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TITLE

CAPSULE IRRADIATION OF URANIUM WITH LOW ALLOY ADDITIONS.

(Letter JR Spink from JH Weber)

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AUTHOR

J. W. Weber

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HW-80433-RD

January 16, 1964

J. R. Spink
Irradiation Testing
1704-K Building
100-K Area

CAPSULE IRRADIATION OF URANIUM WITH LOW ALLOY ADDITIONS

Here is a more complete description of the capsule test we discussed in our initial contact in December. I have included as much detailed description of the test as has been decided on to date. Also, there are some factors which, from previous similar tests, I have found to be pertinent to the successful charging and irradiation performance of the capsules. There is one critical point that needs to be settled as soon as possible. In order to finish machining the outer diameter of the capsules, the expected approximate specific power generation and enrichment in the surrounding process tubes must be known. In addition, there are several other factors which effect the location of the test in the reactors which Bob Marshall and I would like to go over with one of your engineers as soon as possible.

Classification Cancelled and Changed To

DECLASSIFIEDBy Authority of RM & Gen4-5-94, CGPR-2By JE Savely 4-17-94Verified By Gene Mally, 4-18-94.

JWW:lh

J. W. Weber
Senior Engineer
306 Building, 300 Area
Telephone - 3330

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CAPSULE IRRADIATION OF URANIUM WITH LOW ALLOW ADDITIONS

R. K. Marshall - J. W. Weber

January 15, 1964

PURPOSE

A program has been proposed to develop metallic uranium based alloys of improved swelling resistance and corrosion resistance⁽¹⁾. The program includes NaK capsule irradiations of coextruded Zircaloy-2 clad rods to evaluate the alloy fuel swelling performance. The possibility of significantly reducing the amount of fission gas swelling in uranium by alloying with small amounts of various elements is of great interest in the area of metallic fuel development. These tests will provide data helpful in designing metallic fuel elements capable of extended burnup at elevated fuel temperatures.

EXPERIMENTAL DESIGN

Alloys

The twelve alloy compositions planned for study are listed in Table I. Various heat treatments on these compositions will produce certain microstructures which are believed to be beneficial in reducing the migration of fission gas pores.

Fuel Rod Samples

Rods from each of the above compositions will be coextruded to a nominal 0.6-inch O.D. with a nominal 0.025-inch thick Zircaloy-2 cladding.

-
- (1) Last, G. A., and O. J. Wick, "Proposed Program for the Development of Improved Metallic Uranium Fuels," HW-77532, 5-3-63.

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Fuel samples for irradiation will be fabricated by cutting approximately 3-inch long specimens from the coextruded rods counterboring the uranium by machining and chemical etching, and electron beam welding Zircaloy-2 end caps to each sample. Figure 1 shows the nominal dimension of the typical fuel sample. Drawings for the fuel samples will be supplied with the data package.

The uranium in all samples is 1.47 percent enriched.

Capsule

This test requires the irradiation of 34 test capsules and one thermocouple capsule per normal process tube. Four process tubes will be required to investigate the desired number of variables of composition, heat treatment and exposure, with the sufficient number of duplications.

As a check on temperature calculations based on adjacent tube powers, it is necessary to measure the temperature at a known location at the downstream end of the capsule column with the thermocouple leads extending out the rear face nozzle, will accomplish this. From the measured temperatures, the known capsule and fuel dimensions, and the front-to-rear flux distributions it will be possible to calculate the fuel temperatures more accurately.

The proposed charging pattern for the capsule columns is shown in Figure 2. It should be noted that in each column several samples of the reference fuel are included. The irradiation performance of these reference fuel samples will be used as standards against which the performance of the other fuels with various compositions and heat treatments can be compared. Thus the performance of the various samples at equal volume mean fuel temperature along each capsule column and

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[REDACTED]

[REDACTED]

between the four columns of fuel samples can be compared.

The design of the test specimen and thermocouple capsules with nominal dimensions are presented in the attached assembly drawing. Detail dimensions will be presented in the data package.

Material for the capsules is extruded Zircaloy-2 tubing or rod.

