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DP-1300

AEC RESEARCH AND DEVELOPMENT REPORT

SAVANNAH RIVER LABORATORY
COBALT-60 POWER AND HEAT SOURCES

QUARTERLY PROGRESS REPORT

JANUARY - MARCH 1972

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SAVANNAH RIVER LABORATORY
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PREFACE

This report is one in a series on the applied aspects of ^{60}Co that are under study at the Savannah River Laboratory (SRL). These reports are intended to present data that are useful to system designers and also to potential or active user agencies. The reports thus deal with the following subject areas of SRL programs:

1. Properties and reactions of ^{60}Co fuel forms useful or potentially useful as heat sources.

2. Information on the irradiation and postirradiation processing of these materials, when the information is relevant to their use as heat sources and is not in a sensitive area of production technology.

3. Development of design data directed toward the use of and manufacturing capability for isotopic heat sources.

This report contains principally data from work performed during the report period. Previous reports are listed in the Publications section.

SUMMARY

Significant galvanic corrosion occurred on "Inconel" 600, nickel-plated cobalt metal, and couples between cobalt metal and superalloys during 61 days exposure to sea water; negligible corrosion occurred on the other superalloys and the ceramic cobalt compounds. None of the materials corroded significantly when exposed to bottom mud. (p 1)

Preliminary oxidation tests of iridium confirm data reported in the literature and indicate that a secondary capsule of an oxidation resistant material will be required to ensure containment of cobalt under accident conditions. (p 6)

Inactive superalloy capsules being heated at 850 to 1000°C are intact and performing satisfactorily after 39,400 hr (4.5 yr). (p 8)

Fabrication of iridium capsules for ceramic cobalt compounds was begun; initial tests showed that sound welds could be made by TIG welding. (p 11)

The "Hastelloy" X being used to fabricate the fuel capsules and fuel pins for the WANL heat source exhibited satisfactory oxidation resistance during 5000-hr tests at 1000°C; the Nickel 201 being used to fabricate the core also exhibited satisfactory resistance in 500-hr tests at 1000 and 1125°C. (p 12)

The thermoelectric generator fueled with ^{60}Co continued to operate satisfactorily after 13 mo with an electrical output of 58.5 w. (p 12)

CONTENTS

PROGRAM

The purpose of the Savannah River Laboratory (SRL) program on ^{60}Co is to provide data that will be required for designing, fabricating, and operating ^{60}Co heat sources. Primary emphasis is on selecting materials for encapsulating cobalt fuel forms and establishing temperature limits for operation of capsules in normal and accident environments. Development of specific heat source concepts is not at present included in the scope of the SRL program, but assistance is provided when required for the development and testing of demonstration units.

MATERIALS TECHNOLOGY AND DEVELOPMENT

CAPSULE MATERIALS FOR RADIOACTIVE COBALT

Corrosion in Marine Environments

Corrosion tests in sea water and bottom mud were begun on samples of cobalt fuel forms and candidate capsule materials. The tests are being performed by the International Nickel Company at their Francis L. LaQue Corrosion Laboratory in Wrightsville Beach, N. C. Materials in test include bare and nickel-plated cobalt metal, CoO, $CoAl_2O_4$, $Co_{0.5}Mg_{0.5}O$, "Inconel"* 600, "Hastelloy"** C, "Hastelloy" X, "Haynes"** 25, "Haynes" 188, tungsten, tungsten-25 wt % rhenium (W-25 wt % Re) alloy, and samples cut from various inactive superalloy capsules that were previously heated for up to 22,500 hr at 1000°C. Samples of each material have been examined after 61 days (1464 hr) exposure; other samples will be examined after 5000 hr and after 10,000 hr.

* Trademark of International Nickel Co.
** Trademark of Cabot Corp.

Significant galvanic attack from sea water produced weight losses up to 0.3 g on nickel-plated cobalt metal wafers, sections from heated capsules, and on "Inconel" 600, Table I. As observed in a preliminary test of nickel-plated wafers,[1] complete penetration of cobalt wafers occurred wherever there was a break in the nickel coating, Figure 1. The attack on the sections of heated capsules occurred primarily near the interface between the cobalt and the capsule, Figure 2. The greater attack of the section from the "Hastelloy" X capsule is probably the result of the larger cathodic area of the capsule wall (0.100 in. thick compared to 0.050 in. on the "Inconel" and "Hastelloy" C capsules) rather than any intrinsic property of the "Hastelloy" X. The cause of the attack on "Inconel" 600 is not known exactly, but is apparently related to the stringers of impurity phases present in the rod from which the sample was cut, Figure 3. The depth of the pits, 0.125 in., would be sufficient to cause failure of a capsule of the design used in this program; however, the high temperatures that occur during service in a heat source would destroy the stringer pattern.

