**Quarterly Report on the
Strontium Heat Source
Development Program,
Operations and By-Products
Utilization Division for
April Through June 1981**

H. T. Fullam

September 1981

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

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Pacific Northwest Laboratory
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ABSTRACT

All experimental activities related to the Strontium Heat Source Development Program have been completed. The only remaining activities are preparation and issuance of final reports that summarize program results. This report represents the last of the program quarterly progress reports that will be issued.

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STRONTIUM HEAT SOURCE DEVELOPMENT PROGRAM

H. H. Van Tuyl, Program Manager

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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 objective of this program is to obtain the data needed to license $^{90}\text{SrF}_2$ heat sources and specifically the $^{90}\text{SrF}_2$ WESF 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 proceeded concurrently on all three tasks to obtain the required information.

All experimental activities related to the three tasks have now been completed. The only remaining activities are to prepare and issue various reports summarizing the results of the various studies. This report represents the last of the series of quarterly progress reports that will be issued on the Strontium Heat Source Development Program.

TASK 1 - CHEMICAL AND PHYSICAL PROPERTIES OF $^{90}\text{SrF}_2$

The topical report on the migration of ^{90}Sr from a deep ocean source (Yabusaki 1981) has been issued.

The updated Strontium-90 Fluoride Data Sheet (Fullam 1981a) has gone to printing and should be issued in August.

TASK 2 - $^{90}\text{SrF}_2$ COMPATIBILITY STUDIES

The final report (Fullam 1981b) summarizing all of the $^{90}\text{SrF}_2$ compatibility studies carried out during the program has been submitted to the sponsor for review and comment. The results of the studies and the conclusions reached regarding $^{90}\text{SrF}_2$ compatibility with containment materials are summarized below.

Results obtained in the strontium fluoride compatibility tests carried out at Pacific Northwest Laboratory show that attack of metallic containment materials at 600°C to 1100°C is primarily due to fluoride impurities in the strontium fluoride. The fluorides of iron and chromium contribute principally to the metal attack. The data also show that once the critical impurities in the $^{90}\text{SrF}_2$ have been consumed by reaction with the metal, the rate of metal attack decreases to a very low level. In general, the critical impurities react with the metal within 6,000 to 12,000 h, and metal specimens exposed to $^{90}\text{SrF}_2$ for periods of 20,000 to 30,000 h show no more chemical attack than the specimens tested for 6,000 to 12,000 h.

Evaluation of the test data show that WESF-produced $^{90}\text{SrF}_2$ can be adequately contained for the nominal 10-year service life of a heat source by using Hastelloy C-276,[®] Haynes Alloy 25,[®] or TZM as the primary containment material. However, all three alloys suffer significant attack by the $^{90}\text{SrF}_2$ at heat-source operating temperatures, which places certain limitations and requirements on the design and use of the heat source. Thermal aging reactions that affect the microstructure and mechanical properties of Hastelloy C-276 and Haynes Alloy 25 place additional restraints on the heat-source design if either alloy is used in the construction of the heat source. The principal restraints and requirements placed on the heat-source design by $^{90}\text{SrF}_2$ compatibility and alloy-aging reactions include:

- The heat source must provide at least double containment of the $^{90}\text{SrF}_2$ with the inner capsule fabricated from Hastelloy C-276, Haynes Alloy 25, or TZM.
- The outer capsule(s) of the heat source must provide all of the structural strength needed to meet licensing requirements without support from the inner capsule. The inner capsule should only serve as the primary containment barrier for the $^{90}\text{SrF}_2$ since fluoride attack and aging reactions serve to reduce its structural strength. Once the heat source has been at temperatures of 600°C or higher for an extended period of time, mechanical stressing of the inner capsule could result in its fracture and release of radioactivity.
- If Hastelloy C-276 or Haynes Alloy 25 is used as the inner capsule material, the capsule/ $^{90}\text{SrF}_2$ interface temperature should be limited to a maximum of 800°C. If TZM is used for the inner capsule, the interface temperature should be limited to 1000°C. If TZM is used, assurance must be provided that the inner capsule is protected from external oxidation.
- The service life of the heat source should be limited to 10 years if Hastelloy C-276 or Haynes Alloy 25 is used for the inner capsule, and 20 years if TZM is used.

