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December 3, 1950

R. Reidner
Phillips Petroleum Company
MTR, National Reactor Testing Station
Idaho Falls, Idaho

NEPTUNIUM-ALUMINUM FUEL CAPSULE IRRADIATION: GEM-14-60, 61, 62, 63

-- J.L. Bates, W.E. Roake, and E.E. Veillard

We are sending you four irradiation test specimens containing 10 w/w Pu-Al alloy. Segments of alloy rods approximately one inch long are contained in three capsules which, in turn, are enclosed in shrink-fitted aluminum cans in the same manner as the GEM-3-45-48 capsules which are now being irradiated in the MTR. Will you please arrange to have them inserted in either the MTR or the MTR at the suitable flux position at the earliest availability?

Upon completion of each exposure, will you arrange to return the specimens to MTR Radiometallurgy Division for recovery and examination of the test alloy?

The purpose of this test is to examine the irradiation behavior of a proposed target alloy for use in Hanford reactors and to provide material for chemical separation studies.

The pertinent information concerning this irradiation proposal is summarized below. Details of the same are appended in the following order:

- Appendix I Description and Fabrication Details
- Appendix II Thermal Aspects and Calculations

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SUMMARY OF PROPOSED CONDITIONS

	GEH-14-60	GEH-14-61	GEH-14-62	GEH-14-63
Maximum fuel temperature, °F		110		
Maximum surface temperature, °F		107		
Weight of Neptunium-Aluminum Alloy g/in	7.56	7.60	7.61	7.64
Weight of Neptunium-Aluminum Alloy, g	33.69	33.23	32.99	32.58
Weight of Neptunium, g	3.37	3.33	3.30	3.26
Weight of Aluminum in fuel, g	30.32	29.92	29.69	29.32
Maximum heat generation, watts/in		37.5		
Maximum surface heat flux, BTU/hr-ft ²		5000		
Film coefficient, BTU/hr-ft ² -°F		6,026		
External dimensions, inches				
CD Capsule	.565	.565	.565	.565
ID	.905	.905	.905	.905
Length	4.455	4.374	4.465	4.399
Thermal neutron flux, nvt		8.0×10^{13}		
Cumulative Exposure, nvt		7.3×10^{20}		

We would like a thermal flux as close as possible to 1×10^{14} nvt, but realize that such a flux position may require an unacceptable waiting period. We request 7.3×10^{20} nvt exposure with the expectation that one or more capsules may be withdrawn before attaining that exposure.

If you require any further information, please telephone immediately.

J L Bates
Ceramic Fuels Development Operation
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APPENDIX I

HW-55041-PD

A. Fabrication Details

Ten weight percent neptunium-aluminum alloy was cast from the melt into one half inch diameter graphite molds. These short rods, approximately 1.5 inches long were cleaned and found to be completely free of measurable surface contamination. Approximately 4.5 inch long columns of these alloy rods were inserted into 0.505" ID x 0.030" thick Zircaloy-2 tubes, resulting in a diametral clearance of 0.005 inch. The capsules were evacuated, back-filled with helium, and Zircaloy end plugs were fusion welded in place in a purified helium atmosphere. The completed Zircaloy capsules were helium leak tested and autoclaved 24 hours in 170°C water. No evidence of leakage was observed.

The autoclaved capsules were shrink-fitted into thick walled 2-S aluminum cans, and final closure achieved by fusion welding end caps in each end of the aluminum can. You will recognize this technique as identical to that used in preparing test capsules GZH-5-45-48.

B. Hazards

No unusual hazards are anticipated in this irradiation test. The Zr-Al alloy is chemically stable toward demineralized water at MTR coolant temperatures. We have not calculated capsule stresses due to internal pressure, because even if the highly improbable situation of total fission gas release existed, the quantity of gas and its temperature would be far less than that calculated for the example illustrating the hazards for test GZH-5-45-48 (cf. HW-55241-PD). You will recall that at an exposure of 3.25×10^{21} nvt, assuming 100% fission gas release at 3100 K temperature, it was calculated that only 121 psi would be exerted on the aluminum can, a pressure considerably lower than the yield strength of 28 aluminum.

