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SUMMARY OF KER-1 OPERATION
FEBRUARY 15, 1958 - MARCH 1, 1960

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AUTHOR

C. L. Buckner

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SUMMARY OF KER-1 OPERATION
FEBRUARY 15, 1958 - MARCH 1, 1960

by

C. L. Buckner
Coolant Testing Unit
IRRADIATION PROCESSING DEPARTMENT

MASTER

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SUMMARY OF KER-1 OPERATION
FEBRUARY 15, 1958 - MARCH 1, 1960

INTRODUCTION

Recent borescoping of the KER-1 tube revealed several scratches, pits, and gall marks on the internal wall of the tube. These deformations could limit the operating temperature and pressure of KER-1. This report is a summary of operating history and is compiled to assist in determining what contributed to the condition of the tube.

SUMMARY

The out-of-reactor portion of KER-1 was completed in 1956. During 1957 the loop remained idle except for sporadic test operation, flushing, and minor piping revisions. In January, 1958, the in-reactor piping was completed and the Zircaloy-2 process tube installed.¹ There have been five dummy charges and six fuel element charges in the tube of KER-1. There have been two ruptures experienced and the dump valve has opened twice during high-temperature operation. The operational data of KER-1 will be presented in chronological order in the discussion section of this report.

DISCUSSION

The first charge in KER-1 was aluminum dummies, charged January 24, 1958 and discharged February 15, 1958. On this date the tube was charged with nineteen, four-rod, stainless-steel clad, natural uranium, cluster elements with split-ring supports, according to Production Test IP-144-A.² These elements were charged for shakedown operation at elevated temperatures. During the time the charge was in the tube, the following data were noted:

Hours on Process Water			385
Hours on Recirculation:			
Less than 100C	502 hours	$\Delta T.$ = 22C, Flow	54 gpm
100C to 150C	142 hours	$\Delta T.$ = 28C, Flow	51 gpm
150C to 200C	192 hours	$\Delta T.$ = 30C, Flow	51 gpm
200C to 270C	975 hours	$\Delta T.$ = 31C, Flow	50 gpm
Total hours	1811		
Operating Pressure			1325 psi
Average cell background			15 mr
Average Water Quality:			
pH	9.93	Fe	348.8 ppb
O ₂	0.248 ppm	Ni	<0.1 ppb
Total Solids	30.6 ppm	Cr	11.9 ppb

¹HW-56912, Unclassified, "Startup of a Carbon Steel Loop," by E.L.Burley, 7-21-58

²HW-54847, Production Test IP-144-A, "Irradiation of Stainless Steel Jacketed Four-Rod Cluster Elements in KER-1, Tube 2160 KE," by W.K.Kratzer, 2-4-58

On May 15, 1958, the loop had operated at high temperature and pressure for sustained periods and was considered ready for fuel element testing. However, final safety circuit checks showed that the dump valve was partially plugged with solids and could not be depended on to provide an outlet for back-up water flow in case of failure of the recirculation equipment. Therefore, further testing was suspended pending installation of a solids trap to protect this critical valve.¹

The fuel elements were discharged and aluminum dummies charged May 15, 1958. The loop remained on single-pass operation with dummies charged until August 6, 1958. The tube was charged with six, 18-inch, UO₂, stainless-steel clad, four-rod clusters and two 13.3-inch, seven rod clusters, August 7, 1958, according to Production Test IP-146-A, Supplement A.² Operational data collected during the irradiation of these fuel elements are as follows:

Hours on Process Water		308
Hours on Recirculation:		
Less than 100C	516 hours	$\Delta T.$ = 12C, Flow 49.5 gpm
100C to 150C	163 hours	$\Delta T.$ = 15C, Flow 50 gpm
150C to 200C	142 hours	$\Delta T.$ = 10C, Flow 51 gpm
200C to 270C	<u>2654 hours</u>	$\Delta T.$ = 30C, Flow 50 gpm
Total Hours	3475	
Operating Pressure		1325 psi
Average Cell Background		12 mr
Average Water Quality		
pH	10.05	
O ₂	0.194 ppm	
Total Solids	38.0 ppm	

The loop was operated at elevated temperature and pressure with only minor operational changes until January 14, 1959. At this time the fuel elements were discharged. On January 15, 1959, Production Test IP-226-A authorized the charging of a 230-inch thermocouple train, three 30-mil, Zircaloy-2 clad, 1.6 per cent enriched uranium, seven-rod clusters and four 20-mil, Zircaloy-2 clad, 1.6 per cent enriched uranium seven-rod clusters.³

