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HW-73638

ASSEMBLY AND PERFORMANCE OF FUEL ELEMENTS
FOR H-REACTOR E-N DEMONSTRATION LOAD

FINAL REPORT PT-IP-350-C

This document
consists of
16 pages.

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By Authority of PR-24,
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By John Mally 4-6-94
Verified By J. Savelly 4-15-94

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May 29, 1962

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SYNOPSIS

This document reviews the preparation of the fuel elements and subsequent irradiation performance of the fuel elements for a full H-Reactor E-N demonstration loading. Processing and irradiation of unbonded target ("N") elements was completed without incident. Performance of the AlSi bonded enriched ("E") bumper fuel, while predictable, was non-optimum in the sense that a relatively high incidence of fuel oriented "hole" and "end"-type ruptures, normally associated with end closure defects, was sustained. The overall performance level of these fuel elements, however, was not significantly different from other fuel prepared during the same period, after adjustment for differences in severity of service. Observed groove corrosion penetration of the spire walls of two ruptures indicated that changes in fuel design and/or irradiation conditions would be warranted, as well as improvements in closure integrity, for future loadings subjected to equal or higher severity.

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INTRODUCTION

Preparation of enriched fuel elements and target (N) elements for a full H-Reactor E-N demonstration loading was authorized in April, 1960. The objective of this loading was to demonstrate the feasibility of operating a Hanford reactor economically as a plutonium-tritium producer to increase over-all conversion ratio and diversify product output. Irradiation of the E-N load began in May, 1961 and was completed in January, 1962.

This document presents a final report on the assembly and performance of the fuel elements for the E-N load.

SUMMARY

Enriched (0.94% U-235) fuel and lithium-aluminum alloy (3.1% nominal Li content enriched to 38.5 a/o Li 6) target element requirements for the E-N loading are shown in Table I. Extruded solid and tubular lithium-aluminum alloy stock was obtained from the Savannah River Plant for the fabrication and assembly of 6-inch solid and 4-inch I&E target elements in accordance with the unbonded "C" process. Since previous fabrication experience had been confined to solid target elements except for a small-scale test (PT-IP-255-A-9-FP), equipment and process changes necessary to accommodate the I&E geometry were based on this test. After establishing the techniques for I&E core machining, and for the internal sizing and D.C. end closure welding of the I&E elements, no difficulty was experienced in achieving high quality and yields. Irradiation of both the solid and I&E target elements progressed without incident.

Regular AlSi bonded enriched fuel lots from the production stream were used in the E-N loading. In order to minimize possible "hot spot" ruptures in this material, the loading was delayed to permit the attachment of "bumper" rails. Production test data at that time indicated "bumper" rails would effectively prevent fuel misalignment and associated cladding corrosion failures. Several process innovations were either introduced or planned during the period (November, 1960 through August, 1961) the enriched fuel was prepared to reduce braze porosity and improve closure integrity. Consequently, only partial benefits were realized from the following process changes:

- (a) Contour base cans and a 5 mil thicker spire were incorporated in the OIIIE enriched fuel model. Essentially all of the initial loading was the OIIIE model and only 88 percent of the second central "striped" loading was the OIIIE model.
- (b) Conversion to vertical cap-spire pulsing was completed January 6, 1961. About 60 percent of the initial loading was spire pulsed and all of the second central "striped" load.
- (c) Installation of pressurized quenching units on all canning lines was completed August 3, 1961. Only about 30 percent of the second central "striped" load was pressure quenched.

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Further details on the aforementioned improvements are included in the discussion section of this report. A downward trend in total external bond count is shown in Figure I.

Irradiation of the E-N loading was carried out in two cycles, as authorized in H-Reactor. The initial loading was completed in June, 1961, followed by replacement of the central "striped" load in September and October, 1961. Irradiation of the second cycle was completed in January, 1962.

