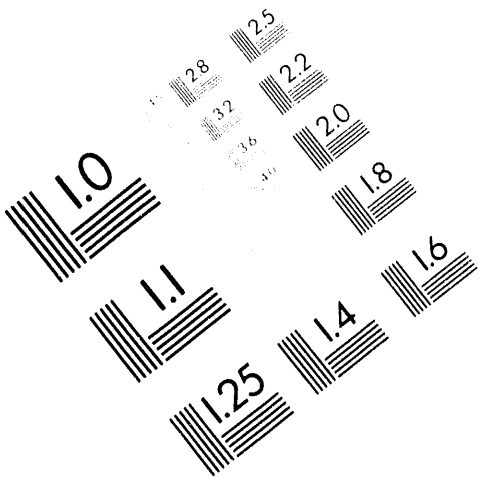

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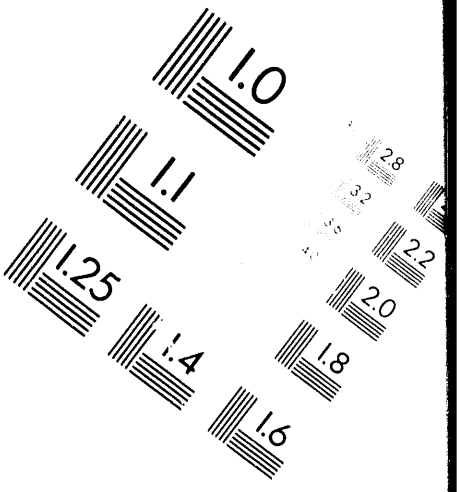

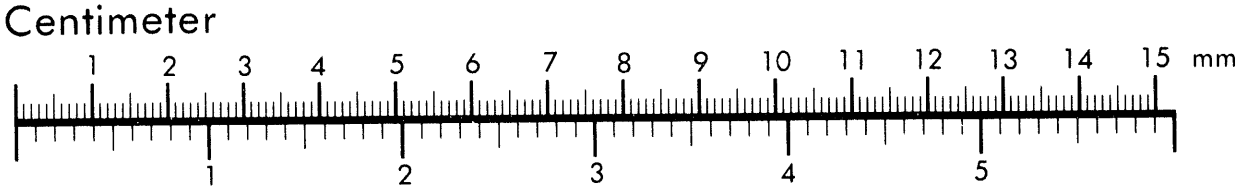

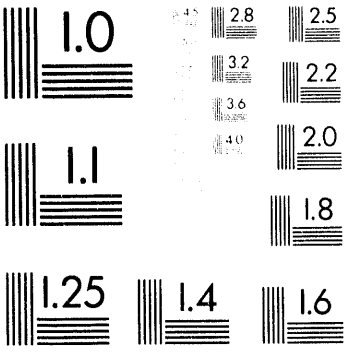

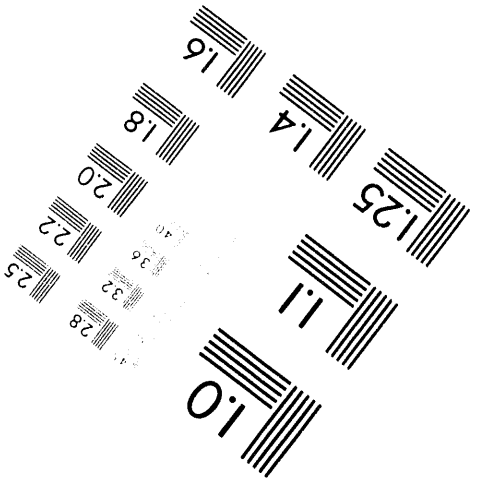

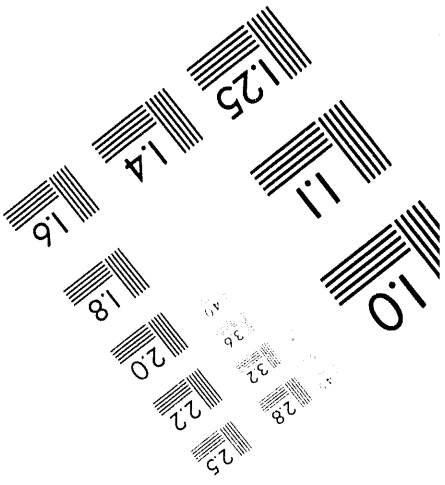

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD THERMOCOUPLED FUEL ELEMENT IN KER LOOP-1 ON MAY 12, 1961

INTRODUCTION

On the 1600-2400 shift, May 12, 1961, the delayed neutron monitor on KER Loop 1 gave a high coolant activity signal indicating a possible fuel element failure in this loop. KE Reactor was shut down immediately thereafter.

This report is being written to summarize the events pertinent to the KE Reactor scram and to discuss the results and significance of data from the analyses of coolant samples taken from the KER Loop-1 System.