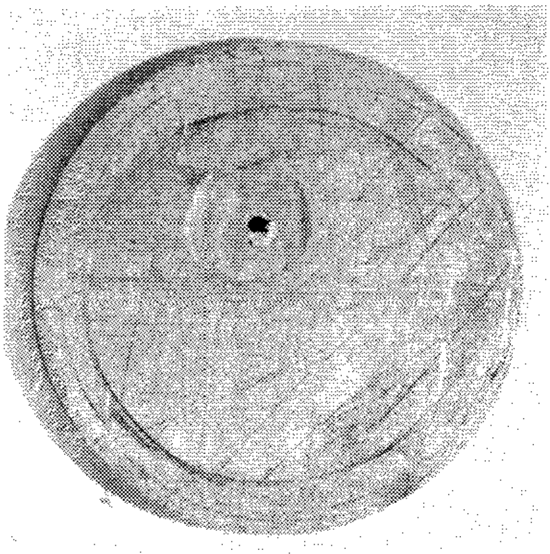
TABLE I

Weight Changes During Corrosion in Marine Environments

(Samples exposed 61 days)

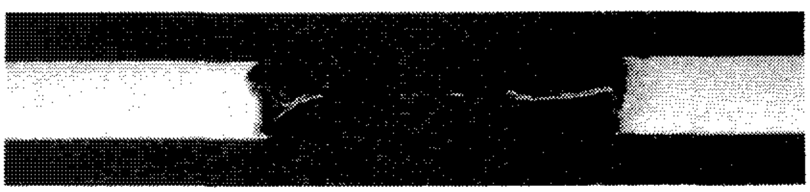
Material	Weight, g					
	Exposed in Water			Exposed in Mud		
	Before	After	Change	Before	After	Change
Bare Cobalt	5.8507	5.8362	-0.0145	6.7272	6.7236	-0.0036
Nickel-plated cobalt	2.2783	2.4078	-0.1705	2.6157	2.6141	-0.0016
Nickel-plated cobalt[a]	2.6322	2.3202	-0.3120	2.6451	2.6430	-0.0021
CoO	5.2779	5.2716	-0.0063	5.2970	5.2987	+0.0017
CoO-MgO	4.1554	4.1090	-0.0464	4.2197	4.2112	-0.0085
$CoAl_2O_4$	3.7818	3.7830	+0.0012	3.8968	3.9018	+0.0050
"Inconel" 600	22.5434	22.4398	-0.1036	21.3526	21.3524	-0.0002
"Hastelloy" C	21.8532	21.8534	+0.0002	21.7365	21.7369	+0.0004
"Hastelloy" X	18.8920	18.8924	+0.0004	19.8338	19.8340	+0.0002
"Haynes" 25	20.7760	20.7760	0	26.4683	26.4685	+0.0002
"Haynes" 188	42.8084	42.8088	+0.0004	23.0386	23.0377	-0.0009
Tungsten	12.7642	12.6019	-0.1623	10.6933	10.6934	+0.0001
W-25 wt % Re	12.8710	12.7871	-0.0839	9.9623	9.9629	+0.0006
"Inconel" 600 capsule[b]	9.2518	9.1280	-0.1238	14.7641	14.7636	-0.0005
"Hastelloy" C capsule[b]	15.5290	15.3928	-0.1361	14.2744	14.2740	-0.0004
"Hastelloy" X capsule[c]	10.8439	10.5953	-0.2486	9.8310	9.8278	-0.0032

a. Letter X scribed on one side to break through nickel coating.
b. Previously heated 1000 hr at 1000°C
c. Previously heated 22,500 hr at 1000°C



0.75 in.

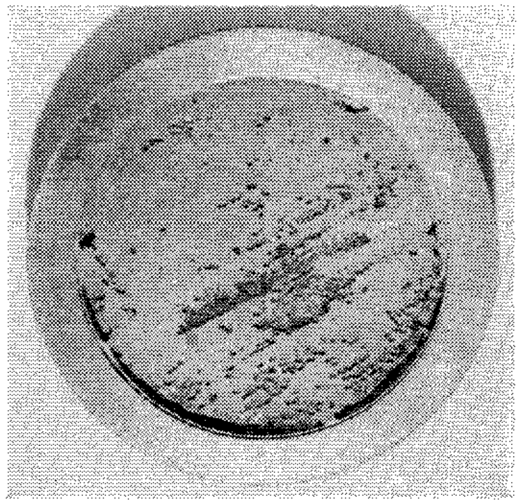
Pinhole in wafer. Circular area around hole corresponds to under-cutting of nickel-plate.



0.1 in.