As expected, the performance level of the E-N loading was largely controlled by the resistance of the enriched bumper fuel to fuel oriented failures, believed to be associated with defective end closures. Fourteen (14) ruptures (1 end, 10 hole, and 3 mechanical damage) occurred in the central "striped" loads and one mechanical damage rupture in an enriched fringe column. A summary of these ruptures is shown in Table III. If adjusted for increased severity of service, the performance level (Q) of the E-N enriched fuel with respect to fuel oriented ruptures (end and hole) was not significantly different from other fuel prepared and irradiated in the old reactors at the same time (Table IV). Based on the adjusted rupture index distribution, fuel oriented ruptures were expected in five enriched fuel lots; seven occurred. Five of these lots had an opportunity for second ruptures and four were experienced.

As a result of Radiometallurgy examination, two of the ruptures originally classified as side other and one as a core split, were reclassified as mechanical damage. Figure 2 shows examples of this damage. The overall extent and effect of this damage is unknown.

Radiometallurgy examination of two "hole" ruptures, which were second failures in lots, revealed the cause of failure was groove corrosion penetration of the spire walls (Figure 3). Considering the operating temperatures and exposures reached, failures of this type in the fuel models irradiated were not unexpected. Internal corrosion of a lesser degree had been observed in fuel subjected to about 50 percent of the severity of the E-N load.

Conclusions and recommendations based on overall experience with the E-N loading are as follows:

- 1) Both unbonded solid and I&E target elements can be assembled with the quality and closure integrity to satisfy irradiation requirements.
 - 2) Use of enriched "bumper" fuel in this type of loading will effectively minimize or prevent fuel misalignment and associated "hot spot" corrosion ruptures.
 - 3) Optimum performance of fuel elements in future E-N loads or other loadings of comparable or higher severity of service will be dependent on the degree of effectiveness of assembly process improvements to assure fuel closure integrity and to prevent "hole" and "end"-type ruptures, and modifications of fuel design and/or irradiation conditions to avoid corrosion limits of the fuel cladding.
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DISCUSSION

E-N Loading Requirements

Authorization was received in April, 1960, to prepare enriched (0.94% U-235) uranium fuel elements, and lithium-aluminum alloy (3.1% nominal lithium content, enriched to 38.5 a/o Li 6) target elements for a full old reactor E-N loading.⁽¹⁾ As conceived, this loading was to consist of 1) a blank or exterior lattice of 6-inch solid target elements, 2) an adjacent five to six lattices of enriched I&E fuel elements, and 3) a central "striped" load of columns containing both I&E enriched uranium and 4-inch I&E target elements.⁽²⁾ Overall finished enriched fuel and target element requirements were based on a 2-cycle central "striped" load. The approximate quantities required were as follows:

TABLE I

ENRICHED URANIUM AND TARGET ELEMENT REQUIREMENTS

	<u>Type of Element</u>	<u>Model</u>	<u>No. of Pcs.</u>	<u>Tons</u>
Blanket	6" Solid Target	OIIT	9,500	----
Adjacent Fringe	6" I&E Enriched U	OIIE and/or OIIIE	27,500	73
Central "Striped"	6" I&E Enriched U	OIIE and/or OIIIE	85,600	227
Loading	4" I&E Target	OIVT	8,500	----

Fabrication and Testing

Target Elements

Extruded lithium-aluminum alloy solid and tubular rod stock, having a total lithium content of $3.1 \pm 0.35\%$ enriched to a nominal 38.5 a/o lithium 6, was obtained from the Savannah River Plant for target ("N")

(1) HAN-75157, "E-N Demonstration Load", A. T. Gifford, HOO, April 11, 1960. (SECRET)

(2) HW-60309, "Proposed E-N Demonstration Load", L. W. Lang, May 18, 1959. (SECRET)

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element fabrication.⁽³⁾ The solid stock was extruded through a shear faced die and the tube stock through a porthole (3 ports) die. Each rod was roller straightened to a maximum warp of 7 mills per foot and cut into nominal lengths of 73 inches prior to shipment in order to facilitate handling and minimize core machining scrap at HAPO.

