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Quarterly Report on the Strontium Heat Source Development Program and the Beneficial Isotopes Utilization Program, Division of Nuclear Research and Application for October-December 1976

H. T. Fullam
J. H. Jarrett

January 1977

Prepared for the Energy Research and Development Administration under Contract EY-76-C-06-1830

Battelle
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QUARTERLY REPORT ON THE STRONTIUM HEAT SOURCE DEVELOPMENT PROGRAM AND THE BENEFICIAL ISOTOPES UTILIZATION PROGRAM, DIVISION OF NUCLEAR RESEARCH AND APPLICATIONS FOR OCTOBER-DECEMBER 1976

H. T. Fullam and J. H. Jarrett

January 1977

BATTELLE
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Richland, Washington 99352

SUMMARY

Metallographic examination of the Hastelloy C-276 specimens from the 1000-hr tests with WESF $^{90}SrF_2$ has been completed. The specimens exhibited much more attack than was observed in the equivalent nonradioactive test specimens or in the original $^{90}SrF_2$ tests. Decreasing the S/V ratio of the test couples produced a marked increase in the metal attack observed.

The 6000-hr tests with WESF $^{90}SrF_2$ have been completed. When the test couples were removed from the furnaces it was found that a number of couples which had been held at 800°C had failed. The couples were contained in protective jackets of Inconel 600 and both the Inconel 600 capsules and the test couples were badly corroded. There was no visual indication of problems with the couples tested at 600 and 1000°C or with couples tested at 800°C in a second furnace. The furnace containing the failed capsules gave no indication of a malfunction or overheating and was in good working condition when the test was terminated. Reasons for the capsule failures are now being investigated.

The program plan for Task 3 - Capsule Qualification and Licensing has been issued. The topical report summarizing the results of the $^{90}SrF_2$ dissolution studies has been issued (BNWL-2101).

A flowsheet has been postulated for the recovery of potentially useful waste fission products, a report describing this process is being reviewed internally. A draft report on Cold Regions Isotope Heaters is being revised with data obtained during a trip to Alaska.

Support to the Sandia Sewage Irradiation Program consisted of providing cost information to evaluate alternative sewage treatment processes and analyzing of odors from treated and untreated sludge.

A draft report on the use of solidified high level waste canisters to fuel Army steam plants should be available for review in February.

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STRONTIUM HEAT SOURCE DEVELOPMENT PROGRAM

J. H. Jarrett, Program Manager
H. T. Fullam, Principal Investigator
D. G. Atteridge

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 $^{90}SrF_2$ heat sources and specifically the WESF $^{90}SrF_2$ capsules. The information needed for licensing can be divided into three general task areas:

Task 1 - Chemical and Physical Properties of $^{90}SrF_2$
Task 2 - $^{90}SrF_2$ 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 $^{90}SrF_2$

Dissolution Behavior of $^{90}SrF_2$

The topical report[1] on the dissolution behavior of $^{90}SrF_2$ has been issued.

TASK 2 - $^{90}SrF_2$ COMPATIBILITY STUDIES

Long-Term Compatibility Tests

ORNL has completed the metallographic examination of the Hastelloy C-276 specimens from the 1000-hr tests with $^{90}SrF_2$. Estimates of metal attack based on the micrographs obtained are presented in Table 1. Attack of the Hastelloy C-276 specimens was much greater than was observed in the equivalent tests with nonradioactive SrF_2 (see Table 2) or in the original short-term tests with $^{90}SrF_2$ (see BNWL-1967). The specimens tested at 600°C

TABLE 1. Attack of Hastelloy C-276 Specimens Exposed to WESF $^{90}SrF_2$ for 1000 hr

Temperature, °C	S/V Ratio[b] cm^{-1}	Depth of Metal Affected,[a] mils	
		Chemical Attack	Change in Microstructure
600	4.5	3	4
600	4.5	3	5
600	2.5	10	12
600[c]	4.5	1	2
800	4.5	7	12
800	4.5	6	11
800	2.5	30	35
800[c]	4.5	2	5
1000	4.5	7	15
1000	4.5	10	15
1000	2.5	12	15
1000[c]	4.5	3	7

(a) Attack estimated from micrographs
(b) S/V - the test couples exposed metal surface to $^{90}SrF_2$ volume ratio
(c) The $^{90}SrF_2$ was spiked with ZrF_4 and Zr metal powder to simulate the decay product buildup equivalent to 10 years decay

exhibited a uniform attack of the metal surface with slight evidence of grain boundary attack (Figure 1-A). At 800°C and 1000°C the attack was also uniform across the metal surface, but appeared to proceed primarily along grain boundaries leaving free grains of unreacted metal in the reaction layer (Figure 1-B). Decreasing the S/V ratio of the test couples produced marked increases in the metal attack observed (see Figure 2). Similar results were observed in the tests with nonradioactive SrF_2 and in the tests with TZM and $^{90}SrF_2$ (see BNWL-1845-28); providing additional evidence that impurities in the $^{90}SrF_2$ are a primary cause of the metal attack observed.

