CA7602451

PREPARATION OF THIN ACTINIDE METAL DISKS USING A MULTIPLE DISK CASTING TECHNIQUE

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ACKNOWLEDGEMENT

The information contained in this article was developed during the course of work under contract AT(29-1)-1106 with the U. S. Atomic Energy Commission.

ABSTRACT

A casting technique has been developed for preparing multiple actinide metal disks which have a minimum thickness of 0.006 inch. This technique was based on an injection casting procedure which utilizes the weight of a tantalum metal rod to force the molten metal into the mold cavity. Using the proper mold design and casting parameters, it has been possible to prepare ten 1/2 inch diameter neptunium or plutonium metal disks in a single casting. This casting technique is capable of producing disks which are very uniform. The average thickness of the disks from a typical casting will vary no more than 0.001 inch and the variation in the thickness of the individual disks will range from 0.0001 to 0.0005 inch.

INTRODUCTION

The Rocky Flats Plant has been involved for several years in the preparation of actinide metal targets and target materials for research and diagnostic purposes.[1,2] The target materials are usually highly purified both isotopically and chemically. Since these materials are expensive to prepare and are available only in limited quantities, the techniques used to prepare targets from these materials should generate as little scrap as possible. Precision casting techniques have been developed at Rocky Flats for preparing small actinide metal targets.[3] These casting techniques were developed to eliminate the large amounts of scrap generated by rolling procedures formerly used for preparing targets.[4]

One of the techniques developed was an injection casting process which utilizes the weight of a tantalum metal rod to force the molten metal into the mold cavity. A recent development program has resulted in a new mold design which makes it possible to cast multiple actinide metal disks which have a minimum thickness of 0.006 inch. Using the new mold design and the proper casting parameters, it has been possible to prepare up to ten 1/2 inch diameter disks in a single casting. This paper describes the mold design which was developed for preparing these thin metal disks and the procedures and casting parameters which are necessary for successful castings.

EXPERIMENTAL

Equipment

The furnace used for the multiple disk castings was a System VII general purpose metallurgical facility manufactured by Vacuum Industries (Figure 1). The furnace consisted of a tilt-pouring 4 inch diameter by 6 inch high water cooled induction coil enclosed in a water cooled vacuum chamber. The coil contained a quartz insulator sleeve and a 1/4 inch thick sleeve of WDF graphite felt insulation manufactured by Union Carbide. The power for the coil was supplied by an inductotherm 15 kw motor-generator unit. Temperature measurements were obtained using a chromel-alumel thermocouple. The vacuum system consisted of a 4 inch diffusion pump with a mechanical roughing pump.

Several different mold designs were evaluated for the multiple disks castings. Most of these mold designs proved to be only partially successful, that is, only a few of the disk cavities would fill. Other designs were successful insofar as filling the disk cavities was concerned, but the dimensional tolerances produced were very poor. The mold design which finally proved to be successful is shown in Figure 2. This design was for a split mold capable of producing ten 1/2 inch diameter disks per casting. The mold was designed with a 0.020 inch thick by 1/8 inch wide central sprue which extended from the metal reservoir in the bottom