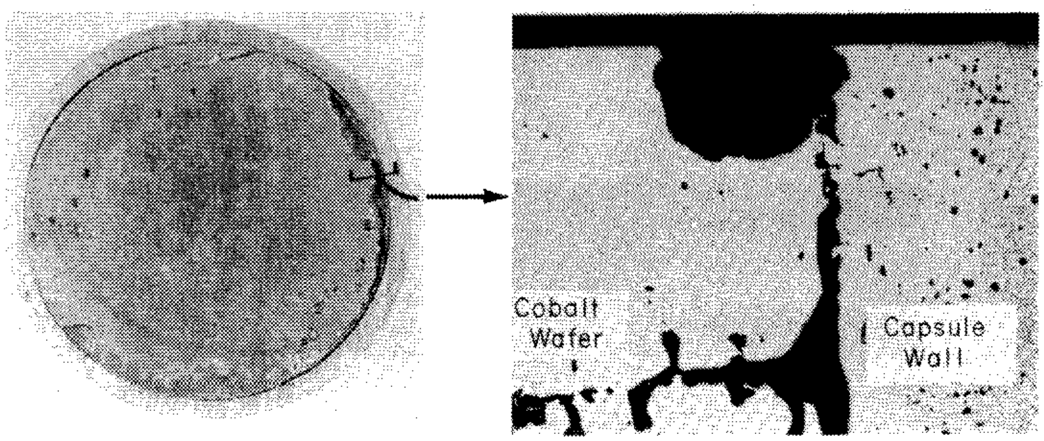
Section through pinhole. Nickel-plate was deformed during mounting for examination.

FIG. 1 GALVANIC ATTACK OF NICKEL-PLATED COBALT IN SEA WATER



0.75 in.

Section from "Hastelloy" X capsule



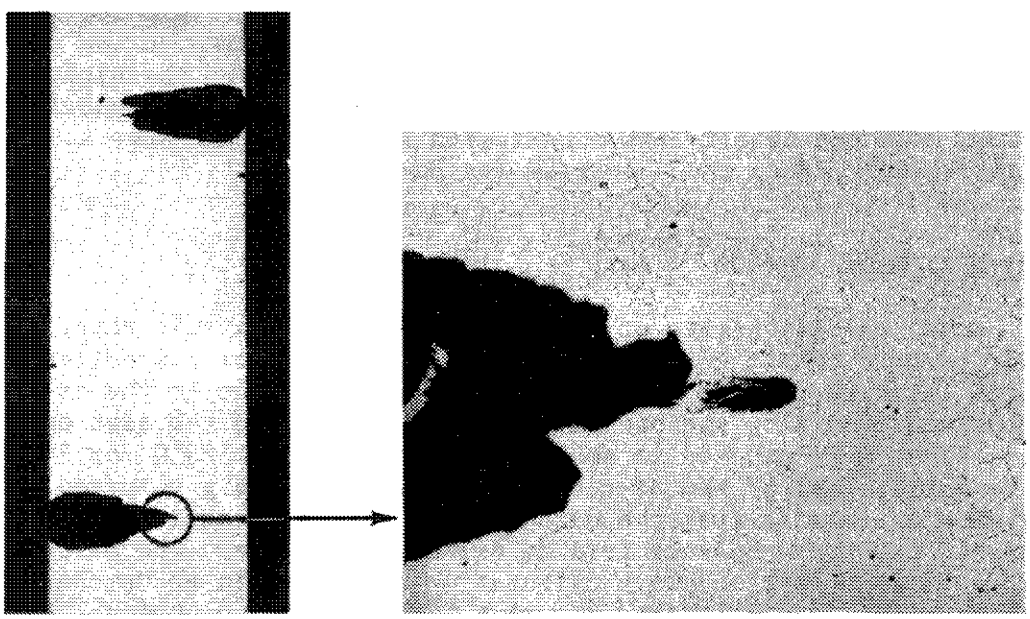
0.75 in. 0.01 in.

Section from "Hastelloy" C capsule

FIG. 2 GALVANIC ATTACK OF CAPSULE SECTIONS IN SEA WATER

1.0 in.

Hole in "Inconel" 600 wafer. Second hole on other side



0.2 in. — 0.01 in.

Section through holes — Tip of hole between impurity stringers

FIG. 3 GALVANIC ATTACK OF "INCONEL" 600 IN SEA WATER

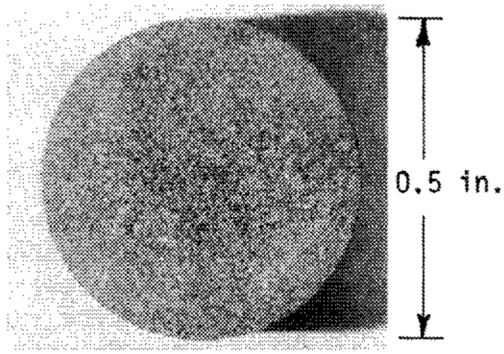
More uniform corrosion occurred on the tungsten and W-25 wt % Re alloy samples, but the attack was associated with the grain boundaries, Figure 4. The measured weight losses would correspond to reductions in wall thickness of 0.015 in. for tungsten and 0.008 in. for the W-Re alloy if capsules were exposed under similar conditions.

