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AEC RESEARCH AND DEVELOPMENT REPORT

SAVANNAH RIVER LABORATORY ISOTOPIC POWER AND HEAT SOURCES

QUARTERLY PROGRESS REPORT

JULY - SEPTEMBER 1968

PART I - COBALT-60

Savannah River Laboratory

Aiken, South Carolina

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H. S. Hilborn, Compiler

October 1968

This document is

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Jo Ann Wingard (SRS)

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by Donald Williamson 11/24/03

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SAVANNAH RIVER LABORATORY
AIKEN, S. C. 29801

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PREFACE

This report is one in a series on the applied aspects of isotopes that are under study at the Savannah River Laboratory (SRL), and that are of interest as isotopic heat source materials. Principal emphasis is on isotopes that are produced by neutron addition, since these are the materials for which the production capabilities of the Savannah River Plant (SRP) reactors and other facilities can be used effectively. Data for other materials will be included if pertinent -- such as the isotopic or chemical composition of fission products that can be recovered from Savannah River process wastes.

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 isotopes 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 manufacturing capability for isotopic heat sources.

The report is issued in two parts: Part I includes only information on cobalt; Part II includes information on the other isotopic heat source materials. Both parts contain principally data from work performed during the report period. Previous reports are listed on the last page.

SUMMARY

Acceptable oxidation behavior was shown by "Inconel" 600, "Hastelloy" C, and "Hastelloy" X in accelerated tests that simulated operation at 1000°C for 50,000 hr. "Haynes" 25 oxidized more than expected. (p 2)

Seventeen capsules containing high activity ^{60}Co wafers were fabricated, and heating tests were begun at 900 and 1000°C in the High Level Caves. (p 8)

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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. The initial objective is to establish allowable operating limits for capsules of radioactive cobalt metal contained in oxidation resistant alloys. Development of specific heat source concepts is not at present included in the scope of the SRL program.

MATERIALS TECHNOLOGY AND DEVELOPMENT

EVALUATION OF ENCAPSULATING MATERIALS FOR RADIOACTIVE COBALT METAL

The materials evaluation program is designed to select the most promising alloys for encapsulating ^{60}Co , to define the limiting operating conditions of these alloys, and to demonstrate capsule integrity at conditions typical of heat source operation. The kinetics of cobalt-capsule compatibility reactions, ^(1,2) diffusion of ^{60}Co , ⁽²⁻⁶⁾ and oxidation, ^(4,6,7) are being measured using short-term (<500 hr) laboratory tests. Selection of the most promising alloys is based on extrapolation of these results to the expected service life (1 to 5 years). Limiting operating conditions are defined by the time and temperature dependency of each of the reactions. Published data on mechanical properties, such as creep, have been evaluated, and will be confirmed as necessary by tests with pressurized capsules. The predicted behavior of the materials is being verified by 1000-, 5000-, 10,000-, and 50,000-hr heating tests of experimental capsules, Table I. Tests of companion capsules containing unirradiated or irradiated cobalt measure any effects of the radiation field and the increased nickel content (from radioactive decay of the cobalt) on the performance of the capsule materials.

Diffusion of ^{60}Co

Diffusion of ^{60}Co through prospective encapsulating materials is being measured to determine whether it will be a limiting factor in the design of heat sources. Earlier calculations showed that diffusion would not be a limiting factor for "Haynes"* 25, "Hastelloy"* C, or "Hastelloy"* X during operation for 5 years (one half-life of the ^{60}Co) because the maximum specified concentration of 1 ppm ^{60}Co in the capsule material does not occur beyond 0.080 inch from the surface of the cobalt -- a typical capsule wall is 0.100-inch thick. Use of "Inconel"** 600 for 5 years would be limited by diffusion at 1000°C, but not at

* Trademark of Union Carbide Corp.

** Trademark of International Nickel Co.

800°C,⁽⁵⁾ in situations where the capsule wall is exposed to a flowing coolant.

