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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD SEVEN ROD CLUSTER FUEL ELEMENT IN KER LOOP 2

L. D. Perrigo

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD SEVEN ROD CLUSTER FUEL ELEMENT IN KER LOOP 2

INTRODUCTION

On the 0000-0800 shift, October 15, 1959, the delayed neutron monitor on KER Loop 2 gave a high coolant activity signal indicating a possible fuel element failure in this loop. KE reactor was shutdown immediately thereafter.

This report is being written to summarize the events pertinent to this KE reactor scram and to discuss the results and significance of data from analyses on coolant and coupon samples taken from KER Loop 2.

SUMMARY AND CONCLUSIONS

A high delayed neutron signal on the coolant in KER Loop 2 on October 15, 1959 indicated the possibility of a fuel element rupture. The KE reactor was shut down. The seven-rod cluster fuel elements in this loop were discharged during the outage. An examination of the discharged elements in the KE viewing pit revealed a blister on one of the outer rod surfaces. Further investigations in the 300 Area Radiometallurgical Facility showed that there was a slit traversing this blister, baring the uranium to the loop coolant.

Coolant samples were drawn from the KER Loop 2 system and subjected to a radiochemical analyses. Concentrations of fission products much higher than normal were discovered; Np^{239} and La^{140} were found also to be adsorbed on the surface of metal coupons removed from this loop. This information, from a radiochemical standpoint, indicates a rupture and it concurs with the indication seen on the delayed neutron monitor.

DISCUSSION

One thirty mil jacketed seven rod cluster element and six twenty mil jacketed seven rod cluster elements were charged into KER Loop 2 to compare the behavior of Zircaloy-2 clad elements with these two jacket thicknesses. The operating conditions in KER Loop 2 for this test were as follows:

1. Temperature - 255°C
2. Coolant pH - 10.0, maintained by flow through a lithium based ion exchange resin and LiOH additions.
3. Loop flow - 60 gpm
4. Cleanup flow - 2 - 3 gpm
5. System pressure - 1600 psi
6. Degasification rate - $\sim$.25 gpm

The operational chronology pertinent to this fuel failure is as follows:

1. May 19, 1959 - charged seven Zircaloy-2 clad seven rod cluster elements into KER Loop 2.

2. ~0021, Oct. 15, 1959 - delayed neutron monitor warning alarm sounded. Monitor at 64% of full scale.

3. ~0022, Oct. 15, 1959 - changed delayed neutron scale from 0-250 neutrons/sec to 0-500 neutrons/sec range. Monitor went full scale. KE reactor shutdown. KER Loop 2 began depressurization cycle.

4. ~0030, Oct. 15, 1959 - KER Loop 2 began single pass operation.

5. ~1030, Oct. 15, 1959 - discharged seven rod cluster elements from KER Loop 2 process tube.

No noticeably discolored liquid passed from the process tube at the time of the fuel element discharge. Visual inspection of the seven rod cluster elements in the KE viewing facility revealed that all were covered with dark, adherent, comparatively thin oxide coatings. The failure was found as a blister on the surface of one of the outer rods.(1) Inspection in the Radiometallurgical Facility, 300 Area revealed that there was a transverse slit through a blister on one of the 20 mil jacketed rods of seven rod cluster element baring the uranium to the loop's coolant.(2)

A. Coolant Radiochemical Analyses

Two water samples were drawn from the KER Loop 2 emergency storage tank approximately five minutes after the depressurization operation was completed. These samples were subjected to certain radiochemical procedures to determine fission product activity loadings. These loadings are, however, lower by a factor of greater than 2.5 than those that actually were in the loop because depressurization dilutes the coolant.

Some settling of relatively large particulate matter probably, also, occurred in the tank prior to sampling. This would also influence the data and the results from this radiochemical analysis shown in Table I, therefore, should be lower than the undiluted unsettled coolant. The second sample drawn contained more suspended material than the first, perhaps because of some agitation of settled material in the tank in the sampling operation.

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(1) D. R. Dickinson - personal communication.
(2) G. T. Geering - personal communication.

TABLE I

Radioanalysis of KER Loop 2 Emergency Storage Tank Water

Analysis	Activity in μμc/ml	
	Sample 1	Sample 2
I^{131}	370	880
Np^{239}	1400	5900
Zr^{95}-Nb^{95}	5400	23000
Sr^{89}	690	1600
Ba^{140}	2100	5000
Ru^{106}	900	1000
Y^{90}	51	130

Exposure time = 294 equivalent full power hours.
All activities calculated to four hours after beginning of KE outage on 10-15-59.

