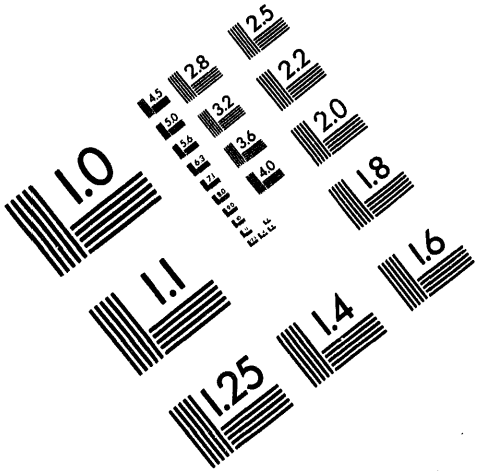

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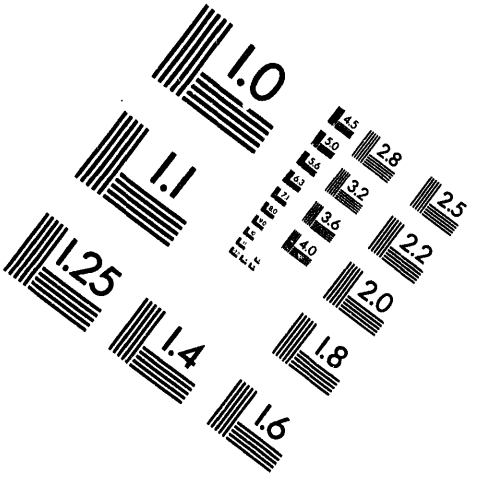

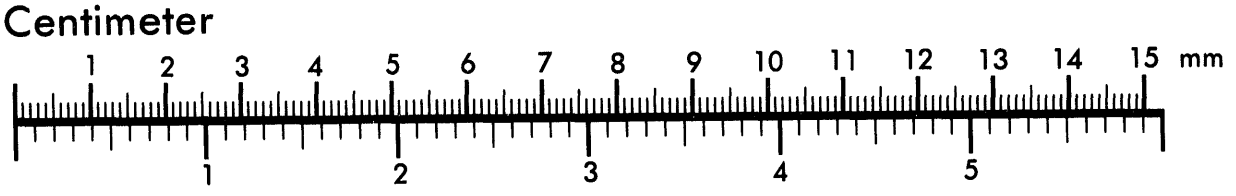

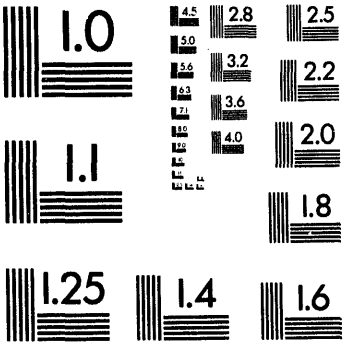

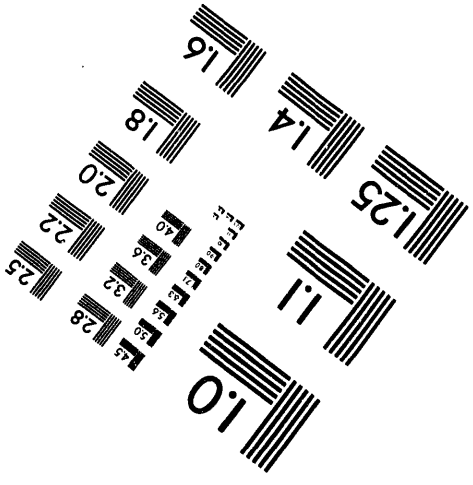

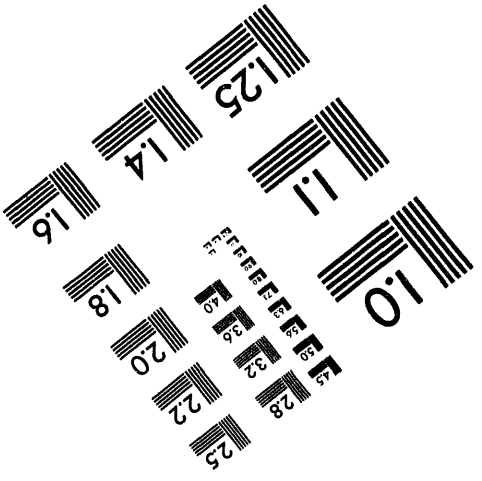

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD, NATURAL URANIUM THERMOCOUPLE FUEL ELEMENT IN KER-1.