Heat treatment and sectioning were completed on six additional samples of candidate superalloys; calculation of the diffusion coefficients is in progress. This work completes the planned experiments to measure diffusion kinetics for times up to 100 hr at temperatures between 800 and 1200°C. Future work will emphasize measurement of the ⁶⁰Co concentrations in capsule walls and special samples heated for 5000 hr or more at 850 to 1000°C.

Although tests were started to measure the diffusion of ⁶⁰Co in tungsten and rhenium, potential capsule materials for service at 1200°C or above, further analyses will be deferred until FY 1970 because of emphasis on superalloys. Conditions have been developed for electrodepositing cobalt and for sectioning samples after the diffusion anneals. In an initial test with rhenium, heating for 4 hours at 1200°C produced too little diffusion of the cobalt to be accurately detected by the sectioning technique.

Oxidation Resistance

Oxidation characteristics of two groups of encapsulating alloys have been defined at 1000°C for periods up to 10,000 hr.^(4, 6, 7) The amount of oxidation observed in specimens of "Inconel" 600, "Hastelloy" C, "Hastelloy" X, "Haynes" 25, TD Nickel Chromium,* GE 2541,** and "Tophet"*** C exposed to still air indicated that these alloys were sufficiently resistant to oxidation for use in air-cooled heat sources. The amount of oxidation was roughly proportional to the square root of the exposure time. The temperature dependence of oxidation was found from 500-hr tests at 850 to 1150°C. Recent work measured the oxidation resistance in an accelerated test at 1150°C and identified the constituents present in oxide scales.

Accelerated Oxidation Tests

Acceptable oxidation behavior was exhibited by "Inconel" 600, "Hastelloy" C, and "Hastelloy" X in an accelerated test in still air at 1150°C for 3000 hr. The observed oxidation was equivalent to that predicted for reference service conditions of a heat source capsule (50,000 hr at 1000°C). In the same test higher rates of oxidation than expected were observed over the entire surface of a "Haynes" 25 specimen and in a localized area of a TD Nickel

* Product of Fansteel Metallurgical Corp.