Core machining and assembly of the solid (OIIT) and I&E (OIVT) target elements conformed with specifications for the unbonded "C" process.⁽⁴⁾ Primary dimensions of the as-received lithium-aluminum alloy rod stock, the machined cores, C-64 aluminum alloy components, and the finished target elements, including applicable reference drawings, are shown in Table II.

Prior to the preparation of target elements for the E-N loading, experience had been confined to the assembly of unbonded solid target elements except for a small-scale E-N demonstration production test.⁽⁵⁾ One of the objectives of this test was to develop techniques and specifications for the assembly of I&E target elements. Equipment modifications and additions necessary to accommodate the I&E geometry were also based on the test results. Major equipment and process changes were as follows:

- a) A turret lathe with a bar feed attachment was provided to drill and ream the I.D. of the lithium-aluminum alloy tube stock and cut off the I&E cores to final dimensions. Each piece was then chucked between the center in an existing lathe to turn the O.D. concentric with respect to the I.D.
- b) In order to size the I&E target elements assemblies internally, a punch was adapted to the sizing press ram to force a nylon "insert" of pre-established dimensions through the spire prior to forcing each assembly through an external sizing die.
- c) A D-C welder was provided to assure high quality end closure welds. This unit was equipped with a water-cooled "chill block" around the collet to conduct heat directly away from the weld fusion zone, thus preventing possible thermal expansion of any gasses entrapped in the I&E target elements which might contribute to weld "blow-outs" or other defects.

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- (3) HW-64765, "Procurement of Enriched Lithium-Aluminum Alloy for E-N Demonstration Loading", F. W. Grubb, April 12, 1960. (SECRET)
 - (4) HW-47029, "Process Specifications, Fuel Element Manufacturing Processes, Section II". (CONFIDENTIAL)
 - (5) HW-60097 A, "Design of Production Test IP-255-A-9-FP, E-N Demonstration Test", W. H. Hodgson and R. E. Hall, June 9, 1959. (SECRET)

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The as-received lithium-aluminum alloy stock conformed with specifications except for approximately 542 solid cores rejected from two heats. Analysis indicated that these pieces were contaminated with refractory material, the most likely source being the alloy casting furnace.

After the necessary tooling and techniques were established for the assembly of I&E target elements, no difficulty was experienced in producing the quantities of solid and I&E target elements required for the E-N loading. Quality of the end closures was closely controlled through visual inspection, bubble test, and radiography. Machined core to acceptable finished target element yields were as follows:

<u>Type of Element</u>	<u>% Yield</u>
Solid	90
I&E	85

Enriched Fuel Elements

Beginning in August, 1960, the receipts of "0" size enriched (0.94% U-235) uranium cores from Fernald were increased to fulfill the requirements of the E-N loading. Fuel component inspection, fuel assembly and testing were performed in accordance with the "Process Specifications" and "Quality Control Standards" for AlSi bonded fuel.(6,7)

Because the incidence of enriched fuel external cladding corrosion ruptures in the fringe columns of the old reactors had increased by a factor in excess of 3, a decision was reached in October, 1960, to defer the E-N loading until about May, 1961, in order to attach "bumper" rails to the enriched fuel. Preliminary production test data at that time had confirmed "bumper" rails would effectively minimize fuel misalignment in existing ribbed process tubes and associated "hot spot" corrosion ruptures. Since projection rail welders were not installed in the AlSi Shop until August, 1961, essentially all of the enriched bumper fuel produced for the E-N loading was processed using a prototype ultrasonic welder located in the AlSi Pilot Plant.

