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PROPOSAL FOR KER LOOP IRRADIATION OF COEXTRUDED

DEFECT TEST FUEL SPECIMENS

J. W. Goffard

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HW-62966
12/16/59

PROPOSAL FOR KER LOOP IRRADIATION OF COEXTRUDED DEFECT TEST FUEL SPECIMENS

J. W. Goffard

(Reference: Letter Containing Preliminary Information, 11/11/59)
W. K. Kratzer, Reactor Fuels Operation, IPD, 1703-D Bldg.

Objective

The objective of the proposed irradiation is the attainment of nominal low and intermediate in-reactor exposures of coextruded fuel specimens in the high-temperature, high-pressure environment of a KER loop facility.

Purpose

The purpose of the irradiation is to provide properly irradiated coextruded fuel specimens for post-irradiation defect testing. Defect testing of the irradiated specimens will provide kinetic autoclave defect test data for comparison with unirradiated specimen data. (1,2,3,4,5,6) Such data will be most revealing as to the behavior and performance of coextruded Zr-2 clad fuel failures and should reveal the effect of exposure on the nature of the coextruded U-Zr-2 bond.

Description of Fuel Assemblies

A. Size and Geometry

The size and geometry of the fuel assemblies to be irradiated are shown in the attached drawings. There will be two assemblies of each of two types.

B. Material

All fuel materials are NMI coextruded Zr-2 clad and of reactor quality grade. The necessary items of assembly hardware are Zr-2. Fuel in the 7-rod assemblies is natural uranium, and fuel in the 1-rod assemblies is natural uranium - 2 w/o Zr alloy.

- (1) HW-61378, Interim Report #1: Rupture Kinetics - Equipment & Procedures, V. H. Troutner, Unclassified.
- (2) HW-61379, Interim Report #2: Rupture Kinetics - Behavior of Pin-Hole Defects in Coextruded Rods, V. H. Troutner, Unclassified.
- (3) HW-61799, Interim Report #3: Rupture Kinetics - Mechanism of the U-H₂O Reaction, V. H. Troutner, September 29, 1959, Unclassified.
- (4) HW-60054, Interim Report: Corrosion Rate & Failure Behavior of Defected Coextruded U-Zr-2 Fuel Rods, J. W. Goffard, 5/8/59, [REDACTED]
- (5) HW-60775, Coextruded Fuel Defect Test with Internal Heat Generation in a 300 C Out-of Reactor Water Loop, K. D. Hayden, 6/22/59, [REDACTED]

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HW-62966
12/16/59

C. Fabrication

The fuel material and its integral Zr-2 clad was fabricated by the co-extrusion process. End caps will be vacuum electron beam welded in place with adequate end clearance to avoid stressing of the welds by thermal expansion and/or swelling of the fuel during operation. All counterbored recesses for end caps will be freed of fuel material by chemical etching prior to end-cap welding. Assembly of necessary Zr-2 support hardware will also be accomplished in vacuum by electron beam welding.

D. Inspection

All coextruded fuel pieces will be inspected during and after fabrication for overall quality and freedom from contamination. Clad thickness and bond integrity will be determined non-destructively by the currently available means. Ultimate proof-testing of the completed assemblies will be accomplished by autoclaving in 400 C high pressure steam.

Expected Performance

A. Mechanical Behavior

It is not expected that fuel distortion and swelling will effect the specimen assemblies in any way to cause concern. Seven-rod cluster fuel elements almost identical to the 7-rod cluster assembly proposed for use in this irradiation have been irradiated to exposures of 2500 MWD/T in the KER facility.(7,8) Although a rupture was incurred in the reference test, (with enriched U) there was no indication of fuel distortion or severe swelling resulting from the irradiation. The failure occurred in a fuel rod with 0.020" clad thickness for unknown reasons. Fuel material with 0.030" clad thickness is used in fabricating the 7-rod cluster assemblies described here and proposed for this irradiation. Distortion of the rod bearing the fuel specimens in the 1-rod assembly should not present a serious problem even if it does occur. The rod is provided with a very generous coolant annulus and is contained in a substantial non-power generating Zr-2 tube. This assembly is similar to short tube-and rod fuel elements which have been irradiated in the KER facility without incident.

