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By

C. L. Buckner

January 7, 1960

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KER LOOP RUPTURE SUMMARY

Introduction

This report is a compilation of available data on ruptures that have occurred since KER start-up. Some of the data presented in this report are inconclusive, but are reported to insure a complete summary of all potential and confirmed ruptures.

Summary

There have been four confirmed ruptures and five potential ruptures in the KER loops since start-up. The four confirmed ruptures, their dates, and charges are as follows:

March 24, 1959 - Loop 2 Rupture

The charge consisted of four enriched uranium 7-rod clusters, one enriched uranium 3-rod cluster, and two UO_2 7-rod clusters, all Zr-2 clad. The loop was discharged and subsequent examination at the Radio Metallurgy Laboratory revealed a crack in the Zr-2 can between the metal and cap on one of the enriched 7-rod clusters.

July 11, 1959 - Loop 3 Rupture

The charge consisted of aluminum clad Doe fuel elements. Examination of these fuel elements, following discharge, revealed blisters immediately adjacent to element supports.

September 30, 1959 - Loop 3 Rupture

The charge consisted of three enriched uranium Zr-2 clad tube-in-tube fuel elements. Subsequent examination after the tube had been discharged confirmed the rupture.

October 15, 1959 - Loop 2 Rupture

The charge consisted of seven enriched uranium Zr-2 clad 7-rod cluster fuel elements. The rupture was confirmed visually in the 105-KE Viewing Pit.

The preceeding confirmed ruptures and the five potential ruptures will be discussed more thoroughly in the discussion section of this report.

Discussion

The basis used for determining a potential rupture was as follows:

Cell background readings, strainer readings, loop water samples gamma-scanned for the presence of fission products, and neutron monitor readings. The basis used for final confirmation of a potential rupture was visual detection and/or detection by Radio Metallurgical examination.

The ruptures, both potential and confirmed, as they occurred chronologically, are presented in the following discussion.

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August 13, 1957 - Loop 3 Rupture

The charge consisted of 38 pieces of 1.44-inch cored uranium with an aluminum jacket. The charge was removed from the loop and examined, but nothing was observed to substantiate a rupture. These fuel elements were examined in the 105-C Metal Examination Basin, and no rupture was confirmed; however, following reactor start-up, the neutron activity level on Loop 3 remained approximately five times higher than previously experienced. Samples of loop water, taken immediately after shutdown, were gamma-scanned, but results were inconclusive. The fuel elements were in the loop at approximately 230°C, 850 psi, and pH 4.5, for a total of thirty days before the delayed neutron monitor trip on the above date. The other three loop neutron monitors gave no sympathetic responses to this trip. These fuel elements were boiled in water at 105-C and still no rupture indications appeared. This rupture was classified a potential rupture.

November 17, 1958 - Loop 4 Rupture

The charge consisted of fourteen X-8001 aluminum alloy clad Doe elements and an X-8001 thermocouple element. Increased activity on the delayed neutron monitor resulted in a full-scale deflection of the instrument, causing a reactor scram. This charge was in the loop 103 days at 230°C, 850 psi, and a pH of 4.5. The fuel elements were discharged and visually examined with no indication of a rupture. A gamma-scan of loop water samples indicated the presence of fission products, but the readings were too low for accurate measurement. Excessive activity on the rear face and push pole, following discharge of the elements, was an indication that a rupture did exist, but was inconclusive. This rupture was classified a potential rupture.

March 24, 1959 - Loop 2 Rupture

The fuel elements in this charge were four Zr-2 clad enriched uranium 7-rod clusters, two Zr-2 clad UO₂ 7-rod clusters, and one 3/8 inch Zr-2 clad enriched uranium 3-rod cluster. While the temperature was being raised on loop 2, following the March 13 outage, an abnormal increase in activity and the delayed neutron monitor was observed. The loop temperature was immediately lowered, with a resulting decrease in loop activity. The loop temperature was held at a minimum until March 24. At this time, strong rupture indications were observed in a KE Reactor production tube. During the time this rupture was being confirmed, a test was ran on loop 2 in which the loop temperature was raised to normal to check for further rupture indications. The delayed neutron monitor again showed rupture indications and at the same time, loop water activities increased from a normal of 100 mrads/hr. to a maximum of 4200 mrads/hr., as observed on one-pint loop water samples. The reactor was shut down and the fuel elements were discharged. This charge was visually examined and no evidence of a rupture was observed. Subsequent investigation at the Radio Metallurgical Laboratory revealed a crack in the Zr-2 can between the uranium metal and end cap on one of the enriched 7-rod clusters. This charge was in the loop 105 days of which there were 90 days at 190 to 205°C, 830 psi, and pH of 10.0. This rupture was classified as a confirmed rupture.

