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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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STATUS REPORT: PROJECTION FUEL TESTING PROGRAM
JULY 1960

INTRODUCTION

This is the second in a series⁽¹⁾ of reports issued to discuss the accomplishments, status, and future testing of the projection fuel element concept. Its purpose is to serve as a reference for projection fuel element testing.

OBJECTIVE

The program's objective is to develop the technical foundation for use of projection fuel elements through an accelerated testing program. Two types of projection fuel elements are being considered (1) Self-Supported Fuel Elements for use in ribless aluminum or zirconium process tubes, and (2) Bumper Fuel Elements for use in ribbed process tubes. A further objective of the program is to determine the most desirable method of fabrication and type of support for projection fuel elements. The program must develop the self-supported concept in time to meet the proposed ribless zirconium process tube installation schedule. Parallel development of the bumper fuel element is an interim program to realize immediate gains in reduced hot spot rupture tendency, during the change over to zirconium tubes.

SUMMARY

The appended charts indicate the proposed accelerated testing and development schedules being followed. Testing of the self-support concept has indicated that the collapsible supports are adequate to maintain fuel centering, do not introduce additional corrosion problems resulting from the supports, and do in fact greatly reduce the incidence of hot-spot flow patterns. Reductions in rupture potential of at least a factor of 30 have been demonstrated at the 95% confidence level. Bumper fuel testing has indicated that the concept is feasible for K Plant use, and current testing is being done to evaluate this concept at the old reactors.

DISCUSSION

Two projection concepts are to be considered for initial testing in this program; 1) the self-supported fuel element for use in ribless or vestigial ribbed process tubes, and 2) the bumper fuel element for use in ribbed process tubes in which the element is tube-rib supported and the projections act only as bumpers to guarantee the annular flow area.

It is assumed that the optimum fuel concept will be a self-supported element in which fuel-tube flexibility is attained. The bumper concept may provide an economic means of reducing the incidence of hot spot ruptures pending the change-over to zirconium tubes. The initial tube replacement schedule calls for 300 zirconium tubes in C Reactor by January 1961 and complete C Reactor conversion by December 1961. The K Plant and the Old Reactors will then follow with complete HAPO conversion by mid-CY 1965.⁽²⁾ However, recent information indicates that this program may be delayed approximately one year.

1. HW-64321, "Status Report: Projection Fuel Element Testing Program", R. E. Hall, March 10, 1960. (██████)
2. HW-62862-A, "Plant Improvement Program, Irradiation Processing Department", A. B. Greninger, June 1, 1960. (██████)

I. Support Design

Projection fuel elements are I&E fuel elements with the projections attached after canning. The types of projections or rails are outlined below:

A. Collapsible Bridge-Rail Design

This initial design postulated that fuel elements having projections could cause higher rupture removal forces, more severe tube damage, and an increased incidence of stuck charges. For these reasons it appeared desirable to design the support such that it would collapse under normal discharge forces and permit removal without excessive discharge forces or resultant tube damage. The collapsible bridge-rail design is not optimum with respect to fabrication costs. Because each fuel element requires 16 welds to attach the supports, this complicates mechanization of the welding equipment and associated support handling devices. In addition, although each support is tested for resistance to shear stress, the large number of welds increases the probability of weld failures.

B. Collapsible End-Spider Design

The collapsible end-spider design has half the welds required for the bridge-rail design, while retaining the advantage of collapsibility. Aluminum tabs extending from a support ring attached to the ends of the fuel element form the bridge rail supports. Two models are being considered: 1) long end-spider and, 2) short end-spider. In the long end-spider design the tab extends over a heat generating surface without bonding and this may provide a corrosion problem which will have to be reactor tested. The short end-spider design, currently being evaluated, demands that the tab extend over the aluminum can base only, which should eliminate the above corrosion problem. The proposed incentive for the end-spider concept is a lower manufacturing costs resulting from the decreased number of welds (8 instead of 16) and simplification of the support tab handling equipment. The actual costs of fabricating the end-spider have not been established, but this will establish the incentive to use or discard the concept when the technical feasibility has been demonstrated.