B. Failure Behavior

Should a failure occur in any of the specimens, its damaging effect should be minimized because of the compartmentalized nature of the specimen rods. A limited amount of fuel is contained in each specimen and this fact itself will limit the amount of damage and the degree of loop decontamination that can result from a failure.

(5) HW-60039, Interim Report: Defect Testing of Coextruded U-Zr-2 Fuel in a 300 C Out-of-Reactor Water Loop, K. D. Hayden, J. W. Goffard, 9/25/59, [REDACTED]

(7) HW-60112, Supplement A to PT-IP-226-A, W. K. Kratzer, 4/21/59.

(8) Drawing SK-3-8070. [REDACTED]

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HW-62966

12/7/59

C. Physical Ability to Use in Loops

It is probable that only one of each type assembly will be loaded into a KER loop. Thus, the total pressure drop across the two assemblies (one of each of two types) will be small. The drop and flow effects across the 7-rod cluster assembly should be the same as for PT-IP-226-A, Supp. A, (7) except as modified by the much shorter length of the active charge. The two types of assemblies proposed for irradiation are similar in construction and details to 7-rod fuel element clusters and tube-and-rod fuel element components. The capability of these designs during charge-discharge operations have been demonstrated and no difficulties are foreseen.

Calculations of flow split, coolant velocities, and film coefficients (attached) for the 1 rod assembly indicates that heat transfer requirements can be readily met. Flow split will be 80% through the inner or fuel-bearing annulus and 20% through the outer annulus. Flow velocities through the inner annulus may vary from 10.6 to 12.7 feet/sec, and through the outer annulus from 5.8 to 6.9, depending upon the bulk flow and temperature. A film coefficient in the inner annulus of approximately 3700 BTU/hr/sq/ft F will prevail.

Limitations on Normal Operations

A. Temperature, Flow, Pressure

There are no rigid limitations upon the KER facility temperature, flow and pressure parameters. Coolant temperatures in the 250-300 C range at pressures required to suppress boiling and at flows necessary to permit normal and safe operation of the facility are the only requirements during the irradiation of the specimen assemblies. Loop coolant pH should be in the 9.0 - 11.0 range.

B. Mechanical Limitations

The assemblies have been designed to permit ready separation of the many fuel material specimens by routine procedures at the Radiometallurgy facility. To assure efficient processing at Radiometallurgy, special discharge into trays is required so that damage or breakage of the irradiated fuel specimen assemblies may be avoided.

Irradiation Conditions

Powers generated in the fuel materials will be equivalent to or less than power of production material in adjacent tubes as natural uranium specimens are used. No excessive fuel or surface temperatures are foreseen. One assembly of each type (2 total assemblies) is to be irradiated to the nominal exposure level of 300-600 MWD/T. The remaining one assembly of each type is to be irradiated to the nominal exposure level of 2000-3000 MWD/T.

Disposition of Irradiated Fuel Specimen Assemblies

Discharged assemblies are to be shipped to the HAPD radiometallurgy facility for post-irradiation testing and evaluation.

JWG/lh

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APPENDIX

Flow calculations for 1-md assembly

Conditions

48-60 indicated gpm in KER at inlet temp. range
180-250°C

indicated $\times R$ = true bulk flow

R at 180°C = 475

R at 250°C = 453

(48)(453) = 21,744 #/K0/hr. (min.)

