37. ✓ Isotopic Power Source Development

R. J. Beaver

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The materials program in support of isotopic power source development programs was continued. The stringent engineering and safety requirements involved demand very-high-quality materials for containing the isotopic fuels and procedures for sealing these containers. The materials of interest for these applications are the superalloys and refractory-metal alloys.

Our efforts were centered mainly on welding development, nondestructive testing, and a design study on a Brayton cycle power system. Welding development was conducted on refractory-metal capsules of the molybdenum alloy TZM as well as on Hastelloy C capsules for SNAP-21. The non-destructive testing effort was devoted to the evaluation of capsule components and more recently to the inspection of welded fuel-containing capsules for the SNAP-21 program.

In addition, a paper was presented describing work on the compatibility of curium fuels with candidate container materials.¹

WELDING OF REFRACTORY-ALLOY CAPSULES

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The sealing of containers for alpha-emitting isotopic heat sources requires that sound welds having full penetration be made in heavy-walled refractory-metal capsules. This requirement stems from the fact that the helium generated by the decay of the isotope is of sufficient magnitude that these capsules must serve as pressure vessels.

¹J. R. DiStefano and W. D. Box, "Compatibility Studies for High-Temperature Radioisotopic Power Source Applications," paper presented at the 1966 IEEE Thermionic Conversion Specialist Conference, Nov. 3 and 4, 1966, Houston (classified).

Previously,² we described equipment used for making joints of this type by electron-beam welding. However, under certain conditions it may not be desirable or feasible to use the electron-beam welding process. Therefore, we evaluated the conventional gas tungsten-arc welding process as a method for making joints of this type.

With the electron-beam method, adequate atmosphere purity during the welding operation is assured by the high vacuum (approximately 5×10^{-5} torr) inherent with the process. However, to prevent contamination of refractory metals by interstitial elements such as C, O, H, and N during arc welding, the operations must be carried out in a chamber purged of air and containing only high-purity argon or helium. Using a specially designed and constructed chamber, the welding of end caps to molybdenum alloy TZM containers with a 0.150-in.-thick wall was investigated. The heat buildup inside the capsule while making full-penetration welds of this type was so intense that a vent was needed for the expanding gas. After the primary weld had been made, the small-diameter vent could be welded shut with much less total energy input.

Techniques using this procedure were developed to make full-penetration primary welds successfully and repeatedly. A typical weld of this type is shown in Fig. 37.1. As can be seen from the figure, the weld is sound and has a penetration of at least the wall thickness of the capsule. This particular joint design employed a recess in the cap in the area of the weld to assist in assuring full penetration. The conditions used in making this weld were: welding current, 360 amp; travel speed, 10 in./min; revolutions, 1. The vent hole

²R. G. Donnelly, *Metals and Ceramics Div. Ann. Progr. Rept.* June 30, 1966, ORNL-3970, pp. 225-27.

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Fig. 37.1. Typical Primary Closure Weld of a TZM Container. 3.5 $\times$. Note that the weld is sound and that full penetration was achieved.

was subsequently sealed by inserting a tapered pin to help fill the hole and then welding for 7 sec at 230 amp, using the same equipment that was used for the primary weld.

WELDING DEVELOPMENT FOR SNAP-21

R. G. Donnelly

The SNAP-21 heat source is being developed by ORNL in cooperation with the 3M Company. This $^{90}\text{SrTiO}_3$ source will generate 200 w (thermal) and is intended for use under the sea. The capsule is $\frac{1}{4}$ -in.-thick Hastelloy C and must be sealed by welding to ensure mechanical strength and leak-tightness. A requirement of the joint design is that the weld be inspectable by ultrasonic techniques. Ideally, this means that the top outside edge of the capsule should remain undisturbed by welding; at least, the weld penetration must be greater than the depth of edge melting. If these conditions are not met, the joint to be inspected is masked by the surface of the weld.

Figure 37.2 compares joints made by three techniques. Initial gas tungsten-arc welding experiments failed to attain the required 0.100 in. of defect-free weld-metal penetration without edge melting (Fig. 37.2a). This weld was obtained with the end cap beveled at a 30° angle for 0.100 in.

