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DEFECT TEST OF TARGET COMPONENT OF CO-PRODUCER TEST ELEMENT

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DEFECT TEST OF TARGET COMPONENT OF CO-PRODUCER TEST ELEMENT

J. W. Weber

September 1, 1964

Fuel Design
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DEFECT TEST OF TARGET COMPONENT OF CO-PRODUCER
TEST ELEMENT

J. W. Weber

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INTRODUCTION

Irradiation tests of aluminum-lithium co-producer target elements are planned for charging in the N-reactor. Although the target elements are subjected to extensive non-destructive testing to assure that defective pieces are not charged, it is necessary to have some knowledge of the failure characteristics of the targets under reactor conditions. To study the possible behavior of in-reactor failures, a series of defected test elements were tested in the high temperature, pressurized TF-9 facility located at 100 KE.

The test objectives were: 1) to follow the progress of the failures of target elements with several types of intentional defects, and 2) to run the tests until, on several of the elements, the failure and corrosion had progressed essentially to a point of total destruction of the core.

This report describes the intentionally defected elements used in the test and the progressive results of subjecting these defected elements to high temperature water.

SUMMARY

Twelve 0.560 inch diameter x 6 inch long rod samples of Li-Al alloy clad with an inner can of C-64 aluminum and an outer can of Zr-2 were intentionally defected and subjected to recirculating 280 C, 1500 psi, PH₁₀ water flowing at 60 gpm in the TF9 test facility. The defects were either a 0.025 inch diameter hole in the cladding, a 0.025 inch hole in the end cap, or a 1/32-inch wide by 1 inch long slit in the cladding. Each sample was tested with a defect through the Zr-2 can only or with a defect through both the Zr-2 and aluminum cans. Visual examination and dimensional measurement of each sample was made in the course of testing.

After approximately 300 hours, no significant evidence of corrosion or dimensional change was observed on any samples with defects cut through the outer Zr-2 can only. Corrosion of the exposed Li-Al core in the samples with the 1/32-inch slit through the Zr-2 and aluminum cans began in less than 4 hours. Corrosion of the cores in these samples resulted in further splitting of the cladding and loss of the corrosion product until, after 209 hours of exposure, the core was essentially destroyed. In the samples with 0.025 inch diameter holes drilled through both the Zr-2 and aluminum caps at one end of the rod, bulging of the Zr-2 can appeared in

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less than 16 hours. After 104 hours of exposure, the diameter had increased to 0.75 inch and the cladding had begun to split longitudinally. Destruction of the sample and core through an additional 100 hours of exposure then progressed in a manner similar to the samples with the 1/32-inch side slit.

III. TEST DETAILS

The defect samples were cut from coextruded rod sections used in fabrication of the irradiation target elements. The rods had been coextruded with a coating of graphite between the Li-Al core and the 0.035 inch thick C-64 aluminum cladding to prevent a metallurgical bonding of the core and cladding. The cut samples were counterbored on each end and solid end caps welded into the recessed ends. These samples were then slipped into Zr-2 tubes having a 0.030-inch wall and end caps welded in place. The finished assemblies were 0.560 inch on the outer diameter and approximately 6 inches long.

Six types of intentional defects were chosen for the test:

- 1) 0.025 inch diameter hole in the side of the sample through the Zr-2 cladding;
- 2) 0.025 inch diameter hole in the Zr-2 end cap;
- 3) 1/32-inch wide x 1 inch long slit in the side through the Zr-2;
- 4) 0.025 inch diameter hole in the side of the element through both the Zr-2 and aluminum cladding;
- 5) 0.025 inch diameter hole through both the Zr-2 and the aluminum end caps;
- 6) 1/32 inch x 1 inch long slit in the side through both the Zr-2 and aluminum.

Duplicate samples were run for each defect type. Table I lists the samples and the type of defects in each.

Three samples were spaced and rigidly held in each of four sample holders and the four sample holders placed end to end in the TF-9 test facility.

The nominal water conditions during testing were as follows:

Temperature:	280 C
Pressure:	1500 psi
Flow:	60 gpm through the test section.
pH:	10.1 ± .1 with NH ₄ OH.

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The samples were periodically removed from the test facility for observation and measurement.

IV. TEST RESULTS AND DISCUSSION

The results of visual examination and dimensional measurements of the defect samples after each period of run are shown in Table I. Figures 1 through 6 show the progress of corrosion on some of the defects. Figure 7 shows the final condition of each of the 12 samples.

With the exception of sample 12, where a slight increase in diameter was detected after 297 hours, none of the samples with only the Zr-2 cladding defected showed evidence of corrosion of the aluminum cladding.

Where both of the cladding layers were intentionally penetrated, significant corrosion occurred only in those where there was substantial surface area of the core exposed. This was the case for the side slits of samples 9 and 10 and for the end defect in samples 1 and 2. In these latter two samples there would be the full cross section at the end cap-core interface. In the case of the side hole defects through both cladding layers it is believed that either a tight mechanical fit between the unbonded core and aluminum cladding or metal burrs from the defect drilling operation prevented any sizeable area of core from being exposed to the water. This would account for the lack of observable corrosion and diameter change on these samples.

Although the corrosion rate of the core material was much faster than the high purity aluminum cladding, the reaction was not violent or catastrophic.

From the torn and open appearance of the samples 9 and 10, and sample 2 after the cladding had split, there would not appear to be a problem of water flow blockage prior to clad failure unless the flow annulus is quite small. A maximum observed bulging without cladding splitting occurred on sample 2 at about 100 hours of exposure. The increase from a diameter of 0.560 to 0.75 inch represents a diameter increase (and Zr-2 cladding strain) of 34 percent. Data on the effects of irradiation on the properties of Zr-2 show that the strain to be expected prior to failure would decrease as exposure increases. Thus, the above results represent a probable maximum strain condition for the cladding of a target element.