Enriched fuel produced for the initial full reactor E-N loading consisted almost entirely of the OIIE bumper fuel model. The second central "striped" load contained about 12 percent OIIE and 88 percent OIIIE bumper fuel. A comparison of the dimensions of the two fuel models are shown below:

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- (6) HW-72029, "Process Specifications, Fuel Element Manufacturing Processes, Section I". (CONFIDENTIAL)
 - (7) HW-50377, "Quality Control Standards, Fuel Element Manufacturing Process, Section I". (CONFIDENTIAL)

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COMPARISON OF OIIE AND OIIIE
COMPONENT AND FUEL NOMINAL DIMENSIONS

	<u>OIIE</u>	<u>OIIIE</u>
Uranium Cores O.D.	1.351	1.356
I.D.	0.416	0.423
<u>Aluminum Components</u>		
Can Wall Thickness	0.040	0.037
Can Base	Thick-Flat	Contour
Spire	0.045	0.050
Finished Fuel O.D.	1.444	1.444
I.D.	0.310	0.310

It will be noted that the finished dimensions are the same for both fuel models. Major differences in the OIIIE model are the contour base can and a 5 mil thicker spire wall. The relatively small increases in core O.D. and I.D. were essentially offsetting with respect to core reactivity values.

Contour base cans and sleeves were introduced with the OIIIE model to accelerate can-base preheating rates to a temperature above the eutectic temperature of the canning bath during the normal can-sleeve preheat cycle, thus minimizing base braze porosity and spire wrinkling caused by AlSi freeze-out in the former thick base can design.⁽⁸⁾ A production evaluation of fuel models assembled in contour-base components showed a significant reduction (factor of 1.3) in average external bond count and a reduction in bonding layer integrity rejects by a factor of 2.3. Base closure braze voids measured by xeroradiography indicated an improvement factor of 1.3; however, the statistical significance of this factor has not been proven.

Other major process improvements affecting the quality of enriched fuel elements prepared for the E-N loading included vertical cap-spire pulsing and a pressurized fuel assembly quench. Cap-spire pulsing was developed⁽⁹⁾ and introduced on all production canning lines January 5, 1961. Advantages of this technique over the previous vibrating well for preheating the cap-spires were as follows: 1) a reduction in cap wafer non-wetting by a factor of 4, 2) a reduction in cap wafer braze porosity by a factor of 1.4, 3) a reduction in cap braze line porosity by a factor of 2.5, and 4) a reduction in bond layer contamination by a factor of 2.4.⁽¹⁰⁾ Approximately 60 percent of the enriched fuel assembled for the initial E-N load was spire pulsed and all of the second central "striped" load.

(8) HW-72665, "Design, Development and Production Evaluation of I&E Contour-Base Components", E. V. Padgett, February 13, 1962. (CONFIDENTIAL)

(9) HW-65800, "Cap-Spire Pulsing", C. A. Burgess, June 15, 1960. (CONFIDENTIAL)

(10) HW-66299, "Production Evaluation of Spire Pulse Preheating Technique", H. G. Powers, August 2, 1960. (CONFIDENTIAL)

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In order to further minimize braze voids in finished fuel elements, techniques and equipment were developed to apply air pressure to the molten braze of canned fuel assemblies prior to and during water quenching. Installation of pressurized quenching units was started in May, 1961 and completed on all production canning lines August 3, 1961. Operating under a nominal air pressure of 40 psi, significant decreases resulted in average external total bond count (factor of 2.3), base braze voids (factor of 3.3) and cap braze voids (factor of 1.4) based on visual inspections after fuel element facing, and external bond layer integrity rejects by a factor of 2.5.⁽¹¹⁾ Only about 30 percent of the enriched fuel for the second central "striped" load of the E-N load was canned after complete conversion to a pressurized quench.

Based on "Quality Certification" data from about 1 percent of the production throughput, the distribution of external total bond counts during and subsequent to the period enriched fuel for the E-N loading was produced is shown in Figure 1. It will be noted that the process improvements introduced over this period had a marked effect toward reducing the population of fuel elements accepted with total external counts in excess of 10. About 16 counts are recorded per centimeter of unbonded area by the total count bond tester, as measured circumferentially on a 1/12 inch scanning pitch. Although it has not been feasible to evaluate individual process improvements in terms of advances in fuel performance, the combined effect has resulted in a steady upgrading of fuel quality.