The outer diameter of the clad fuel rods and the inner diameter of the capsule body are constant for each capsule. To compensate for the variation in specific power from end to end of the capsule column the capsule wall in the region of the fuel specimens will be machined to different thicknesses. The power generation differences will cause some difference in fuel ΔT but by adjusting the thermal resistance through the capsule walls, the mean volume fuel temperature can be maintained approximately the same along the capsule column. The wall thickness and, therefore, the final outer diameters will depend on selection of a satisfactory reactor adjacent tube power.

Proper functioning of the NaK expansion chamber depends on maintaining the proper rotational orientation of the capsules. Rails on the outer aluminum sleeves which are matched with the ribs of the process tube guide the capsule in proper orientation during charging, and maintains the orientation during irradiation.

The aluminum perf train will run from the thermocouple capsule to the rear face of the reactor to provide support for the thermocouple lead and to locate the capsules at the desired position in the process tube.

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Instrumentation

The only special instrumentation required for this test will be a recorder for the fuel thermocouples.

The normal pressure and temperature measurements on the capsule column process tubes and the adjacent process tubes will be used.

TEST CONDITIONS

Temperature of Fuel

The proposed temperature conditions for this test are as follows:

Center uranium temperature	600 C (1112 F max.)
Uranium surface temperature	400-450 C (552-842 F)
Volume mean fuel temperature	500-525 C (932-977 F)
Cladding outer surface temperature	325-350 C (617-662 F)

Specific Power Generation

Calculations show that the specific power generation in the fuel specimens will be a maximum of 25 kw/ft.

Because of physical limitations on capsule wall thicknesses and the desirability of maintaining the above volume mean fuel temperature along the capsule columns and between the capsule columns, the range of acceptable adjacent tube powers is rather limited. Based on the available physics calculations for the ratio of specific power in the test samples to the specific power in the adjacent normal fuel columns, the approximate tube power desired will be 900 KW.

Total Exposure

Two exposure levels are planned for this test. The first 1500 MWD/T will be the exposure for one tube. Results of post-irradiation examina-

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tion of these samples will be used to establish a second higher exposure for the remaining three tubes. At present, based on the available swelling data for uranium of the reference composition, the maximum exposure will be from 2500-3000 MWD/T.

Design Calculations

Calculations supporting the physics, temperatures, and other pertinent parts of the capsule design will be included with the data package.

Special Instructions

Special Handling

After the capsules have been filled with NaK, they are welded shut and placed in special boxes in a vertical position--with the expansion chamber up. They are then X-rayed to determine that all the NaK is in the correct position in the fuel chamber. From the time of X-ray until charging the capsules should be under close control of the sponsor or other responsible individuals to prevent inverting of the capsules.

For charging the capsules in the rear of the process tubes, a special orientation tool and spline were fabricated and used with complete success in other irradiation tests of similar capsules.

The complete thermocouple train will be assembled by the sponsor.

DATA REQUIRED

At least once per day, preferably at about the same time each day, the following data readings will be required:

Date:

Time:

Reactor Power Level:

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[REDACTED]

Inlet Water Temperature:

Outlet Water Temperature from Test Porcess Tubes:

Thermocouple Reading from the Strip Chart Recorder

for Each Test Process Tube:

From each Immediate Surrounding Adjacent Process Tube:

Outlet Temperature -

Flow Factor -

In the past, it has been most convenient to have a data sheet filled in each day--even when the reactor is down. This way it is known that a day hasn't been skipped, and it is easier to keep track of the total days of exposure.

In addition, the charge pattern in the adjacent tubes should be recorded as to number, enrichment, and upstream and downstream dummy charge.

For the purpose of establishing the flux distribution from front-to-rear along the capsule column, one adjacent numbered column should be charged and discharged at the same time as each capsule column. Weasel readings on the numbered column should be made soon after discharge and then again about 20 or 30 days later.

DESIRED SCHEDULE

Present scheduling on the availability of the fuel material would set the completion date for the capsules about May 1, 1964. If problems occur in the fuel fabrication, this date may have to be moved back. You will, of course, be kept informed of any major changes in the scheduling.

