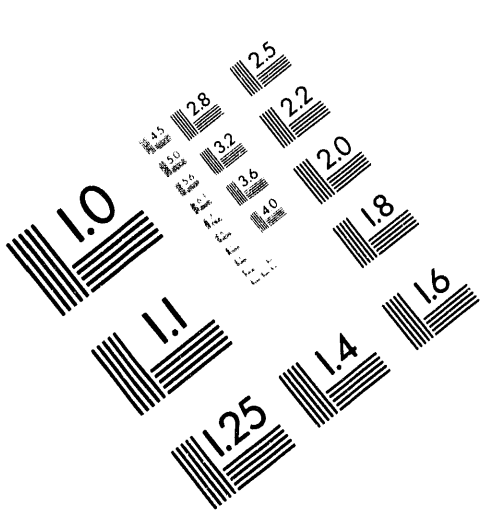

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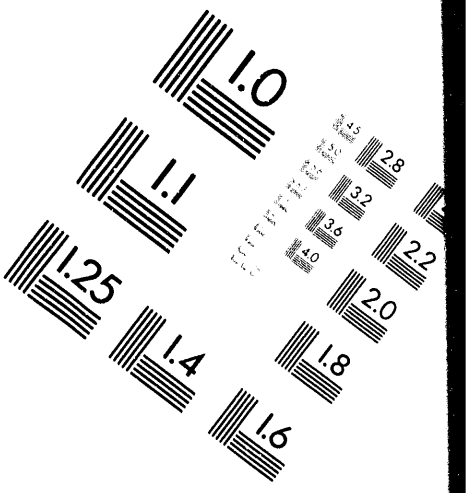

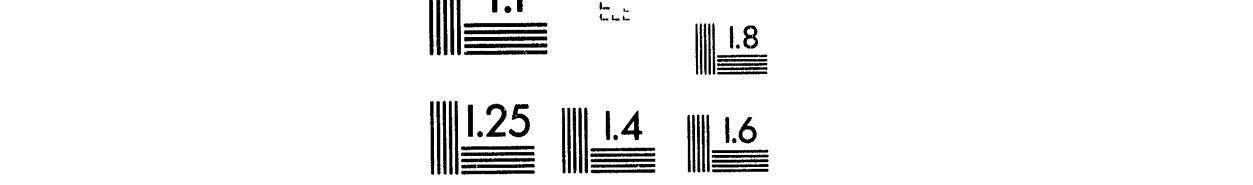

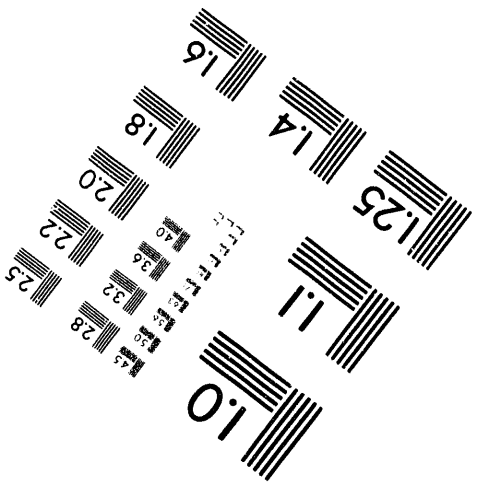

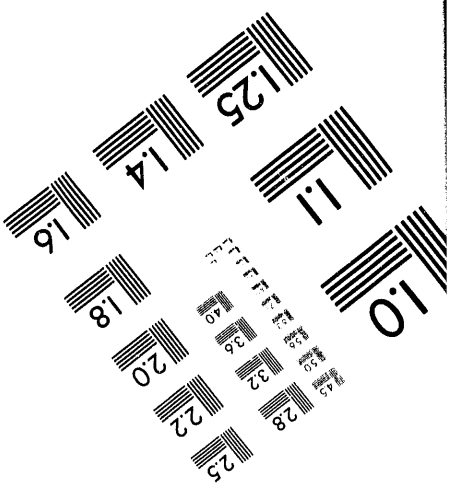

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RADIOCHEMISTRY FOR THE RUPTURE OF A ZIRCALOY-2 CLAD URANIUM FUEL ELEMENT IN KER-1

INTRODUCTION

During the 0800-1600 shift on July 7, 1960, the delayed neutron monitor on KER Loop 1 indicated a high coolant activity level. Sympathetic responses were also recorded on the Loop 3 and Loop 4 instruments indicating a possible fuel element failure in Loop 1. The KE 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 samples and a thermocouple wire sample 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 a section of thermocouple wire was removed from the fuel element charge for examination. The fission product concentrations in the coolant samples were much higher than those observed under normal conditions. Examination of the thermocouple wire sample indicated the presence of adsorbed Np^{239} and $Zr\text{-}Nb^{95}$. This information indicated the presence of a ruptured fuel element in the system.