Temperature drop across the Zr-Al interface is estimated to be 2000 BTU/hr ft² (cf. HW-55241-PD). Temperature drop between fuel alloy and Zircaloy can was assumed to be that across a 0.005 inch helium gap.

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Heat contributions of other fissioning materials produced during the Np-237 irradiation cannot be greater than 50% of that of the Np-238 fission; hence, total heat generation will be less than 450 watts/ft for $7.5 \times 10^{-3} \text{ n/cm}^2$ flux.

B. THERMAL CALCULATIONS

The thermal calculations are identical to those of ORE-3-45, 46, 47 and 48.

Thermal flux, unperturbed	$8 \times 10^{14} \text{ n/cm}^2 \text{ sec}$
Np - Al alloy diameter	0.500 inches
Outside diameter Zircaloy cladding	0.565 inches
Cladding thickness, Zircaloy	0.030 inches
Conductivity of Zircaloy-2	0.5 watts/in C
Conductivity of 2S Aluminum	5.6 watts/in C
Cladding to Core Conductivity (assume same as 2S aluminum)	5.6 watts/in C
Coolant temperature	100 F (38 C)
Power Generation	450 watts/ft or 37.5 watts/in
Water film drop	
a. Flow Area	0.00162 ft ²
b. Equivalent diameter	0.022 ft
c. Reynold's Number	8.389×10^3
d. Water film coefficient	6026 BTU/hr ft ²
e. Water film temperature drop	< 2 F (< 1 C)
Temperature drop through cladding	
Zircaloy	< 2 F (< 1 C)
2S Aluminum	< 2 F (< 1 C)
Temperature drop through fuel	
Neptunium - 10% aluminum	< 3 F (< 2 C)
Temperature drop across Al-Zr interface	< 3 F (< 2 C)
Maximum heat flux	5,000 BTU/hr ft ²

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APPENDIX II

A. THERMAL ASPECTS

Heat generation from Np-238 fission.

Rate of fission of Np-238 is equal to the rate of formation of Np-238 multiplied by the branching ratio defined as $\frac{\sigma_f}{\sigma_c}$ which for

$\frac{\sigma_f}{\sigma_c}$

$\sigma_f = 1600$ b and $n\nu = 7.5 \times 10^{13}$ n/cm² equals 0.030

Np-238 production rate is expressed by

$$\frac{dN_{38}}{dt} = \frac{dN_{37}}{dt} = R_{37} \frac{\sigma_c}{\sigma_f} n\nu$$

Assuming no flux depression in the fuel sample, the rate of fission thus equals

$$0.03 R_{37} \frac{\sigma_c}{\sigma_f} n\nu \text{ or } (0.03) (170) (10^{-24}) (7.5) (10^{13}) R_{37}$$

For a 10 w/o Np-Al alloy rod 0.5" in diameter, there will be 0.504 g Np/cm² or 7.72×10^{20} at Np/cm

hence the fission rate will be

$$(0.03) (170) (10^{-24}) (7.5) (10^{13}) (7.72) (10^{20}) = 2.96 \times 10^{11} \text{ f/sec cm}$$

Heat generation per foot equals

$$(2.96) (10^{11}) \text{ f sec}^{-1} \text{ cm}^{-1} (3.21) (10^{-11}) \text{ wsec f}^{-1} (2.54) (12) \text{ cm ft} =$$

$$(2.96) (10^{11}) (3.21) (10^{-11}) (2.54) (12) \text{ w/ft} = 290 \text{ watt/ft}$$

Fission heat will be proportional to the neutron flux:

$$7.5 \times 10^{13} = 290 \text{ watt/ft}$$

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