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of Pt + 20 Wt % Rh Heat
Source (ACE) Liner Bodies***

D. A. Pawlak and W. C. Wyder

June 15, 1973

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ABSTRACT

This report describes the fabrication of Pt + 20 wt % Rh liner bodies for a U. S. Army Corps of Engineers radioisotopic heat source similar in design to the Milliwatt Generator (MWG) heat source. Strain hardening, component design and poor draw quality material required a two-stage drawing operation with an intermediate anneal. First and second draw tooling were designed, fabricated and successfully applied in the forming of liner bodies to desired specifications.

INTRODUCTION

Fabrication of the Pt + 20 wt % Rh liner body was developed as part of the U. S. Army Corps of Engineers (ACE) heat source program. This program required the production of a heat block into which four individual radioisotopic heat sources would be welded. These individual heat sources are identical to the Milliwatt Generator (MWG) Heat Source, with the exception that the liner assembly is fabricated from 0.020-in. thick Pt + 20 wt % Rh instead of the T-111 (Ta + 8 wt % W + 2 wt % Hf) alloy used in the MWG source (see Figure 1A).

The T-111 liner components for the MWG source were fabricated by blanking the shims, blanking and coining the caps, and blanking and drawing the bodies. The T-111 bodies were drawn in one operation using conventional drawing dies. Similarly, the Pt + 20 wt % Rh shims and liner caps were blanked and coined. However, the drawing of the liner bodies presented new problems which are discussed in this report.

MATERIAL

The use of Pt + 20 wt % Rh as an encapsulating material for a radioisotopic heat source was not unique to the ACE program. The alloy was first used to encapsulate the fuel for the Artificial Heart heat source. Power demands and dimensional requirements were different for both programs.

The nominal dimensions of the liner body for the ACE source were 0.715-in. i.d., 0.775-in. inside length, and a 0.020-in. thick wall. An exception was made in the wall thickness; it was permitted to be 0.015-in. thick in the bottom or spherical end. The 0.015-in. thick bottom was the result of stretching and subsequent thinning which occurred when the spherical portion of the shell was formed. Therefore, it was necessary to procure 0.020-in. thick starting material.

The only Pt + 20 wt % Rh on hand at Mound Laboratory consisted of 8-in. diam blanks 0.026-in. thick which were rejected from use on the Pioneer* and Transit** programs because of poor surface finish and some identified

*The AEC "Pioneer" program supported the NASA Jupiter flyby mission wherein Mound Laboratory fabricated heat sources for the Radioisotopic Thermoelectric Generator.

**In cooperation with TRW systems, Mound Laboratory participated in the fabrication and testing of the isotopically-fueled 5-year-life Transit generator for the U. S. Navy's advanced navigational satellite.

(A)

(B)

FIGURE 1 - (A) U. S. Army Corps of Engineers (ACE) heat source design and (B) photograph depicting the relative size of the liner components.

surface defects. These blanks were also poor in drawability because of the large degree of preferred grain orientation which resulted in extensive earring. Therefore, strips 1.6-in. wide were sheared from the blanks, care being taken not to include any of the identified defective material. These strips were cross-rolled 0.020-in. thick, cleaned, and annealed for 1 hr at 1600°F in a vacuum. The strips were then sheared into squares for fabrication into circular blanks.

HYDROFORMING

Because of the preferred orientation of the Pt + 20 wt % Rh, the first attempt at forming the liner body utilized the hydroform process. Several Pt + 20 wt % Rh 1.600-in. diam blanks were individually centered, sandwiched between two 2-in. diam waster sheets (0.030-in. thick mild steel outside and 0.010-in. thick brass inside), and hydroformed. It was hoped that the waster sheets would reduce the earring. Unfortunately, the results were negative and the spherical bottom of the shells fractured at all hydroform parameters (see Figure 2). Failure was attributed to a waster sheet with too large of a diameter. This resulted in too great a reduction (62%) from the original waster sheet diameter to final diameter.

Waster sheet diameters were then reduced to 1.75 in. and several more assemblies hydroformed. The results were positive in that a shell was formed. However, the body was too short and wrinkled on the top edge. These problems were also related to waster sheet size inadequacy since the blank was too small to provide an adequate flange at the end of the forming cycle.

Larger size waster sheets with a 1.87-in. diam were then made and deep drawn along with the Pt + 20 wt % Rh blanks. These drew well to approximately 1 in., at which point all of the shells wrinkled at the top edge (see Figure 2). The wrinkling indicated that the blank holddown pressure was insufficient and would have to be increased. It was also noted that the spherical radius on the punch surface had to be grit blasted or the centers of the blanks would pop out. Grit blasting the punch uniformly distributes the forming stresses in the blank farther back from the center of the blank, whereas the smooth spherical surface of the punch concentrates the forming force near the center where the resulting stresses exceed the strength of the material.

After grit blasting the punch, the shells were formed but they again wrinkled at the top edges. Attempts to reduce wrinkling by increasing blank holddown pressure were unsuccessful. When the pressure was increased, the centers of the blanks separated. Therefore, another technique would have to be applied since the liner body could not be drawn on the hydroform press in one step.