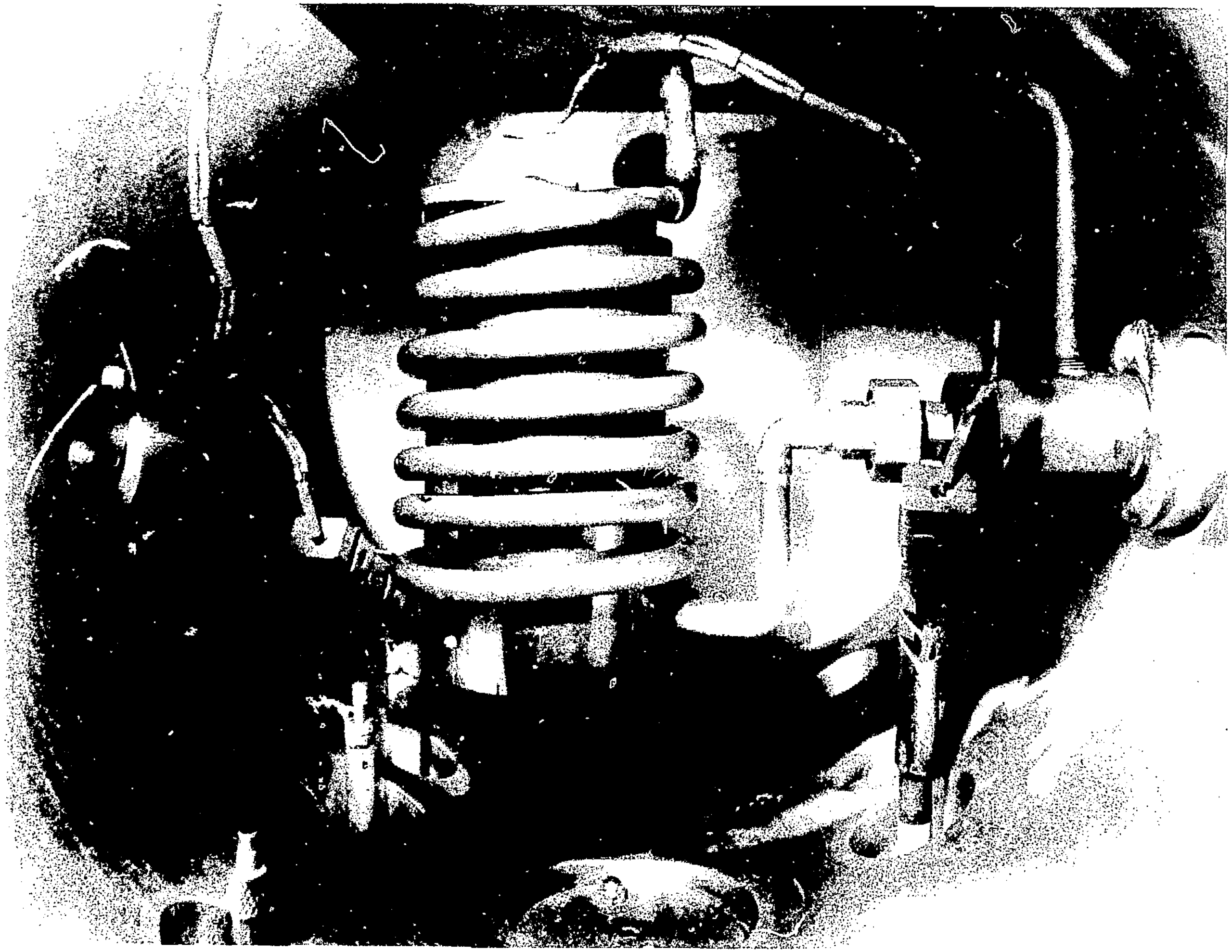

Figure 1. Interior of Vacuum Casting Furnace Used For Multiple Disk Castings

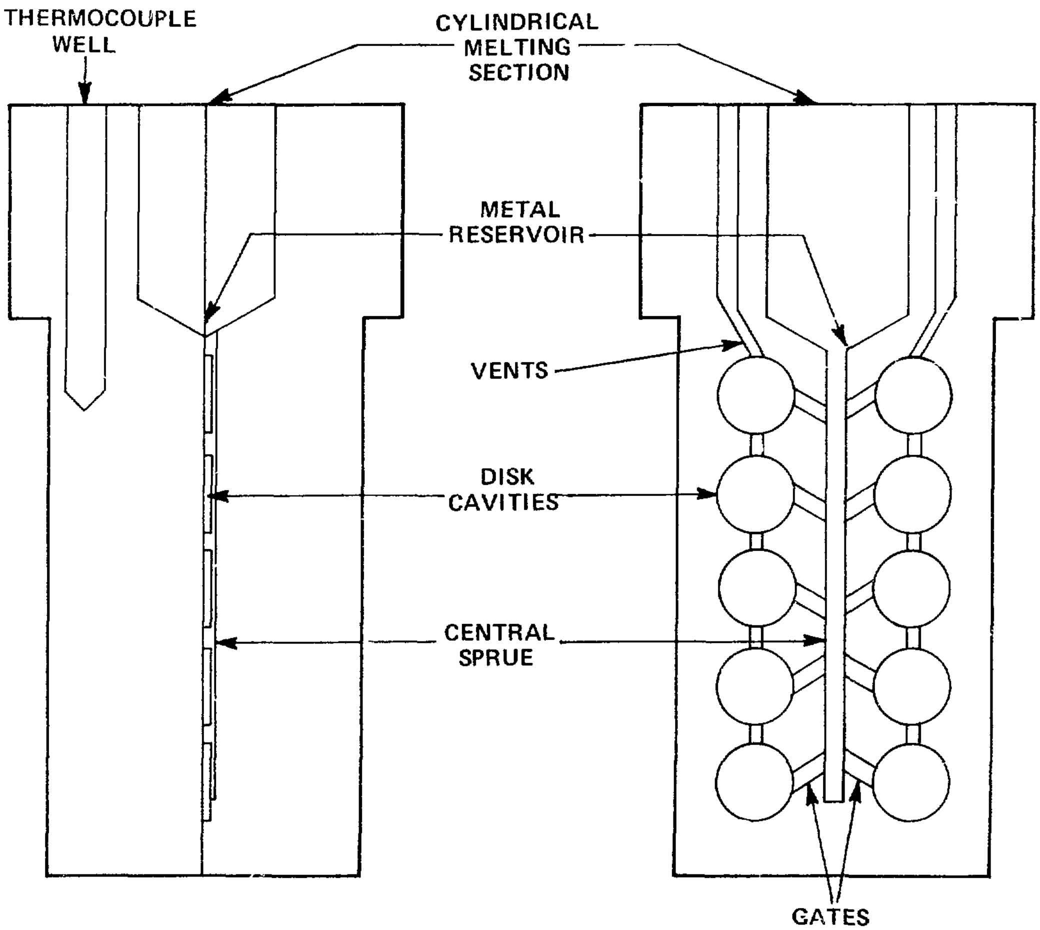

Figure 2.

Cross Section Showing the Design of
the Multiple Disk Mold

of the melting section to the bottom of the mold. The disk cavities were joined to the central sprue with tapered gates. The molds were fabricated from stack pole graphite, and the inner surfaces of the molds were coated with a CaF_2 mold coating preparation before being used. The tantalum metal rod used to force the molten metal into the mold cavity was 0.865 inch in diameter and 2-1/2 inch long. The weight of the rod was 410 grams. The end of the rod which contacted the molten metal was coated with a CaF_2 mold coating before each casting.

Procedure

The metal to be cast was placed in the melting section of the mold and the mold was placed in the induction coil. The coil was tilted at a 45° angle, and the tantalum metal rod was placed in the upper portion of the melting section of the mold. The vacuum chamber was then sealed and evacuated. The mold was heated over a 10 to 12 minute period to between 800 and 850°C. The induction coil and mold were then moved to a vertical position, allowing the tantalum metal rod to drop onto the molten metal which forced the metal into the disk cavities. The mold was allowed to cool under vacuum.

Results

The multiple disk casting technique has been used to prepare alpha plutonium, delta plutonium, and neptunium metal disks. The product from a typical casting is shown in Figure 3. This figure shows ten delta plutonium metal disks as they appeared after they were removed from the mold, but before they were separated from the central sprue, gates, and vents. These disks were 1/2 inch in diameter and 0.011 inch thick. The disks were separated from the rest of the casting using a precision ground tool steel punch.

The dimensional accuracy obtainable with the technique is illustrated by the data given in Table I. This table gives the weights and thicknesses of ten 1/2 inch diameter alpha plutonium metal disks. The charge for this casting contained 19.7 grams of alpha plutonium and the casting produced ten well formed metal disks. The average thickness of the individual disks ranged from 0.0060 to 0.0063 inch. The spread in the thickness of the individual disks ranged from 0.0001 to 0.0005 inch.