Because iron and chromium fluorides in the $^{90}\text{SrF}_2$ are principal causes of metal attack, operational changes at WESF that reduce their concentrations in the fluoride would improve the compatibility of the $^{90}\text{SrF}_2$ with containment materials in heat-source service. Replacement of the Inconel[®] boats used in firing the $^{90}\text{SrF}_2$ with a more corrosion-resistant material, or a material free of iron and chromium, should serve to effectively reduce the iron and chromium content of the $^{90}\text{SrF}_2$.

TASK 3 - CAPSULE QUALIFICATION AND LICENSING

All qualification testing of the as-fabricated and thermally aged capsules has been completed. Each of the 15 Hastelloy S and seven Hastelloy C-4 prototype outer capsules was subjected to one primary and four secondary qualification tests. In addition, selected capsules were subjected to three supplemental tests. The supplemental tests, described in Table 1, are

[®]Cabot Corp., Kokomo, Indiana.

[®]Cabot Corp., Kokomo, Indiana.

[®]Huntington Alloys, Inc., Huntington, West Virginia.

TABLE 1. Supplemental Qualification Tests for the $^{90}\text{SrF}_2$ Heat-Source Outer Capsules

1. Supplemental Pressure Test

The heat-source outer capsule shall not leak at a rate greater than $1 \times 10^{-8} \text{ cm}^3/\text{s}$ after being subjected to an external hydrostatic pressure of 24,000 psi, or the pressure at which the capsule collapses, whichever is lower.

2. Supplemental Percussion Test

The capsule shall not leak at a rate greater than $1 \times 10^{-8} \text{ cm}^3/\text{s}$ after being struck by the flat face of a 2.5-cm-dia (~ 1 -in.) steel billet with an impact energy equivalent to 20 kg-m (~ 145 ft-lb). The billet edges shall be rounded off to a radius of not less than 3 mm, and the capsule shall rest on a lead sheet equal to or less than 25 mm thick with a Brinell hardness of 3.5 to 4.5. The lead sheet shall cover a greater area than the capsule and shall rest on a smooth, solid surface. A fresh lead sheet shall be used for each test, and the capsule shall be struck in such a manner that the maximum possible damage will result.

3. Puncture Test

The capsule shall not leak at a rate greater than $1 \times 10^{-8} \text{ cm}^3/\text{s}$ after being struck by a 3-mm-dia pin rigidly attached to a 2.5-cm-dia steel billet, with an impact energy equivalent to 1 kg-m. The pin shall be 6 mm long and machined from one end of the steel billet. The impact end of the pin shall be hemispherical. The capsule shall rest on a steel plate at least 1.25 cm (0.5 in.) thick and which covers an area greater than that of the capsule and which rests on a smooth, solid surface. The capsule shall be struck in such a manner that the maximum possible damage will result.

not currently part of the heat-source licensing requirement, but are requirements defined in ANSI-N542 (Anon. 1977) for sealed radioisotope sources.

The results obtained in the qualification tests are summarized in Tables 2 through 4. The results show that the as-fabricated and thermally aged Hastelloy S outer capsules passed the primary and secondary qualification tests without difficulty. The capsules also passed the supplemental percussion and puncture tests without problems. The capsules subjected to the supplemental pressure test partially collapsed at a pressure of 24,500 psi. The partially collapsed capsules passed the helium leak test (leak rate $< 1 \times 10^{-8} \text{ std cm}^3/\text{s}$).

The as-fabricated Hastelloy C-4 capsules and the Hastelloy C-4 capsules aged at 725°C passed the primary and secondary qualification tests without difficulty. They also passed the supplemental percussion and puncture tests without a problem. The capsules subjected to the supplemental pressure test partially collapsed at a pressure between 20,000 and 21,000 psi. The partially collapsed capsules passed the helium leak test (leak rate $< 1 \times 10^{-8} \text{ std cm}^3/\text{s}$).

The only capsule that failed the qualification tests was the Hastelloy C-4 capsule aged at 650°C for 8000 h. The capsule passed the primary pressure and secondary impact and percussion tests, but failed the secondary thermal test. Examination of the capsule showed a crack in one of the seal welds. Destructive examination of the capsule indicated that the crack was initiated by stresses encountered in the impact test and propagated to the point of failure by stresses developed in the thermal test. Micrographs of the seal weld at the point of failure showed that the weld penetration was only 40% of the required 0.10 in. The results of the other tests with Hastelloy C-4 indicate that use of a full-penetration seal weld would eliminate the problem.