** Product of General Electric Co.

*** Trademark of Wilbur B. Driver Co.

TABLE I

Summary of Cobalt Capsule Heating Tests

Capsule Materials	Heating		Wall, mils	No. of Capsules	Activity		Approx. Starting Date	Approx. Completion Date	Remarks	
	Time, hr	Temp, °C			Specific Ci/g	Total, Ci				
A. Inactive Capsules										
"Inconel" 600	1,000	850	50	1	-	-	12-66	2-67	Capsule intact	
	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	Examination in progress	
	-50,000	850	95	1	-	-	7-67	3-73		
	1,000	1000	50	4	-	-	8-66	10-66	3 capsules intact; 1 capsule oxidized ^b	
	5,000	1000	50	1	-	-	4-67	11-67	Capsule intact	
	1,000 ^a	1000	95	2	-	-	7-67	9-67	No severe oxidation of Co	
	1,000 ^f	1000	95	1	-	-	2-68	4-68	No oxidation of Co or capsule	
	-5,000 ^f	1000	95	1	-	-	2-68	9-68	Examination in progress	
	5,000	1000	95	1	-	-	8-67	2-68	Capsule intact	
	10,000	1000	95	1	-	-	8-67	10-68		
	10,000+	1000	95	1	-	-	10-67	12-68+		
	"Hastelloy" C	1,000	1000	50	4	-	-	8-66	10-66	3 capsules intact; 1 capsule oxidized ^b
		5,000	1000	95	1	-	-	10-67	5-68	Capsule intact
10,000		1000	95	2	-	-	10-67	12-68		
10,000+		1000	95	1	-	-	5-68	7-69+		
TD Nickel	1,000	850 ^c	95	1	-	-	10-67	12-67	Capsule intact	
	5,000	850	95	1	-	-	10-67	5-68	Capsule intact	
	10,000	850	95	1	-	-	10-67	12-68		
	10,000	850	95	1	-	-	10-67	12-68		
	1,000	1000	50	1	-	-	12-66	2-67	Capsule intact	
	1,000 ^a	1000	95	2	-	-	10-67	12-67	No severe oxidation of Co	
TD Nickel Chromium	1,000 ^a	1000	95	2	-	-	10-67	12-67	Co near pinhole oxidized	
	1,000	1000	95	1	-	-	10-67	12-67	Capsule intact	
	5,000	1000	95	1	-	-	10-67	5-68	Capsule intact	
	10,000	1000	95	1	-	-	10-67	12-68		
	10,000	1000	95	1	-	-	10-67	12-68		
"Haynes" 25	1,000	1000	95	1	-	-	10-67	12-67	Capsule intact	
	5,000	1000	95	1	-	-	10-67	5-68	Capsule intact	
	5,000	1000	95	1	-	-	5-68	12-68		
	10,000	1000	95	1	-	-	10-67	12-68		
	10,000	1000	95	1	-	-	10-67	12-68		
	10,000+	1000	95	1	-	-	5-68	7-69+		
"Hastelloy" X	1,000	1000	50	1	-	-	4-67	6-67	Capsule intact	
	5,000	1000	50	1	-	-	4-67	11-67	Capsule intact	
	-5,000	1000	95	2	-	-	2-68	9-68	Examination in progress	
	10,000	1000	95	2	-	-	2-68	4-69		
	10,000+	1000	95	2	-	-	5-68	7-69+		
B. ⁶⁰ Co Capsules										
"Inconel" 600	130	850 ^d	50	1	120	16,000	2-67	2-67	Swelled due to overheating	
	1,000	~900	50	1	100	5,000	4-67	6-67	Capsule intact	
	5,000	~900	50	1	150 ^e	15,000 ^e	4-67	10-67	Capsule intact	
	10,000	~900	50	1	150 ^e	15,000 ^e	4-67	6-68	Examination in progress	
	-10,000	870	50	1	150 ^e	9,000 ^e	5-67	10-68 ^h		
	-10,000	900	95	1	255 ⁱ	36,500 ⁱ	2-68	8-69 ^h		
	-10,000+	900	95	1	285 ⁱ	13,700 ⁱ	7-68	8-69+		
	-50,000	900	95	1	282 ⁱ	13,400 ⁱ	7-68	3-74		
	-5,000	1000	95	1	295 ⁱ	14,000 ⁱ	9-68	4-69		
	-10,000	1000	95	1	288 ⁱ	13,700 ⁱ	9-68	11-69		
	-10,000+	1000	95	1	263 ⁱ	12,500 ⁱ	9-68	11-69+		
	-50,000	1000	95	1	255 ⁱ	12,100 ⁱ	9-68	5-74		
	-10,000	850	95	1	g	-	9-68	11-69		
	"Hastelloy" C	100	850	50	1	120	9,000	1-67	1-67	Capsule intact
		-10,000	900	95	1	276 ⁱ	13,100 ⁱ	7-68	8-69	
-10,000		1000	95	1	282 ⁱ	13,400 ⁱ	9-68	11-69		
-50,000		1000	95	1	270 ⁱ	12,800 ⁱ	9-68	5-74		
"Haynes" 25	-5,000	1000	95	1	263 ⁱ	12,500 ⁱ	9-68	4-69		
	-10,000	1000	95	1	268 ⁱ	13,700 ⁱ	9-68	11-69		
	-10,000+	1000	95	1	282 ⁱ	13,400 ⁱ	9-68	11-69+		
	-50,000	1000	95	1	295 ⁱ	14,000 ⁱ	9-68	5-74		
	-10,000	850	95	1	g	-	9-68	11-69		
"Hastelloy" X	-5,000	1000	95	1	250 ⁱ	11,900 ⁱ	9-68	4-69		
	-10,000	1000	95	1	263 ⁱ	12,500 ⁱ	9-68	11-69		
	-10,000+	1000	95	1	263 ⁱ	12,500 ⁱ	9-68	11-69+		
	-50,000	1000	95	1	301 ⁱ	14,300 ⁱ	9-68	5-74		

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 DF-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 Excursion to >1100°C for 3-6 hr.

e Activity as of 2-67.

f Internal atmosphere air instead of helium.

g Capsule contains ⁶⁰Co but is being heated along with ⁶⁰Co capsules.

h Removed from furnace in April during equipment modifications.

i Activity as of 6-68.