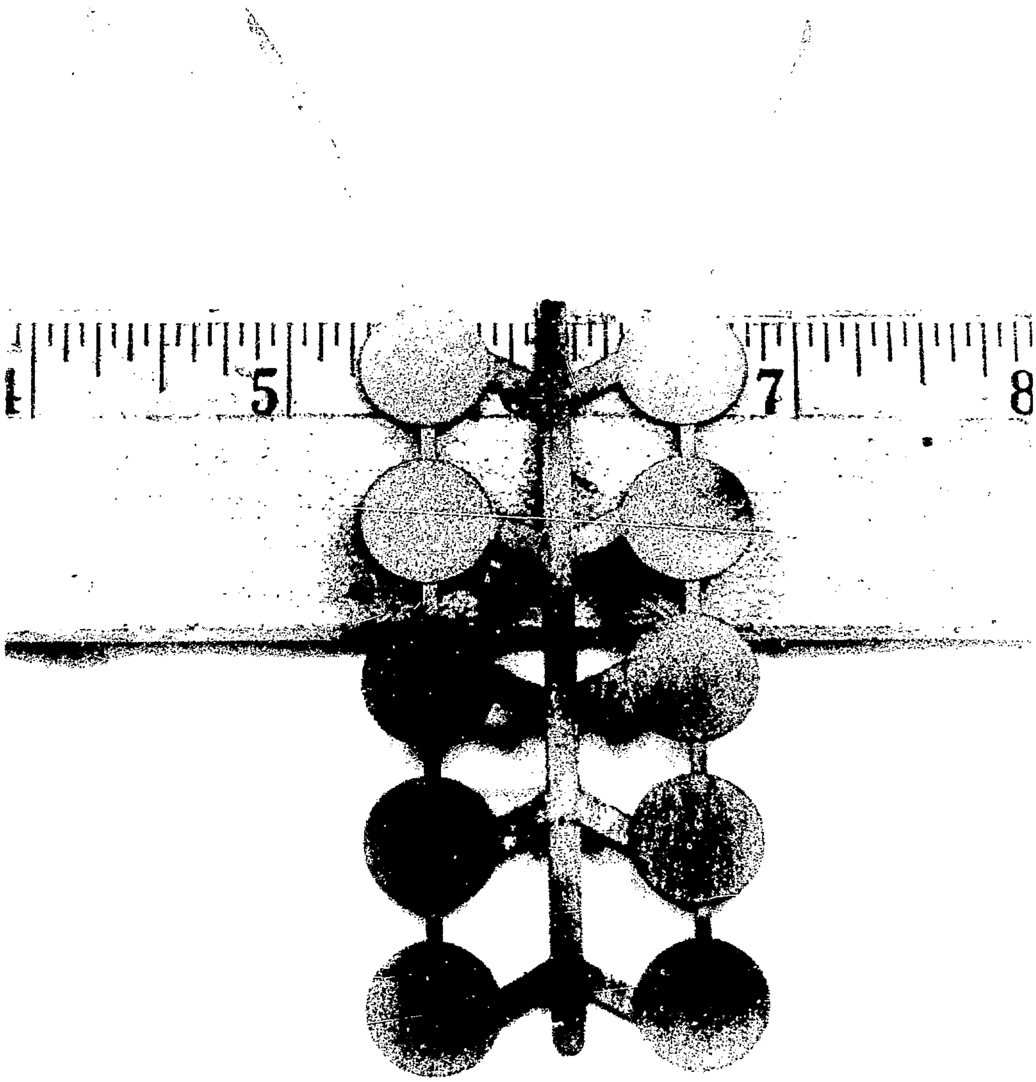

Figure 3.

Multiple Disk Casting As It
Appeared After Removal From the Mold

Similar results were obtained from castings using neptunium metal. The dimensions of the disks obtained from one of the neptunium castings are shown in Table II. This casting produced ten 1/2 inch diameter neptunium metal disks, the average thickness of which ranged from 0.0102 to 0.0112 inch. The spread in the thickness of these disks ranged from 0.0001 to 0.0005 inch.