(60)(475) = 28,500 #/K0/hr. (max.)

$$\begin{aligned}\text{Inner flow channel (\#1) area} &= \frac{\pi}{4} (1.56^2 - 0.890^2) \\ &= 1.29 \text{ m}^2 = 0.00896 \text{ ft}^2 \leftarrow\end{aligned}$$

$$\begin{aligned}\text{Outer flow channel (\#2) area} &= \frac{\pi}{4} (2.02^2 - 1.82^2) \\ &= 0.605 \text{ m}^2 = 0.00421 \text{ ft}^2 \leftarrow\end{aligned}$$

Equivalent Dns.

$$D_{e1} = 1.56 - 0.890 = 0.67" = 0.0558 \text{ ft.} \leftarrow$$

$$D_{e2} = 2.02 - 1.82 = 0.20" = 0.01667 \text{ ft.} \leftarrow$$

For both channels, assume friction factor, F , pressure drop, ΔP , and length, L , are equal

$$\Delta P = F \frac{L}{D_e} \frac{V^2}{2g} = K \frac{V_1^2}{D_{e1}} = K \frac{V_2^2}{D_{e2}}$$

$$Q_T = V_1 A_1 + V_2 A_2$$

$$Q_T = (D_{e1})^2 \left(\frac{\Delta P}{K} \right)^{1/2} A_1$$

$$Q_T \left(\frac{K}{\Delta P} \right)^{1/2} = (D_{e1})^2 A_1 + (D_{e2})^2 A_2$$

$$\begin{aligned}\text{Flow ratio} &= \frac{\text{Flow \#1}}{\text{Flow Total}} = \frac{(D_{e1})^2 A_1}{(D_{e1})^2 A_1 + (D_{e2})^2 A_2} \\ &= \frac{(0.67)^2 (1.29)}{(0.67)^2 (1.29) + (0.20)^2 (0.605)} \\ &= \frac{1.057}{1.057 + 0.27} = 0.796 \leftarrow\end{aligned}$$

$$\begin{aligned}\frac{\text{Flow \#2}}{\text{Flow Total}} &= \frac{0.27}{1.057 + 0.27} = 0.204 \leftarrow\end{aligned}$$

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Flow velocities - at max. flow of 28,500 #/hr. at 180°C
 $\rho_{H_2O} = 55.5 \text{ #/ft}^3$

$$V_{1 \text{ max.}} (\text{channel } \#1) = \frac{(28,500)(0.796)}{(3600)(55.5)(0.00896)} \\ = 12.7 \text{ ft./sec.} \leftarrow$$

$$V_{2 \text{ max.}} (\text{channel } \#2) = \frac{(28,500)(0.244)}{(3600)(55.5)(0.00421)} \\ = 6.90 \text{ ft./sec.} \leftarrow$$

at min. flow of 21,750 #/hr. at 250°C
 $\rho_{H_2O} = 50.4 \text{ #/ft}^3$

$$V_{1 \text{ min.}} = \frac{(21,700)(0.796)}{(3600)(50.4)(0.00896)} \\ = 10.6 \text{ ft./sec.} \leftarrow$$

$$V_{2 \text{ min.}} = \frac{(21,700)(0.244)}{(3600)(50.4)(0.00421)} \\ = 5.79 \text{ ft./sec.} \leftarrow$$

Using Fig. 1.4.2, REACTOR HANDBOOK, Vol 2 and conservative values of mass flow (21,750 #/hr) and Temp. (180°C, 350°F), the film coeff. for the main flow channel (power generating) is -

$$\frac{(21,750)(0.796)}{0.00896} = 1.72 \times 10^6 \text{ #/hr. sq. ft.}^{\circ}\text{F}$$

$$h_{0.25} = 4600$$

$$h_{0.25} K = (4600)(0.8) = 3680 \text{ BTU/hr. sq. ft. }^{\circ}\text{F.}$$

the film coeff. for the outer flow channel (non-power generating) is -

$$\frac{(21,750)(0.244)}{0.00421} = 1.05 \times 10^6 \text{ #/hr. sq. ft.}^{\circ}\text{F}$$

$$h_{0.25} = 2800$$

$$h_{0.25} K = (2800)(1.05) = 2940 \text{ BTU/hr. sq. ft. }^{\circ}\text{F.}$$

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ROD FOR 7 ROD CLUSTERS - 2 SAMPLES EACH ROD

ROD FOR 1 ROD ASSEMBLY - 4 SAMPLES EACH ROD

7 ROD CLUSTER ASSEMBLY (ALL MATLS ZR-2)

1 ROD ASSEMBLY (ALL MATLS ZR-2)

DATE

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8/17/94

END