+ Heating time may be extended depending upon results of other tests.

- New information reported.

Chromium specimen. Observed and predicted amounts of oxidation are compared in Table II. Alloys GE-2541 and "Tophet" C had shown excessive interaction with cobalt in earlier compatibility tests and were not tested.⁽⁸⁾

TABLE II

Comparison of Observed and Predicted Oxidation
of Candidate Encapsulating Alloys
in Still Air at 1150°C for 3000 hr

Material	Total Depth Affected by Oxidation, mils	
	Observed	Predicted
"Hastelloy" X	18.0	19.0
"Hastelloy" C	20.5	25.0
"Inconel" 600	38.5	49.0
TD Nickel Chromium	4.0 (40.0) ^a	5.0
"Haynes" 25	175	41.5

^a 40.0 mils in localized area.

Although oxidation of the TD Nickel Chromium was generally as predicted, a tenfold increase was noted in one sector of the specimen, Figure 1. This attack occurred by formation of a subsurface oxide layer and intergranular penetration of oxide along grain boundaries that were depleted of thoria particles. The depleted boundaries did not extend to the center of the specimen nor were they observed in other areas of the specimen that exhibited only surface oxidation. The surface of this rod specimen was covered with a thin, continuous scale typical of the oxidation observed in the previous tests at less severe conditions. Re-examination of samples of TD Nickel Chromium from previous tests revealed another instance of this anomalous attack in a rod specimen oxidized 500 hr at 1000°C, and indicates that the cause may be a fault in the rod sample or a nonuniformity in the alloy.

Contrary to the results of previous tests at less severe conditions, "Haynes" 25 oxidized severely in the accelerated test to form a surface scale approximately four times as thick as that predicted, Table II. A major constituent of the scale was CoWO₄ (see the following section). Tungsten oxides are known to be volatile. Possibly, the increase in oxidation rate occurred when a sufficient amount of tungsten, one of the alloying elements in "Haynes" 25, diffused to the surface to form the volatile oxide. Although tungsten oxides were not detected in samples oxidized for 10,000 hr at 1000°C, a change in rate may occur after some longer time at 1000°C when the tungsten content of the scale reaches a critical level.

a. Transition region between anomalous oxidation (on left) and normal oxidation

b. Anomalous oxidation and depletion of ThO_2 along grain boundaries

c. Surface scale typical of normal oxidation

FIG. 1 ANOMALOUS OXIDATION OF TD NICKEL CHROMIUM (3000 hr in still air at 1150°C)

The results of the accelerated oxidation test at 1150°C promotes confidence that the performance of "Hastelloy" X, "Hastelloy" C and "Inconel" 600 as encapsulating alloys for ^{60}Co can be predicted satisfactorily. The test results, however, reduce the attractiveness of TD Nickel Chromium and "Haynes" 25 as encapsulating alloys. Difficulties have also been encountered in producing sound weldments with these two alloys. Because of these problems no additional studies of oxidation resistance will be started on TD Nickel Chromium and "Haynes" 25, but existing capsules will be continued in test.

Identification of Oxide Scales on Encapsulating Materials

To give added confidence in extrapolating the results of oxidation tests to long service times, the oxidized surfaces of specimens of "Inconel" 600, "Hastelloy" X, "Haynes" 25, and TD Nickel Chromium were examined by X-ray diffraction to identify the compounds present in the oxide. The formation of relatively volatile oxides of certain alloy constituents, such as molybdenum or tungsten, could portend a change in the kinetics of oxidation. Specimens were examined after oxidation in air for 500 hours at 850°C, for 10,000 hours at 1000°C and for 3000 hours at 1150°C.