Little, if any, attack occurred on the cobalt compounds, "Hastelloy" C, "Hastelloy" X, "Haynes" 25, or "Haynes" 188 exposed in sea water or on any of the samples exposed to bottom mud. The slightly larger weight losses of the $Co_{0.5}Mg_{0.5}O$ samples exposed to both water and mud may be due to leaching of MgO, as observed in previous tests in fresh water.[2]

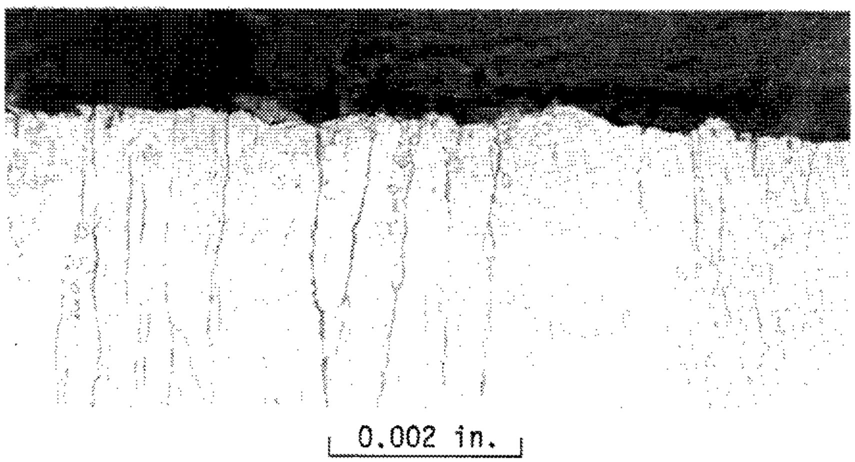
The observed weight losses from the galvanic attack of nickel-plated metal wafers and capsule sections correspond to releases of $\sim$1.5 Ci/day if the cobalt had a specific activity of 350 Ci/g. This release rate exceeds the value for the permissible daily release from nuclear powered ships in regions within 12 miles of the coast line, but is less than the permissible release in regions beyond the 12-mile limit.[3] The release rate calculated from the weight losses could be considered to be a maximum value because the full cross sectional area of the cobalt wafers (0.750 in. dia) on both surfaces of the samples were exposed to the sea water. The probability of a capsule breaking during an accident is expected to be extremely low. Moreover, the nickel that would be formed during the radioactive decay of the cobalt would make the cobalt less anodic with respect to the superalloy capsule and reduce the potential for corrosion.

Oxidation of Iridium

The oxidation rate of iridium, a candidate capsule material for ceramic cobalt compounds, is being measured for comparison with literature data. Two pieces of bar stock, one in the as-received condition and one with a weld bead around the edge on one side, were exposed to ambient furnace air at 1125°C for 500 hr. The weight loss of the as-received sample was 1.35 g compared to 1.61 g calculated from the data of Phillips.[4] No scale is formed during oxidation because iridium oxide is volatile. The oxidation rate is dependent on grain orientation resulting in an "etched" appearance after exposure, Figure 5. There were no obvious differences between the oxidation of the weld-metal and the base-metal. The calculated uniform metal loss, 0.013 in./side, is substantial and indicates that iridium capsules would have to be re-encapsulated in a more oxidation resistant metal (such as platinum) for safe use in a heat source, particularly under accident conditions. The specimens will be sectioned after an additional 500-hr exposure to measure the maximum penetration.



