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INTERIM REPORT:
SWELLING BEHAVIOR OF KSE-5 FUEL ELEMENTS;
KER TEST K-1-22

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September 23, 1964

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INTERIM REPORT:
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INTRODUCTION

Production Test IP-544-A⁽¹⁾ authorized the irradiation testing of coextruded Zr-2 jacketed, single tube, thick walled, 1.6 percent enriched tubular elements (KSE-5's) in KER loops 1 and 2 to evaluate swelling behavior at high uranium temperatures. This PT was intended to permit the evaluation of uranium swelling at N-reactor environmental conditions but at considerably higher uranium temperatures than those occurring in N-reactor fuel. Evaluation of the fuel performances at the authorized maximum fuel temperatures in the 550-600 C temperature range is essential in the design and analysis of single tube fuel elements for use in N-reactor. The test was subsequently supplemented⁽²⁾ to authorize the irradiation of uranium fuel containing up to 3000 ppm alloying agents for the evaluation of swelling behavior at the high uranium temperatures.

This report describes the swelling behavior of a charge of 8 KSE-5 fuel elements⁽³⁾ irradiated in KER loop 1 to approximately 2500 MWD/T as Test K-1-22. KER Test K-1-22 is similar (except for exposure level) to KER Test K-2-21 in which a charge of 8 KSE-5 fuel elements were irradiated to 1500 MWD/T.⁽⁴⁾ In both tests the charges consisted of 4 KSE-5's containing uranium with low iron and silicon additions (N-reactor fuel composition) and 4 KSE-5's containing uranium with 400 ppm iron and 800 ppm aluminum. The objective of both tests was to obtain comparative swelling performance data for the two fuel compositions under identical irradiation conditions.

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- (1) HW-75456, Production Test IP-544-A, Irradiation of 1.6% Enriched Thick Walled Single Tube Elements in KER-1 & 2, W. K. Kratzer and J. J. Wise, December 12, 1962. (Secret).
 - (2) HW-79796, PT IP-544-A, Supplement A, Irradiation of 1.6 Percent Enriched Thick-Walled Single Tube Elements in KER-1 and KER-2. J. T. Knight, December 6, 1963. (Confidential).
 - (3) HW-80397, Loading and Operating Conditions for a Charge of Eight Enriched Single Tube Elements, PT IP-544-A, Supplement A, J. T. Knight, January 14, 1964. (Confidential).
 - (4) HW-84198, Interim Report: Swelling Behavior of KSE-5 Fuel Elements; KER Test K-2-21, J. W. Goffard, 9-23-64. (Secret).

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SUMMARY & CONCLUSIONS

A test charge of KSE-5 fuel elements was irradiated in KER Loop 1 (K-1-22) to 2500 MWD/T exposure as a higher exposure follow-up to a previous 1500 MWD/T test in KER-Loop 2 (K-2-21). The purpose of the test was the further evaluation of the swelling performance of uranium containing iron and aluminum additives as compared to the swelling performance of N fuel (uranium containing iron and silicon). The fuel elements containing the two fuel compositions were alternately loaded in the test loop so that nearly identical irradiation histories over a range of exposures and operating temperatures could be obtained.

Post-irradiation evaluation from pre- and post-irradiation bulk density measurements has shown that the iron and aluminum bearing fuel swells only about one-half as fast as N-fuel. This confirms the observation made on the earlier KSE-5 test (K-2-21). The data obtained from this higher exposure test is nearly identical with that obtained from the previous and lower exposure test, even though the exposure was approximately 60 percent greater. A 10-15 percent lower specific power in the high exposure test may account for the lower swelling rate. Radio-metallurgical examination of the elements and detailed analysis of fuel operating temperatures should verify this explanation.

It remains evident, however, that the iron and aluminum additives markedly reduce fuel swelling. Effective use of these additives should be fully exploited in future N-fuels development programs. The effectiveness of other additives and the influence of heat-treatment variables upon irradiation performances should be explored.

IRRADIATION TEST K-1-22

The fuel element test charge was nearly identical to that of the previous, lower exposure KSE-5 test charge in KER loop 2.⁽⁴⁾ Four fuel elements containing uranium with low additions of iron and silicon (140 and 120 ppm respectively) and four fuel elements containing uranium with 400 ppm iron and 800 ppm aluminum made up the charge. These were loaded so that the two different fuel materials occupied alternate positions as indicated in Table I. After irradiation, the elements were discharged and transferred to the KER viewing pit for post-irradiation examination and weighing.

MEASURED FUEL SWELLING AND COMMENTS

Swelling of the fuel materials in the KSE-5's has been calculated from the pre- and post-irradiation bulk density measurements made in the K basin on the individual test elements. The swelling performances indicates a significant difference in the behavior of the two fuel compositions with the iron and aluminum bearing uranium being the better, just as in the previous and lower exposure test.⁽⁴⁾ Peak fuel swelling of the iron and aluminum bearing fuel was about 1.2 v/o compared to the peak swelling of the N fuel composition of 2.2 v/o. These data are nearly identical with

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those obtained from the previous test. It was unexpected that the data from the two tests would match so closely considering that the exposure of the second test was 60 percent higher than that of the first test (2500 vs. 1500 MWD/T). Examination of the loop operating records shows the higher exposure test operated at an average specific power of 10-15 percent lower than that of Test K-2-21. This difference of specific power possibly resulted in a reduction of the fuel operating temperatures such that the fuel swelled at a slower rate. Detailed analysis of loop operating data may, therefore, establish the cause of the reduced swelling rate observed in this test.

Individual fuel element swelling data, relative exposures or powers, and estimated exposures are tabulated in Table I. The data are also portrayed graphically in Figure I and compared with the data from the earlier, lower exposure test.

Table I - SUMMARIZED LOADING ORDER, OPERATIONAL AND SWELLING PERFORMANCE
OF KSE-5's (TEST K-1-22)

<u>Position</u>	<u>Element Identification*</u>	<u>Fuel Swelling %ΔV</u>	<u>Relative Exposure or Power from Weasel</u>	<u>Estimated Exposure MWD/T</u>
Upstream				
1	346-13	0.58	0.81	2200
2	345-16	0.81	0.80	2200
3	346-12	0.75	0.87	2375
4	345-8	1.59	0.92	2525
5	346-7	1.13	0.96	2650
6	345-6	2.22	0.98	2675
7	346-2	1.17	1.00	2750
8	345-3	2.02	0.97	2650

Downstream

*345 series elements are N fuel compositions (iron and silicon).

*346 series elements contain iron and aluminum additions.

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FIG. I Comparison of exposures and fuel swelling in two test charges of KSE-5's.

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