C. Solid Rail Design

Recent experimental results from HLO(3) indicate that the collapsible support incentive for bumper fuel may not be as large as previously thought. This test indicated little difference in tube damage and fuel element removal forces, regardless of support type, for pieces intentionally ruptured in a ribbed process tube in an autoclave. In order to have a collapsible rail bumper element the rails must be fabricated from 20 mil stock. Supports of this dimension are difficult to weld and are thought to be too fragile for reactor use. Consequently, a solid rail appears to be a method of obtaining a guaranteed annular clearance and this concept will be evaluated for bumper use under Supplement B to PT-262.(4)

3. HW-65352, "Supplement to Projection Fuel Element Autoclave Rupture Test", W. I. Steincamp, May 25, 1960. ()
4. HW-60444-E, "Supplement B to PT-IP-262-A-11-FP, Evaluation of Projection Fuel Elements for Use in Ribbed Process Tubes", M. A. Clinton, June 20, 1960. ()

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II. Method of Attachment

Projections are attached to the fuel elements by two methods: 1) resistance spot-welding and, 2) ultrasonic welding. The following is a short condensation of the advantages and disadvantages for each method.

A. Resistance Spot-Welding (fusion bond)

Resistance spot-welding (fusion bond) has proven to be a satisfactory method of support attachment; however, being a short time, high current density process, all variables must be closely controlled to preclude arc burns, excessive weld penetration, or other damage to the fuel element surface. The principal advantage of resistance welding is the well established technology and welding speed. Specific disadvantages are:

1. Automation is complicated by associated electrode problems:
 - a. Electrode pickup - it is necessary to brush the electrode after 16 welds (one fuel element) to prevent copper contamination of the can surface.
 - b. Tip contour - repeated brushings can alter the electrode shape and affect the quality of the weld.
2. Cleanliness is critical since control of the weld penetration depends on current control to the weld area.
3. Operator dependability - this is a problem resulting from the large number of process variables affecting weld quality.

B. Ultrasonic Welding (plastic and elastic deformation)

Ultrasonic welding (plastic and elastic deformation) has fewer associated welding variables and is easier to control than resistance welding. It is a cold process with the bonding occurring in the surface layer of the fuel element jacket (2-3 mils deep); therefore, eliminating the weld penetration problem.

1. Additional advantages are:
 - a. No electrode contamination problem.
 - b. No electrode brushing required.
 - c. No ground clamp or current problems.
 - d. Easier to automate.

Disadvantages are:

- a. New process and new technology
- b. Excessive power may produce fatigue or stress cracks in the parent metal.

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c. More difficult to determine bond quality.

d. Welding time is increased by a factor of 20.

III. Completed Testing

A. B Reactor

1. Nine columns of self-supported solid fuel elements in ribless aluminum process tubes were irradiated to 500 MWD/T without evidence of hot-spot flow patterns. Hot-spot patterns were observed on the control elements, but the test was not of sufficient size to be significant.
2. Thirty-nine columns of I&E natural self-supported fuel elements in ribless aluminum process tubes have been irradiated (up to a maximum of 950 MWD/T) and visual examination has revealed no hot-spots. These data are significant statistically and indicate a factor of improvement in hot-spot reduction of at least 7 at the 99% confidence level and a factor of 12 at the 95% confidence level, when compared to a random sample of regularly discharged production elements.*
3. A run-to-rupture test to determine relative rupture resistance of self-supported fuel elements at specific powers up to 110 KW/ft. was performed with 1.47% enriched I&E material. The control material was discharged at an average exposure of 340 MWD/T, and the test material was discharged at an average exposure of 890 MWD/T. Examination of the elements showed no hot-spots or ruptures on the test elements and thirteen hot-spots and two side failures were found on the control material. These data yield the following improvement in rupture resistance:

<u>Factor of Improvement</u>	<u>Confidence Level</u>
100	50%
30	95%
11	99%

B. C Reactor

Six columns of I&E self-supported fuel elements have been irradiated at C Reactor in ribless zirconium tubes. Only two columns have been examined, and these showed no unusual characteristics.

C. KW Reactor

Ten columns of I&E bumper fuel elements and ten control columns were charged during March 1959 to investigate difficulties associated with this concept. One column was inadvertently discharged during the next outage, and one column was discharged at 600 MWD/T without evidence of hot-spots. The remainder of the test was discharged at 800 MWD/T. Examination of the test elements showed no hot-spots but only one hot-spot was observed on the control material where 7-10 were expected; consequently, the test was not significant. No difficulties were encountered with the bumpers during the test, and the concept is assumed feasible for the K geometry.

* Visual examination of 700 irradiated normal production fuel elements revealed a 7-1/2% hot-spot incidence.

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IV. Current Testing

A. B Reactor

1. Nine columns of I&E self-supported fuel elements are scheduled to 1200 MWD/T goal exposure. These columns have the collapsible bridge rail support attached by either resistance or ultrasonic welding techniques.
2. Three columns of I&E end-spider fuel elements were charged on June 8, 1960 and are goaled to 1200 MWD/T exposure. (Short End-Spider)

Higher than normal charging forces were experienced during this charging, but an examination of two columns in storage from the same shipment showed oversized fuel elements which could produce higher than normal charging forces.