IRRADIATION SCHEDULE

Irradiation of the E-N loading was carried out in two cycles, as authorized, in the H-Reactor. Charging progressed on the following schedule:

- 1) Fringe poison loading,⁽¹²⁾ consisting of a blanket of 6 inch target elements and adjacent fringe of enriched fuel, in April, 1961.
- 2) An initial 270-tube block of the central E-N striped charges in May, followed in about two weeks (May and June) by the remaining central striped charges.⁽¹³⁾

(11) HW-71095, "Production Evaluation of Spire Pulse Preheating Technique", H. G. Powers, August 2, 1960. (CONFIDENTIAL)

(12) HW-66300 PT1, "Production Test IP-350-C - E-N Demonstration Load at H-Reactor, Part I, Fringe Poison Loading", R. D. Carter, March 22, 1961. (SECRET)

(13) HW-66300 PT2, "Production Test IP-350-C - E-N Demonstration Load at H-Reactor, Part II, Flattened Zone striped Loading", R. D. Carter, April 4, 1961. (SECRET)

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- 3) Replacement of initial central striped charges at goal exposure during September and October, 1961.

Since the fringe loading required more than twice the residence time of the central charges to reach goal exposure, this portion of the loading was charged first. The initial 270-tube central block of "striped" enriched fuel and target elements was made to determine the final patterns of the "striped" load and the surrounding enriched columns required for reactivity balance. About 80 percent of the central "striped" columns contained 40 I&E enriched fuel elements, 1 natural water mixer, and 3 I&E target elements. The remaining columns contained one less enriched fuel element and one additional target piece. Goal exposure for the initial "striped" load was 1000 MWD/T. Because of an abnormal incidence of enriched fuel ruptures, the goal exposure for the second cycle was reduced to 800 MWD/T. Irradiation of the second E-N cycle was completed in January, 1962, at which time the H-Reactor was converted back to the conventional uranium loading for plutonium production.

IRRADIATION EXPERIENCE

Irradiation of both the 6-inch solid target elements in the blanket loading and the 4-inch I&E target elements in the central "striped" loadings was completed without incident.

Fourteen (14) enriched bumper fuel ruptures (1 end, 10 hole, and 3 mechanical damage) occurred in the central "striped" loadings, and one (1) mechanical damage rupture was sustained in a fringe column of enriched bumper fuel. A summary of these ruptures is shown in Table III. As expected, performance of the E-N loading was largely dependent on the resistance of this material to fuel oriented "hole" and "end" failures. Use of "bumper" fuel was successful in preventing "hot spot" corrosion ruptures. It will be noted that three lots in the first and four lots in the second central "striped" load incurred fuel oriented ruptures. Four of five lots having an opportunity experienced two ruptures each.

Although the performance of the E-N load was adversely effected by fuel oriented ruptures, believed to be associated with end closure defects, if corrected for differences in severity of service the performance level (Q) of the enriched fuel was consistent with that of other fuel processed and irradiated during the same period. This can be seen from the data in Table IV. The small differences noted between the observed and expected "hole" and "end" type ruptures will occur over 70% of the time due to chance alone.

As indicated in Table III, two of the mechanical damage ruptures in tubes 1581 and 4177 were initially classified as "side other" and another in tube 2864 as a core split. After a more detailed examination in the Radiometallurgy Laboratory, it became evident that all three ruptures were caused by a portion of the periphery of the can-base being damaged during reactor charging.⁽¹⁴⁾ Examples of this damage are shown in Figure 2.

(14) HW-73181, "Radiometallurgy Examination of Two Enriched I&E Bumper Fuel Failures from H Reactor (RM 441)", R. Teats, March 29, 1962. (UNCLASSIFIED)

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Since damage of this type was not readily observed in the reactor basin, and was only evident on three of five ruptures examined in Radiometallurgy from the E-N loading, the extent of charging damage to other pieces is unknown.

