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DESIGN OF SUPPLEMENT A
TO PRODUCTION TEST IP-183-A-98-FP
EVALUATION OF PROJECTION FUEL
ELEMENTS IN K PROCESS TUBES

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DESIGN OF SUPPLEMENT A TO PRODUCTION TEST IP-183-A-98-FP

EVALUATION OF PROJECTION FUEL ELEMENTS IN K PROCESS TUBES

by

W. H. Hodgson

and

M. A. Clinton

July 27, 1961

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INTRODUCTION:

Fuel element misalignment is an apparent cause of "hot-spot" ruptures. Several methods of eliminating hot spots have been tried, i.e., tru-line end contours, X-8001 nickel aluminum alloy jacketing material and hand seating. However, none appear to have completely solved the hot-spot problem.

Attachment of projections to the side of fuel elements appears to offer a means of minimizing misalignment since they act as bumpers against the side of the process tubes. Preliminary data from tests now in progress or recently completed[1,2] indicate excessive corrosion rates are not to be expected on fuel elements with projections attached. In fact, no hot spots were found on 39 columns of normal self-supported I&E fuel elements discharged at normal goal or on four columns of enriched (1.47% U-235) self-supported I&E elements irradiated to 850 MWD/T exposure.

Previous testing of "bumper" fuel elements in KW Reactor[3] indicated that a fuel design of the desired geometry was feasible, fuel distortion did not yield discharge problems, and that the presence of the supports did not create localized areas of rapid corrosion. One of the major objectives of this test, however, was not achieved. To provide sufficient data to indicate a statistically significant difference in hot-spot incidence at least a one per cent incidence on the control material was required. In actuality, only one hot spot was observed on the control material. Even though the bumper elements had no indications of uneven heat transfer (hot spots and hot areas), similar results on the control material invalidated this comparison. Since the incidence of hot spots and associated ruptures appeared to be low at the K Reactors, further testing was authorized for the older reactors where more severe corrosion is experienced. Testing in the older reactors was delayed because limitations imposed on support height and thickness adversely affected rail strength. These same difficulties would not be expected with the K design, and it appears prudent to initiate a test for the K plant in order that backup experience be obtained with present fuel and bumper designs should extended use of bumper fuel elements in K Reactors become desirable.

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(1) HW-50991 A, "Production Test IP-84-A, Evaluation of Slugs Having Projection for Use in Ribless Tubes", R. E. Hall, March 12, 1958 ([redacted]).

(2) HW-59756, "PT-IP-247-A-FP, Irradiation of 1.47% Enriched Self-Supported I&E Fuel Elements in Ribless Process Tubes", R. E. Hall, July 29, 1959 ([redacted]).

(3) HW-56525 C, "PT-IP-183-A-98-FP, Evaluation of Projection Fuel Elements for Use in K Process Tubes", R. E. Hall, November 5, 1958 ([redacted]).

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OBJECTIVE

The objective of this supplement(4) is to prepare and irradiate up to ten tubes of "bumper" fuel elements and controls in each K Reactor. The test is designed to re-evaluate 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(5,6,7), 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(7) 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(8).

B. While the test(6) 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(9):

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(4) IBID, HW-56525 C

(5) HW-60444 C, "PT-IP-262-A-11-FP, Evaluation of Projection Fuel Elements for Use in Ribbed Process Tubes - Demonstration Loadings", RE Hall, 5/25/59.

(6) HW-60444 D, "Supplement A to IP-262-A", RE Hall, 10/7/59 - - - Authorized 20 tubes in D Reactor.

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(7) HW-60444 E, "Supplement B to IP-262-A", MA Clinton, 6/20/60. - - - Authorized 4 tube run-to-rupture test and 100 tube demonstration load at D Reactor.

(8) HW-32687 REV, "Statistical Distribution Theory Underlying the Reactor Fuel Element Failure Problem", JL Jaech, 1/18/55.

(9) Test was conducted with collapsible bumpers which were fabricated from 20 mil stock. The reasons why some bumpers were ineffective is under investigation.

Item	Effective Bumpers	Ineffective Bumpers	Non-Bumper Control	Significance
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(10) (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(11) 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(12). When the previous test was run, mid-1959, the hot-spot incidence in the control material was low(13) - 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 clearance 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.

(10) Op. cit., HW-56525 C, page 2.

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

(12) 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 per tube. The hot spots observed varied from 0 to 15 per tube.

(13) 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 0.94% 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 in-line.

4) Nominal Dimensions - The finished fuel elements will have the following nominal dimensions:

Dimension (inches)	KIV-N	KIV-E
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	2.312
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(14) and all finished dimensions will be within normal fuel tolerances(15).

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.

(14) HW-47029, "Process Specifications, Fuel Element Manufacturing Processes", FPD.

(15) H-3-7350 REV 9, "Canned Uranium Fuel Elements", 8/4/60.

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7) Quantity - Twenty tubes of natural uranium and twenty tubes of 0.94% enriched I&E fuel will be required by this test. Half of each metal type will be fabricated with 60-mil-high collapsible bumpers.

Columns	Type	Pieces/Charge	Spares	Total
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
				1,700

TESTING

1. 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[16]. It will not be necessary to obtain pre-irradiation measurements on the spares; however, they will be numbered to facilitate identification.

2. 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.

(16) HW-65068 REV 3, "Fuel Element Lot Identification and Component Codes".

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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. 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.

3. 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.

TEST AUDIT

The 300 Area data for this production test will be recorded in HW-56525. The location of the 100 Area data will be noted in the final report of this test. Any unusual incidents, whether or not they seem important at the time, are to be recorded in the notebook. The appendix of this report is a guide for the preparation of the notebook.

TEST LIMITATIONS AND HAZARDS

The fact that no early corrosion effects have been noted in the B tests indicates that very little rupture potential is associated with this test. It is possible, however, that problems in column discharge may arise due to fuel element instability. The collapsible supports should do much to minimize this risk, since moderate pushing forces will cause rail collapse. Should forces in excess of charge machine forces be required (greater than 2500 pounds), tube removal may be at least costly; however, normal pushing forces for rupture removal may be used if desired.

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Reactor Fuels Operation
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

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DATA TO BE RECORDED IN PRODUCTION TEST NOTEBOOK

I. Fuel Element Core Lot Numbers

II. Can-Lot Numbers

III. Assembly Process

A. Protective Coating
B. Autoclaving
C. Support-Type and Welding Procedure
D. Inspection

IV. Pre-Irradiation Examination

A. Weight
B. O.D. and I.D.
C. Length
D. Warp or Ellipticity

V. Log

Running account with dates recording the progress of the PT, unusual incidents (such as a slight change in process during assembly), and other deviations whether or not they seem pertinent at the time of occurrence.

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