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TIS File

November 9, 1967

Mr. N. J. Donahue, Chief
Reactor Materials Branch
Technical and Production Division
Savannah River Operations Office
U. S. Atomic Energy Commission
Aiken, South Carolina 29801

Dear Mr. Donahue:

In accord with your request as coordinator of the U. S. Canadian Sheath Program, we are transmitting 25 copies of the papers presented at the Sheath Meeting at Battelle-Northwest on October 3, 1967, as follows:

1. "Temperature-Exposure Thresholds for Cavitational Swelling of Dilute Uranium Alloys" by W. R. McDonell, W. N. Rankin, C. L. Angerman, and R. T. Huntoon. DP-MS-67-48 (Unclassified).
2. "Irradiation Stability of Uranium Alloys at High Exposures" by W. R. McDonell and W. N. Rankin. DPST-67-539 (Secret).
3. "Irradiation Results on Cast Uranium Fuel Elements" by W. R. McDonell. DPST-67-540 (Secret).

Advance copies of these papers were sent to J. E. Minor, Battelle-Northwest, before the meeting. We are also enclosing 25 copies of the paper "Irradiation Behavior of British Fuel Alloy" by C. L. Angerman and W. R. McDonell (DPST-64-470, Rev. - Official Use Only), as requested by you as a supplement to Paper No. 3.

We understand these papers will be assembled along with others presented at the meeting into a proceedings of the meeting.

Sincerely yours,

W. R. McDonell
Nuclear Materials Division

WRM:jm

The document transmitted herewith contains RESTRICTED DATA. [redacted]

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DPST-67-539

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IRRADIATION STABILITY OF URANIUM ALLOYS AT HIGH EXPOSURES*

SPECIAL RE-REVIEW

FINAL DETERMINATION

Unclassified

R. Coylewer

Date: 7/15/86

by

W. R. McDonell
W. N. Rankin

Savannah River Laboratory
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Postirradiation examinations were begun of a series of unrestrained dilute uranium alloy specimens irradiated to exposures up to 13,000 MWD/T in NaK-containing stainless steel capsules. This test, part of a program of development of uranium metal fuels for desalination and power reactors sponsored by the Division of Reactor Development and Technology, has the objective of defining the temperature and exposure limits of swelling resistance of the alloyed uranium. The uranium specimens contain small additions of Fe, Si, Al, Cr, Mo, or Zr, and were heat treated by various procedures to determine the stabilizing effects of different microstructural distributions of the alloy constituents. The specimens were irradiated to three exposures (3,000, 9,000, and 13,000 MWD/T) at calculated central temperatures from 300 to 800°C. The results at 13,000 MWD/T are summarized in the following paragraphs. Examination of specimens irradiated to 9,000 MWD/T and 3,000 MWD/T is partially completed.

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Among the production-type alloys irradiated, the compositions that had best stability at high exposures (13,000 MWD/T) were those containing high (800 ppm) concentrations of aluminum and silicon, in contrast to the better performance of intermediate (350 ppm) silicon compositions in previous tests at lower exposures (5000 MWD/T).

The swelling data for the specimens irradiated to 13,000 MWD/T are arranged in the following table in the order of decreasing stability as determined by the threshold temperature for cavitation swelling. The threshold temperature for cavitation swelling at this exposure was taken as the temperature at which the total swelling was 6% -- 2% in excess of the volume increase due to solid fission products. In most cases, density was not measured for those specimens that had obviously swelled a great deal more than 6%. The listed

* The information contained in this article was developed during the course of work under Contract AT(07-2)-1 with the U. S. Atomic Energy Commission.

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Date 12-12-73

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temperatures are the nominal values and are subject to downward revision by 50-150°C when the swelling of calibration specimens at lower exposures is compared to the results of previous tests. The following principal conclusions were drawn:

The highest stability is exhibited by U - 1.5 to 4.0% Mo - 0.1% Si alloys (Alloys 1, 2, and 3) that were solution-treated in the high gamma-phase region (1050°C) and quenched in water. However, a U - 0.5% Mo - 0.1% Si (Alloy 24) swelled severely -- probably due to internal cracking during the severe water quench.

Among the more dilute alloys, the specimens containing high (800 ppm) aluminum or silicon additions (Alloys 5,6,8,9,10,11,12) were more stable at 13,000 MWD/T than those containing intermediate (250-350 ppm) silicon without high aluminum (Alloys 15,17,19). This contrasts with the results from a previous test at 5000 MWD/T, in which the intermediate-silicon alloys were the most stable.

