total</u>
1 thru 10	KIV-N	38	5	385
11 thru 20	KIV-N-B	38	5	385
21 thru 30	KIV-E	46	5	465
31 thru 40	KIV-E-B	46	5	465
				<u>1,700</u>

- 8) Pre-Irradiation Measurements - All material, except the spares, shall have measurements of diameter and warp recorded. Pieces 1 through 15 shall have weights recorded. Each piece shall be numbered to identify its position and column in addition to other required numbers⁽¹²⁾. It will not be necessary to obtain pre-irradiation measurements on the spares; however, they will be numbered to facilitate identification.

B. Process Tubes

Existing K ribbed aluminum process tubes located in the central flow zone shall be utilized for this test.

C. Dummies and Seating

The downstream dummy pattern and seating method in use at the time this test is charged will be used.

D. Thermocouple Probes

Downstream thermocouple trains to measure annular temperature distribution may be utilized as specified by the test author. A maximum of ten probes is authorized by this test. They may be used in either the bumpered test columns or the non-bumper control columns or both and in either reactor.

One of the problems requiring better definition is that of process tube corrosion associated with the three-rail bumpered fuel element. Also, since the KIV element is slightly smaller and will rest closer to the bottom of the ribbed process tube than the KIII, it appears prudent to acquire data to evaluate this condition for the control elements.

E. Probolog

Each tube selected for downstream thermocouple trains shall be probologged before and after irradiation of the test material.

F. Nozzles

Inlet nozzles modified as per Design Change No. 448 should be installed on those tubes selected to be charged with bumper fuel elements prior to charging; however, removal of the inlet nozzle to facilitate charging is authorized if the above nozzle modification cannot be accomplished without interfering with other scheduled programs.

(12) HW-65058 Rev 3, "Fuel Element Lot Identification and Component Codes".

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G. Charge Machine

It is recommended that all elements be charged with a charge machine.

3. Irradiation

A. Charging

All columns will be serially numbered and will be charged in numerical order with piece number one downstream. Each column charged shall have the lot number and series number recorded opposite the tube number on the front face sequence sheets. Machine charging of the control material is required. Hand charging of the bumper material is authorized if a charge machine is not available.

- 1) Natural - The ten bumper and ten control columns are to be charged in a localized pattern within the high flux region of KE Reactor. As far as is possible, a location which will provide similar irradiation conditions for both the bumper and non-bumper fuel will be selected by the assigned Process Engineer and Physicist. The area selected is to have higher than average powers with normal rod configurations.
- 2) Enriched - Since it will probably not be possible to charge the enriched material in a localized pattern, the material is to be charged in pairs; i.e., a bumper column should be charged in near proximity to a control column within a high flux region in the fringe enrichment pattern.
- 3) Selection - The tubes will be selected from those scheduled for regular discharge.
- 4) Column Length - Natural uranium I&E charges will consist of 38 pieces and enriched I&E charges will be 46 pieces long.

B. Irradiation

Daily temperature data will be recorded for all tubes equipped with downstream thermocouple probes on data sheets which will be provided by the test author. No special data recordings will be required routinely for tubes not equipped with T/C probes.

C. Goal Exposure

All material charged under authorization of this test shall be irradiated to a 1200 MWD/T goal exposure unless two failures in the same type of metal occur first, at which time the test may be discharged provided all columns can be specially picked up. The rupture columns should be obtained if at all possible. The enriched metal and the natural uranium metal fuel charges are considered separate tests; hence, the occurrence of two failures in one uranium metal type will not constitute grounds for discharge of the material in the other reactor unless requested by the test author with the concurrence of the Manager of the affected reactor. Goal exposure changes may be made by request from the test author with the concurrence of the Manager of the affected Processing Operation.

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D. Discharge

All columns of this test will require special pickup and shipment to the 105-C-MEF for post-irradiation examination and measurement. During discharge operations involving bumper fuel elements, particular care should be taken to report pertinent observations relative to post discharge handling.