March 24, 1959 - Loop 3 Rupture

While shutting down for the confirmed rupture in loop 2, an indication was received of a rupture in loop 3. This charge consisted of 25, 1.44 inch X-8001 aluminum alloy clad depleted uranium elements. The fuel elements were discharged

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but subsequent investigation failed to reveal a rupture. The delayed neutron monitor was out of service for maintenance, but the activity at the ion-exchanger and strainer rose sharply. A loop water sample was evaporated and read 4.7 R. It is strongly suspected that the high activity was due to a crud burst occurring in the tube following shutdown, rather than a rupture. These fuel elements were charged in loop 3 on February 4, 1959 - and operated at 220°C, 850 psi, and pH 4.5 until discharged. This rupture was classified as a potential rupture.

June 28, 1959 - Loop 3 Rupture

The charge was made up of Doe elements clad in X-8001 and C-810 aluminum alloy. Immediately following the reactor shutdown of June 28, 1959, a high cell activity was noted on loop 3. Since the activities were of such a high nature as to make entries into the cell impractical, the fuel elements were discharged. Examination of the elements revealed about half the charge to be covered with a deep rust-colored deposit; the others were white in color and generally appeared in good condition. This charge had been in the loop about thirty days at pH 4.5, 230°C, and 850 psi. It is assumed that the high activity was a result of a crud burst, rather than a rupture, since the activity decayed with a half-life of only a few hours and no rupture was visually detected. This rupture was classified as a potential rupture.

July 11, 1959 - Loop 3 Rupture

The charge consisted of twenty C-810 and X-8001 aluminum alloy clad Doe elements. During swing-shift July 10, and the first four hours of graveyard shift July 11, a gradual increase of cell activity and neutron activity was noted. However, at 0430 July 11, the neutron activity began increasing more rapidly, and the loop strainer activity registered full scale on the recorder (1-R). The tube ΔP increased about 7 psi, during the activity build-up on swing and graveyard. This increase in tube ΔP occurred in increments of 1/2 psi. The reactor was scrammed when the activity reached 85 per cent of the chart and occurred at 0530. The rear nozzle read greater than 5 rad at four feet and the loop strainer read 40-50 rad. The loop was discharged and subsequent flushing of the loop and tube decreased the activity to a low value. The Doe fuel elements had been charged June 29, 1959 for loop conditioning. The loop had been operated at 200 to 250°C, 850 psi, and pH 4.5 since the above date. The fuel elements were examined in the 105-KE Examination Pit. Examination of the fuel elements revealed blisters on two Doe pieces immediately adjacent to the element support. No swelling of the elements was observed; however, there appeared to be a tear in the can along one of the element supports. A more thorough examination of the fuel elements at 105-C Basin revealed ruptures at several spots where the supports had been spot-welded to the can. In a few places, slight swelling had occurred, but no serious deformation of the elements was observed. This was classified as a confirmed rupture.

July 30, 1959 - Loop 1 Rupture

The fuel elements in this charge were two tube-in-tube elements containing natural uranium alloyed with Zr, 2 per cent by weight, and two unalloyed natural uranium tube-in-tube elements. A high radiation alarm was received on loop 1 at 1705 hours on the above date. The delayed neutron monitor was switched from the 250 cps range to the 500 cps range, and manual decreasing of loop temperature was initiated. The delayed neutron monitor continued to climb in level to 80-84 per cent of scale, the north corridor strainer activity increased to 500 mr/hr.,