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD, NATURAL URANIUM THERMOCOUPLE FUEL ELEMENT IN KER-1

T. F. Demmitt

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD, NATURAL URANIUM THERMOCOUPLE FUEL ELEMENT IN KER-1

INTRODUCTION

During the 0000 - 0800 shift on August 21, 1960, the delayed neutron monitor on KER Loop 1 indicated a high coolant activity level. Sympathetic responses were also recorded on the Loop 2, 3 and 4 monitors indicating a possible fuel element failure in Loop 1. The KER Reactor began shutdown operations immediately thereafter.

The purpose of this report is to summarize the events pertinent to this reactor outage and to discuss the results obtained from coolant and coupon samples taken from Loop 1.

SUMMARY AND CONCLUSIONS

Samples were taken from the KER Loop 1 system for radiochemical analysis after the reactor was shutdown. Coolant samples were taken from the loop emergency storage tank and coupons were removed from the mockup tube for examination. The fission product concentrations in the coolant were much higher than those observed under normal conditions. Examination of the coupon samples indicated the presence of Np^{239}, Cr^{51} and Co^{60}. This information strongly indicated the presence of a ruptured fuel element in the system.

The fuel elements discharged from the loop were examined visually in the KE viewing pit. The Zircaloy-2 cladding was separated from the end cap nearly all around the circumference of the thermocouple element. Two jagged longitudinal cracks about two inches long extended along the two thermocouples under the cladding. The heater fuel elements had raised areas on the surfaces but no ruptures were discernible. The fuel element cladding was still bright and shiny with no evidence of crud deposits.

DISCUSSION

The fuel elements discharged on August 21, 1960, had been in Loop 1 since August 3, 1960. The elements included in this charge were 5 tubular heater elements and a 1 inch diameter by 12 inch long, natural uranium thermocouple element with a 20-mil Zircaloy-2 clad. These elements along with 12, 8-inch perfs and spacers comprised the thermocouple train authorized under Supplement D of PT-IP-314-A.(1)

The thermocouple train was irradiated to determine the temperature variations in the fuel element caused by crud deposition on the element surface. Two thermocouples measured the coolant temperature upstream and downstream of the element, two measured the temperature at the bond between the uranium and the cladding, and one measured the element core temperature.

The KER-1 operating conditions during this run were as follows:(2)

Temperature	46 hours	@	0-100 C
	10 hours	@	100-150 C
	48 hours	@	150-200 C
	235 hours	@	200-300 C
Coolant pH	10.1 ± 0.1 (maintained by cleanup with a lithium based ion exchanger and lithium hydroxide additions)		
Loop Flow	Approximately 50 gallons per minute		
Cleanup Flow	2.1 gallons per minute (average)		
Degas Rate	0.4 gallons per minute (average)		

The chronology of operation pertinent to this fuel element failure is discussed below. The following information was taken directly from, "Rupture Report R-60-7," August 21, 1960, by W. A. Oldham, Coolant Testing Unit, IPD.

> "KER-1 was operating at 268 C with fuel elements authorized by PT-IP-314-A, Supplement D.
>
> At 5:40 PM the process activity alarm was received with the delayed neutron monitor instrument on the 0-250 cps range. The instrument was changed to the 0-500 cps range and the activity continued to increase, scramming the reactor at 5:42 PM. The loop progressed through a normal depressurization cycle to single-pass operation at 5:49 PM."

The fuel elements were then discharged into the KE basin.

