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AEC RESEARCH AND DEVELOPMENT REPORT

QUALITY ASSURANCE SPECIFICATIONS AND TESTING METHODS FOR BONDED COBALT SLABS

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Savannah River Laboratory

Aiken, South Carolina

Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65

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DP-1152

Engineering and Equipment
(TID-4500)

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July 1968

Issued by

E. I. DU PONT DE NEMOURS & COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, S. C. 29801

CONTRACT AT(07-2)-1 WITH THE
UNITED STATES ATOMIC ENERGY COMMISSION

ABSTRACT

Quality assurance specifications have been established and test procedures have been developed for the production of stainless-steel-bonded slabs of irradiated cobalt. This program assures that the cladding is sound and that the dimensions will allow each slab to be placed into a second standard sheath.

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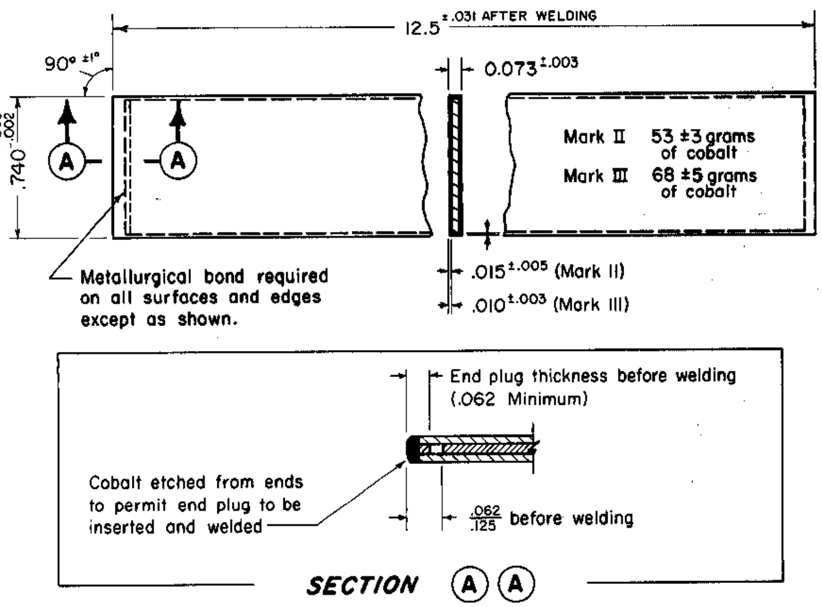
INTRODUCTION

Brookhaven National Laboratory designed cobalt slabs to be irradiated for use as a gamma source in commercial irradiators.[1,2] Slabs of the Mark II and Mark III design are to be irradiated in Savannah River reactors and shipped offsite for final encapsulation. These bonded slabs (Figure 1) are made by coextruding stainless steel and cobalt. The extrusions are cut into 12-1/2-inch lengths, the cobalt is etched out of the ends, stainless steel end plugs are inserted, and a weld is then used to seal each end. All bonded slabs irradiated to date have been fabricated by the Nuclear Metals Division of the Whitaker Corporation, Concord, Massachusetts, by a proprietary process.



NOTES:

- Thickness of finished slab not to vary more than 0.002 inch from end to end. Including weld overhang, thickness must not exceed 0.082.
- Slab bow must not exceed 0.02 inch per foot of length and 0.0025 inch per inch of width.
- Slab twist must not exceed 1° per foot of length.
- Maximum permissible surface mar: 0.003 inch on sheath; 0.001 inch on weld.
- Including weld overhang, width must not exceed 0.755 inch.

FIG. 1 MARK II AND MARK III STAINLESS-STEEL-BONDED COBALT SLABS

To assure the quality of the irradiated slabs to be shipped, the Savannah River Plant specified the purity of the cobalt and the quality of the slabs, certified a fabrication process, and developed a series of preirradiation and postirradiation tests.

SPECIFICATIONS FOR RAW MATERIALS

Cobalt Purity

Specifications for cobalt purity were set to minimize unwanted neutron-induced radiations in the irradiated slabs and to reduce parasitic neutron capture during irradiation. These specifications and a typical analysis are shown below.