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and the cell background went up to 250 mr/hr. The neutron effect was observed on the delayed neutron recorder of the other three loops in decreasing magnitude corresponding to respective location. The reactor was manually shut down when it was evident there would be a scram, because of high activity on the delayed neutron monitor. The fuel elements were discharged and examined in the 105-KE Basin. Examination of the elements revealed a crinkled condition and small slightly raised areas on the surface of both unalloyed elements. Loop water samples were analyzed for fission products and iodine isotopes of a very short half-life were found. There was also some indication of other fission products further substantiating the rupture. The loop had been operating at low temperature for a few days because of an instrument malfunction. The rupture occurred a few hours after the loop was returned to high temperature. The charge was in loop 1, a total of 32 days; of these days, 28 days had been at 270°C, pH 10.0, and a pressure of 1325 psi. Although this rupture was detected by several means, it is still classified potential, because it has never substantiated by radio metallurgical means.

September 30, 1959 - Loop 3 Rupture

The fuel elements in this charge were three 36 inch tube-in-tube elements of unalloyed enriched uranium with 20 mil, Zr-2 jackets. The reactor was scrammed by the Loop 3 delayed neutron monitor trip. Full-scale sympathetic responses developed in the delayed neutron monitor of the other three loops. Radiation readings as high as 300-500 rads were measured in the north corridor. Cell backgrounds were 250 mr/hr. Water samples of the loop water were taken for radio-chemical analysis and significant amounts of Zr⁹⁵, Nb⁹⁵, Ru¹⁰⁶, I¹³¹, Np²³⁹, and Cu⁶⁴ isotopes were found. The elements were discharged and examined in the 105-KE Viewing Pit. The outer surfaces of the large tubes of the tube-in-tube elements showed no signs of significant corrosion or rupture and were covered with a moderate rust-colored film, characteristic of pH 4.5 operation. The two inner tubes had extensive regions of heavy corrosion with a dull metallic appearance and spots of white oxide. The fuel elements were shipped to the Radio Metallurgy Laboratory for further examination. The rupture was found on the inside of one of the inner tubes, and the region near the rupture contained several deep pits. This was classified as a confirmed rupture.

October 15, 1959 - Loop 2 Rupture

The charge in this loop consisted of seven enriched uranium 7-rod clusters; six with 20 mil and one with 30 mil Zr-2 jackets, and a thermocouple dummy to measure flow channel temperatures. The reactor was scrammed when the delayed neutron monitor rose rapidly off-scale. Activity responses on the other three loops were noted. A gamma backup monitor positioned under loop 2 also went full scale. High activities noted throughout the loop are as follows:

<u>Location</u>	<u>Readings, Following Scram</u>	<u>Readings, 10/13/59</u>
Dump Valve	800 Mr/hr.	
Emergency Storage Tank	1700 Mr/hr.	
North Corridor Strainer	1000 Mr/hr.	
Primary Heat Exchanger	40 Mr/hr.	18 Mr/hr.
Pressurizer	40 Mr/hr.	
#1 Pump Strainer	1500 Mr/hr.	23 Mr/hr.
#2 Pump Strainer	900 Mr/hr.	31 Mr/hr.
Mockup, Upstream end	700 Mr/hr.	20 Mr/hr.
Mockup, Downstream end	500 Mr/hr.	20 Mr/hr.
Cell Background	80 Mr/hr.	15 Mr/hr.

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Water samples of the loop water were taken and sent to the 202-A Laboratory for analysis. The radio chemical analysis revealed high concentrations of Ru¹⁰⁶, I¹³¹, and Zr-Nb. The fuel elements had been charged May 19, 1959 and had been operated at 255°C, 1600 psi, and pH 10.0 for approximately four and one-half months. The fuel elements were discharged and examined in the 105-KE Viewing Pit. A one inch longitudinal split was observed on one of the external rods. The rupture was classified as a confirmed rupture.

Conclusion

It is believed that a large percentage of the potential ruptures are actually ruptures, but since they were not visually confirmed, they have been classified as potentials. In some cases there were no sympathetic responses on the other delayed neutron monitors or cell backgrounds; chemical analysis of loop water samples failed to verify a rupture indication. All of the ruptures experienced in the KER Loops, both potential and confirmed, have to some degree, been verified by one or more of the methods previously mentioned.

Acknowledgement

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