TABLE 2. Attack of Metal Specimens Exposed to Nonradioactive SrF_2[a]

Material Tested	Temperature, °C	Couple S/V Ratio,[c] cm^{-1}	Depth of Metal Affected,[b] mils			
			1000 hr		6000 hr	
			Chemical Attack	Change in Microstructure	Chemical Attack	Change in Microstructure
Hastelloy C-276	600	4.5	<1	0	3	4
	600	4.5	1	5	4	5
	600	2.5	<1	2	5	5
	600	0.9	1	4	6	6
	800	4.5	<1	<1	2	3
	800	4.5	1	3	2	3
	800	2.5	<1	2	2	2
	800	0.9	10	15	10	15
	1000	4.5	2	4	2	7
	1000	4.5	3	4	3	6
	1000	2.5	3	5	7	10
Hastelloy C-276	1000	0.9	4	6	8	12
Haynes Alloy 25	600	4.5	<1	5	2	3
	600	4.5	<1	3	1	2
	600	2.5	<1	2	2	3
	600	0.9	1	2	3	3
	800	4.5	<1	3	3	6
	800	4.5	<1	1	3	4
	800	2.5	<1	1	2	3
	800	0.9	1	2	5	17
	1000	4.5	2	1	3	7
	1000	4.5	2	1	3	4
	1000	2.5	2	0	6	8
Haynes Alloy 25	1000	0.9	3	2	12	15
TZM	600	4.5	0	0	<1	0
	600	4.5	<1	0	<1	0
	600	2.5	<1	0	1	0
	600	0.9	<1	0	2	0
	800	4.5	<1	0	<1	0
	800	4.5	<1	0	<1	0
	800	2.5	<1	0	1	0
	800	0.9	1	0	4	0
	1000	4.5	<1	0	<1	0
	1000	4.5	<1	0	<1	0
	1000	2.5	<1	0	<1	0
TZM	1000	0.9	<1	0	1	0

(a) Nonradioactive SrF_2 containing impurities approximating those found in WESF $^{90}SrF_2$
(b) Attack estimated from micrographs
(c) S/V ratio - the test couples' exposed metal surface to SrF_2 volume ratio

The addition of Zr metal powder and ZrF_4 to the $^{90}SrF_2$ to simulate decay product buildup, equivalent to 10 years decay, produced a marked decrease in the metal attack observed (see Figure 3).

Electron microprobe analysis of the Hastelloy C-276 specimens is now underway at ORNL; and a discussion of attack mechanisms will be provided when the microprobe data are available.

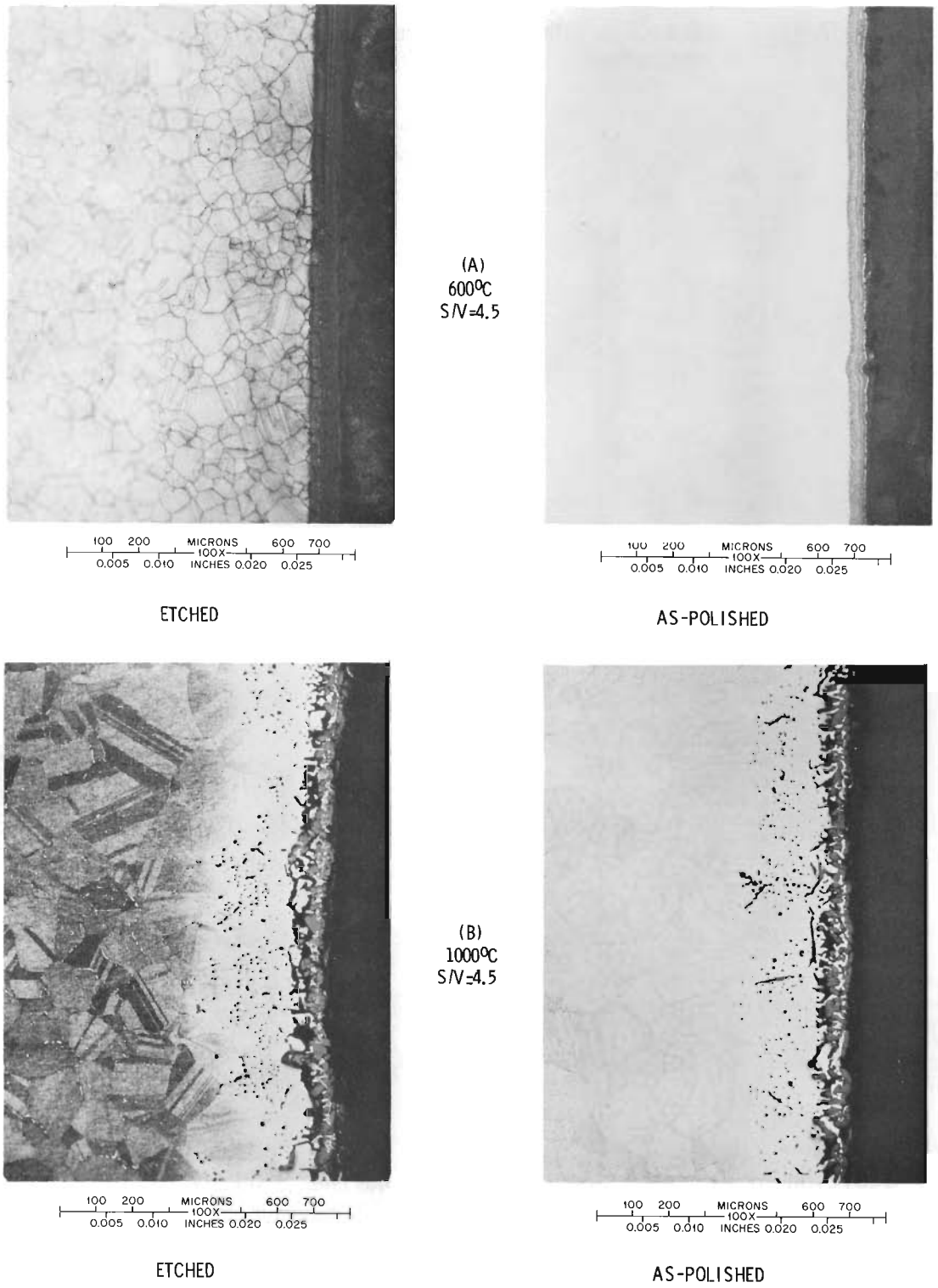

FIGURE 1. Micrographs of Hastelloy C-276 Specimens Exposed to $^{90}SrF_2$ for 1000 hr