Operational data pertaining to this period of operation are as follows:

Hours on Process Water		171
Hours on Recirculation:		
Less than 100C	908 hours	$\Delta T.$ = 12C, Flow 50.5 gpm
200C to 250C	<u>691 hours</u>	$\Delta T.$ = 72C, Flow, 50 gpm
Total Hours	1599	
Operating Pressure		1325 psi
Average Cell Background		5 mr
Average Water Quality:		
pH	9.8	Fe 0.61 ppm
Cl	0.14 ppm	Total Solids 17.0 ppm
PO ₄	<0.02 ppm	O ₂ 0.013 ppm
SiO ₂	1.17 ppm	Sp.Res. 22,695 ohms/cm ²

¹Design Change 224, Loop-1 Solids Trap

²Kratzer, WK, Supplement A to PT-IP-146-A, "Irradiation of Coextruded Bonded Zircaloy-2 Jacketed, Seven-Rod Cluster Fuel Elements in the KER Recirculation Test Facility, HW-55814, 4-21-58. (Sec.)

³Kratzer, WK, "Irradiation of Enriched Seven-Rod Cluster Elements with 20 and 30 Mil Zircaloy-2 Jackets, HW-58781, 1-8-59

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The loop was operated at reduced temperature and pressure during the month of March due to a flow reduction caused by increased pressure drop in the reactor portion of the loop. The loop continued low temperature recirculation operation until March 26, when the loop was put on single-pass operation due to a failure of a canned motor pump. At this time the front and rear nozzles were examined for possible restrictions; however, nothing was found. The fuel elements were discharged March 29, 1959, and examined but nothing was found to indicate the flow restriction. A flow test was conducted with the tube empty and above normal pressure drop across the tube was noted. The front nozzle was removed and examined for possible causes. The diffuser ring was found to be partially plugged, a new nozzle was installed and dummies charged in the tube. When the loop was returned to normal operation, the flow restriction had been corrected. The dummies charged March 29, 1959, remained in the tube until April 16, 1959, at which time they were discharged in preparation for an extended outage at KE Reactor. During the extended outage, pump and various maintenance revisions were completed. The loop was charged with dummies May 7, 1959, and operated on an in-reactor recirculation shake-down run following the extended outage.

The dummies were discharged May 19, 1959, and new fuel elements charged in the tube as authorized by Production Test IP-246-A, Supplement A.¹ The fuel elements, as authorized by this Production Test, were one 13-inch, natural uranium seven-rod cluster with circular end supports, one 13-inch, enriched uranium, seven-rod cluster, with triangular end supports, one 36-inch tube-in-tube fuel element, and one 33-inch rod-in-tube fuel element. The tube was on process water for 39.5 hours during the entire run and on recirculation for 949 hours. The length of time at various temperatures during the recirculation portion of the run were:

Less than 100C	151 hours	$\Delta T.$	= 15C
100C to 150C	293 hours	$\Delta T.$	= 12C
150C to 200C	34 hours	$\Delta T.$	= 21C
200C to 250C	471 hours	$\Delta T.$	= 36C
Operating Pressure			1325 psi
Average Flow			50.1 gpm
Average Cell Background			6 mr
Average Water Quality:			
pH	10.07	H ₂ O ₂	< 0.10 ppm
Cl	< 0.10 ppm	O ₂	0.042 ppm
SO ₄	< 1.00 ppm	*SiO ₂	0.473 ppm
PO ₄	< 0.02 ppm		
Specific Res.	51,600 ohms/cm ²		

*The SiO₂ increased to a maximum of 5.50 ppm during the run due to a leak through the KM ion exchangers. After the beds had been regenerated the SiO₂ leveled out at approximately 0.03 ppm.