MWG CONVENTIONAL TOOLING

Although the size and configuration of the ACE heat source liner body was the same as the MWG heat source, one significant difference was the use of Pt + 20 wt % Rh material in place of the much stronger T-111 alloy. Subsequently, attempts were made to conventionally draw the ACE liner body using 1.555-in. diam blanks (annealed and unannealed states) on MWG tooling. However, they would not draw; the centers of the blanks fractured

FIGURE 2 - Results of first attempts at hydroforming the liner body.

at all the various forming parameters applied (see Figure 3). It was then concluded that the ACE liner body could not be drawn in one step (as in the case of the MWG T-111 liner body) either on the hydroform press or by using MWG one-stage conventional tooling. A two-stage draw technique would have to be developed and applied.

NEW CONVENTIONAL TOOLING

Because of the manner in which the forming procedure was developed, two different sets (punches, dies, pressure pads) of tooling were used (Figures 4 and 5). The first draw tooling design (Figure 6) consisted of the following: a brass punch 1.002-in. diam with a 45° taper, a 0.357-in. spherical nose radius and a 1/8-in. side blend radius; an Ampco DiBronze 25 die with a 1.047-in. diam hole and 3/16-in. radius; and a brass pressure pad with a blank retainer cavity. Second or final draw tooling (Figure 7) was fabricated using hardened 55-60 Rc tool steel and consisted of a 0.715 ± 0.0005 -in. diam punch with a 0.357/0.358-in. spherical radius, and a die with a 0.760/0.761-in. diam hole, a 1/4 in. die radius, and a 45° and 5° lead and exit angles, respectively. The pressure pad contained a sleeve 1-in. long with a 0.995/0.999-in. o.d., a 45° taper and a 1/8-in. side blend radius.

Dimensional reliability of both sets of tooling had to be quite strict, since the first draw form had to be sized to fit the second draw tooling, and the second draw form was the desired final product. It should also be noted that the second draw punch spherical radius was grit blasted providing a rough surface for slippage reduction between the cup and the punch. This reduced material elongation and thinning. Also, the same type lubricant, Cimflo-10, a product of Cincinnati Millicron Corporation, was used with both sets of tooling.

FABRICATION PARAMETERS

Fabrication of the liner bodies utilized a two-stage drawing process with an intermediate cup edge anneal. Both stages of forming were done on a Tinius Olsen, Model A-40 Ductomatic floor-mounted testing machine which is readily adaptable to forming small cup, cone or shell like parts. Form dimensions cannot exceed approximately 3 x 3 in.

The first draw required a high holddown pressure of 1000 lb and a blank retainer cavity in the pressure pad (see Figure 4). The punch forming rate was 1.75 in./min. Using these conditions, the predraw cup was successfully formed.

The second draw required a very low holddown pressure, approximately 30 to 50 lb. The punch forming rate was 1.0 in./min. These conditions produced the final liner body form (see Figure 8).

FABRICATION PROCEDURE - TWO DRAWS

A 1.555-in. diam blank was drawn to a 1-in. diam cup using the 45° taper spherical-nosed punch with a generous radius. After the second draw, the cup length was a fraction too short because of material earring, hence, a larger size (1.600-in. diam) blank was tried which yielded the desired cup length (see Figure 8).

FIGURE 3 - First draw results using Milliwatt Generator tooling.

FIGURE 4 - First draw tooling.

FIGURE 5 - Second draw tooling.

Punch

Die

Pressure Pad

FIGURE 6 - First draw tooling design.

Punch

Die

Pressure Pad

FIGURE 7 - Second or final draw tooling design.

FIGURE 8 - Final liner body shown in sequential forms.

Initially, forming problems were encountered. The cup would fracture radially during the second draw (see Figure 9). The cause was related to an intermediate vacuum annealing step between draws (1600°F for 1 hr). This caused the first draw cup to become too soft, elongate, thin and fracture along the spherical radius. Unannealed first draw cups were then subjected to a second draw. They also failed by separating equatorially around the bottom of the shell because of strain hardening in the first draw cup at the top (cylindrical shell area). As a result, the first draw cups were gas-hand-torch-edge-annealed (cup cylindrical shell area) in air.

After edge annealing the first draw cups, they were subjected to the second draw. The results were positive; all shells drew well and met liner body specifications. However, all bodies had to be edge-machined to the proper length.

CLEANING AND ANNEALING

After all the liner bodies were fabricated and machine-finished, they were cleaned and annealed. Cleaning consisted of a 2 to 5-min dip in a trichloroethylene ultrasonic bath with an acetone and water rinse. The bodies were further cleaned for 5 min in a 75% nitric acid - 25% hydrochloric acid solution and rinsed in water and ethanol. They were then blown dry with air. After drying, they were annealed in a Brew High Vacuum Furnace for 1 hr at 1600°F. Fabrication procedures were now complete. The liner bodies were ready for Quality Control evaluation, fuel loading and encapsulation.

Paul F. Carpenter, Editor

FIGURE 9 - Second or final draw results showing radial fracture in two cups.

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