[REDACTED]

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SPECIAL CONSIDERATIONS

It is imperative that the capsules be located in the reactor away from control rods, poison columns, or other conditions that may significantly change the flux as transients or over long-time periods.

The physics calculations for this test are based on the assumption of uniform surrounding lattice. As the adjacent tube powers requested are in the range of process tubes near the fringes and the E rings, it is important to keep the capsule columns surrounded by a constant enrichment.

Also, the recent reactor shutdown announcements by the AEC should be factored in when selecting the reactor for these tests.

SPECIAL REFERENCES:

1. Copy of Charge-Discharge Procedure for a similar capsule test in F-reactor.
2. HW-67264, "Proposal for the Irradiation of Cladding Studies Capsules," J. W. Weber, 11-1-60.
3. HW-68970, Production Test IP-402-A, Irradiation of Zr-2 Cladding Studies Capsules, W. K. Kratzer, 3-24-61.
4. HW-71648, Supplement A, Production Test IP402A Irradiation of Zr-2 Cladding Studies Capsules, W. K. Kratzer, 11-9-61.
5. HW-73553, Proposal for the Irradiation of Cladding Studies Capsules - Series II, J. W. Weber, 5-3-62.
6. HW-73936, Production Test IP-510-A, Irradiation of Cladding Studies Capsules, Series II, W. K. Kratzer, 6-14-62.
7. HW-75869, Supplement A, Production Test IP-510-A, Series II, W. K. Kratzer and M. J. Wise, 12-12-62.

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TABLE I

URANIUM ALLOY NOMINAL COMPOSITION

<u>Alloy</u>	<u>Fe</u>	<u>Si</u>	<u>Al</u>	<u>Zr</u>	<u>Nb</u>	<u>Mo</u>	<u>C</u>
1	150	100					500
2	400		800				500
3	150	100					1000
4			800				
5		800					
5a		800					500
6		300	300				
7			800	2 w/o			
8		600		2 w/o			
9			800		2 w/o		
10				2 w/o			
11			800			2 w/o	

All amounts of elements are ppm except Zr, Nb, and Mo which are w/o.

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FIGURE 1

CAPSULE
NUMBER

TUBE — Low EXPOSURE

1	2	3	4	5	6	7		
3		8		14		19		
1 2								
	4 5							
	6 7							
		9 10						
			11 12					
				13 15				
					16 17			
						20		
						18		
							21	

FIGURE 2a

ANSWER

TUBE - HIGH EXPOSURE I

१२ अक्षरः।

CAPSULE
NUMBER

TUBE - HIGH EXPOSURE II

1	2	3	4	5	6	7	8	9
3		8		14	18			25
			11 12					
		9 10						
	6 7							
4 5								
1 2								
				13 15				
					16 17			
						19 20		
								26 27
						21 22		
							23 24	

FIGURE 2c

TUBE - HIGH EXPOSURE III

CAPSULE
NUMBER

1	2	3	4	5	6	7	8	9
3		8		14	18			25
			11 12					
		9 10						
	6 7							
4 5								
1 2								
				13 15				
						21 22		
							23 24	
				16 17				
					19 20			
								26 27

FIGURE 2d

Alloy Number	Alloy Description	Carbide Size	Casting *	Heat Treatment **
1	U+150Fe+100Si+500C Reference	Large	I	β
2	U+400Fe+800Al+500C	Large	I	β
2	"	"	I	$\beta+\alpha$
2	"	"	I	γ
2	"	Small	A	β
2	"	"	A	$\beta+\alpha$
2	"	"	A	γ
3	U+150Fe+100Si+1000C	Small	A	β
4	U+800Al low carbon	Small	A	β
4	"	"	A	$\beta+\alpha$
4	"	"	A	γ
5	U+800Si low carbon	Small	A	β
5	"	"	A	$\beta+\alpha$
5	"	"	A	γ
5a	U+800Si+500C low	Small	A	β
5a	"	"	A	$\beta+\alpha$
5a	"	"	A	γ
6	U+300Si+300Al low carbon	Small	A	β
6	"	"	A	$\beta+\alpha$
6	"	"	A	γ
7	U+2%Zr+800Al low carbon	Small	A	γ
7	"	"	A	$\gamma+\alpha$
8	U+2%Zr+600Si low carbon	Small	A	γ
8	"	"	A	$\gamma+\alpha$
9	U+2%Nb+800Al low carbon	Small	A	γ
9	"	"	A	$\gamma+\alpha$
10	U+2%Zr low carbon	Small	A	γ
10	"	"	A	$\gamma+\alpha$
11	U+2%Mo+800Al	Small	A	γ
11	"	"	A	$\gamma+\alpha$