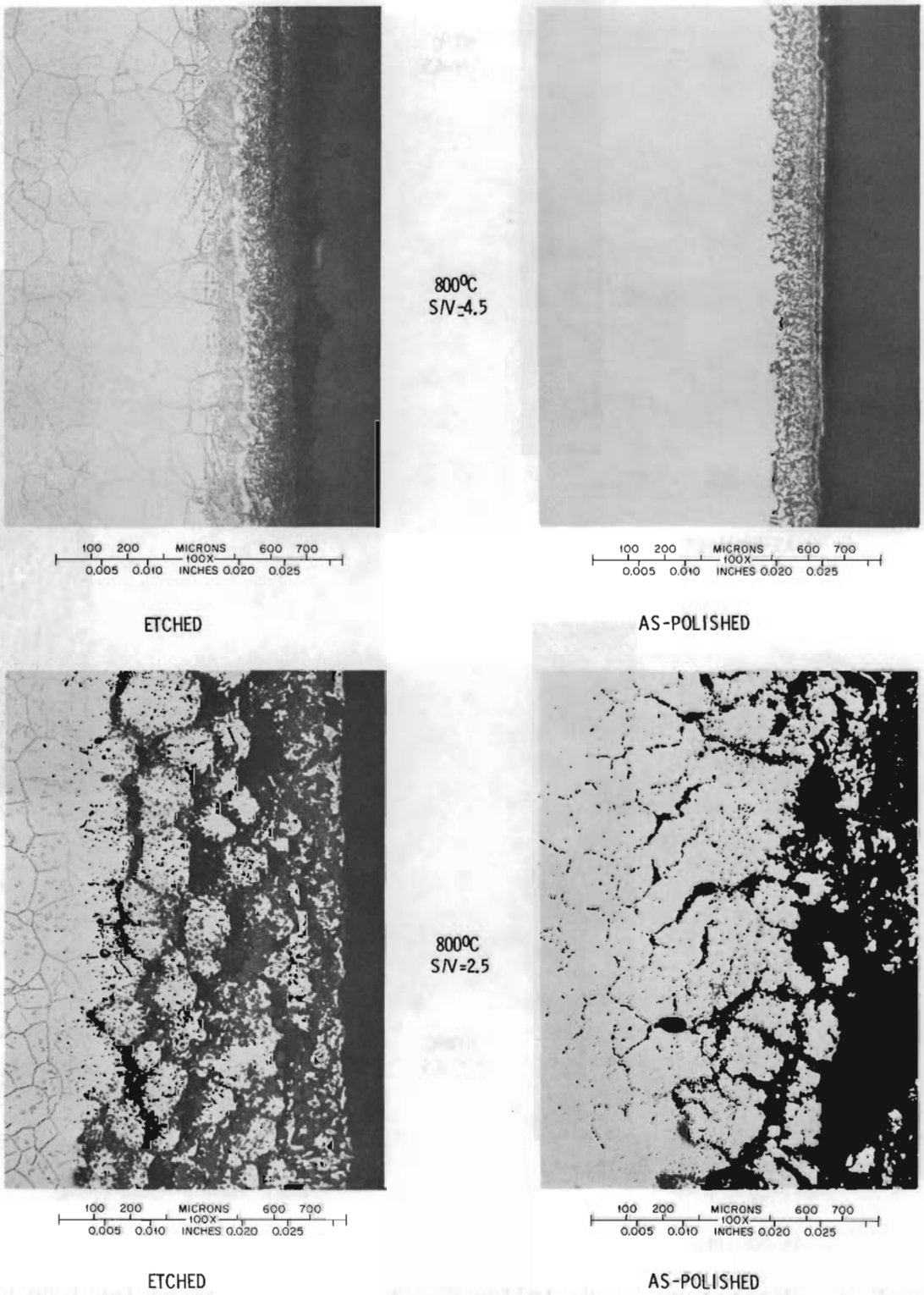

FIGURE 2. Effect of S/V on the Attack of Hastelloy C-276 by $^{90}SrF_2$ After 1000 hr Exposure