ACKNOWLEDGEMENT

A special appreciation and acknowledgement is extended to Ken Hayden of Coolant Systems Development Operation for his help in designing this test, for his time and efforts in making arrangements for running the test, and for his assistance in making measurements and photography of the samples.

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Table I - DEFECT TEST RESULTS

Sample	1	2	3&4	5&6	7&8	9	10	11	12
Defect Type	.025 inch Hole Zr + Al End Caps		.025 inch End Hole Zr	.025 inch Side Hole Zr + Al	.025 inch Side Hole Zr	1/32x1 inch Side Slit in Zr and Al		1/32x1 inch Side Slit in Zr.	
Total Test Time Hrs. 4	No Change	No Change	No Change	No Change	No Change	Bulging started full length of slit. Ex- tends 1/2 way around circumference. Diameter 0.569 to 0.576 to 0.594 0.594 Slit width 0.1 0.125 Figure 1		No Change	No Change
8	No Change	No Change	No Change	No Change	No Change	Bulging continued. Core corroding but no under-cutting. Diameter 0.586 to 0.602 to 0.631 0.635 Slit width 0.18 0.22		No Change	No Change
16 pH 10.3 for this 8-hr. period.	No Change	Bulge starting 1/2" from defected end. 0.677" diameter x 0.25" long. No clad split.	No Change	No Change	No Change	Diameter 0.657 to 0.670 to 0.699 0.702 Flake oxide in core washing or falling out. Slit width 0.40" 0.42"		No Change	No Change

Nominal Diameter - 0.560".

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Table I - DEFECT TEST RESULTS (Cont'd.)

	1	2	3&4	5&6	7&8	9	10	11	12
24 hrs.	Bulge starting 0.6" from defected end 0.568" diameter.	Bulge around circumference 0.600" diameter x 0.75" long.	No Change	No Change #6 removed from test.	No Change #7 removed from test.	Diameter 0.760 to 0.773 Slit width increasing Slit length 2.15" 2.2" Cladding tearing at each end of split. Figure 2	0.760 to 0.764	No Change	No Change
40 hrs. pH 9.92 for last 16 hrs.	Bulge diameter 0.579"	Bulge diameter 0.647"	No Change	No Change	No Change	Maximum diameter 0.943" Slit length 2.6	1.00" 2.75	No Change	No Change
60 hrs. pH 10.2	No Change from 0.579 diameter.	Bulge 0.67" diameter x 1.25" long. Figure 3	No Change	No Change	No Change	Maximum diameter 0.970" Slit length 3.85" Core corroded the full cross section. Figure 3	1.24" 3.5"	No Change	No Change
104 hrs.	Diameter 0.583"	Bulge 0.778" diameter Zr and Al cladding split 0.32" wide x 1.25" long. Figure 4	No Change	No Change	No Change	Slit length 4.03" Split opened at 180° from slit 0.64" wide x 1.42" long. Figure 4	3.5"	No Change	No Change
209 hrs. pH 10.5 for last 105 hrs.	Diameter 0.597" Figure 5	Diameter 0.866" to 0.877" Split 0.5" wide x 2.5" long.	No Change #3 removed from test.	No Change	No Change	Core continued to corrode out Little change in diameter or split sizes. Split now at 180° from original slit. Figure 5. Removed from test.		No Change Removed from test.	No Change
297 hrs.	Diameter 0.610" Bulge length 0.85" Figure 6	Diameter 0.85" to 0.862" Split 0.6" wide x 3.22" long.	No Change	No Change	No Change	Out of test.		Out of test.	Diameter may be increasing 0.565"

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FIGURE 1

Samples 9 and 10. 1/32 x 1 inch
Slit Through Zr-2 and Aluminum

Exposure: 4 Hrs. ~1/2X

FIGURE 2

Samples 9 and 10. Number 10 is
Stuck in Sample Holder

Exposure: 24 Hrs. Total
Laminated Appearances of Core is
due to Fissures in the Wet Oxide
~1/3X

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FIGURE 3

Exposure 60 Hrs. Total. Diameter of Sample 2, with 0.025 in. Hole in Zr-2 and Aluminum End Caps, is 0.67 inch. Core Corrosion in 9 and 10 has Started Cladding Bulging on Side Opposite Original 1/32 inch Wide Slit.

10

9

2

FIGURE 4

Exposure 104 Hrs. Cladding on Sample 2 Split After the Diameter had Increased to 0.75 inch. Cladding has Split on side Opposite Original Slit of Samples 9 and 10.

-7-

HW-84243

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FIGURE 5

Exposure 209 Hrs. Total

Sample 1 has Started to Bulge and Number 2 is Continuing to Split the Cladding as Corrosion Product Builds up Underneath. The Core is Almost Completely Corroded Away from Samples 9 and 10.

Samples 9 and 10 Removed from Test at this Point.

FIGURE 6

Exposure 297 Hrs. Total

This was Maximum Exposure at Test. Damage to Sample 2 is Progressing Similar to that of Samples 9 and 10 in Early Stages.

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Defect Type	Exposure Time Hrs.	Sample	Sample	Sample	Sample	Exposure Time Hrs.	Defect Type
0.025" Side Hole in Zr-2	24	7			1	297	0.025" Hole in Zr-2 and Al End Cap
	297	8			2	297	
1/32" x 1" Slit in Zr-2 and Al	209	9			3	209	0.025" Hole in Zr-2 End Cap
	209	10			4	297	
1/32" x 1" Slit in Zr-2	297	11			5	297	0.025" Side Hole in Zr-2 and Al
	297	12			6	24	

-9-

FIGURE 7

Condition of each Sample After its Final Exposure Period

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