Cr_2O_3 was a principal constituent of the oxide scales with NiCr_2O_4 or CoCr_2O_4 , CoNiO_2 , ThO_2 , or CoWO_4 also present depending on the alloy and the oxidation conditions, as shown in Table III. The lattice parameters of Cr_2O_3 , NiCr_2O_4 , and CoCr_2O_4 , showed no significant change with time or temperature indicating that other alloying elements, such as iron or molybdenum, did not appreciably contribute to the formation of the scale.

Because of the very small amounts of oxide present on most specimens, X-ray diffraction patterns were taken of the scales directly on the samples. The oxides were identified by comparing the "d" spacings observed on the diffractometer tracings with those reported in the ASTM Index of X-Ray Patterns. Relative intensities of the strongest lines of the different phases in a given scale were used to indicate changes in the concentration of these phases in scales formed at different conditions.

The oxide scales on "Inconel" 600 and "Hastelloy" X were composed of Cr_2O_3 and NiCr_2O_4 as reported in the literature for tests of shorter duration.^(9,10) In general the amount of NiCr_2O_4 relative to the amount of Cr_2O_3 increased as the exposure time increased. The apparent reduction in concentration of NiCr_2O_4 in "Hastelloy" X after 3000 hr at 1150°C may be associated with the observed spalling of the scale.

TABLE III

Phases Detected by X-Ray Diffraction
Examination of Oxidized Superalloys

Material	500 hr at 850°C		10,000 hr at 1000°C		3000 hr at 1150°C	
	Phase	I ^a	Phase	I	Phase	I
"Inconel" 600	Inconel	100	Inconel	13	Inconel	-
	Cr ₂ O ₃	32	Cr ₂ O ₃	33	Cr ₂ O ₃	54
	NiCr ₂ O ₃	35	NiCr ₂ O ₄	100	NiCr ₂ O ₄	100
"Hastelloy" X	Hastelloy	46	Hastelloy	34	Hastelloy	50
	Cr ₂ O ₃	100	Cr ₂ O ₃	100	Cr ₂ O ₃	100
	NiCr ₂ O ₄	68	NiCr ₂ O ₄	77	NiCr ₂ O ₄	<10
"Haynes" 25	Haynes	100	Haynes	100	Haynes	-
	MoC	19	MoC	-	MoC	-
	Cr ₂ O ₃	25	Cr ₂ O ₃	50	Cr ₂ O ₃	-
	CoCr ₂ O ₄	51	CoCr ₂ O ₄	90	CoCr ₂ O ₄	100
	CoNiO ₂	10	CoNiO ₂	-	CoNiO ₂	45
					CoWO ₄	100
TD Nickel Chromium	Ni-Cr	100	Ni-Cr	10	Ni-Cr	20
	ThO ₂	<5	ThO ₂	20	ThO ₂	55
	Cr ₂ O ₃	95	Cr ₂ O ₃	45	Cr ₂ O ₃	35
			NiO	100	NiO	100
					NiCr ₂ O ₃	36

^a Relative intensity of strongest diffraction peak.

The composition of the scale on "Haynes" 25, as well as the oxidation rate, changed with increasing temperature. As noted in the preceding section, the occurrence of CoWO₄, detected only after oxidation at 1150°C, may be responsible for the increased rate of oxidation. The phase "CoCr₂O₄" may also contain nickel because both CoCr₂O₄ and NiCr₂O₄ have the same structure and lattice parameters.

Two changes in the compositions of scales formed on TD Nickel Chromium were noted. The scale was enriched in ThO₂ at higher oxidation temperatures (and amounts of oxidation). In addition, NiCr₂O₄ was present only after exposure to 1150°C.