The fuel elements discharged from the loop were examined usually in the KE viewing pit. There was no discernible evidence of a rupture. The thermocouple element (12-inch, natural uranium) was examined by Radiometallurgy Operation and no evidence of a rupture was found. Since the rupture indications were very definite, it is assumed that one of the 36-inch enriched uranium heater elements ruptured. These elements were not examined by Radiometallurgy Operation so this conclusion has not been substantiated.

DISCUSSION

The fuel elements discharged on July 7, 1960, had been in Loop 1 since May 14, 1960. The elements included in this charge were 2, 36-inch enriched uranium, outer tube heater elements and 1, 12-inch natural uranium thermocouple element. These elements along with 25, 8-inch perfs and spacers comprised the thermocouple train authorized under 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 Zr-2 cladding, and one measured the element core temperature.

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

Temperature	-	288 C for the first 22 days and approximately 100 C for the remainder of the test.
Coolant pH	-	10.0 ± 0.1, maintained by cleanup with a lithium based ion exchanger and lithium hydroxide (solution) additions.
Loop Flow	-	50 gallons per minute.
Cleanup Flow	-	1.5 - 2 gallons per minute.
System Pressure -	-	1500 pounds per square inch.
Degas Rate	-	0.33 gallons per minute.

The chronology of operation pertinent to this fuel element failure is discussed below. The following information was taken directly from, "Rupture Report R-60-5," July 11, 1960, by W. A. Oldham, Coolant Testing Unit, IPD.

> "The loop was operating at 225 C with the temperature increasing slowly as the reactor power level increased following startup on July 6, 1960.
>
> At 7:59 AM, an alarm was received on KER-1 Process Radiation Recorder. The recorder was observed to be reading approximately 35 to 40 percent of scale and then gradually decreasing to about 20 per cent. After about one-half minute, the recorder was observed to be gradually increasing until it indicated 50 percent of scale at which time the range of the recorder was switched from the 250 cps to 500 cps range. The percentage momentarily decreased and then gradually began to increase again. For approximately one minute, the indicated percentage oscillated between 50 per cent and 75 per cent of scale. At 8:04 AM, the process radiation safety circuit trip occurred and the loop underwent a normal loop depressurization cycle with single-pass operation achieved at 8:15 AM.
>
> KER-3 process radiation recorder was observed increasing gradually until it reached 65 per cent of scale at which time the range was switched from the 250 cps to 500 cps range. KER-4 process radiation alarm increased to 50 per cent, at which time the range was also switched. After changing the ranges, the KER-3 and KER-4 recorders returned to normal."

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 did not reveal any noticeable rupture on any of the elements. The thermocouple element was examined thoroughly by the personnel of Radiometallurgy Operation without finding a rupture. The enriched uranium heater elements were not

examined in detail but it is almost certain that a rupture occurred on one of these elements. The coolant and thermocouple wire radiochemical analyses indicate that a rupture definitely occurred.

Coolant Analyses

Coolant samples were drawn from the KER-1 emergency storage tank approximately 35 minutes after loop depressurization was completed. These samples were subjected to radiochemical analyses to determine fission product activity loadings. Since the loop coolant is diluted by a factor of at least 3 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 sample was drawn. This would further reduce the solution activity prior to sampling.(4) These are important considerations in analyzing the analytical results.

Table I contains a summary of the radiochemical analysis data obtained from the coolant samples along with data for a sample drawn from the loop during normal operation. The sample taken during normal operation was drawn directly from the recirculating coolant. These analytical results are therefore 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 samples were taken. 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[4] (uuc/ml)
I_{total}	1,000	250
I^{131}	450	6
Np^{239}	250	72
$Zr\text{-}Nb^{95}$	1,500	34
Ba^{140}	2,300	0.2
Fe^{59}	1	1
Co^{60}	17	0.5
Sr^{89}	780	0.2
Sr^{90}	36	0.1
Xe^{54}	260	-
Cr^{51}	Not obtained due to isotopic interference	25
Mn^{56}	" " "	41
As^{76}	" " "	58
Cu^{64}	" " "	33

A comparison of the data in Table I shows that the fission product activity loading in the suspected 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 Zr-2 process tube, and diffusion from the fuel elements to the coolant.

Thermocouple Wire Analyses

A section of stainless steel jacketed thermocouple wire was removed from the thermocouple train after discharge and was subjected to radiochemical analysis. This analysis showed the presence of significant amounts of Np^{239} and $Zr\text{-}Nb^{95}$. Quantitative data are not available at this time.

These results further confirm that there was a rupture in the KER-1 system.

Loop Radiation Levels

High activity levels were encountered in the KER-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. It should be noted that in each case the activity levels after shutdown were considerably higher than those during normal operation.

TABLE II

KER Loop 1 Component Activity Levels

Component	Normal	Shutdown (0815) (All readings are in mr/hr)	1000	2000
Emergency Storage Tank	10	4,000 (max.)	-	2,500 (max.)
Dump Valve	30	1,000	-	140
Cell Background	3	8	5	3
Crud Trap	400	5,000	-	1,200
Rear Pigtail	125	3,600	-	200

ACKNOWLEDGEMENTS

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HANFORD LABORATORIES OPERATION

TFD:mf

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