KER-1 is predominantly a carbon steel system with Zircaloy-2 in-reactor and mockup tubes. Some stainless steel piping is also included along with some Stellite, Teflon and asbestos as valve seating surfaces and gasket materials.(3)

The coolant discharged from the loop with the fuel elements was not noticeably discolored. Visual inspection of the discharged elements in the KE basin revealed that the cladding was separated from the end cap nearly all around the circumference of the thermocouple element. Two jagged longitudinal cracks about two inches long, with blistered areas beneath, extended along the two thermocouples located just under the cladding. The heater elements had raised areas (bumps) on the surfaces but no ruptures were discernible. The fuel element cladding appeared bright and shiny with no evidence of crud deposits.

These elements were left in place in-reactor when the loop was decontaminated on August 19-20, 1960. The decontamination test was conducted using Phos-1 as the decontaminant. The decontamination procedure is described in HW-69507,(4) and coupon corrosion data are described in HW-67111.(5)

Coolant Samples

Coolant samples were drawn from the Loop 1 emergency storage tank approximately 35 minutes after loop depressurization was completed. These samples were subjected to radiochemical analysis to determine fission product concentrations. Since the loop coolant is diluted by a factor of at least three during the depressurization operation, the measured activity loadings should be considerably lower than the actual coolant loadings prior to depressurization. In addition some settling of particulate matter probably also occurred before the samples were taken. This would further reduce the solution activity prior to sampling.

Table I contains a summary of the radiochemical analysis data obtained from the coolant samples along with the data for a sample drawn from the loop during normal operation. The sample taken during normal operation was drawn directly from the recirculating coolant so these analytical results are not subject to the dilution and settling effects previously discussed for the rupture samples.

The data in Table I were calculated to a reference time of 4 hours after the rupture occurred. This reference time is arbitrary and was selected for convenience only.

TABLE I

Radioanalysis Data For KER-1 Coolant

Isotope	Rupture Sample Activity (uuc/ml)	Normal Coolant Activity (uuc/ml)
I_{total}	7,000	250
I^{131}	2,900	6
Np^{239}	630	72
$Zr \cdot Nb^{95}$	950	34
Ba^{140}	-	0.2
Fe^{59}	1.4	1
Co^{60}	23	0.5
Sr^{89-90}	4,600	0.3
Cu^{64}	Not obtained due to isotopic interference	33
Cr^{51}	Not obtained due to isotopic interference	25
Mn^{56}	Not obtained due to isotopic interference	41
As^{76}	Not obtained due to isotopic interference	58

A comparison of the data in Table I shows that the fission product activity loading in the rupture sample was much higher than that normally encountered in the same system under normal operating conditions. This conclusion is apparent in spite of the effects of dilution and settling previously discussed.

The small amounts of fission products observed in the coolant during normal operation are presumed to be primarily due to fissioning and recoil of the products of the uranium impurity in the Zircaloy-2 tubes, and diffusion from the fuel elements to the coolant.

Coupon Samples

Coupons removed from the mockup tube after depressurization showed the presence of Np^{239}, Cr^{51}, $Zr\text{-}Nb^{95}$ and Co^{60}. Only qualitative data were obtained from these samples since the ruptured area on the fuel element was plainly visible and detailed sample data were not needed to substantiate the rupture.

Loop Radiation Levels

High activity levels were encountered in the Loop 1 cell and the north corridor following reactor shutdown. A comparison of these levels with those observed during normal operation is shown in Table II.

TABLE II

KER Loop 1 Component Activity Levels

Component	Normal	6:00 PM	10:00 PM	6:00 AM
		(all readings are in mr/hr)		
Emergency Storage Tank	10	2,000 (max)	2,000 (max)	2,000 (max)
Dump Valve	30	500	-	900
Cell Background	3	5	4	3
Crud Trap	400	75,000 @ 5'	75,000 @ 5'	50,000 @ 5'
Rear Pigtail	125	700	-	-

ACKNOWLEDGEMENTS

The assistance of the Purex and Redox Analytical Operations are gratefully acknowledged. The KER-1 Loop is operated by Coolant Testing Unit, IPD.

Thomas F. Demmitt
Coolant Systems Development Operation
HANFORD LABORATORIES OPERATION

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