**Quarterly Report
on the Strontium Heat Source
Development Program, Advanced
Systems and Materials Production
Division for January - March 1979**

H. T. Fullam

April 1979

**Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830**

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DIVISION FOR JANUARY-MARCH 1979

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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

Sectioning of the WESF $^{90}\text{SrF}_2$ capsule held at 800°C for one year was completed. Ring sections cut from the Hastelloy C-276 inner capsule will be shipped to ORNL for examination.

Design of the prototype outer capsule has been completed. The design calls for a capsule having a 0.5-in. wall thickness. An order has been placed with Cabot Corporation to supply the materials for the prototype outer capsules and to fabricate the capsule parts. Delivery of the capsule components is scheduled for July of this year.

Tests lasting up to 10,000 hr and measuring the rate of oxidation of Hastelloy S and Hastelloy C-4 in air at 600° to 800°C have been completed. Specimens oxidized for 5000 to 10,000 hr exhibited erratic oxidation behavior, apparently because of spalling of the oxide layer.

Hastelloy S and Hastelloy C-4 specimens exposed to flowing seawater for 7500 hr suffered very little corrosion. Some isolated pitting to a depth of 0.1 mils was evident in the 7500-hr specimens. The corrosion, however, had no significant effect upon the room-temperature tensile properties of the two alloys.

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STRONTIUM HEAT SOURCE DEVELOPMENT PROGRAM

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D. G. Atteridge
F. A. Simonen

At Hanford, strontium is separated from the high-level waste, converted to the fluoride, and doubly encapsulated in small, high-integrity containers for subsequent long-term storage. The fluoride conversion, encapsulation, and storage take place in the Waste Encapsulation and Storage Facilities (WESF). The encapsulated strontium fluoride represents an economical source of ^{90}Sr if the WESF capsule can be licensed for heat source applications under anticipated use conditions. The objectives of this program are to obtain the data needed to license $^{90}\text{SrF}_2$ heat sources and specifically the WESF $^{90}\text{SrF}_2$ capsules. The information needed for licensing can be divided into three general task areas:

Task 1 - Chemical and Physical Properties of $^{90}\text{SrF}_2$

Task 2 - $^{90}\text{SrF}_2$ Compatibility Studies

Task 3 - Capsule Qualification and Licensing.

Efforts are proceeding concurrently on all three tasks to obtain the required information.

TASK 1 - CHEMICAL AND PHYSICAL PROPERTIES OF $^{90}\text{SrF}_2$ (H. T. Fullam)

(No activity this quarter.)

TASK 2 - $^{90}\text{SrF}_2$ COMPATIBILITY STUDIES (H. T. Fullam)

All of the remaining strontium fluoride compatibility tests are proceeding on schedule. The last of the scheduled tests will be completed in October of this year, and analysis of the test specimens will be completed by the end of FY 1980.

Rockwell has completed the sectioning of the WESF $^{90}\text{SrF}_2$ capsule which was held at approximately 800°C for one year. Ring sections about 1/2 in. wide were cut from four locations in the Hastelloy C-276 inner capsule. The ring sections will be shipped to ORNL for examination as soon as a cask is available, hopefully in April. It was found that the Hastelloy C-276 from the inner capsule was quite brittle, and one of the rings shattered when partially compressed into an oval shape. This brittleness was not observed with rings taken from the WESF $^{90}\text{SrF}_2$ capsule that was held at 800°C for 5000 hours.

TASK 3 - CAPSULE QUALIFICATION AND LICENSING (D. G. Atteridge)

Capsule Design

This quarter's effort has been concentrated upon determining the wall thickness of the Hastelloy alloy prototype outer capsule and upon ordering the material for these capsules. We have decided to use a 0.5-in. wall thickness and are currently negotiating with the Stellite Division of the Cabot Corporation for delivery schedules.

