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THE FEASIBILITY OF CENTRIFUGAL CASTING
FOR MANUFACTURING MASURCA ELEMENTS

by

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ABSTRACT

Experiments were performed to establish the feasibility of manufacturing Masurca* elements by centrifugal casting U-25w/oPu-1.5w/oFe alloy into thin-walled, stainless steel jackets. This process simplifies the fabrication of jacketed elements and reduces the number of steps required to fabricate the fuel element. One casting was made with U-6w/oFe alloy, two others with the plutonium alloy. One plutonium alloy element was finished after casting. The process appears practical. The jackets were not attacked by the plutonium alloy and no bonding occurred.

INTRODUCTION

Masurca is a fast zero-power assembly at Cadarache, France. The Masurca element is shown in Figure 1. This work was intended to show whether it is possible to manufacture Masurca elements by centrifugal casting the fissile alloy cores into the stainless steel jackets.

Figure 1. Masurca Element (all dimensions in mm)

No bonding or reaction between the steel and the plutonium fissile alloy is desired, but the core slug should closely fit the jacket. To prevent such bonding during the casting of the core alloy the stainless steel jackets, which served as mold liners, were clamped between close-fitting,

*Masurca is the fast zero-power assembly at Cadarache, France.

split copper molds. During casting, the molds acted as heat sinks which drain heat from the thin steel walls and prevent reaction between the steel and the plutonium alloy. After the casting operation, the sprue was counter-bored below the lip of the jacket, the jacket opening was carefully cleaned, and the closure plug inserted and welded.

THE FABRICATION SEQUENCE

The stages in the fabrication of Masurca elements, shown schematically in Figure 2, were as follows:

1. Jacket Preparation

The jacket material consisted of commercially available Type 304 stainless steel seamless tubing and bar stock. The tubing (ID: 12.10 ± 0.102 mm; wall thickness: 0.25 mm) was within specified tolerances. End-plugs were machined from the bar stock and TIG welded to the tubes. The welded seams were leak tested with a helium mass spectrometer leak detector.

STAINLESS STEEL TUBE AND END PLUG

TUBE WITH GRAPHITE SLEEVE AND SILVER FOIL

CENTRIFUGAL CASTING

MACHINED TOP, DECONTAMINATION

POSITIONING END PLUG AND WELDING

Figure 2. Fabrication Stages

The jackets were clamped between copper split molds in the centrifugal casting furnace. Figure 3 is an illustration of the mold-foil-jacket assembly.

3. Casting

The furnace used for these experiments has been described in report ANL-5499.⁽¹⁾

2. Casting Preparation

A close-fitting graphite sleeve was slipped into the open end of each jacket. This prevented the molten metal from contacting the top end of the jacket, thereby eliminating gross contamination. The graphite sleeve reduced the sprue diameter, allowing it to be broken near the casting, and limited waste in a subsequent turning operation. The assembly was wrapped in two layers of 25- μ silver foil, which reduced contamination of the outside of the jacket during casting and machining. The prepared jackets were

Figure 3
Cross Section of Fuel
after Casting

The first melt was a U-6w/oFe alloy. In this experiment four open-end steel jackets were used. Four 6.35-mm-diameter molds were bored and reamed to 12.7-mm diameter. Twelve other molds were left with the original cavity dimensions, i.e., a 6.35-mm inside diameter; 240 mm deep. Both jacketed and bare castings were made in this operation. The conditions for centrifugal casting are shown in Table I.

Table I

CASTING CONDITIONS FOR U-6w/oFe ALLOY

Charge Weight	3700 g
Temperature of Melt Prior to Casting	1170°C
Vacuum	1×10^{-2} torr
Temperature of Distributor Prior to Casting	370°C
Maximum Temperature of Distributor while Casting	860°C
Rotor Speed	350 rpm

All four steel tubes are shown in Figure 4 after filling. During disassembly, the alloy broke in the graphite sleeve, as desired. The twelve 6.36-mm-diameter bare castings are shown in Figure 5.

Figure 4
Steel Tubes Filled
with U-6w/oFe

350-565

Figure 5
6.35-mm-diameter
Bare Pins of U-6w/oFe

350-566

A U-25w/oPu-1.5w/oFe alloy was prepared for the second melt. The solidus-liquidus range of this alloy is from 665 to 825°C. A new distributor which reduced the number of mold locations from 16 to 6 was designed and built. Stainless steel jackets were placed in four molds. The other two molds were left with the 6.35-mm diameter and were used without jackets. The conditions for casting this melt are shown in Table II.