Adequate weld penetration was obtained by melting over the edge of the capsule as shown in Fig. 37.2b, but this violated the requirement for ultrasonic weld inspection.

The desired combination of weld penetration and inspectability was ultimately provided by electron-beam welding. Figure 37.2c shows an electron-beam weld made at 30 kv with 130 ma of beam current and a travel speed of 35 in./min. Equipment capable of making welds of this type is presently being assembled in cooperation with Isotopes Division personnel for installation in the hot cells.

NONDESTRUCTIVE TESTING SUPPORT

K. V. Cook

Because of the toxic and radioactive nature of the core materials contained in isotopic heat sources, the integrity of the container must be assured through a reliable nondestructive testing program. Most of the isotope-enclosure materials are refractory alloys or superalloys, and there is very little nondestructive testing experience with these materials. Our purpose is to satisfy two basic requirements: (1) to assure the material integrity and (2) to build a background of familiarity with the testing characteristics of these materials.

Fig. 37.2 Experimental Hastelloy C Welds for SNAP-21 Heat Source Program. 10 $\times$. (a) Tungsten-arc weld made with beveled joint. Insufficient weld penetration was obtained. (b) Tungsten-arc weld with adequate penetration but unacceptable because the capsule edge contour prevents weld inspection. (c) Electron-beam weld having both adequate penetration and acceptable edge contour. Reduced 42%.

Basically, we are adapting or developing non-destructive testing techniques for two separate tasks. The first is testing the capsule material before loading. The second is remote inspection of the closure weld following the capsule loading.

For the raw material evaluations, we have generally used fluorescent penetrant and ultrasonic inspection methods, although at times other techniques have been required. While the penetrant test is relatively easy to adapt to the isotope program, one must be careful because meaningless results are possible. For instance, with tantalum-base alloys, we found that smearing of the surface during capsule machining could close cracks or discontinuities normally open to the surface and thus render them undetectable by the penetrant examination. A very light etch removes this smearing and allows a meaningful test to be performed.

The ultrasonic pulse-echo technique normally used for plate, sheet, bar, and tubing inspections is presently being applied to the inspection of capsule materials. Our major problems in applying the ultrasonic technique have involved the fixtures necessary for adequate mechanical scanning of the various capsule configurations and the establishment of reliable and reproducible reference discontinuities.

Our work involving the second-stage evaluation has dealt entirely with the SNAP-21 Program. The Pacific Northwest Laboratory was assigned the responsibility by the 3M Company for developing an inspection technique and remote inspection equipment to evaluate the closure weld on the SNAP-21 capsule. Our responsibility is to follow this development to assure a smooth transfer of technology, to ensure a well-designed remote inspection facility by supplying necessary design criteria, and, following the delivery and installation of the system at ORNL, to operate the remote system for hot-cell testing of both fueled and unfueled capsule weldments.

BRAYTON CYCLE STUDIES

R. J. Beaver

As part of an integrated effort at ORNL, we reviewed materials that appeared attractive as encapsulating materials for isotopic heat sources with energy potential for powering a 25-kw Brayton

engine for space application.^{3,4} The results of these studies indicated that either of the tantalum-base alloys T-111 or T-222 was acceptable for the stress-bearing encapsulating member. However, because of their poor oxidation resistance at elevated temperatures, these alloys would have to be protected with a thin cladding of platinum. Thoria was suggested as a barrier to prevent diffusion between the tantalum and the platinum, and iron titanate was recommended as a coating for

the platinum to achieve an acceptable value of emissivity.

³R. A. Robinson, R. J. Beaver, D. W. Burton, T. C. Chapman, C. W. Craven, Jr., S. T. Ewing, A. J. Miller, J. P. Nichols, and R. L. Stephenson, *Brayton-Cycle Radioisotope Heat Source Design Study Phase I (Conceptual Design) Report*, ORNL-TM-1691 De1. (NASA CR-72090) (August 1967).

⁴R. A. Robinson *et al.*, *Brayton-Cycle Radioisotope Heat Source Design Study Phase II (Preliminary Design) Report*, ORNL-TM-1829 (NASA CR-72151) (August 1967).