Element	Specified Maximum, ppm	Typical Analysis, ppm
Nickel[(a)]	1500	450
Iron	1000	20
Copper	100	3
Oxygen	100	ND
Silicon	100	<1
Thorium	100	ND
Uranium	100	ND
Aluminum	50	<10
Cadmium	50	ND
Manganese	50	<10
Lead	50	<10
Sulfur	50	39
Chromium	20	<10
Molybdenum	20	10
Vanadium	20	<1
Tungsten	20	ND
Phosphorus	10	ND
Boron	5	<5
Gadolinium	5	ND
Lithium	5	ND

(a) Cobalt + nickel must be ≥99.9%. This purity is calculated as 100% less the total of all impurities except nickel.

Stainless Steel

No additional specifications were set for the AISI 316L stainless steel to be used for the sheaths, but a certified mill analysis for each lot will be approved before use.

FABRICATION PROCESS

The process used by the manufacturer to clad the cobalt is certified by the Savannah River Plant. Any changes from the certified process must be approved. The certified process requires that:

- Cobalt and stainless steel surfaces be cleaned before extrusion to reduce contamination at the cobalt-stainless steel interface.
- Stainless steel be free from sensitization and intergranular attack on both inside and outside surfaces before and after extrusion.
- The surface of each completed slab be cleaned by an acid etch.

SPECIFICATIONS FOR SLABS

1. Dimensional specifications are given in Figure 1.
2. End welds must have a minimum throat thickness of 0.007 inch. Welds may not be ground because defects may be obscured.
3. Welds may not contain more than 4000 ppm of cobalt.
4. No individual nonbonded areas may exceed one-eighth-inch diameter.
5. Stainless steel sheaths must not be sensitized, and must be free from any intergranular attack.
6. Each slab is to be identified by extrusion number and slab position within the strip. The identification number is to be etched on each slab near one end; the depth of the etching must not exceed 0.002 inch.

PREIRRADIATION TESTS

Nondestructive Testing

All slabs to be irradiated are tested for the following:

Surface Condition. Slabs are visually inspected to detect surface irregularities.

External Dimensions. Slabs are measured to check external dimensions.

Cladding Thickness. Cladding thickness is determined with a Magnetic Reaction Analyzer* Model 1090.

Bond Integrity. Bond integrity is determined by an ultrasonic test with a "Reflectoscope"** Model UM700 with a "Transigate Alarm"** Model E550.

Internal Dimensions. Slabs are X-rayed to measure the length of the cobalt core, widths of gaps under the end caps, thicknesses of the weld throats, and the thickness of the cladding at the edges.

Weld Integrity. Slabs are sent to the General Electric Pinellas Peninsula Plant in St. Petersburg, Florida, for krypton leak testing. This test will detect leaks greater than 1 x 10^{-5} atm cc/sec.

Destructive Testing

At least 3% of the slabs received from the supplier are destructively examined at Savannah River. Slabs are selected to represent as many extrusions as possible. In addition, one-quarter-inch-long sections at the front, middle, and rear of each extrusion are furnished by the supplier for metallographic examination.

The destructive examination includes determination of the following:

Weld Integrity. The thicknesses of the weld throats are measured.

Cobalt Content of Welds. The cobalt content of the welds is determined chemically by a colorimetric test.

Bond Quality. Bond quality is determined by photomicrographic examination as illustrated in Figure 2.

Sensitization and Intergranular Corrosion of the Cladding. This is determined by photomicrographic examination. Intergranular attack is illustrated in Figure 3. Sensitization is illustrated in Figure 4.

* F. W. Bell, Inc., Columbus, Ohio.