Radiometallurgy examination of two "hole" ruptures from tubes 2669 and 3174, which were second ruptures in their respective lots, showed the failures resulted from corrosion penetration of the spire walls.⁽¹⁵⁾ The corrosion was manifest by a general reduction in spire wall thickness to 18 mils near the point of failure and the presence of grooves which penetrated to within 5 mils of the braze layer on either side of the failure zone. The underlying braze layers were also less than 5 mils thick. Figure 3 shows a section of the rupture from tube 3174 adjacent to the point of failure. Spire corrosion was not unexpected, since it had been observed to a lesser degree previously⁽¹⁶⁾ during routine fuel examinations. Based on conservative theoretical calculations, Bloomstrand⁽¹⁷⁾ estimated that for the exposures reached by the E-N load the temperature "threshold" for uniform corrosion failures was at least 5°C above those experienced at maximum average outlet temperatures of about 110°C. This was close enough, however, that the possibility of uniform corrosion could not be rejected. If this mechanism was causing ruptures, fuel failures in "old" process tubes would be expected to occur "between the ribs" with about the same frequency as in the "hole". In "new" and "intermediate" aged tubes, fuel failures in the "hole" would be most likely. Actually, one of the corrosion failures occurred in a tube (2669) which had 8 months service, and the other in tube 3174, which was in service 5-1/4 years.

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(15) HW-73587, "Radiometallurgy Examination of Two Enriched Hole Failures from H-Reactor (RM 444)", R. Teats, May 8, 1962. (UNCLASSIFIED)

(16) "Routine Fuel Examination, PT-IP-216-A", March, 1960. (UNCLASSIFIED)

(17) "Memo on Rupture Performance of the E-N Loads", R. R. Bloomstrand to J. T. Stringer, February 14, 1962. (UNCLASSIFIED)

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TABLE II

TARGET (N) MATERIAL DIMENSIONS

<u>Li-Al Rod Stock</u>	<u>O.D. (Inches)</u>	<u>I.D. (Inches)</u>	<u>Nominal Length (Inches)</u>
Solid	1.385 ± 0.010	--	73
Tube	1.400 ± 0.010	0.375 ± 0.010	73

<u>Cores (Li-Al Alloy)</u>	<u>SOLID (OIIT)</u>		<u>I&E (OIIT)</u>	
	<u>Dimensions (Inches)</u>	<u>Reference Dwg. No.</u>	<u>Dimensions (Inches)</u>	<u>Reference Dwg. No.</u>
O.D.	1.341 ± 0.002	H-3-16869	1.365 ± 0.002	H-3-16870
I.D.	---	----	0.404 ± 0.002	----
Length	5.700 ± 0.010			

Aluminum Components (C-64 Alloy)

Cans	O.D.	1.428 ± 0.002	H-3-16802	1.452 ± 0.002	H-3-16800
	Wall Thickness	0.040 ± 0.005	----	0.040 ± 0.005	----

Cap Wafers

Top Wafer O.D.	1.322 + 0.002 - 0.001	H-3-6325	---	----
Thickness	0.100 + 0.010 - 0.000	----	---	----
Bottom Wafer O.D.	1.342 + 0.002 - 0.001	H-3-6109	---	----
Thickness	0.100 + 0.010 - 0.000	----	---	----

Cap Spires

Wafer O.D.	---	----	1.366 + 0.002 - 0.001	H-3-16801
Wafer Thickness	---	----	0.260 ± 0.010	----
Spire O.D.	---	----	0.396 ± 0.002	----
Spire Thickness	---	----	0.040 ± 0.005	----

Finished Target Elements

O.D.	1.428 ± 0.006	H-3-17338	1.445 ± 0.005	H-3-17339
I.D.	---	----	0.404 ± 0.002	----
Length	6.110 ± 0.090	----	4.220 ± 0.002	----