E. Operating Conditions and Limits

A column of bumpered fuel element will have about 5% less flow than the non-bumpered controls in the KIV geometry and about 3% less flow when compared to KIII geometry non-bumpered elements on an individual tube basis. Normal TAI and TOA boiling limits specified for KIV size elements shall apply to all columns charged under this test.

F. Special Procedures

- 1) Process Standards - Compliance with all Process Standards not specifically excepted by this test must be maintained.
- 2) Water Shut Off - Existing curves for KIV size elements will be applicable.
- 3) Rupture and Stuck Charge Removal - existing procedures will be applicable.

4. GENERAL

A. Duration

Since this test will require about 5 months irradiation time, the test authorization will be terminated on August 1, 1962. In addition, the test will be cancelled if reactor charging has not begun by August 1, 1961.

B. Schedule

- 1) The natural uranium I&E fuel elements have been fabricated and may be charged on the first convenient outage following approval of this test.
- 2) The enriched material is being prepared and should be ready by 5/1/61.

C. Post-Irradiation Examination

All fuel elements shall be weaseled, visually examined, measured to determine post-irradiation diameter, warp, and ellipticity; and the downstream fifteen pieces shall be weighed. Elements having unusual warp, diameter increase, ellipticity, surface bumping, or corrosion patterns shall be set aside for further examination. If deemed beneficial, selected pieces may be sent to Radiometallurgy for further detailed examination.

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D. Costs

All incremental costs associated with the performance of this test may be charged to XXXX-5R24-XXX.73. Outage time requirements are listed below for scheduling purposes.

<u>Job</u>	<u>Processing Time</u>	<u>Elevator Time</u>
1. Remove and Replace Inlet Nozzle	1/2 mh/tube	1/4 hr/tube
2. Install T/C Probes	1/2 mh/tube	1/2 hr/tube
3. Remove T/C Probes	1/2 mh/tube	1/4 hr/tube
4. Probolog (Includes Flushing)	1 mh/5 tubes	1 hr/5 tubes
5. Special Pickup	1/2 mh/tube	---

In addition, up to four ruptures are authorized - two in each type of metal - if necessary.

E. Hazards

Hazards peculiar to this test are primarily associated with the presence of the bumper projections on the fuel surface. It is conceivable that these bumpered elements could stick tighter than do non-bumpered elements since the bumpers restrict fuel displacement within the ribbed process tube; however, it appears that no extreme risk is involved in this testing program with regards to safety.

RESPONSIBILITIES

Fuels Preparation Department

Manufacturing Operation shall be responsible for fabrication of all elements used in this test, providing the elements to others for attachment of the projections, element quality, and pre-exposure measurements of all pieces.

Engineering Operation shall be responsible for attachment of the projections, liaison contact and coordination of the 300 Area portion of the test.

Irradiation Processing Department

Research and Engineering Operation

Process Technology Operation will be responsible for providing assistance in pre-shutdown scheduling and charging, reporting of operating data to the author, for specifying of operating limits and for specifying column locations.

Process and Reactor Development Operation shall be responsible for coordination of the test, analysis of operating data, reporting of inreactor performance, and for provision of bases for operating limits. Specifically, Reactor Engineering Unit will concur with the choice of tubes selected for thermocouple probes.

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Operational Physics Operation shall be responsible for assistance in choice of test location and reactivity changes required.

Component Testing Operation shall be responsible for post-irradiation fuel element examination and measurement.

KE-KW Processing Operations

KE-KW Processing Operations shall be responsible for scheduling, the operational safety, and production continuity of the reactor, charging of test material under the direction of representatives of Research and Engineering, and for collection of operating data.

KE-KW Maintenance Operations shall be responsible for all maintenance required by this test to include nozzle modifications, nozzle removal and installation, and thermocouple probe installation and removal.

M. A. Clinton

Reactor Fuels Unit
Process and Reactor Development Subsection
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

MA Clinton:mm

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