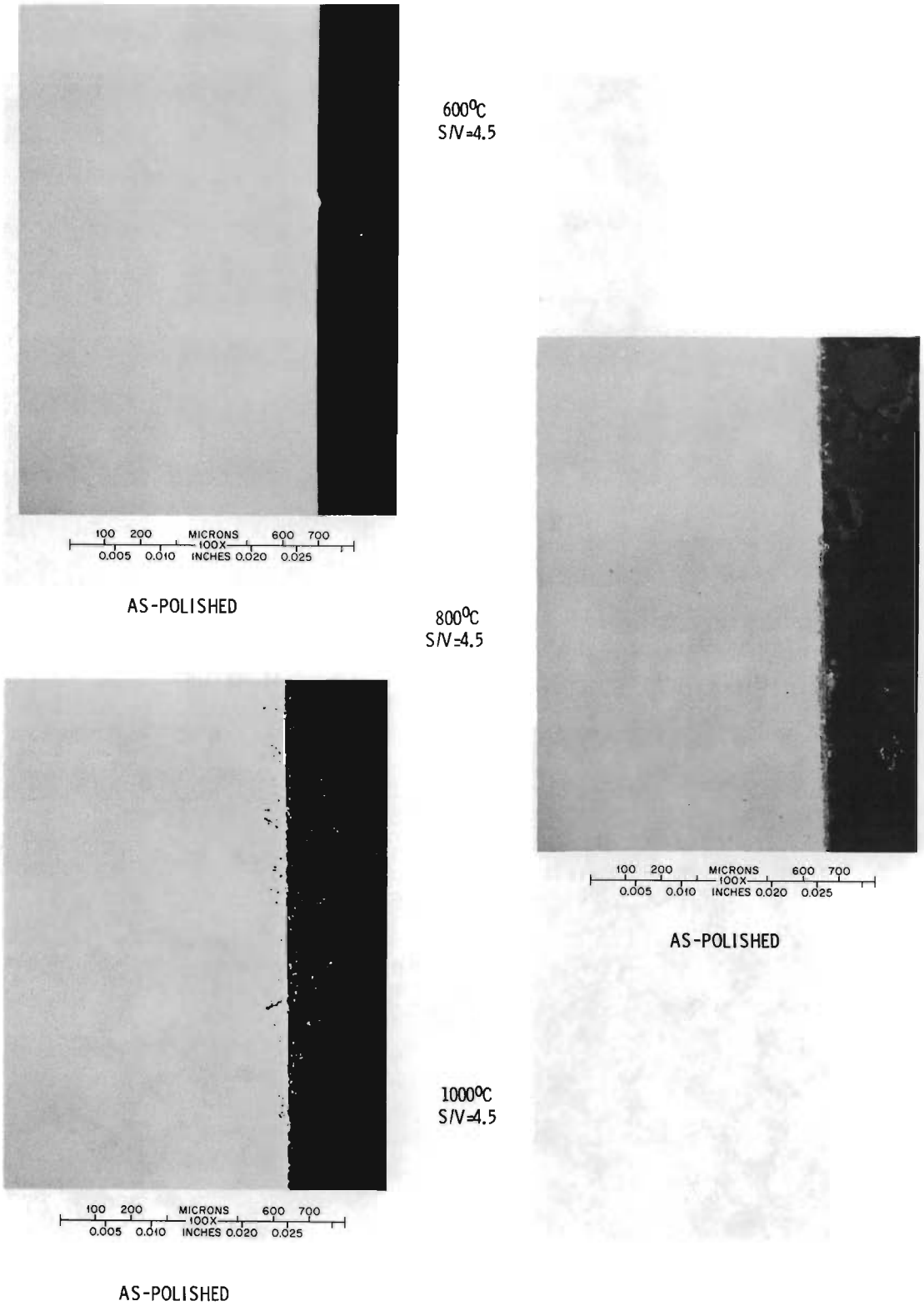

FIGURE 3. Micrographs of Hastelloy C-276 Specimens Exposed for 1000 hr to $^{90}SrF_2$ Containing Zr and ZrF_4

Metallographic examination and electron microprobe analysis of the Haynes Alloy 25 specimens exposed to WESF $^{90}SrF_2$ for 1000-hr is also continuing at ORNL.

Metallographic examination of the specimens from the 6000 hr tests with nonradioactive SrF_2 has been completed, and microprobe analysis of the specimens is now underway. Estimates of metal attack, based on the micrographs are presented in Table 2. Micrographs of the test specimens and a detailed discussion of attack mechanisms will be presented in a subsequent report when all of the microprobe data are available.

The 6000 hr tests with $^{90}SrF_2$ have been completed. Sectioning of the test couples will start in January. One very serious problem was encountered when the test couples were removed from the furnaces. All of the test couples had been sealed in protective jackets of 1 1/2 in. sch 40 Inconel 600 pipe to prevent external oxidation of the couples during testing. It was found that a number of the couples which had been held at 800°C had failed. The Inconel 600 capsules were very badly corroded, as were the test couples contained in the capsules. All of the failed capsules were from one furnace, while capsules being held in a second furnace at 800°C showed no visual indication of failure. Similarly, capsules held at 600 and 1000°C showed no visual evidence of excessive attack. The 800°C furnace which contained the failed capsules showed no indication of a malfunction during the test and was in good working condition when the tests were terminated. The furnace temperature was continuously monitored with a strip chart recorder, and the furnace was equipped with two over-temperature switches operating off separate thermocouples. Both switches were designed to shut-off the furnace if the temperature exceeded approximately 820°C or a thermocouple failed. There was no indication at any time during the test that the furnace had overheated. An investigation is now underway to determine why the capsules failed. In the meantime testing of the remaining couples has been halted until the cause(s) of the capsule failure can be identified.

Testing of Full-Size WESF $^{90}SrF_2$ Capsules

In November ARHCO began the sectioning of the full-size WESF $^{90}SrF_2$ capsule which had been held at approximately 800°C for 5000 hr. The outer capsule was removed, but before the inner capsule could be sectioned the power hack-saw being used failed. Sectioning of the capsule will be delayed until a new saw is installed in the cell.

Thermal Gradient Test

The thermal gradient test has been completed after 4400 hr exposure. During the test a Hastelloy C-276 capsule filled with WESF grade nonradioactive SrF_2 was subjected to a thermal gradient of 560°C (from 360 to 920°C). The capsule has been sectioned and specimens obtained at various locations along the length of the capsule. Metallographic examination of the specimens is now underway. Visual examination of the SrF_2 in the capsule showed a variation in color of the fluoride along the length of the capsule; but there was no indication of the formation of a molten phase in the capsule. The SrF_2 taken from various locations in the capsule is now being analyzed to see if migration of impurities in the fluoride has occurred due to the thermal gradient.