TABLE III

ENRICHED BUMPER FUEL RUPTURE SUMMARY
H REACTOR E-N LOADING

<u>Failure Date</u>	<u>Tube No.</u>	<u>Loading</u>	<u>Exposure MWD/T</u>	<u>Tube Power At Failure (KW)</u>	<u>Rupture Classification</u>	<u>Canning Date</u>	<u>Lot No.</u>	<u>Fuel Model</u>
6/18/61	2767	1st Cen. Stripe	314	1107	End	3/9/61	KH289D	OIIIEB
8/7/61	2476	1st Cen. Stripe	663	1016	Hole	3/9/61	*KH289D	OIIIEB
8/30/61	1379	1st Cen. Stripe	745	1020	Hole	12/14/60	KH273D	OIIIEB
9/2/61	2667	1st Cen. Stripe	843	950	Hole	12/16/60	KH274D	OIIIEB
9/6/61	1581	1st Cen. Stripe	554	990	**Mechanical Damage	5/22/61	KY081D	OIIIEB
10/5/61	1978	2nd Cen. Stripe	109	857	Mechanical Damage	5/11/61	KY057D	OIIIEB
12/13/61	2864	2nd Cen. Stripe	605	1171	**Mechanical Damage	7/6/61	KY087D	OIIIEB
12/24/61	4177	Enriched Fringe	1050	1088	**Mechanical Damage	4/18/61	KY030D	OIIIEB
12/28/61	2872	2nd Cen. Stripe	760	1052	Hole	7/9/61	KH830D	OIIIEB
12/31/61	2667	2nd Cen. Stripe	793	1063	Hole	7/19/61	KH831D	OIIIEB
1/7/62	2580	2nd Cen. Stripe	746	1113	Hole	8/11/61	KY097D	OIIIEB
1/9/62	2576	2nd Cen. Stripe	738	1085	Hole	8/11/61	*KY097D	OIIIEB
1/16/62	1968	2nd Cen. Stripe	890	1157	Hole	5/11/61	KY057D	OIIIEB
1/21/62	2669	2nd Cen. Stripe	881	1034	Hole	7/19/61	*KH830D	OIIIEB
1/25/62	3174	2nd Cen. Stripe	829	1105	Hole	7/19/61	*KH831D	OIIIEB

* Second ruptures in lot.

** In the order listed, these ruptures were originally classified as a side other, core split, and side other. On the basis of Radiometallurgy examination, all three were reclassified as mechanical damage.

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TABLE IV

COMPARISON OF SEVERITY OF SERVICE
AND FUEL PERFORMANCE LEVEL (Q)

<u>Fuel Type</u>	<u>Irradiation Period</u>	<u>Severity of Service (ΣARI)</u>	<u>*No. of "Hole" and "End" Ruptures</u>		<u>Q (R/ΣARI)</u>
			<u>Observed</u>	<u>Expected</u>	
Natural Old Reactors	**1/61-1/62	464.6	9	10.3	0.023
Enriched Old Reactors (Excludes E-N)	**1/61-1/62	203.2	4	4.5	0.021
Enriched E-N	5/61-1/62	235.1	7	5.2	0.030
1st Cycle E-N	5/61-9/61	105.3	3	2.3	0.028
2nd Cycle E-N	10/61-1/62	129.8	4	2.9	0.031
Overall ΣARI and Expected Q	.	902.9	20	----	0.022

* Excludes second ruptures in production test.

** Period most closely approximating the time span natural and enriched material of the same vintage as the E-N load was irradiated in the old reactors.

DISTRIBUTION OF TOTAL EXTERNAL BOND COUNT

"O" Size Enriched Fuel - Quality Certification Data

DECLASSIFIED

HM-73638

Neg A 8288

1.2X

Male End of 4177 H After Cleaning Showing Mechanical Damage at Top of End Cap.

Neg A 8565

2.4X

FIGURE 2

Male End of 2864 H After Cleaning Showing Mechanical Damage at Top of End Cap

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FIGURE 3

Section of 2669 H, One-Half Inch From the Point of Failure Showing
Groove Corrosion of the Spire Wall.

UNCLASSIFIED

DATE

FILMED

8/16/94

END