SUMMARY AND CONCLUSIONS

A high delayed neutron signal on the coolant stream in KER Loop 1 on May 12, 1961 indicated the possibility of a fuel element rupture. The KE Reactor was shut down. The fuel elements were discharged during the outage. An examination of the discharged elements in the KE viewing pit revealed that the thermocoupled fuel element was ruptured for 3/4 of the circumference at the weld on one end cap and it also had a longitudinal split extending approximately three inches down the side with two 1/2-inch diameter blisters.

Coolant samples were drawn from the KER Loop 1 system and subjected to a radiochemical analysis. Very low activity levels were observed. However, these data should give an indication of fission product loadings in the coolant following the rupture of a "green" fuel element since this element had been irradiated for only a few hours.

DISCUSSION

One coextruded natural uranium thermocoupled fuel element rod with 20 mil Zircaloy-2 cladding was charged into KER Loop 1 to determine the temperature effects resulting from film buildup on heat generating surfaces following a loop decontamination. Five uranium metal coextruded tubular fuel elements were charged with the thermocoupled element to provide coolant heating.(1) The operating conditions in KER Loop 1 for this test were as follows:

1. Temperature during duration of test - 20-216 C.
   (216 C at time delayed neutron monitor went off scale).

2. Coolant pH - 10.0 maintained by feed and bleed of a LiOH solution into loop at 1.0 gpm.

3. Loop flow - 40-50 gpm.

4. System pressure - 1600 psi.

5. Degasification rate - 0.25 gpm.

KER Loop 1 is a carbon steel system with a Zircaloy-2 in-reactor tube.

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

1. 0000 - 0800 shift, May 11, 1961 - charged fuel elements into KER Loop 1.
2. 0800 - 1600 shift, May 11, 1961 - decontaminated KER Loop 1 with Phos-1.
3. 1621, May 12, 1961 - KE Reactor started up.
4. 1830, May 12, 1961 - KER Loop delayed neutron monitor began to rise above normal readings.
5. 2230, May 12, 1961 - delayed neutron monitor began rise from 10% of full scale (0 - 500 neutrons/second range).
6. 2253, May 12, 1961 - delayed neutron monitor went full scale. KE Reactor scrams. KER Loop 1 began depressurization cycle.
7. ~2300, May 12, 1961 - KER Loop 1 began single pass operation.
8. 0000 - 0800 shift, May 13, 1961 - discharged KER Loop 1 fuel elements.

Visual inspection of the thermocoupled rod-type fuel element in the KE viewing pit revealed an opening of 3/4 of the rod's circumference at one end cap weld. In addition there was longitudinal split extending approximately 3 inches down the side with 2 blisters about 1/2 inch in diameter. A small amount of dark adherent crud was observed to be on all the fuel elements when they were inspected in the viewing pit.(2,3)

A. Coolant Radiochemical Analyses

Water samples were drawn from the KER Loop 1 emergency storage tank approximately forty minutes after the depressurization operation was completed. These samples were subjected to certain radiochemical procedures to determine fission product activity loadings. These loadings, however, are lower by a factor of 3 than those that actually were in the loop because depressurization dilutes the coolant.

Some settling of relatively large particulate matter probably 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.

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TABLE I

Radioanalysis of KER Loop 1 Emergency Storage Tank Water

Isotope	Activity (in μc/ml)	Isotope	Activity (in μc/ml)
Y^{90}	24	Sm^{153}	ND*
Zr^{95}	21	Np^{239}	ND*
Zr^{95}-Nb^{95}	48	Na^{24}	ND*
Ru^{103}+Ru^{106}	320	Sc^{46}	0.31
I^{131}	3.6	Cr^{51}	270
I_{Total}	7100	Mn^{56}	8000
Cs^{137}	2.6	Fe^{59}	<1.0
Ba^{140}	19	Co^{60}	2.0
La^{140}	0.5	Cu^{64}	530
Ce^{141}+Ce^{144}	21	Zn^{65}	40
Ce^{143}	<0.7	As^{76}	1100
Eu^{152}	61		

* ND = nondetectable.

The data given in Table II were acquired from KER Loop 1 six hours after startup after the loop had been decontaminated with the Phos-1 Process. This information, then, gives a means for a direct comparison between operation in a freshly decontaminated loop system with and without a fuel element rupture

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TABLE II

Radioanalysis of KER Loop 1 Coolant Following a Decontamination

Isotope	Activity (in μμc/m)	Isotope	Activity (in μμc/m)
I^{131}	0.12	Na^{24}	850
Cs^{137}	3.7	P^{32}	106
La^{140}	<1	Sc^{46}	0.1
$Ce^{141}+Ce^{144}$	<2	Mn^{56}	4400
Ce^{143}	6	Co^{60}	1.3
Eu^{152}	<20	Cu^{64}	190
Sm^{153}	8	Zn^{65}	1.2
Np^{239}	2		