Supplemental Short-Term Tests

The 4400 hr tests with nonradioactive SrF_2 have been completed and the couples sectioned. Metallographic examination of 22 of 32 test materials has been completed; and estimates of metal attack, based on the micrographs, is given in Table 3. The results obtained in the 1500 hr tests are also included in Table 3 for comparison purposes. Micrographs of the various specimens and a detailed discussion of the various materials will be provided when analysis of the remaining ten specimens is completed.

TASK 3 - CAPSULE QUALIFICATION AND LICENSING

Program Plan

The initial draft of the program plan for Task 3 was submitted to DNRA for review and evaluation. The revised version of the program plan incorporating DNRA comments was issued in December. The program plan is aimed

TABLE 3. Estimated Attack of Test Specimens Exposed to Nonradioactive SrF_2[a] at 800°C

Material	Depth of Metal Affected,[b] mils			
	1500 hours		4400 Hours	
	Chemical Attack	Change in Microstructure	Chemical Attack	Change in Microstructure
Hastelloy C-276[c]	3	7	3	5
Haynes Alloy 25[c]	2	3	1	2
TZM[b]	1	0	1	0
Hastelloy C-4	5	12	3	13
Hastelloy B	4	15	3	11
Hastelloy B-2	10	18	(f)	(f)
Hastelloy S	7	15	3	12
Haynes Alloy 556	5	6	(f)	(f)
Inconel 617	7	14	(f)	(f)
Inconel 671	15	25	20	26
Incoloy 800	8	0	( )	(f)
Rene 41	10	14	11	13
Udimet 700	>25	0	>25	>25
Monel 400	5	8	(f)	(f)
Nickel 200	7	10	8	8
Ingot Iron	3	0	4	7
Ductile Cast Iron	CR	CR[d]	CR	CR
316L SS	6	0	22	0
JS 777	6	7	(f)	(f)
Copper	>25	0	>25	0
Titanium	>25	(e)	>25	(f)
Hafnalloy 2525	>25	(e)	CR	CR
Molybdenum	2	0	<1	<1
Niobium	3	2	2	2
Ta-10% W	10	0	2	0
Mo-50% Re	2	0	(f)	(f)
W-26% Re	2	0	1	0
Rhenium	<1	0	<1	0
Iridium	0	0	(f)	(f)
Ir-0.3% W	0	0	(f)	(f)
Platinum	>25	(e)	>25	(f)
Gold	>15	(e)	>15	(f)

(a) The SrF_2 contained impurities approximating those found in the WESF 90 SrF_2

(b) Estimated from photomicrographs

(c) Tested as reference specimens

(d) CR - Complete Reaction

(e) Could not be estimated because of extensive chemical attack

(f) Results not yet available

specifically at developing sufficient capsule design and test data that a $^{90}SrF_2$ capsule can be used as a heat source in the proposed NASS 2 kW(e) terrestrial power generator. The plan calls for all Task 3 activities to be completed by the end of FY 1980.

Heat Source Capsule Qualification Requirements

A "first cut" list of capsule qualification requirements was compiled for and discussed with DNRA personnel. The list is currently being revised and added to for subsequent resubmission to DNRA. The major problem areas include the determination of the need for a "no plastic deformation" hydrostatic pressure test requirement and a realistic vibration resistance testing procedure.

Capsule Design Philosophy

PNL personnel attended a program review at ERDA Headquarters in December of conceptual designs for the NASS 2 kW unattended power system presented by General Electric Company. This afforded the opportunity for PNL to interact with potential users and suppliers of isotope heat engine systems. Additional meetings were also held with DNRA personnel to establish the basic design-philosophy for the $^{90}SrF_2$ heat source capsule. It was agreed that the capsule design would be based on the current WESF Hastelloy C-276 inner capsule while utilizing a new outer capsule to provide the required mechanical strength and external corrosion resistance needed for the NASS application.

A low level effort in conjunction with PNL Structures and Mechanics Section toward determining the critical design-limiting outer capsule component was begun in December. The effort will include a study of the resistance to impact failure of various welded end-cap configurations. Methods to assure minimum relative movement between inner and outer capsules are also being studied, as this problem is expected to be important to resistance to capsule failure during vibration.

Outer Capsule Material Selection

Outer capsule material options are being explored through a continuing literature review and manufacturing contracts as well as the mechanical and corrosion resistant property tests being run at PNL. PNL personnel have visited both major U.S. superalloy producers and are currently consulting with them on possible material selections. Second iteration problems such as the potential for marine fouling of submerged capsules are currently being added into the outer capsule alloy selection matrix. The effect on material selection of a potential reduction in the WESF capsule use temperature if the Organic Rankine Heat Engine is used is also being investigated.