Tungsten wafer



Cross section showing intergranular attack

FIG. 4 UNIFORM CORROSION OF TUNGSTEN IN SEA WATER

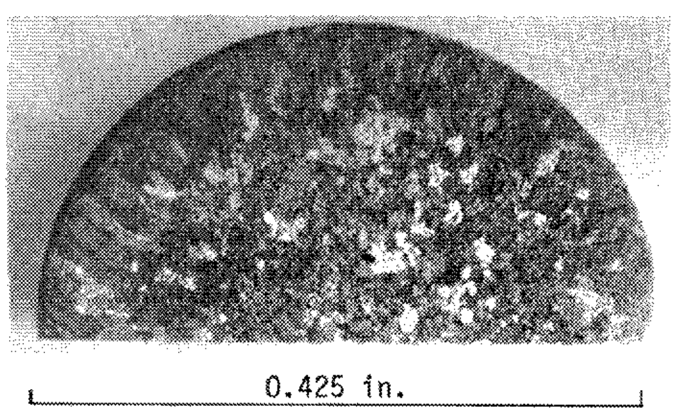


FIG. 5 OXIDIZED IRIDIUM

CAPSULE FABRICATION AND TESTING

Heating Tests of Capsules with Unirradiated Cobalt Metal

Superalloy Capsules

Superalloy capsules being heated toward goal exposures of 50,000 hr at 850 to 1000°C were examined nondestructively after times up to 39,400 hr, Table II. Leak tests showed that all capsules were intact. Weight losses from spalling of the oxide scale corresponded to diameter decreases ranging from <0.001 in. on the "Inconel" 600 capsule heated at 850°C and 0.0015 in. on the "Hastelloy" X capsule heated at 1000°C to 0.005 in. on the "Inconel" 600 capsule heated at 1000°C. Measured diameter changes, corrected for the spalling, indicated that the capsules continued to creep at a rate of $\approx 10^{-7}$ in./in./hr, as observed during exposures up to 29,300 hr.[5] Heating was resumed on all capsules.

Refractory Metal Capsules

A W-25 wt % Re alloy capsule was removed from test after attaining its goal exposure of 10,000 hr at 1400°C; evaluation of capsule performance is in progress. Heating is continuing toward 10,000 hr at 1200°C with one tungsten capsule, Table III.

TABLE III

^{59}Co — Refractory Metal Capsule Tests[a]

Capsule Material	Heating Time, hr	Heating Temp, °C	Approx. Starting Date	Approx. Completion Date	Welding Diameter, inch	Welding Technique	Remarks
Tungsten	1,000	1,200	9/70	4/71	0.745	TIG	Capsule intact
	10,000	1,200	9/70	6/72	0.745	TIG	
W-25 wt % Re	1,000	1,200	8/70	10/70	0.745	TIG	Capsule intact
	1,000	1,400	8/70	10/70	0.745	TIG	Capsule intact
	5,000	1,400	8/70	6/71	0.745	TIG	Capsule intact
	→ 10,000	1,400	8/70	3/72	0.745	TIG	Examination in progress

a. One capsule containing ∿10 Co wafers 0.073 in. thick at each listed condition.
→ New information reported.

TABLE II

Summary of ^{59}Co Capsule Heating Tests

Capsule Material	Heating Time, hr	Heating Temp, °C	Wall, mils	No. of Capsules	Approx. Starting Date	Approx. Completion Date	Remarks
"Inconel" 600	1,000	850	50	1	12-66	2-67	Capsule intact
(m.p. 1370°C)	5,000	850	50	1	12-66	7-67	Capsule intact
	10,000	850	50	1	12-66	1-68	Capsule intact
	10,000	850	95	1	7-67	9-68	Capsule intact
	→ 50,000	850	95	1	7-67	3-73	Intact at 37,200 hr
	1,000	900	95	1	11-68	12-68	Capsule intact
	5,000	900	95	1	11-68	6-69	Capsule intact
	5,000[e]	900	95	1	3-69	10-69	Increased Co/capsule reaction
	10,000	900	95	1	11-68	1-70	Capsule intact
	20,000	900	95	1	11-68	5-71	Capsule intact
	10,000[e]	900	95	1	3-69	5-70	Increased Co/capsule reaction
	→ 50,000	900	95	1	11-68	7-74	Intact at 27,400
	1,000	1,000	50	4	8-66	10-66	3 capsules intact; 1 capsule oxidized[b]
	5,000	1,000	50	1	4-67	11-67	Capsule intact
	1,000[a]	1,000	95	2	7-67	9-67	No severe oxidation of Co
	1,000[d]	1,000	95	1	2-68	4-68	No oxidation of Co or capsule
	5,000[d]	1,000	95	1	2-68	9-68	No oxidation of Co or capsule
	5,000	1,000	95	1	8-67	2-68	Capsule intact
	10,000	1,000	95	1	8-67	10-68	Capsule intact
	→ 50,000	1,000	95	1	10-67	6-73	Intact at 39,400 hr
	10,000[d]	1,000	95	1	11-68	1-70	No oxidation of Co or capsule
"Hastelloy" C (m.p. 1270°C)	1,000	1,000	50	4	8-66	10-66	3 capsules intact; 1 capsule oxidized[b]
	5,000	1,000	95	1	10-67	5-68	Capsule intact
	10,000	1,000	95	1	10-67	12-68	Capsule intact
	→ 50,000	1,000	95	1	10-67	6-73	Intact at 39,400 hr
	20,000	1,000	95	1	5-68	9-70	Capsule intact
TD Nickel	1,000	850[c]	95	1	10-67	12-67	Capsule intact
(m.p. 1450°C)	5,000	850	95	1	10-67	5-68	Capsule intact
	10,000	850	95	1	10-67	12-68	Capsule intact
	50,000	850	95	1	10-67	6-73	
	1,000	1,000	95	1	12-66	2-67	Capsule intact
	1,000[a]	1,000	95	2	10-67	12-67	No severe oxidation of Co
TD Nickel Chromium	1,000[a]	1,000	95	2	10-67	12-67	Co near pinhole oxidized
(m.p. 1430°C)	1,000	1,000	95	1	10-67	12-67	Capsule intact
	5,000	1,000	95	1	10-67	5-68	Capsule intact
	10,000	1,000	95	1	10-67	12-68	Capsule intact
	→ 50,000	1,000	95	1	10-67	6-73	Intact at 39,400 hr
"Haynes" 25	10,000	850	95	1	11-68	1-70	Capsule intact
(m.p. 1330°C)	1,000	1,000	95	1	10-67	12-67	Capsule intact
	5,000	1,000	95	1	10-67	5-68	Capsule intact
	5,000	1,000	95	1	5-68	12-68	Capsule intact
	10,000	1,000	95	1	10-67	12-68	Capsule intact
	29,300	1,000	95	1	10-67	11-70	Failed at 29,300 hr from oxidation
	20,000	1,000	95	1	5-68	9-70	Capsule intact
"Hastelloy" X	1,000	1,000	50	1	4-67	6-67	Capsule intact
(m.p. 1260°C)	5,000	1,000	50	1	4-67	11-67	Capsule intact
	5,000	1,000	95	2	2-68	9-68	Capsules intact
	10,000	1,000	95	1	2-68	4-69	Capsule intact
	→ 50,000	1,000	95	1	2-68	10-73	Intact at 32,400 hr
	20,000	1,000	95	1	5-68	9-70	Capsule intact
	22,500	1,000	95	1	5-68	12-70	Capsule intact