U - 350 ppm Si - 1000 ppm Mo (Alloy 13), which was the most stable in the previous tests, was the best of the intermediate-silicon specimens in the present test, but was less stable than those containing 800 ppm aluminum (Alloys 5,6,8,9,10,12).

Among the beta-treated, oil-quenched alloys with 800 ppm aluminum, those containing silicon, molybdenum, and possibly chromium, as well as iron (Alloys 5,6,8,9,10) were somewhat more stable than the alloy containing only iron and aluminum (Alloy 12). As expected, the very dilute alloys of iron and silicon (100-150 ppm) (Alloy 21) and unalloyed ingot uranium (Alloy 22) swelled more than the alloys containing larger amounts of additives.

A high-temperature treatment of the dilute alloys in the gamma phase, designed to produce finely dispersed carbide in the metal, effectively increased the stability of U - Fe - Al alloy (Alloy 4) as well as that of unalloyed ingot uranium (500 ppm C) (Alloy 18).

The binary U - 1.5% Mo alloy without silicon (Alloy 14) swelled more than the similar composition with 0.1 wt % Si (Alloy 3). Oil quenching the U - 1.5% Mo (Alloy 7) from 800°C (low-temperature region of the gamma phase) produced better stability than cooling slowly from the same temperature (Alloy 16). This test demonstrated that, in relatively concentrated alloys, the effect of heat treatment may persist to high exposures, whereas, in dilute alloys, little persistent effect of heat treatment was observed.

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The U - 2% Zr binary (Alloy 23) was less stable than U - 1.5% Mo (Alloy 16); little difference was noted between U - 2% Zr (Alloys 20,23) quenched or cooled slowly from 800°C.

Swelling of Uranium Specimens Irradiated to 13,000 MWD/T

Alloy	Decrease in Density After Irradiation at Indicated Nominal Temperature, %[a]					Alloy Composition, ppm[b]					Heat Treatment			
	300°C	450°C	550°C	590-660°C	700-830°C	Fe	Si	Al	Cr	Mo	Phase	°C	Time	Cooling
1	2.8	2.7		2.6	7.2		0.1 wt %			4.0 wt %	γ	1050	24 hr	Water
2	3.3	2.6		4.8	10.3		0.1 wt %			2.25 wt %	γ	1050	24 hr	Water
3	1.2	3.2	4.6		10.3		0.1 wt %			1.5 wt %	γ	1050	24 hr	Water
4	3.6	4.1	7.2	S	S	350		800			γ	950	20 min	Oil
5	3.8	3.4	15.6	15.3	18.4	350	350	800		1000	β	725	10 min	Oil
6	3.7	3.9	S	-	-	250	300	800	200		β	725	10 min	Oil
7	3.5	4.8	S	-	S					1.5 wt %	γ	800	20 min	Oil
8	5.1	4.2	25.6	43.5	S	350	350	800			β	725	10 min	Oil
9	4.1	3.9	31.0	38.8	S		800	800			β	725	10 min	Oil
10	4.4	3.7	35.0	-	-		350	800			β	725	10 min	Oil
11	4.5	5.4	38.4	-	-		800				β	725	10 min	Oil
12	4.5	5.0	41.5	-	-	350		800			β	725	10 min	Oil
13	4.6	9.4	S	-	-		350			1000	β	725	10 min	Oil
14	3.4	10.6	S	-	-					1.5 wt %	γ	1050	24 hr	Water
15	5.0	13.7	-	-	S	250	350				β	725	10 min	Oil
16	3.9	17.0	-	-	-					1.5 wt %	γ	800	20 min	Furnace to 500°C, Oil
17	4.4	19.0	-	S	-	250	250	250			β	725	10 min	Oil
18	4.4	26.0	S	-	-	(Unalloyed ingot uranium)					γ	950	20 min	Oil
19	4.9	26.0	-	S	-		350				β	725	10 min	Oil
20	5.7	S	-	S	-	(2 wt % Zr)					γ	800	20 min	Water
21	6.1	S	S	-	-	150	100	100			β	725	10 min	Oil
22	6.1	S	-	-	-	(Unalloyed ingot uranium)					β	725	10 min	Oil
23	6.3	48.0	S	-	-	(2 wt % Zr)					γ	800	20 min	Furnace to 500°C, Oil
24	19.1	21.4	-	-	21.7		0.1 wt %			0.5 wt %	γ	1050	24 hr	Water

(a) Actual temperatures probably 50-150°C lower.
(b) Composition in ppm, except as noted.
S Specimen obviously swelled more than 6%.
\- Specimen not examined since threshold had been found at lower temperature.

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