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The tube was discharged June 28, 1959, after a failure of the Low-Low Flow Instrument at 105-KE dumped the loop during high temperature-pressure operation. The possibility of boiling in the tube during this rapid depressurization was limited to the time interval between the closing of a block valve and the entrance of process back-up water into the loop.¹ On June 29, 1959, the tube was charged with two unalloyed tube-in-tube elements, 36 inches long, Zircaloy-2 clad, and two tube-in-tube elements, alloyed with Zircaloy-2, two per cent by weight. 36 inches long, and Zircaloy-2 clad, as authorized by Production Test IP-250-A, Supplement A.² The test started on June 29, 1959, and ran for a period of 32 days. On July 30, 1959, the delayed neutron monitor reading and loop activities increased to a point that required a manual reactor shutdown. The fuel elements were discharged and examined in the 105-KE Basin. Examination of the fuel elements revealed a crinkled condition and small slightly raised areas on the surface of both unalloyed elements.³ The loop had been operated 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 operation.

The tube was on process water a total of eight hours during the entire run and on recirculation for 742 hours. The length of time at various temperatures during the recirculation portion of the run were:

Operating Pressure		1325 psi
Less than 100C	185 hours	$\Delta T.$ = 16C
100C to 150C	89 hours	$\Delta T.$ = 8C
150C to 200C	27 hours	$\Delta T.$ = 8C
200C to 270C	441 hours	$\Delta T.$ = 49C
Average Flow		50.2 gpm
Average Cell Background		5 mr
Average Water Quality:		
pH	10.20	Total Solids 14.2 ppm
Cl	<0.10 ppm	H ₂ O ₂ <0.10 ppm
SO ₄	<1.0 ppm	O ₂ 0.030 ppm
PO ₄	<0.02 ppm	SiO ₂ 0.76 ppm
Sp. Res.	23,350 ohms/cm ²	

On July 30, 1959, the tube was charged with aluminum dummies. This loading was in the tube until August 24, 1959, at this time the tube was charged with a new fuel element charge as authorized by Production Test IP-226-A, Supplement B.⁴

¹Kratzer, WK, Suppl. A to PT-IP-250-A "Irradiation of Zircaloy-2 Jacketed Tube-in-Tube Elements In The KER Loops," HW-60719. 6-12-59 (Sec.)

²Norwood, KW, "KER-1 Loop Rapid Depressurization Incident of June 28, 1959," HW-61447 RD. 8-7-59, (Sec.)

³Buckner, CL, "KER Loop Rupture Summary," HW-63404, 1-7-60 (Sec.)

⁴Kratzer, WK, Supplement B to Production Test IP-226-A, "Irradiation of Enriched Seven-Rod Cluster Elements with 20 and 30 mil Zircaloy-2 Jackets," HW-61541. 8-13-59, (Sec.)

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This production test authorized the irradiation of one 28-inch plutonium-aluminum, seven-rod cluster, two 30-mil jacketed, natural uranium, seven-rod clusters and four 20-mil jacketed, natural uranium, seven-rod clusters. This run ended February 7, 1960, when the delayed neutron on KER-1 went full scale and scrammed the reactor. The fuel elements were discharged, subsequent examination revealed a rupture on one of the external rods of the natural uranium, seven-rod cluster.

The rupture area had a blister 30 to 40 mils high, 1-1/4-inch long, and a 1/2 inch side-wall split. Effluent samples taken at the time of the rupture indication also verified the rupture by revealing the presence of iodine and neptunium isotopes in amounts approximately 50 and 20 times normal, respectively. Following the rupture, the tube was borescoped to determine the condition of the internal walls. The borescope revealed several scratches, "gall" marks, and a few pits on the internal wall of the tube.¹ The length of time at various temperatures during the test are as follows:

Hours on Process Water				135
Hours on Recirculation:				
Less than 100C	596 hours	Δ T. =	50C	
100C to 150C	158 hours	Δ T. =	42C	
150C to 200C	118 hours	Δ T. =	34C	
200C to 270C	3897 hours	Δ T. =	60C	
Operating Pressure				1325 psi
Operating Flow				50 gpm
Average Cell Background				5 mr
Average Water Quality:				
pH	10.23	PO ₄	0.02 ppm	H ₂ O ₂ < 0.10 ppm
Cl	< 0.10 ppm	Sp.Res.	30,184 ohms/cm ²	O ₂ 0.15 ppm
SO ₄	< 1.0 ppm	Total Solids	11.5 ppm	SfO ₂ 0.148 ppm

The tube was charged with aluminum dummies and put on single-pass operation, pending further decisions on the reliability of the KER-1 tube. The status of KER-1 is unchanged to this date.

¹ DeMers, AE, to SL Nelson, "Borescope Results, 105-KE," 2-9-60

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