** Trademark of Sperry Products, Inc., Danbury, Conn.

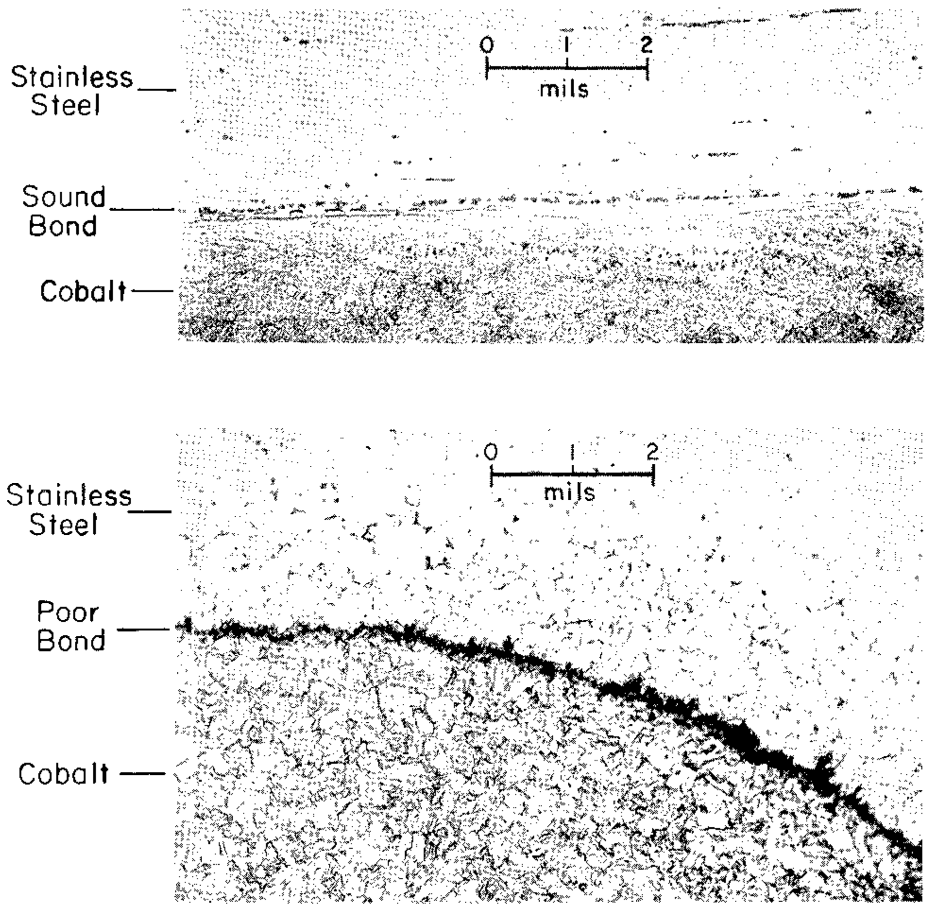
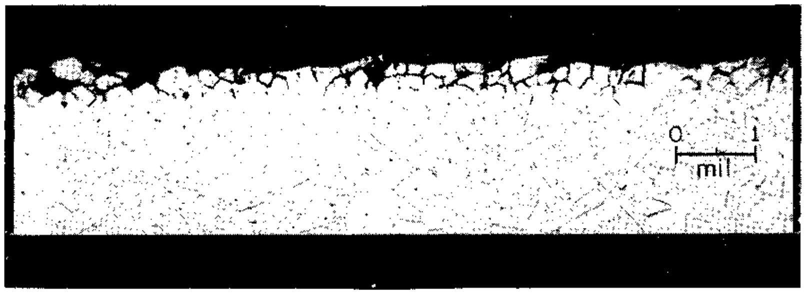
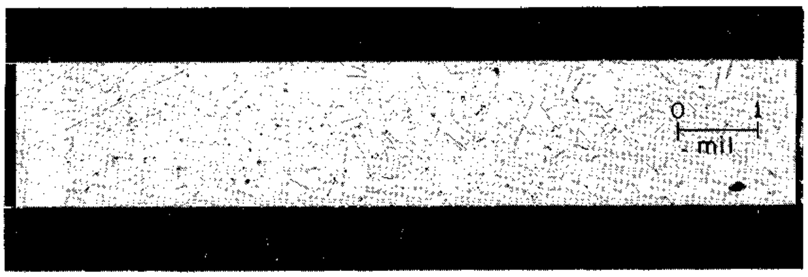