The data given in Table II were accumulated from KER Loop 2 in the three months prior to fuel element rupture. This information, then, gives a means for a direct comparison between normal coolant conditions and those found following a fuel element failure.

TABLE II

Fission Product Activity in High pH Coolant During Normal Operation

Sample	Exposure eq. full power hrs	(all activities in μμcuries/ml) Np^{239}	Zr^{95}-Nb^{95}	I^{131}
1	14	90	N.D.	-
2	40	20	220	-
3	79	150	N.D.	-
4	482	280	N.D.	.94

All activities calculated to four hours after sampling time.

Even with the diluting factors that influence the data shown in Table I there were much greater concentrations of Np^{239}, Zr^{95}-Nb^{95} and I^{131} than are encountered during normal operation of stainless steel systems maintained at

high pH with LiOH (Table II). A portion of this trace of a fission product spectrum found in the KER Loop coolants during normal operation is believed to be the result of the fissioning and resulting recoil of the products from the uranium impurity found in the Zircaloy-2 process tubes. Probably there is also some contribution from diffusion from fuel elements to the loop coolants. Comparable fission product levels during normal operation were also found in a loop system with a low pH coolant.(1)

B. Coupon Analyses

Several carbon steel, Zircaloy-2 and stainless steel washer type coupons were in KER Loop 2 mockup tube at the time of the KE reactor outage. These were removed and subjected to a gamma scan analysis. Significant quantities of Np^{239} and La^{140} were found to be adsorbed on the coupon surfaces. Quantitative data are not available at this time.

After consideration of this analytical information from two sources, the liquid and metal samples, and other associated factors already mentioned, it seems certain that there was a rupture in KER Loop 2 on October 15, 1959.

C. Instrumentation Response

The first indication of a fuel failure in KER Loop 2 was given by the delayed neutron monitor jumping to 64% of full scale. By changing the range from 0-250 neutrons/sec to 0-500 neutrons/sec the indication monetarily dropped to 45% of full scale. Immediately thereafter it went off scale causing the shutdown of KE reactor. These fluctuations can be seen in Figure 1.

The effect of the depressurization cycle is shown in Figure 2 for the KER Loop influent flow immediately after reactor shut down. Figures 3 and 4 show effluent pressure and temperature fluctuations.

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(1) Perrigo, L.D., Radiochemistry for the Rupture of a Tube in Tube Fuel Element in KER Loop 3, HW-62677, [redacted].

[redacted]