Table II

CASTING CONDITIONS FOR U-25w/oPu-1.5w/oFe ALLOY

Charge Weight	1925 g
Temperature of Melt Prior to Casting	1170°C
Vacuum	1×10^{-3} torr
Temperature of Distributor Prior to Casting	295°C
Maximum Temperature of Distributor while Casting	640°C
Rotor Speed	350 rpm

The results of this casting were unsatisfactory. Two of the four jackets were only three-fourths filled and the others were one-half full. The distributor was somewhat cooler (205°C) when these specimens were cast than during the first experiment (370°C). Much more of the metal remained frozen in the distributors. Three of the partially charged and one new, empty steel jacket were used in the third casting. During this cast the three partially charged jackets were filled, while the empty one was filled to within 15 mm of the rim. Table III shows the conditions for the third cast.

Table III

RECASTING CONDITIONS FOR U-25w/oPu-1.5w/oFe ALLOY

Charge Weight	1340 g
Temperature of Melt Prior to Casting	1230°C
Vacuum	1×10^{-3} torr
Temperature of Distributor Prior to Casting	362°C
Maximum Temperature of Distributor while Casting	780°C
Rotor Speed	350 rpm

Although optimum casting parameters were not yet established, extrapolation of casting length vs. distributor temperature indicated that a distributor temperature of 450 to 500°C should be reached before casting to assure complete filling of the jackets.

Two conditions contributed to the casting difficulties. The distributor heater used for these experiments was not designed for operation at sufficiently high temperature and, with the relatively small quantity of U-25w/oPu-1.5w/oFe alloy cast, insufficient heat is transferred to the distributor from the melt. A part of the value of this study is the recognition of such problems and the suggestion of solutions.

4. Machining and Decontamination

One of the cast elements was completed. The casting sprue and graphite sleeve were removed by boring.

The first step in decontamination was a careful cleaning of the open end of the jacket by wiping with dry tissue. The protecting silver foil was then removed from the jacket. Further decontamination steps reduced the surface activity until no more activity could be wiped off. The jacket rim was again wiped until alpha counts on the wipes were below 500 dpm.

5. Welding

The end plug was inserted and TIG welded to the steel jacket under the conditions given in Table IV.

Table IV

WELDING CONDITIONS

DC Machine	-
Diameter of Electrode	1.0 mm
Rotating Speed of Work Piece	13 rpm
Arc Starting Current	20 A
Welding Current	17 A
Inert Gas Flow	56 liters/hr
Inert Gas Composition	50 v/o Ar-He

EXAMINATION OF THE FINISHED ELEMENT

Figure 6 shows the completed element. The total length was 101.92 mm; the OD of the jacket, which was not changed by the casting, was 12.6 mm; the element weight was 208.18 g; the plutonium alloy core weight was 197.86 g. At a density of 18.33 g/cm^3 the core should have weighed 4 to 5 percent more. Photomicrographs showed small cavities in the alloy.

350-618

Figure 6. Finished Masurca Element

As required, there was no evidence of reaction between the jacket and core. A radial shrinkage gap of 0.02 to 0.03 mm was observed between the casting and the jacket wall. As a result, it was possible to push the cast slug from the jacket. Such a decanned piece of U-6w/oFe alloy, together with the empty steel tube, is shown in Figure 7. The inner surface of the jacket appeared to be unaffected by the casting operation.

After welding, the alpha activity near the top of the finished element was 9000 dpm. On the outer surface of the jacket an activity of 1500 dpm was measured. No further effort was made to reduce this activity, although a slight etching of the surface with acid might have been effective. Remaining alpha activity then could be fixed by electroplating the element with nickel.

Figure 7
Decanned U-6w/oFe
Fuel Pin

350-620

The gamma radiation of the finished element was 18 mr/h measured at a distance of 25 mm. This gamma radiation level may be a factor of consideration for large-scale manufacture and is a function of the isotopic composition of the plutonium which was:

Pu^{239} - 91.36%; Pu^{240} - 7.86; Pu^{241} - 0.75; Pu^{242} - 0.03.

SUMMARY AND CONCLUSION

Centrifugal casting of the U-25w/oPu-1.5w/oFe alloy into steel jackets can be considered a feasible method for the manufacture of Masurca elements. No major difficulties appear to exist. In the case of a large-scale fabrication, further development of casting parameters, decontamination procedures, electroplating, and leak detection is recommended.

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REFERENCE

1. A. B. Shuck and R. M. Mayfield, The Process Equipment and Protective Enclosures Designed for the Fuel Fabrication Facility No. 350, ANL-5499 (Jan. 1956).