Two materials being considered for use in fabricating the outer capsule are Hastelloy C-4 and Hastelloy S. Tests are underway at PNL to measure the oxidation resistance and seawater corrosion resistance of the two alloys in their solution heat treated forms, and the effects which thermal aging has on the two properties. It was reported earlier (BNWL-1845-28) that when solution heat treated Hastelloy C-4 was heated in air at 1000°C and higher for extended periods of time the specimens lost weight because of the spalling of the oxide layer. At 1100°C the weight loss of the Hastelloy C-4 exhibited a linear time dependence (see Figure 4 - Series #1). It was felt that the spalling of the oxide layer may have been due to the thermal stresses produced when the test specimens were removed periodically from the furnace, cooled to room temperature, weighed and then returned to the furnace for additional exposure. Therefore a second series of tests was carried out in which several solution heat treated Hastelloy C-4 specimens were held at 1100°C for different times and then removed from the furnace and weighed. This eliminated the thermal cycling the specimens in the first series of tests were subjected to. The results of the second series of tests showed that spalling of the oxide layer occurred at 1100°C even when the specimens

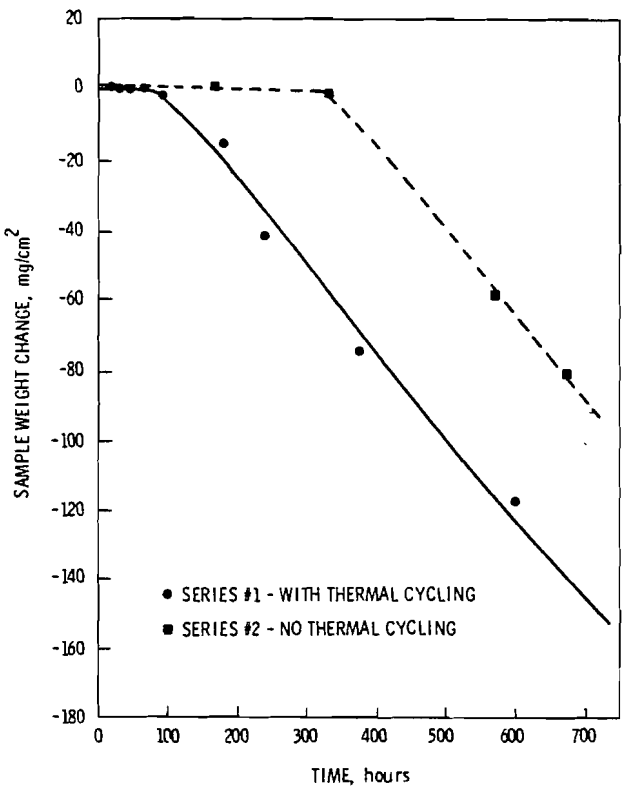

FIGURE 4. Oxidation of Hastelloy C-4 at 1100°C

were not thermally cycled (see Figure 4 - Series #2). Without thermal cycling a much longer exposure time was required before spalling started; but once spalling began the weight loss exhibited a linear time dependence.

The oxidation resistance of solution heat treated Hastelloy S was determined at temperatures of 600, 700, 800, 900, 1000 and 1100°C. The test specimen was cut from 0.063 in. sheet and were 2.00 in. x 1.00 in. The specimens were degreased prior to testing but the mill scale was not removed. The cleaned specimens were weighed and then placed in preheated air atmosphere

muffle furnaces. Periodically the specimens were removed from the furnaces, cooled to room temperature, weighed, and then returned to the furnaces. The tests lasted for 1000 hr. At 1000°C or less the specimens formed an adherent oxide scale and specimen weights increased continuously with time at temperature (see Figure 5). The formation of the adherent oxide scale followed a parabolic time dependence. At 1100°C an adherent oxide scale formed initially; but spalling of the oxide scale began after about 50 hr exposure with a corresponding loss of weight (see Figure 6). Only slight spalling was observed up to 550 hr exposure, but then the samples began to lose weight very rapidly.

