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INTERIM REPORT: SWELLING BEHAVIOR OF CO-PRODUCER
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INTERIM REPORT:
SWELLING BEHAVIOR OF CO-PRODUCT DRIVER ELEMENTS;
KER TEST K-3-19

J. W. Goffard

September 23, 1964

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INTERIM REPORT:
SWELLING BEHAVIOR OF CO-PRODUCT DRIVER ELEMENTS:
KER TEST K-3-19

INTRODUCTION

The irradiation testing of co-product fuel-target assemblies in KER loops 3 and 4 was authorized by PT-IP-645-D⁽¹⁾. The purpose was to demonstrate and characterize the simultaneous generation of plutonium and tritium during the irradiation of simulated N-Reactor co-product assemblies. Thirteen assemblies,⁽²⁾ each consisting of a 1.25% enriched outer fuel or driver tube and an inner, coaxial, lithium bearing target rod,⁽³⁾ were loaded in KER-3 and irradiated to approximately 1300 MWD/T tube average at N-Reactor conditions⁽⁴⁾. One of the important aspects of the test was the fuel swelling performance in the large, tubular, enriched driver elements. This report describes the fuel swelling behavior of the driver elements.

SUMMARY & CONCLUSIONS

A test charge of thirteen co-product assemblies was irradiated in KER loop 3 to 1300 MWD/T fuel exposure to evaluate the simultaneous production of two nuclear products in an N-Reactor environment. One of the important evaluations to be made was the swelling performance of the enriched N-Reactor fuel in the large tubular driver element of the co-product assembly. Pre- and post-irradiation bulk density measurements showed fuel swelling from 0.25 v/o to 3.32 v/o in the thirteen driver elements with a marked peaking of swelling at the center of the charge.

Post-irradiation radiometallurgical examination of the fuel shows a considerable amount of grain-boundary tearing type porosity in the fuel adjacent to the clad. The central fuel shows considerable fine porosity that appears to be clustered and oriented with deformation

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- (1) HW-80175, Production Test IP-645-D, Co-Product Producing Element Irradiation, R. Neidner, 12-27-63, (Confidential).
 - (2) HW-80466, Loading and Operating Conditions for a Charge of Thirteen Co-Product Test Assemblies in KER-3 or 4, PT-IP-645-D, R. Neidner, 1-20-64, (Confidential).
 - (3) HW-81198, Design and Fabrication of Target Elements for PT-645-D, J. C. Tverberg, 3-9-64, (Secret).
 - (4) HW-79808, PT IP-638, Operation of KER-1, 2, 3 and 4, Simulating N-Reactor Conditions, R. Neidner, 12-5-63, (Secret).

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bands in this hotter and recrystallized fuel region. Neither form of porosity is believed to be associated with the agglomeration of fission gases.

On the basis of the results obtained from KSE-5 comparative fuel swelling tests at fuel operating temperatures above those attained in N-Reactor fuel elements(5,6), fueling the driver elements with iron and aluminum bearing uranium, rather than the standard iron and silicon additive fuel, should be strongly considered in order to reduce fuel swelling.

TEST K-3-19

The co-product test charge consisted of thirteen driver-target assemblies and was loaded into KER loop 3, February 14, 1964. The test charge was operated at simulated N-Reactor conditions (1350 psi coolant) to a tube average fuel exposure of about 1300 MWD/T and was discharged June 8, 1964.

The driver element, with which this report is concerned, is a N-Fuels coextruded tube of standard N-Reactor grade uranium (150 ppm iron and 100 ppm silicon) but enriched in U-235 to 1.25%. Closures are fabricated as are standard NAE components, except that 90° tapered end caps mating with a 90° groove in the fuel are used. Fuel dimensions were as follows:

Jacketed O.D.	2.292 inch
Jacketed I.D.	1.441
Outer Zr-2 clad	0.035
Inner Zr-2 clad	0.025
Fuel wall thickness	0.366
Length	26.1

The inner coaxial target rod is 0.565 inch in diameter and is supported in the driver tube by modified "buggy spring" supports.

-
- (5) HW-83198, Interim Report: Swelling Behavior of KSE-5 Fuel Elements; KER Test K-2-21, J. W. Goffard, 9-23-64, (Secret).
- (6) HW-83199, Interim Report: Swelling Behavior of KSE-5 Fuel Elements; KER Test K-1-22, J. W. Goffard, 9-23-64, (Secret).

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MEASURED FUEL SWELLING

After discharge from KER-3, the assemblies were transferred to the KER viewing pit for post-irradiation examination and evaluation. Fuel material swelling was calculated from the pre- and post-irradiation driver element bulk density measurements made on the individual pieces. Swelling ranged from 0.25 v/o to 3.32 v/o for the test driver elements and showed a marked peaking at the center or higher exposure positions of the column. Fuel swelling and other available data are tabulated in Table I and are graphically illustrated in Figure I.

SUMMARIZED LOADING ORDER, OPERATING CONDITIONS, AND FUEL SWELLING PERFORMANCE OF DRIVER ELEMENTS OF CO-
Table I - PRODUCT ASSEMBLY TEST (K-3-19).

<u>Position</u>	<u>Element Identification</u>	<u>Fuel Swelling %ΔV</u>	<u>Relative Exposure or Power from Weasel Data</u>	<u>Approximate Exposure MWD/T</u>
Upstream				
1	X-114-7	0.25	0.26	500
2	X-114-6	0.24	0.40	800
3	X-114-5	0.55	0.49	1000
4	X-114-2	0.58	0.60	1200
5	X-114-1	0.92	0.77	1550
6	X-112-8	2.31	0.92	1850
7	X-112-4	3.27	1.00	2000
8	X-112-3	3.32	0.95	1900
9	X-112-2	2.74	0.90	1800
10	X-111-7	1.18	0.74	1500
11	X-111-6	0.65	0.61	1200
12	X-111-3	0.55	0.49	1000
13	X-114-4	0.37	0.33	650
Downstream				

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FIG. I FUEL EXPOSURE AND FUEL SWELLING
OF CO-PRODUCT 1.25% ENRICHED DRIVER ELEMENTS
(Test K-3-19).

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PRELIMINARY RADIOMETALLURGICAL EXAMINATION

Radiometallurgical examination is currently being performed on the driver element that occupied Position #7 (X-112-4, maximum weasel) of the test charge. Both closures have been sectioned and prepared for micro examination. The tapered or "chevron" design appears to have performed well with no indications of instability at the various metal junctures of the closure. A crack has been observed in the fuel between the clad wall and the tapered side of the cap, but with no accompanying deformation in the clad. It is possible that this crack is a result of post-irradiation handling.

Microstructure examination shows a considerable amount of small grain-boundary tearing in the fuel adjacent to the clad. The fuel in this region displays a "hashed" or swirled microstructure that is characteristic of uranium irradiated at about 400 C. It appears that there is more grain-boundary tearing on the O.D. side of the fuel wall than on the I.D. side. The hotter central zone of the fuel displays a defined metallographic structure that is somewhat more heavily twinned than the unirradiated fuel. There is considerably porosity resolvable at 1000X magnification that is clustered and oriented to some degree with the deformation bands or twins. Replication and electron microscopy is yet to be done.

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