Bids were solicited for material acquisition and fabrication of the prototype Hastelloy S and Hastelloy C-4 outer capsules, and Stellite Division of Cabot Corporation

was subsequently chosen to be the outer capsule supplier. It is anticipated that the capsule deliveries will take place during the early part of the fourth quarter of this fiscal year.

The wall thickness decision was based upon the experimental results from the stand-in AISI-1018 steel capsules that were hydrostatically tested during the last fiscal year. We feel that the stand-in capsule collapse results bear a one-to-one correspondence to our design requirements for the aged Hastelloy prototype capsules, as the yield strength of the steel capsules (41,350 psi) agrees with the lower yield strength level of $\sigma \geq 40,000$ psi decided upon as our design criterion for the Hastelloy prototype capsules. The results of the pressure tests are plotted in Figure 1 as a function of wall thickness and collapse pressure. The resultant experimental capsule wall thickness/collapse pressure data can be readily described as a straight line function, with a 0.47-in. wall resulting in capsule collapse at the 14,500 psi licensing requirement pressure.

Our wall thickness determination is based on the need for the outer capsule to withstand a 14,500 psi hydrostatic pressure without rupturing. Analysis of the plastic deformation data from the experimental hydrostatic tests performed on the AISI-1018 steel capsules indicates that very little plastic deformation (<1%) takes place prior to total capsule collapse, but that a considerable amount of plastic deformation takes place during the collapse event. The stand-in capsules withstood collapse without rupturing, and it is anticipated that the as-fabricated prototype capsules could also withstand collapse without difficulty. We do not feel, however, that we want to assume that the aged prototype

FIGURE 1. Collapse Pressures for Low-Carbon Steel Capsules: 0.2% Yield Strength - 41,350 psi; Inside Diameter - 2.375 in.

capsules will be able to withstand the large amounts of plastic deformation that take place during capsule collapse. Thus, we have decided on an essentially "no plastic deformation during hydrostatic testing" design criterion for the prototype capsule. Our experimental results indicate that an essentially "no plastic deformation" criterion can be met by selecting a wall thickness that will not collapse at the 14,500 psi design requirement. We have taken the 0.47-in. stand-in steel capsule wall thickness needed to withstand collapse until 14,500 psi and have increased this wall thickness to 0.5 in. for our prototype wall thickness requirement.

Oxidation of Hastelloy S and Hastelloy C-4 (H. T. Fullam)

The tests to measure the rates of oxidation of Hastelloy S and Hastelloy C-4 in air at 600⁰ to 800⁰C and to determine the effects of oxidation on the room-temperature tensile properties of the two alloys have been completed. The alloy specimens heated in air for 10,000 hr exhibited the same erratic oxidation behavior as did the specimens oxidized for 5000 and 7500 hr. In every case, the weight gains of the test coupons were less than predicted by parabolic rate equations developed from the short-term (140- to 2500-hr) rate data. Careful examination of the 10,000-hr test specimens showed that some spalling of the oxide layers had occurred, especially at 700⁰ and 800⁰C. In addition, certain areas of the oxide layers formed at the higher temperatures possessed a powdery surface which was easily removed by abrasion. The Hastelloy C-4 was worse in this regard than the Hastelloy S. The spalling of the oxide layer would account for the erratic oxidation behavior observed with the 10,000-hr specimens. Although there was no visual indication of oxide spalling in the 5000- and 7500-hr tests, spalling probably was responsible for the erratic oxidation results observed in those tests as well.

The oxidation coupons from the 10,000-hr tests have been submitted for metallographic examination, and room-temperature tension testing of the 10,000-hr tensile specimens is now underway. A detailed discussion of the oxidation tests will be presented as soon as all of the 10,000-hr data are available.

Tests are planned to determine the effects of air oxidation at 600⁰ to 800⁰C on the impact properties of Hastelloy S and Hastelloy C-4. The tests will last up to 10,000 hr, and data on oxidation rates will also be obtained to supplement the data discussed above. The Charpy specimens have been fabricated, and the tests will start as soon as the control specimens are sealed in evacuated quartz ampules. The tests will use sub-size specimens that are 0.098 in. thick and which adhere to ASTM Specification E-23.