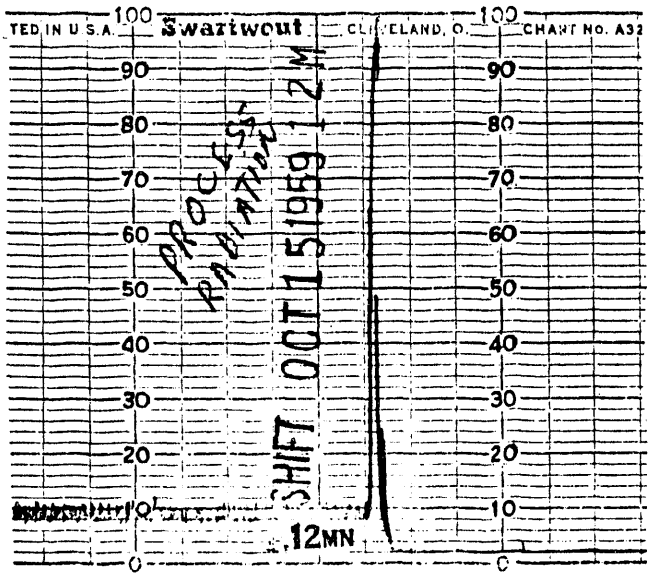

FIGURE 1. KER Loop 2 Delayed Neutron Monitor Indications

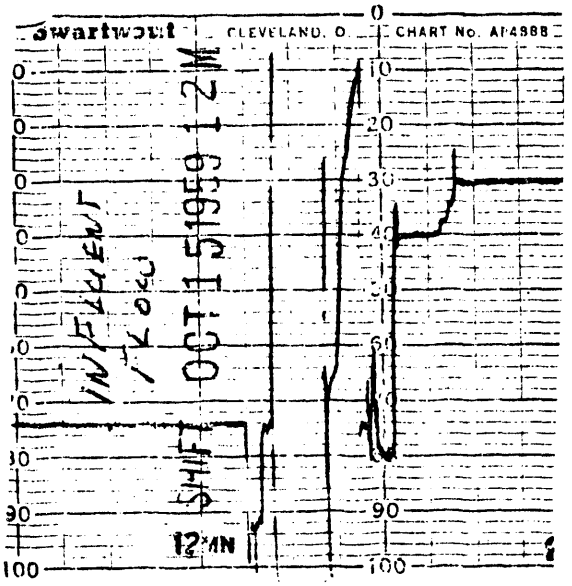

FIGURE 2. KER Loop 2 Process Tube Influent Flow Indications

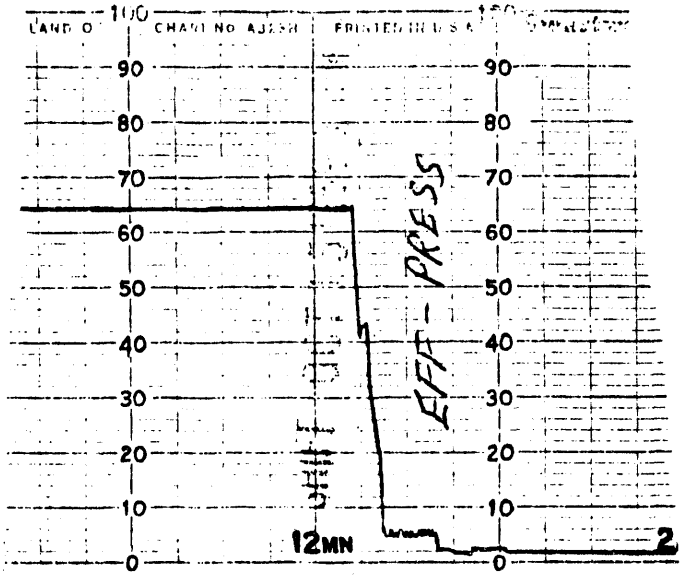

FIGURE 3. KER Loop 2 Process Tube Effluent Pressure

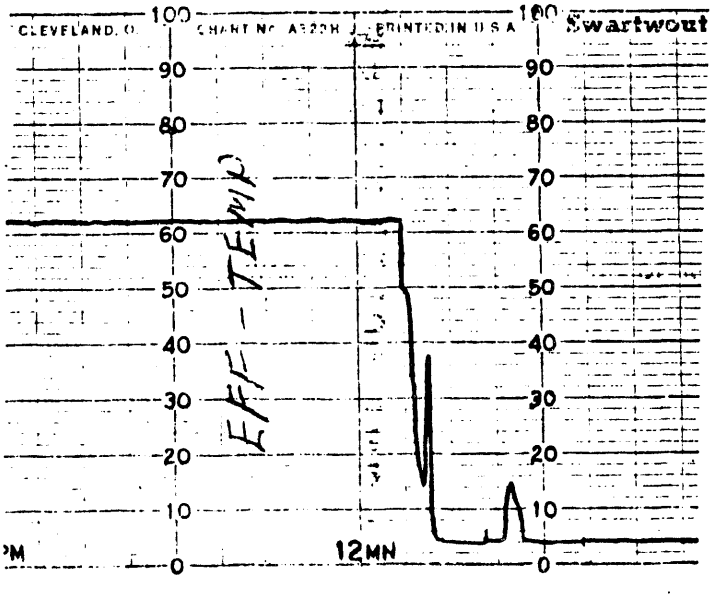

FIGURE 4. KER Loop 2 Process Tube Effluent Temperature

D. Loop Radiation Levels

The loop gamma monitor went off scale during the period of reactor shutdown. High activity levels were encountered in the cell and North Corridor when surveyed following shutdown. A comparison of these levels with those during normal operation are found in Table III. There was a significant increase in each point that was monitored.

TABLE III

KER Loop 2 Radiation Levels

Point	Normal Operation (10/11/59)	After Rupture
	(All readings in mr/hr)	
Cell background	15	80
#1 Pump strainer	23	1500
#2 Pump strainer	31	900
North corridor strainer	-	1700
Pressurizer	15	40
Primary heat exchanger	18	40
Primary heat exchanger air-operated valve	27	70
Mockup tube	20	700

Water flushing was begun on KER Loop 2 following reactor shutdown and depressurization. This reduced piping activity to a level only slightly above normal.

ACKNOWLEDGEMENT

The efforts of R.W.James, W.H.Zimmer and their coworkers in the Purex and Redox Analytical Operations are gratefully acknowledged. The helpful suggestions and comments of L.M.Eikum and R.V.Dulin, IPD, on the sections covering KER Loop 2 operation are appreciated. KER Loop 2 is operated by the Coolant Testing Operation, IPD.

Lyle D. Perrigo
Coolant Systems Development Operation
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