[a] Two capsules, one not welded and one with drilled hole in wall, to test effects of capsule defects.
[b] Capsules reacted with fire-brick. See DP-1094, "SRL Isotopic Power and Heat Sources - Quarterly Progress Report," October-December 1966.
[c] Tests of TD Nickel at 850°C in flowing argon. [d] Internal atmosphere air instead of helium.
[e] Caustic residue on wafers.
→ New information reported.

Heating Tests of Capsules with Irradiated Cobalt Metal

Cobalt-60 Test Facility

Practice operations with unirradiated materials are in progress in the Cobalt Test Facility (CTF), the new shielded cell for long-term heating tests of active capsules. Preparation of the safety analysis report was completed; preparation of the operating procedures is in progress. Included in the practice operations is a 2000-hr test of the muffle furnaces to be used for heating superalloy capsules containing cobalt metal and high-vacuum furnaces to be used for heating noble metal capsules containing ceramic cobalt compounds. Upon completion of these tests, the five superalloy capsules currently in storage in the High Level Caves (HLC), Table IV, will be transferred to the CTF and heating resumed at 900 and 1000°C toward goal exposure of 50,000 hr.

TABLE IV

Summary of ^{60}Co Capsule Heating Tests

Capsule Material	Heating Time, hr	Heating Temp, °C	Wall, mils	No. of Capsules	Activity Spec, Ci/g	Activity Total, Ci	Approx. Starting Date	Approx. Completion Date	Remarks
"Inconel" 600	130	850[a]	50	1	120	16,000	2-67	2-67	Swelled due to overheating
(m.p. 1370°C)	1,000	∿900	50	1	100	5,000	4-67	6-67	Capsule intact
	5,000	∿900	50	1	150[b]	15,000	4-67	10-67	Capsule intact
	10,000	∿900	50	1	150[b]	15,000	4-67	6-68	Increased Co/capsule reaction
	11,000	∿900	50	1	150[b]	9,000	5-67	10-68	Increased Co/capsule reaction
	10,380	900	95	1	255[c]	36,500	2-68	8-69	Increased Co/capsule reaction
	19,460	900	95	1	288[c]	13,700	7-68	11-70	Capsule intact
	→ 50,000	900	95	1	282[c]	13,400	7-68	4-74	In storage
	4,660	1,000	95	1	295[c]	14,000	9-68	4-69	Capsule intact
	9,380	1,000	95	1	288[c]	13,700	9-68	11-69	Capsule intact
	18,100	1,000	95	1	263[c]	12,500	9-68	3-71	Capsule intact
	50,000	1,000	95	1	255[c]	12,100	9-68	1-75	In storage
	→ 9,740	850	95	2[e]	d	-	9-68	11-69	Capsule intact
"Hastelloy" C	100	850	50	1	120	9,000	1-67	1-67	Capsule intact
(m.p. 1270°C)	9,740	900	95	1	276[c]	13,100	7-68	8-69	Capsule intact
	9,650	1,000	95	1	282[c]	13,400	9-68	11-69	High He leak rate
	→ 50,000	1,000	95	1	270[c]	12,800	9-68	1-75	In storage
"Haynes" 25	4,660	1,000	95	1	263[c]	12,500	9-68	4-69	Capsule intact
(m.p. 1330°C)	9,650	1,000	95	1	288[c]	13,700	9-68	11-69	Capsule intact
	18,100	1,000	95	1	282[c]	13,400	9-68	3-71	Capsule intact
	→ 50,000	1,000	95	1	295[c]	14,000	9-68	1-75	In storage
"Hastelloy" X	4,660	1,000	95	1	250[c]	11,900	9-68	4-69	Capsule intact
(m.p. 1260°C)	9,380	1,000	95	1	263[c]	12,500	9-68	11-69	Capsule intact
	18,360	1,000	95	1	263[c]	12,500	9-68	3-71	Capsule intact
	→ 50,000	1,000	95	1	301[c]	14,300	9-68	1-75	In storage