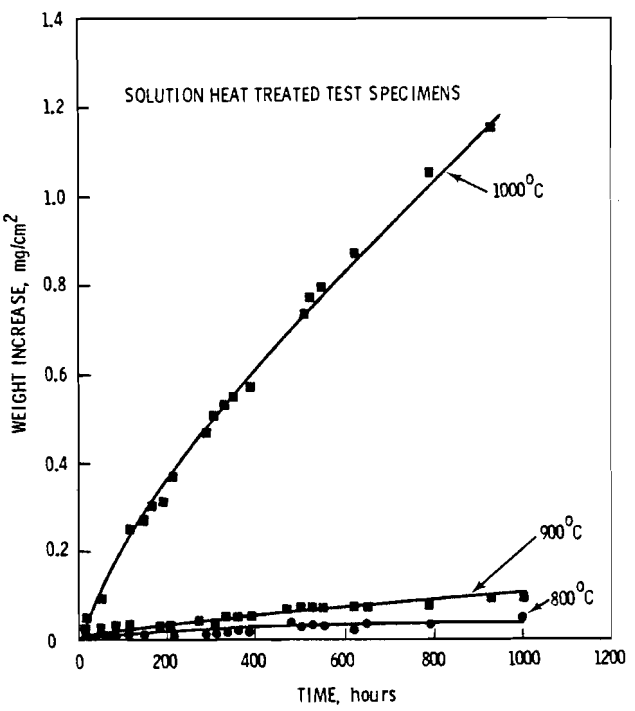

FIGURE 5. Oxidation of Hastelloy S

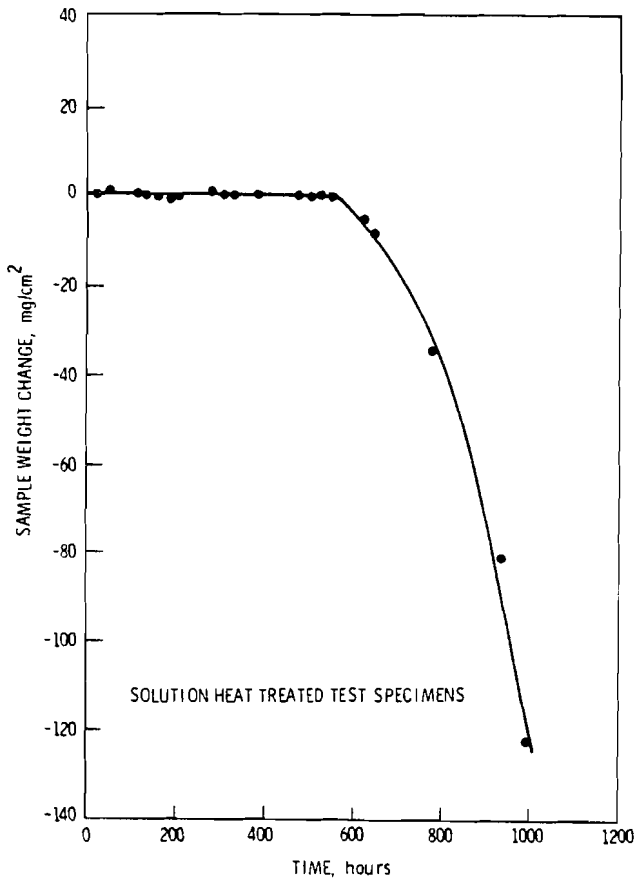

FIGURE 6. Oxidation of Hastelloy S at 1100°C

Comparison of the oxidation data for solution heat treated Hastelloy S with the data previously reported for solution heat treated Hastelloy C-4 (BNWL-1845-28) shows that the Hastelloy S oxidizes at a slower rate than Hastelloy C-4 at all temperatures. However, both alloys suffer the problem of oxide spalling at higher temperatures.

The oxidation resistance of Hastelloy S and Hastelloy C-4 specimens which had been thermally aged at 600, 700, 800, or 900°C for 1000 hr was determined using the same procedure as was used with the solution heat-treated

specimens. The thermally aged specimens were prepared from alloy sheets which had been heated in air at the prescribed temperature for 1000 hr. Each specimen was approximately 1 in.^{2}; and the oxide scale which formed on the alloys during thermal aging was removed from the specimens and the surfaces polished prior to testing. The test results indicate that thermal aging had little effect on the oxidation resistance of the alloys at 900°C or less. At 1000°C and higher, however, thermal aging appeared to lower the temperature at which spalling of the oxide layer began and increase the severity of spalling. Some of the tests provided conflicting results, however, and a number of tests are being repeated. A detailed discussion of the effects of thermal aging on oxidation resistance of the two alloys will be presented when the supplemental tests are completed.

Laboratory tests were carried out to measure the corrosion resistance of solution heat treated Hastelloy S to natural seawater. The test procedure was identical to that used with Hastelloy C-4 (BNWL-1845-28). The test specimens were cut from the same sheet as the specimens used for the oxidation tests. Specimen dimensions were 2.00 x 1.00 x 0.063 in. Some specimens were in the "as received" condition with mill scale on the major surfaces. Other specimens were polished to remove the scale prior to testing. TIG welded specimens were also evaluated. The tests were carried out at 23°C ± 1°C with and without aeration. The tests lasted 1000 hr, and the Hastelloy S was found to be very resistant to attack by the seawater. Metallographic examination of the specimens showed no evidence of attack; and the maximum weight loss observed with any specimen was less than 1 mg, which corresponds to a weight loss of <0.04 mg/cm^2. Simple bending tests indicated the specimens had suffered no loss of ductility.

Similar seawater corrosion tests were carried out using Hastelloy C-4 and Hastelloy S specimens which had been thermally aged at 600, 700, 800, or 900°C for 1000 hr. The oxide scale was removed from the specimens and the surfaces polished prior to testing. The results show that thermal aging at 600 to 900°C had no effect on the seawater corrosion resistance of the two alloys as compared to their solution heat treated forms.

Material Property Testing Equipment

An instrumented Tinius Olsen Universal Impact Testor having a capacity of 240 ft-lb was recently obtained. Efforts are now underway to fabricate a specimen heating chamber and transfer apparatus which will permit testing of Charpy impact specimens at temperatures up to 1000°C.

A helium leak detector has been obtained; and a test chamber is now being designed which will permit leak testing of full size WESF strontium capsules. The chamber and leak detector will be used in qualification testing of the WESF capsule.

REFERENCE

1. H. T. Fullam, The Solubility and Dissolution Behavior of $^{90}SrF_2$ in Aqueous Media, BNWL-2101. Battelle, Pacific Northwest Laboratories, Richland, WA, November 1976.

BENEFICIAL ISOTOPES UTILIZATION PROGRAM

J. H. Jarrett,
Program Manager and Principal Investigator

The objectives of the program are to identify and develop beneficial uses of nuclear reactor by-products through: 1) estimation of long-term availability and cost of useful isotopes from commercial suppliers; 2) identification and development of beneficial applications of isotopes, including their use in remote regions of the world; 3) identification and evaluation of the actions required to optimize the $^{90}SrF_2$ *and* $^{137}CsCl$ *products from the Hanford Waste Encapsulation and Storage Facility (WESF) for beneficial use; and 4) review and evaluate the use of radioisotopes for fueling thermal systems which might be used by the U.S. Army.*

The program is divided into four tasks:

Task I - Isotopes Availability
Task II - Cold Regions Applications
Task III - WESF Product Utilization
Task IV - General Application of Radioisotopes in Army Thermal Systems

TASK 1 - ISOTOPES AVAILABILITY

Flowsheet Calculations (D. K. Davis)

A postulated flowsheet has been developed to recover various useful isotopes (such as americium, cesium, curium, neptunium, promethium, and strontium) and the solid precious metals from high-level liquid waste (HLLW).

The process uses liquid-liquid separation techniques for making the large cuts between the various elements and ion-exchange columns for final purification of the elements. A report describing this process has been drafted and is undergoing internal review.