A final report summarizing all of the Task 3 activities is now being prepared (Fullam 1981c).

TABLE 2. Results Obtained in the Qualification Testing of the As-Fabricated Hastelloy S and Hastelloy C-4 Prototype Outer Capsules

Qualification Tests	Hastelloy S Capsule Number					Hastelloy C-4 Capsule Number		
	S-12(a)	S-13	S-15	S-17	S-20	2(a)	3	7R
A. Primary Qualification Tests								
Impact	Pass	-	-	-	-	Pass	-	-
Pressure	-	-	-	Pass	-	-	Pass	-
Percussion	-	-	-	-	Pass	-	-	Pass
Thermal	-	-	Pass	-	-	-	-	-
Thermal Quench	-	Pass	-	-	-	-	-	-
B. Secondary Qualification Tests								
Impact	-	Pass	Pass	Pass	Pass	-	Pass	Pass
Pressure	Pass	Pass	Pass	-	Pass	Pass	-	Pass
Percussion	Pass	Pass	Pass	Pass	-	Pass	Pass	-
Thermal	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass
Thermal Quench	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass
C. Supplemental Tests								
Pressure	-	-	P-C ^(b)	-	-	-	-	P-C
Percussion	Pass	Pass	Pass	-	Pass	Pass	-	Pass
Puncture	-	Pass		-	-	-	Pass	-

(a) Capsule contained a Hastelloy C-276 inner capsule filled with inert SrF₂.

(b) Some distortion of capsule, but the capsule passed the helium leak test.

TABLE 3. Results Obtained in the Qualification Testing of Hastelloy S and Hastelloy C-4 Prototype Outer Capsules Aged at 650°C for 8000 Hours

Qualification Tests	Hastelloy S Capsule Number					Hastelloy C-4 Capsule No. 4
	S-8(a)	S-14	S-18	S-22	S-23	
<u>A. Primary Qualification Tests</u>						
Impact	Pass	-	-	-	-	-
Pressure	-	-	-	Pass	-	Pass
Percussion	-	-	-	-	Pass	-
Thermal	-	Pass	-	-	-	-
Thermal Quench	-	-	Pass	-	-	-
<u>B. Secondary Qualification Tests</u>						
Impact	-	Pass	Pass	Pass	Pass	Pass
Pressure	Pass	Pass	Pass	-	Pass	-
Percussion	Pass	Pass	Pass	Pass	-	Pass
Thermal	Pass	-	Pass	Pass	Pass	Fail
Thermal Quench	Pass	Pass	-	Pass	Pass	-
<u>C. Supplemental Tests</u>						
Pressure	-	P-C ^(b)	-	P-C	-	-
Percussion	-	-	Pass	-	Pass	-
Puncture	-	-	Pass	-	-	-

(a) Capsule contained a Hastelloy C-276 inner capsule filled with inert SrF₂.

(b) Some distortion of capsule, but the capsule passed the helium leak check.

TABLE 4. Results Obtained in the Qualification Testing of Hastelloy S and Hastelloy C-4 Prototype Outer Capsules Aged at 725°C for 8000 Hours

Qualification Tests	Hastelloy S Capsule Number					Hastelloy C-4 Capsule Number		
	S-9(a)	S-11	S-16	S-19	S-21	1(a)	6	7
A. Primary Qualification Tests								
Impact	Pass	-	-	-	-	Pass	-	-
Pressure	-	-	-	Pass	-	-	Pass	-
Percussion	-	Pass	-	-	-	-	-	Pass
Thermal	-	-	-	-	Pass	-	-	-
Thermal Quench	-	-	Pass	-	-	-	-	-
B. Secondary Qualification Tests								
Impact	-	Pass	Pass	Pass	Pass	-	Pass	Pass
Pressure	Pass	Pass	Pass	-	Pass	Pass	-	Pass
Percussion	Pass	-	Pass	Pass	Pass	Pass	Pass	-
Thermal	Pass	Pass	Pass	Pass	-	Pass	Pass	Pass
Thermal Quench	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass
C. Supplemental Tests								
Pressure	-	P-C ^(b)	-	-	-	-	P-C	-
Percussion	-	-	Pass	-	-	-	-	Pass
Puncture	-	-	-	Pass	-	-	-	Pass

(a) Capsule contained a Hastelloy C-276 inner capsule filled with inert SrF₂.

(b) Some distortion of capsule, but capsule passed the helium leak check.

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