Seawater Corrosion of Hastelloy S and Hastelloy C-4 (H. T. Fullam)

The 7500-hr seawater corrosion tests have been completed. The test specimens all exhibited the surface discoloration previously reported, but the corrosion rates continue to be very low, as shown in Figures 2 and 3. The test coupons were submitted for metallographic examination and photomicrographs typical of those obtained are shown in Figure 4. The micrographs reveal that each alloy suffered some isolated pitting; the maximum depth of the pitting was about 0.1 mil with each alloy. Some of the Hastelloy C-4 specimens tested for shorter time periods also exhibited evidence of pitting, but this is the first time that there has been visual evidence of attack of the Hastelloy S specimens.

FIGURE 2. Corrosion of Hastelloy S in Flowing Natural Seawater at Ambient Temperature

FIGURE 3. Corrosion of Hastelloy C-4 in Flowing Natural Seawater at Ambient Temperature

HASTELLOY S

500x
0.002 in.

HASTELLOY C-4

500x
0.002 in.

AS-POLISHED

ETCHED

FIGURE 4. Metal Specimens Exposed to Flowing Natural Seawater at Ambient Temperature for 7500 hr

The tensile specimens from the 7500-hr tests were tension-tested at room temperature, and the results obtained are presented in Table 1. Evaluation of the test data shows that exposure to flowing seawater at ambient temperature has no significant effect upon the tensile properties of the two alloys. The results indicate that the pitting observed with the 7500-hr specimens was not sufficient to affect the tensile properties of the two alloys significantly.

Microscopic examination of prestressed alloy specimens exposed to flowing seawater for 7500 hr showed no evidence of stress-corrosion cracking.

Metal-Metal Compatibility (H. T. Fullam)

The tests designed to evaluate the compatibility of Hastelloy C-276 with Hastelloy S and Hastelloy C-4 at 700°C and 800°C have been completed. The 10,000-hr test capsules have been sectioned, and visual examination of the test specimens indicated that very little interaction had occurred at 700°C and 800°C between alloy specimens which had received a surface oxidation treatment prior to testing. The unoxidized specimens tested at 800°C had bonded together and were difficult to separate, indicating significant interaction. No bonding was observed between unoxidized specimens at 700°C, although there was some visual indication of interaction between specimens. The interaction appeared to be more extensive between the Hastelloy C-276 and Hastelloy C-4 specimens than between the Hastelloy C-276 and Hastelloy S. The various specimens have been submitted for metallographic examination to determine the extent and types of interaction.

TABLE 1. Room-Temperature Tensile Properties of Hastelloy S and Hastelloy C-4 Specimens^(a) Exposed to Flowing Natural Seawater at Ambient Temperature

<u>Material</u>	<u>Exposure Time, hr</u>	<u>Ultimate Tensile Strength, ksi</u>	<u>Yield Strength, ksi</u>	<u>Elongation, %</u>	
				<u>Uniform</u>	<u>Total</u>
Hastelloy S	(Sol'n Annealed Alloy) ^(b)	(127.6)	(67.8)	(51.5)	(60.8)
	1,000	129.0	70.6	53.3	61.7
	2,500	126.5	69.5	53.2	62.1
	5,000	127.4	68.0	51.3	61.1
	7,500	126.2	68.2	51.9	60.8
	10,000				
Hastelloy C-4	(Sol'n Annealed Alloy) ^(b)	(121.0)	(55.0)	(60.9)	(71.5)
	1,000	123.7	56.5	59.7	69.7
	2,500	120.5	53.1	58.9	69.1
	5,000	120.8	52.9	59.3	69.5
	7,500	121.8	54.5	57.5	66.8
	10,000				

(a) Four tensile specimens of each alloy tested for each time period and average values reported.

(b) Solution annealed alloy as received from vendor.

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