B. C Reactor

Nine columns of CIVN self-supported fuel elements are in the reactor to evaluate differences in resistance and ultrasonic welding techniques. These are goaled to 900 MWD/T and currently have accumulated an exposure of 870 MWD/T.

C. D Reactor

Twenty columns of bumper fuel elements and twenty control columns were charged on May 13, 1960. This is the first loading of bumper fuel elements at the old reactors.

V. Future Testing

A. B. Reactor

PT-84-A and its supplements are to be completed to evaluate the fuel elements, welding techniques, and tube damage effects.

B. C Reactor

PT-272-A will proceed as authorized until 100 tubes are installed in the reactor and until the relative rupture resistance of this geometry is known.

C. D Reactor

1. The run-to-rupture test portion of PT-262, which involves charging 1.47% enriched bumper fuel elements to operate at high specific powers, is scheduled. This test is similar in nature to the test performed at B Reactor for evaluating the rupture potential of self-supported fuel elements. The test should be ready for charging in July and may require six months irradiation and four ruptures.
2. Charging the 100 tube demonstration loading should be accomplished by September 1960. Supporting programs indicate that this date is reasonable.

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D. KW Reactor

The original inconclusive K Reactor bumper test as authorized by Supplement A(5) to PT-183-A will be repeated. This supplement authorizes charging ten columns of I&E natural bumper fuel elements and ten control columns. This should be accomplished in September 1960.

Since the observed hot-spot incidence at K Reactors was greatly reduced in the first K Reactor bumper test, further bumper testing was authorized for the old reactors where the hot-spot incidence was higher. This test authorized demonstration loadings at B, D, DR, F, and H Reactors to obtain irradiation data on a significant number of fuel elements to pilot the remainder of the demonstration loadings. Material originally prepared for this test did not meet requirements and replacement charges were requested. This phase of the bumper test was charged on May 13, 1960. At the present time the bumper program is about one year behind the originally defined schedule.

In order to complete the bumper testing program in time for pilot use of bumper fuel elements at the lead reactor by December 1960, and general old reactor conversion by late 1961, a highly compressed program is required. The preceding schedule will not allow sufficient test analysis to justify each successive test; however, enough preliminary data should be available to indicate any major unforeseen problems prior to the full reactor pilot loading. The schedule now in effect will be able to supply an ample foundation to justify extending the bumper fuel concept to other old reactors by July 1961.

VI. Associated Programs

A. Overbored Process Channels

Current development effort is underway which may permit eventual use of fuel elements with an OD of approximately 1.600 inches. To assure that the present AlSi dip-canned fuel element processing techniques are applicable to fuel elements of this size, negotiations with tube vendors and designs from Fuel Preparation Department are being secured for small scale testing in late 1960.

Although primary emphasis on overboring was for the old reactors, C and K Plants were also being considered. At the present time it appears that there will be no overboring at C or K Plants. The final decision on these programs should be available before issuance of the next status report.

B. Modification of Charging Machines to Permit Use of Projection Fuel Elements

The C Reactor charging machine prototype is being modified to index the four rail self-supported fuel elements to 45° with the horizontal. This is being done in an attempt to permit spline insertion between the bottom two support ribs. This machine should be ready for use during the July outage. The D Reactor prototype being identical in design should be in use by August. It may be recommended that an adapted old reactor machine be used at K in the interim while some new concepts are considered for the K Reactors.

-
5. HW-56525-E, "Supplement A to Production Test IP-183-FP, Evaluation of Projection Fuel Elements in K Process Tubes", R. E. Hall, M. A. Clinton, to be issued.
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C. Poison Spline Problem

A major problem associated with projection fuel elements is the spline problem. Two solutions are now being considered: 1) the four rail self-supported fuel elements are being indexed 45° to the horizontal allowing room for the spline between the bottom two ribs in ribless process tubes, and 2) three-ribbed bumper fuel elements on 90° centers are being considered for use in existing ribbed process tubes.

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	<u>Reactors</u>			
	<u>B</u>	<u>C</u>	<u>D</u>	<u>KW</u>
A) Total Columns Charged to Date				
1) Self-Supported	67	15	0	0
2) Bumpers	0	0	20	10
B) Columns Currently in Reactor				
1) Self-Supported	12	9	0	0
2) Bumpers	0	0	20	0
C) Total Ruptures or Hot-Spots				
1) Self-Supported	0	0	0	0
2) Bumpers	0	0	0	0

APPENDIX II

Proposed Accelerated Bumper Fuel Element Testing
and Development Schedule

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APPENDIX III

Proposed Self-Supported Fuel Elements
Testing and Development Schedule

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