Generally the level of the fission product activities in the rupture sample is higher than in the reference sample even though it was influenced by the diluting factors mentioned earlier. The overall low level in the rupture sample can be attributed to the very low exposure of the fuel element. The reactor had been in operation for approximately six and one half hours with this new fuel element charge when the rupture caused the shutdown. The trace of fission products that was found in the reference sample represents a normal situation. It has been found repeatedly in earlier tests.(3)

B. Instrumentation Response

The first indication of a fuel element failure in KER Loop 1 was given by a rise in the activity indicated on the delayed neutron monitor at approximately 1830, May 12, 1961. The fluctuations that occurred over the next four and one half period till the reactor was shutdown are shown in Figure 1. The scale was changed from 0-250 neutron/sec to 0-500 neutrons/sec at approximately 1955 hours.

C. Loop Radiation Levels

Higher than normal activity levels were encountered on the KER Loop 1 system piping following reactor shutdown. A comparison of these levels with those during normal operation are found in Table III.

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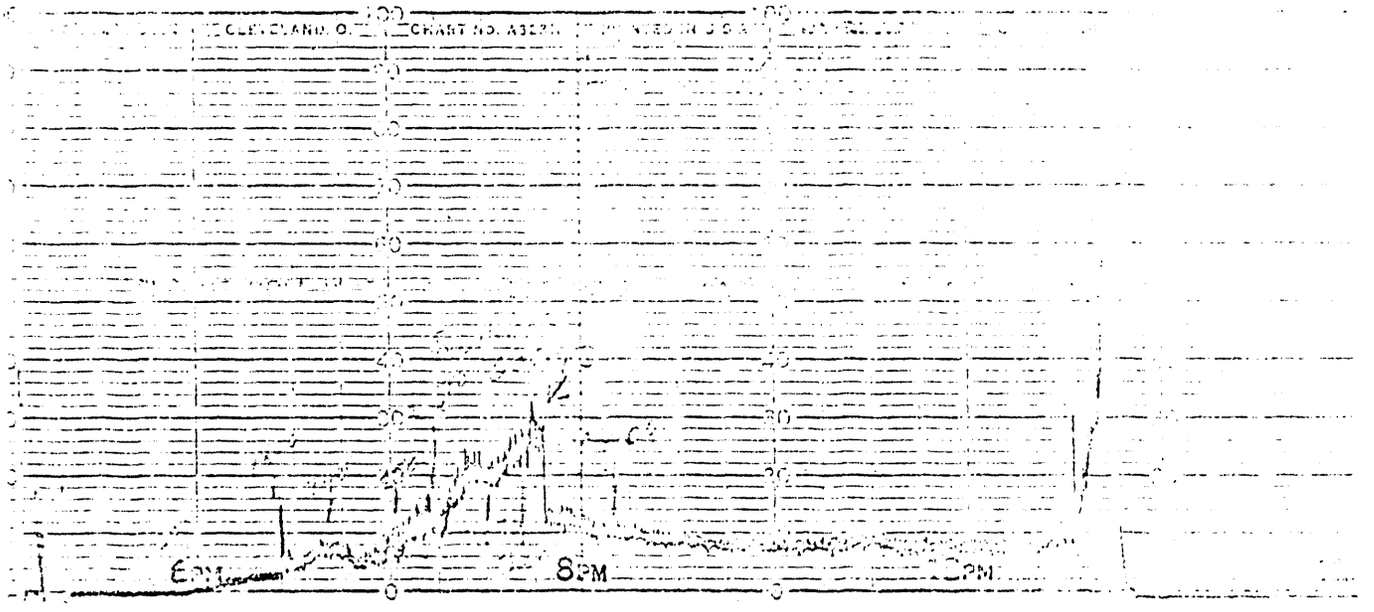

FIGURE 1. MTR Loop 1 Delayed Neutron Indications.

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TABLE III

KER Loop 1 Radiation Levels

Point	Normal	After Rupture (all readings in mr/hr)	
		2315-5/12	0100-5/13
All Background	4	20	10
Pump Strainer #1	10	80	15
Pump Strainer #2	10-15	50	14
Main Loop Flow Valve	5-8	20	14
Heat Exchanger 3-way Valve	10	50	30
Mockup Tube	10	90	50
North Corridor Strainer	-	460	270
Dump Valve	35	130	70
Crud Trap	400	4200	3000
Emergency Storage Tank	10	470	250
Rear Face Pigtail	125	500 (0015-5/13)	

Flushing reduced the general activity level to only slightly above normal.

ACKNOWLEDGEMENT

The efforts of W.C. Johnson and his coworkers in the Purex Analytical Operation are gratefully acknowledged. L.D. Carpenter, IPD, assisted in obtaining KER charts and rupture data. KER Loop 1 is operated by the Coolant Testing Unit, IPD.

L. D. Perrigo
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