CAPSULE FABRICATION AND TESTING

Capsule Fabrication

A total of 17 capsules of "Haynes" 25, "Hastelloy" X, "Hastelloy" C, and "Inconel" 600 containing irradiated cobalt were fabricated for heating tests at 900 to 1000°C for 10,000 hr or more.^(e) This selection was based on evaluations of encapsulating materials described in earlier reports of this series. Each capsule is 1.3-in. long and contains about 13,000 Ci (270 Ci/g), Figure 2. Tungsten wafers are included in some of the capsules to provide data on compatibility of tungsten with cobalt and the respective superalloys. Tungsten is a potential shield material and also a material for encapsulation of cobalt metal for service at 1200°C or higher.

FIG. 2 TYPICAL COBALT TEST CAPSULE

Of the 17 capsules initially fabricated, three were rejected because of leaks. One end was ground off each capsule to recover the ^{60}Co wafers, and new capsules were used to re-encapsulate the wafers. The leak test of these new capsules indicated that two were sound while the third contained a leak. Rewelding one end of the third capsule sealed the leak.

All the capsules rejected because of leaks were made from "Haynes" 25, a material that has previously tended to crack during welding.⁽⁴⁾ Modification of the welding procedures appeared to have corrected this problem,⁽⁵⁾ but, the recent rejection of "Haynes" 25 capsules indicates that the cracking problem has not been entirely solved. Metallography of the rejected ^{60}Co capsules showed that cracks were present in the heat-affected zone of some of the welds, Figure 3. The heat from the ^{60}Co within the capsules may have been sufficient to induce crack formation. The joining

of these cracks to form a path through the wall of the capsule is believed to have caused the observed leaks.

Prior to the long-term heating tests all capsules were heated for 4 hours at the expected test temperature; no dimensional changes or loss of integrity (as measured by helium leak tests) were observed. Thermocouples were spot welded to six selected capsules to measure the capsule temperature during the long-term heating tests.

FIG. 3 WELD FROM "HAYNES" 25 CAPSULES CONTAINING ^{60}Co

Capsule Testing

Heating Tests of Capsules Containing Unirradiated Cobalt

Heating tests are continuing on 18 capsules containing unirradiated cobalt to demonstrate structural integrity for 10,000 hr or more at typical heat source conditions (850 to 1000°C), Table I. Four capsules were removed from tests after reaching their goal exposures and are being examined. These include one "Inconel" 600 capsule heated 10,000 hr at 850°C, one "Inconel" 600 capsule with air instead of helium as the internal atmosphere and heated 5000 hr at 1000°C, and two "Hastelloy" X capsules heated 5000 hr at 1000°C. Another "Inconel" 600 capsule was scheduled to be removed from test after 10,000 hr at 850°C but the test was extended to 50,000 hr.

Heating Tests of Capsules Containing Irradiated Cobalt

Twenty-one superalloy capsules, nineteen containing radioactive and two containing nonradioactive cobalt metal, are currently being heated in air at 900 to 1000°C in the High Level Caves (HLC), Table I. The superalloys include "Haynes" 25, "Hastelloy" X, "Hastelloy" C, and "Inconel" 600. The capsules are distributed among the four furnaces described in References 5 and 6. The surface temperatures of five radioactive capsules in two of the furnaces are ~900°C. One capsule contains only 7500 Ci of ^{60}Co (as of 6-30-68) and is in a furnace with three other radioactive capsules each containing about 13,000 Ci of ^{60}Co ; therefore its surface temperature is estimated to be only 870°C because of its lower internal heat generation. The remaining 14 radioactive capsules in two other furnaces have surface temperatures of ~1000°C ($\pm 20^\circ\text{C}$).

The two nonradioactive capsules were fabricated in an out-of-cell facility, and are included in the in-cell heating tests to indicate any effects of gamma radiation from the radioactive capsule (36,500 Ci of ^{60}Co) in the same furnace. The surface temperature of the nonradioactive capsules is near the furnace atmosphere temperature of 850°C. Duplicate capsules will be heated out-of-cell at 850°C.