a. Excursion to >1100°C for 3-6 hr.
b. Activity as of 2-67.
c. Activity as of 6-68.
d. Capsules contain ^{59}Co but is being heated along with ^{60}Co capsules.
e. One of these capsules was incorrectly identified during fabrication as "Haynes" 25.
→ New information reported

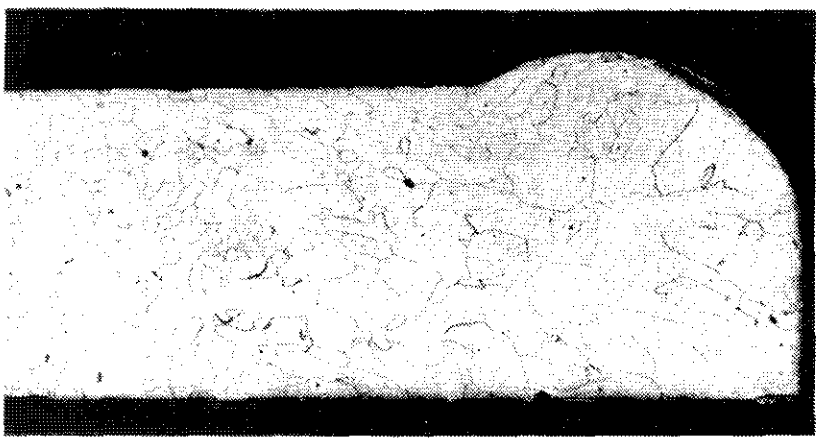
Heating Tests of Capsules with Unirradiated Cobalt Compounds

Iridium Capsules

Preparations were begun for encapsulating inactive ceramic wafers (CoO, $Co_{0.5}Mg_{0.5}O$, and $CoAl_2O_4$) in iridium. Earlier tests showed that iridium was compatible with these compounds and that iridium should not be susceptible to the vapor transport that led to the failure of rhenium capsules containing these compounds.[5] Machining of the ceramic wafers has been completed; machining of the iridium capsules and caps is in progress. Material for 25 capsules is available. In initial tests one capsule containing each of the compounds will be heated for 1000 and 5000 hr at 1600°C.

Development of welding parameters for iridium was begun by melting the periphery of a solid rod with a TIG welder. The resulting "weld" beads contained no porosity or cracks, Figure 6. The flow of helium from the welder shroud was sufficient to prevent serious oxidation. Additional variations in welding parameters will be tried to minimize the grain growth in the heat affected zone.

Heat affected zone



0.04 in.

FIG. 6 IRIDIUM WELD

HEAT SOURCE DEMONSTRATION TESTS

WANL 30 kw(t) UNIT

SRL is providing the irradiated cobalt metal wafers as well as technical assistance in the program to design, fabricate, and test an experimental heat source containing 2 MCi (30 kw) of ^{60}Co. Westinghouse Astronuclear Laboratory (WANL) is the contractor for this project.

Oxidation of "Hastelloy" X

Long-term oxidation of "Hastelloy" X is being measured on samples from the actual heat being used to fabricate the fuel capsules and fuel pins for the heat source. Examination of a sample exposed 5000 hr at 1000°C showed that the total depth affected by oxidation was 0.0055 in., which agrees well with the average value of 0.005 in. observed in previous tests with other heats of "Hastelloy" X. Exposure of an additional sample at 1000°C is continuing toward 10,000 hr.