* I - INDUCTION MELTED + CAST

A - ARC MELTED + CAST

** VARIOUS HEAT TREATMENTS TO GET DESIRED STRUCTURE

2 w notes
506
December 12, 1962

CHARGE-DISCHARGE PROCEDURE FOR FOUR TEST AND
FOUR CONTROL COLUMNS, PT-IP-510-A IN F REACTOR

A. General

Eight tubes will be charged in F Reactor under PT-IP-510-A and Supplement A to PT-510-A. Tubes 0363, 0372, 0383, and 0461 will be charged with capsules and tubes 0364, 0371, 0382, and 0460 with numbered normal elements. The capsule tubes will be partially charged from the rear with the balance of the loading charged from the front. The four monitor tubes will be charged from the front with numbered OIIN elements in order.

All tubes will require individual special pick up. A capsule tube and its companion adjacent monitor tube may be stored in the same bucket. No other combination is permitted to prevent loss of fuel identity and avoid exceeding the allowable mass of enriched uranium in a bucket.

B. Special Equipment

<u>Material</u>	<u>Location</u>	<u>Provided by</u>
4 thermocouple trains	rear elevator	Test Author
32 capsules	rear elevator	Test Author
4 modified perfs	rear elevator	Test Author
4 8" perfs	rear elevator	Test Author
1 capsule positioning wrench	rear elevator	Test Author
1 20' push pole (in sections)	rear elevator	Operations
1 15" long, 1.440" OD probe	rear elevator	Operations
1 20' probe pole	rear elevator	Operations
40 8" solid aluminum pieces	front elevator	Operations
8 Pb-Cd pieces	front elevator	Operations
1 push pole	front elevator	Operations

C. Charging Procedure

1. Capsule Columns 0363, 0372, 0383, and 0461

- The test columns will be flushed leaving the tube completely empty. Tubes will be proven empty by using mouse traps or push pole.
- The 15-inch probe will be inserted 20 feet into the process tube from the rear and withdrawn.

- The following material will be loaded from the rear, in order:

→ 1 8-inch perf →
→ 1 modified perf
8 capsules
1 17-foot thermocouple train

- The rear of the tube will be buttoned up and the thermocouple leads strung across the reactor.

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e. From the front, the tube will be loaded with 10 solid aluminum dummies and 2 Pb-Cd pieces. No material will be loaded from the front until after the rear is buttoned up. This restriction is necessary to permit displacing material to the rear with a push pole if difficulty is encountered in charging the capsules or thermocouple train.

f. The column will be seated to the rear and the front cap installed.

2. Monitor Columns 0364, 0371, 0382, and 0460

The monitor columns will be charged with numbered OIIN elements, number 1 element downstream. Fuel element numbers and series numbers should be recorded for each tube.

D. Discharging Procedure

1. Capsule Tubes

- a. Rupture shielding will be hung under each capsule tube to prevent thermocouple wires from catching on the rear pigtails.
- b. Thermocouple wires will be cut at the cap, the cap and train withdrawn from the tube a few inches, and the wires cut behind the cap and plug.
- c. The tip-off will be installed and the tube discharged into the basin.

2. Monitor Tubes

The monitor tubes will be discharged normally.

W. K. Kratzer
Chemistry and Metallurgy Sub-Section
N-Reactor Department

WKK:mmm

APPROVED:

F Processing Operation

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8/2/94

END