Six of the radioactive capsules have thermocouples spot-welded to the outer surface to measure the surface temperature. One instrumented capsule is included in each of the two 900°C furnaces and in the small 1000°C furnace; the other three instrumented capsules are in the large 1000°C furnace. The electrical input to each furnace is adjusted to provide the desired capsule temperature (either 900 or 1000°C) as indicated by the thermocouples. Out-of-cell tests with an electrically heated capsule in a typical furnace showed that sheathed thermocouples of 0.040-inch OD are the best compromise between true surface temperature measurement and thermocouple durability.^(e)

HIGH-ACTIVITY ^{60}Co FOR HEAT SOURCE DEVELOPMENT

Table IV lists the high-activity cobalt that is being stored at Savannah River for experimental programs and heat source demonstrations. This table updates Table I of Reference 2. A total of 418 wafers of 0.745-inch diameter have been used for experimental programs at SRL, and 76 such wafers were sent to Thermo Electron Corporation for experiments with ^{60}Co -fueled thermionic generators under an Air Force contract. Miscellaneous shapes originally irradiated to 540-590 Ci/g were shipped to ORNL and ENL for their experimental programs.

TABLE IV

⁶⁰Co for Heat Sources^{a,e}

Cobalt Shape	Average Activity, Ci/g	No. of Pieces	Total Activity, 10 ⁶ Ci	Total Power, kw
<u>0.745-inch Wafers</u>				
Fuel form - cobalt metal (wrought)	340	2090	1.77	27.6
Fuel shape - wafers 0.745 ±0.001-inch diameter	300	912	0.68	10.6
0.040 ±0.003-inch thick	280	1368	0.96	14.9
including 0.0005 to 0.001-inch Ni plate	255	1368	0.87	13.6
Cobalt density - 8.80 ±0.05 g/cm ³	270	152	0.10	1.6 ^b
		5890	4.38	68.3
<u>0.800-inch Wafers</u>				
Fuel form - cobalt metal (sintered)	330	255	0.24	3.7
Fuel shape - wafers 0.800 ±0.001-inch diameter	350	136	0.14	2.2 ^c
0.040 ±0.003-inch thick	300	136	0.11	1.7 ^d
including 0.0005 to 0.001-inch Ni plate		527	0.49	7.6
Cobalt density - 8.60 ±0.10 g/cm ³				
<u>Nickel-Plated Slabs</u>				
Fuel form - cobalt metal (wrought)	330	45	0.25	3.9
Fuel shape - slabs 3.00 ±0.03-inch long	305	48	0.25	3.9
0.640 ±0.002-inch wide		93	0.50	7.8
0.060 ±0.001-inch thick				
including 0.0005 to 0.001-inch Ni plate				
Cobalt density - 8.80 ±0.05 g/cm ³				
<u>Stainless Steel-Canned Slabs</u>				
Fuel form - cobalt metal (wrought)	330	45	0.20	3.1
Fuel shape - slabs 2.96 ±0.03-inch long	280	48	0.19	3.0
0.735 - 0.740-inch wide		93	0.39	6.1
0.092 ±0.001-inch thick				
sheath thickness 0.015-inch min				
cobalt dimensions same as nickel-plated slabs above except 2.44-inch long				
Cobalt density - 8.80 ±0.05 g/cm ³				
<u>Stainless Steel-Coextruded Slabs</u>				
Fuel form - cobalt metal (wrought)	330	60	0.23	3.6
Fuel shape - slabs 3.00 ±0.03-inch long	305	64	0.23	3.6
0.740 ±0.002-inch wide		124	0.46	7.2
0.072 ±0.002-inch thick				
SST thickness 0.015-inch min				
Cobalt dimensions: 2.75-inch long				
0.71-inch wide				
0.042-inch thick				
Cobalt density - 8.80 ±0.05 g/cm ³				
Grand Total			6.22 MCi	97.0 kw

a Activity and power as of September 30, 1968.

b Wafers have central hole of 0.070-inch diameter.

c 110 wafers have experimental compositions, to be used at SRL.

d 68 wafers have central hole of 0.070-inch diameter.

e This table updates Table I of DP-1120-I, the quarterly report for April-June 1967.

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