Oxidation of Nickel 201

Long-term oxidation tests were begun on the actual heat of Nickel 201 being used to fabricate the core of the heat source. Tests for 500 hr at 1000 and 1125°C were completed; tests are continuing for up to 10,000 hr at 1000°C and up to 3000 hr at 1125°C. The oxide scale formed during 500 hr at 1000°C was 0.007 in. thick and that formed at 1125°C was 0.018 in. thick. These values are less than those predicted from previous tests of Nickel 201 at 1000°C (0.010 in.) and Nickel 200 at 1000°C (0.011 in.) and 1125°C (0.023 in.).[6]

SRL THERMOELECTRIC GENERATOR

More than 13 mo of satisfactory operation were completed by the ^{60}Co-fueled thermoelectric generator. The measured electrical power output after 409 days of operation was 58.5 w compared to 84.4 w at the time of fueling in February 1971. The rate of decrease in power output is slightly greater than the square of the rate of ^{60}Co decay, as described previously.[7]

^{60}Co LOAN PROGRAM

Because of the potential application of high-activity cobalt metal in heat sources, the AEC has established a loan program for the material. About 9 MCi (140 kw) of ^{60}Co at over 300 Ci/g Co are available for this program. Most of this material is in the form of 0.745-in.-dia wafers, plated with nickel. Individual companies or groups of companies are invited to participate by contacting the Savannah River Operations Office of the AEC. Moderate activities and amounts of ^{60}Co can be obtained commercially.

Radioactive cobalt metal shapes available under this loan program are listed in Table V.

TABLE V

^{60}Co Metal for Heat Source Development

(Activity as of 12/31/71)

	No. of Pieces	Wt of Co, g/piece	Avg Sp Activity, Ci/g Co	Total Activity, MCi	Total Power, kw(t)
Wafers, 0.040-in. thick					
0.745-in. dia.	2090	2.5	220	1.15	17.9
	3800	2.5	175	1.67	26.0
0.800-in. dia.	391	2.8	200	0.22	3.4
Wafers, 0.073-in. thick					
0.745-in. dia.	3080	4.5	410	5.71	89.0
	2360	4.5	310	3.25	50.6
	4560	4.5	175	3.60	56.0
Half-wafers, 0.073-in. thick					
1.00-in. dia.	682	4.1	260	0.74	11.5
1.25-in. dia.	434	6.4	260	0.73	11.3
1.49-in. dia.	620	9.1	260	1.48	23.1
Slabs,					
3.00 x 0.64 x 0.060-in. Ni-plated	93	16.6	200	0.31	4.8
2.96 x 0.735 x 0.092-in. SST-canned	93	13.5	200	0.25	3.9
3.00 x 0.740 x 0.072-in. SST-bonded	124	11.8	200	0.30	4.7
Total				19.4	302

SAVANNAH RIVER LABORATORY ^{60}Co PUBLICATIONS

QUARTERLY PROGRESS REPORTS

"Savannah River Laboratory Power and Heat Sources Quarterly Progress Report"

DP-1088	July - September 1966
DP-1094	October - December 1966
DP-1105-I	January - March 1967, Part I - Cobalt
DP-1120-I	April - June 1967, Part I - Cobalt
DP-1129-I	July - September 1967, Part I - Cobalt
DP-1143-I	October - December 1967, Part I - Cobalt
DP-1155-I	January - March 1968, Part I - Cobalt
DP-1169-I	April - June 1968, Part I - Cobalt
DP-1177-I	July - September 1968, Part I - Cobalt
DP-1192-I	October - December 1968, Part I - Cobalt
DP-1196-I	January - March 1969, Part I - Cobalt
DP-1206-I	April - June 1969, Part I - Cobalt
DP-1216	July - September 1969
DP-1226	October - December 1969
DP-1237	January - March 1970
DP-1247	April - June 1970
DP-1254	July - September 1970
DP-1267	October - December 1970
DP-1272	January - March 1971
DP-1279	April - June 1971
DP-1286	July - September 1971
DP-1293	October-December 1971

TOPICAL REPORTS

DP-974	"^{60}Co Heat Sources for 10-60 kw(e) Generators" by A. H. Dexter, July 1965.
DP-1012	"Radioactive Cobalt for Heat Sources" by J. W. Joseph, H. F. Allen, C. L. Angerman, and A. H. Dexter, October 1965.
DP-1051 (Rev. 2)	"Properties of ^{60}Co and Cobalt Metal Fuel Forms", June 1968.
DP-1096	"Development of ^{60}Co Capsules for Heat Sources" by C. P. Ross, C. L. Angerman, and F. D. R. King, June 1967.
DP-1145	"Experimental ^{60}Co Heat Source Capsules" by J. P. Faraci, May 1968.

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