TASK 2 - COLD REGIONS APPLICATIONS (W. E. Sande)

During their trip to Anchorage and Fairbanks, Alaska, L. D. Perrigo and W. E. Sande determined that the greatest potential application of

isotope systems is for 1- or 2-kW heaters that are enclosed in a heavy-walled container which requires minimum heat transfer equipment.

Other potential applications of isotope systems that were identified include radioisotope thermoelectric generators (RTGs) to power RCA communication systems and isotope heaters for select highway culverts. The Federal Aviation Administration (FAA) will install five RTGs next summer to power remote aircraft navigation aids in Lake Clark Pass between Kenai and Bristol Bay.

A draft report comparing low temperature isotope heater costs with fuel oil systems has been prepared and is now being revised with data obtained during the Alaska trip.

TASK 3 - WESF PRODUCT UTILIZATION

Work continued in two areas in support of the Sandia Sewage Sludge Irradiation Program: development of cost and other information to be used in evaluating alternative sewage treatment processes; and odor analysis of treated and untreated sludge.

- Support to Sandia: Study of Sludge Handling Alternatives (H. E. McGuire, Jr. and G. W. Dawson)

Preliminary treatment sequences for each of the sludge treatment systems have been analyzed by PNL and peer group research. The processes have subsequently been modified to insure that the final products are similar and consistent with common municipal or research operations. A draft report is being written to describe relative treatment processes and costs, and some energy use calculations.

Cost analyses of each unit operation have been made and are being assembled in a graphical and mathematical format to assist in a matrix study.

- Support to Sandia: Odor Panel Evaluation of Treated Sewage Sludge (D. B. Cash)

All odor panel evaluation data on additional digested sludge samples (treated and untreated) delivered by Sandia Laboratories to PNL has been statistically analyzed. For both digested and undigested sewage sludge

the irradiated sludge had higher T.O.N. (Threshold Odor Number)[a] than the non-irradiated sludge. T.O.N.'s changed over the time span for all samples, and in most cases, the T.O.N. peaked at the third or fourth day, then leveled off.

A preliminary odor panel was also conducted on four dry solids samples from Sandia: 1) control - no treatment, 2) heat treatment, 3) irradiation treatment 2 Mrad, and 4) irradiation treatment 1 Mrad. In all cases the irradiated dry solid samples could be distinguished from the control and heat-treated solids. The majority of the panel members indicated that Sample 4 (irradiated at 1 Mrad) had the strongest odor.

The final report, which is near completion, discusses results of the odor panel evaluation of digested and undigested sludge samples (irradiated and nonirradiated).

TASK 4 - GENERAL APPLICATION OF RADIOISOTOPES IN ARMY THERMAL SYSTEMS (W. E. Sande)

Two main concepts for an Army steam plant fueled with high-level waste canisters have been developed based on the heat transfer analysis and preliminary disposal limiting parameters.

- Concept 1 - The high-level waste canisters are inserted into an enclosed boiler with open tubes. Shielding is provided by water tanks located above the boilers.
- Concept 2 - the canisters are placed in a double row in a boiler having sides that are reinforced with concrete to provide structural support. The top of the boiler is a large removable pressure head

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[a] The T.O.N. is the ratio by which a sample must be diluted with odor free water for its odor to just be detectable. The higher the T.O.N., the greater the dilution required and in general, the more noticeable its odor.

$$\text{T.O.N.} = \frac{A + B}{A}$$

A = sample volume

B = diluent (water) volume so odor is just detectable

located above 13 ft of water used for shielding. A secondary heat exchanger is used to transfer the heat from the canister boilers to the steam system.

Designs for Concept 1 have been developed for six different canister diameters with various waste forms and canister resupply schedules while eight canister variations have been used in Concept 2 designs.

Aspects of canister transport are being considered and preliminary results indicate that these transport costs will have a significant impact on the economics of an Army steam plant fueled with the high-level waste canisters. Also, licensing and safety of such a steam plant was considered from four bases:

- direct reference to the Code of Federal Regulations,
- analysis of past work on licensing requirements for the Retrievable Surface Storage Facility (RSSF),
- consideration of the requirements for spent fuel storage facilities, and
- licensing from the standpoint of radioisotopic power generators.

Based on these considerations, it is recommended that the steam plant design closely follow past work on RSSF concepts and spent fuel storage facilities (except for certain capabilities such as hot cell receiving); for example, stainless steel basin liners and the double barrier concept should be maintained. It is expected licensing procedures will follow the requirements for an independent spent fuel storage facility (Reg. Guide 3.24) since the amount of contained radioactivity and heat generation are similar. Licensing the canister as a heat source for a power generator (Reg. Guide 6.3) would be difficult because of an 800°C thermal test.

The overall economics of Army use of high-level waste canisters is being developed based on the following cost estimates for 5-, 10-, and 20-MW steam plants.

- capital investments for canister-fueled steam plants
- operating costs
- savings to the Army for replacing fuel oil boilers

- canister transport costs
- potential savings to fuel reprocessing plants due to canister use by the Army.

A final report, which discusses Army use of high-level waste canisters in steam plants, is being drafted and should be ready for review in mid-February. The following factors significantly reduce the costs of Army steam plants fueled with high-level waste canisters and increase the probability of these plants economically competing with fuel oil systems:

- the steam plant is 200 miles or less from the fuel reprocessing plant,
- a steam plant has a capacity of 20 MW,
- the Army owns the canister rail transport casks, and
- fuel reprocessors pay the Army for canister storage and canister transport.

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