FIG. 2 BOND QUALITY



Intergranular Attack



No Intergranular Attack

FIG. 3 PHOTOMICROGRAPHS DETECT INTERGRANULAR ATTACK

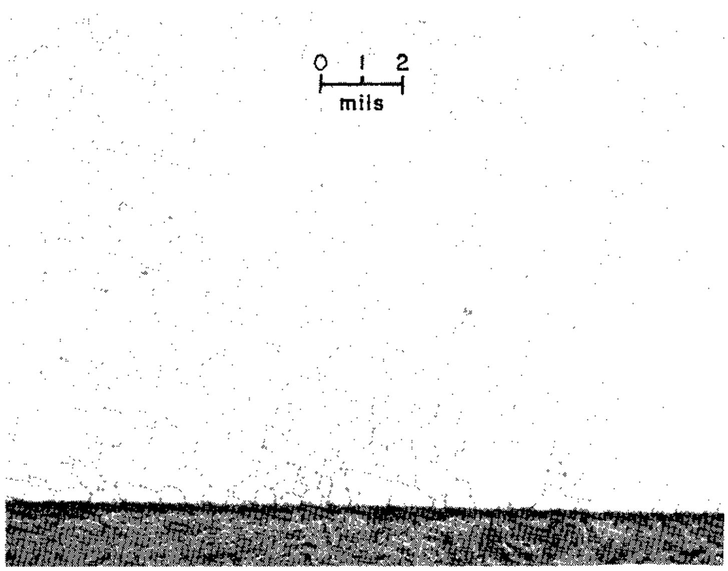


FIG. 4 CARBIDE FORMATION INDICATES SENSITIZATION IN STAINLESS STEEL

POSTIRRADIATION TESTS

Assay

The total activity of the cobalt slabs is measured to within 1% by an ion chamber and underwater calorimeter. The slabs are assayed in pairs. The activity of an average pair is measured accurately with the calorimeter. This pair is then used as a standard to calibrate the ion chamber. Each slab pair is assayed by the ion chamber; the activity in curies (proportional to the current output) is recorded. After assaying a group of slabs, the ion-chamber calibration is rechecked against the calorimeter.

Visual Examination

All slabs are inspected to detect any physical changes that may have occurred during irradiation or postirradiation handling. Slabs that have gouges, scratches, or other physical abnormalities that appreciably reduce the effectiveness of the sheath are rejected. The maximum permissible surface mar is 0.003 inch.

Gaging

All irradiated slabs are passed through a second encapsulation sheath (Figure 5) to eliminate slabs that the second encapsulator would find difficult to process. Slabs that do not pass through the sheath are rejected. (Rejected slabs may be retested after minor straightening.)

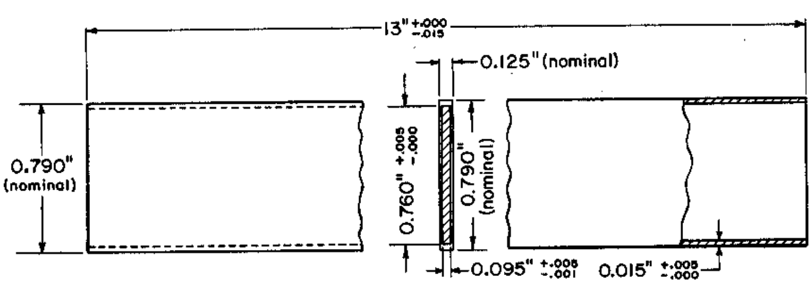


FIG. 5 SECOND ENCAPSULATION SHEATH

Cladding Integrity

In addition to the visual examination, cladding integrity is checked by determining the surface activity of the slab. Since cobalt is a minor constituent in all stainless steels (approximately 0.05%), cobalt-60 will always be present on the surface of the slab after irradiation regardless of the amount of post-irradiation cleaning. Experience of second encapsulators as well as at Savannah River indicates that cobalt activity in the sheath material will be approximately 1×10^6 dis/min for a slab irradiated to a low specific activity (<100 Ci/g).

Surface activity of the cladding is measured by smearing the entire surface of the dry slab. Slabs that smear ≥10 times the average for the group are rejected.

REFERENCES

1. O. A. Kuhl, A. Oltmann, and J. Wagner. Report on the Mark II BNL Standard Cobalt Radiation Source, Bonded Type. USAEC Report BNL 986, Brookhaven National Laboratory, Upton, N. Y. (1966).

2. A. Oltmann and O. A. Kuhl. Fabrication of BNL Standard Cobalt-60 Sources. USAEC Report BNL 848, Brookhaven National Laboratory, Upton, N. Y. (1964).