TABLE I

WEIGHTS AND DIMENSIONS OF 1/2 INCH DIAMETER ALPHA PLUTONIUM METAL DISKS

Disk	Disk	Disk Thickness		Spread in
No.	Wt.(g)	Min.(inch)	Max.(inch)	Thickness(inch)
1	0.3127	0.0060	0.0062	0.0002
2	0.3120	0.0060	0.0062	0.0002
3	0.3009	0.0059	0.0062	0.0003
4	0.3069	0.0057	0.0062	0.0005
5	0.3033	0.0060	0.0062	0.0002
6	0.3219	0.0061	0.0065	0.0004
7	0.3129	0.0062	0.0063	0.0001
8	0.3131	0.0061	0.0064	0.0003
9	0.2970	0.0060	0.0061	0.0001
10	0.3014	0.0061	0.0061	0.0002

TABLE II

WEIGHTS AND DIMENSIONS OF 1/2 INCH DIAMETER NEPTUNIUM METAL DISKS

Disk	Disk	Disk Thickness		Spread in
No.	Wt.(g)	Min.(inch)	Max.(inch)	Thickness(inch)
1	0.6429	0.0109	0.0112	0.0003
2	0.6129	0.0101	0.0104	0.0003
3	0.5975	0.0101	0.0103	0.0002
4	0.6209	0.0103	0.0104	0.0001
5	0.6535	0.0110	0.0113	0.0003
6	0.6573	0.0110	0.0112	0.0002
7	0.6593	0.0110	0.0114	0.0004
8	0.6391	0.0107	0.0109	0.0002
9	0.5919	0.0101	0.0103	0.0002
10	0.5958	0.0107	0.0112	0.0005

DISCUSSION

There are several factors which are important to the success of the multiple disk casting technique. These include the design of the graphite mold, the size of the casting charge, and the casting temperature. The design of the graphite mold was very important to the successful use of this technique. Several different mold designs with various gate angles and venting systems were tested before a successful design was developed.

The first mold tested was designed with horizontal gates between the central sprue and the disk cavities. Other mold designs were tested with the gates entering the disk cavities at various angles. These molds produced results which varied from completely unsuccessful to partially successful. The final mold design (see Figure 1) utilized gates which entered the bottom four disk cavities at 30° above the horizontal and gates for the top six disk cavities which entered at 30° below the horizontal.

The venting of the disk cavities was critical to the success of this technique. Several unsuccessful venting systems were tested before the system shown in Figure 2 was developed. With this system the depth of the vents between the disk cavities were 0.061 inch less than the depth of the disk cavities. However, the depth of the vents from the top two disk cavities were tapered to 0.040 inch and this depth was held to the point where the vents met the top surface of the mold. This venting arrangement relieved the internal pressure in the mold and allowed the molten metal to flow through the disk cavities and up the vents. This venting system solved many of the problems encountered with previous mold designs.

Since this technique was developed for casting actinide isotopes which are highly purified both isotopically and chemically, it was important to minimize the amount of material required for the casting charge. A large portion of the charge is required to fill the metal reservoir at the bottom of the melting section of the mold. Several attempts were made to decrease the volume of the metal reservoir, but the molten metal did not flow properly and these castings were unsuccessful. However, the metal which forms in the metal reservoir is not lost. This metal can be recast into feed ingots and used for subsequent castings. A charge containing 20 to 25 grams of metal was found to be optimum for these castings.

The casting temperature was also found to be very important. If the temperature was 20°C too low, the disk cavities would not fill completely. A temperature which was 20°C too high would result in excessive quantities of metal being forced out of the vents. The optimum temperature varied somewhat depending upon the element being cast, but for plutonium castings, the optimum temperature was found to lie between 820 and 840°C.

One practical application of this casting technique involved the preparation of neptunium metal disks for use in the liquid metal fast breeder reactor neutron dosimeter program. These disks were prepared in cooperation with the Target Preparation Center at Oak Ridge National Laboratory (ORNL). The most recent order was for thirty 1/2 inch diameter by 0.006 inch thick neptunium metal disks. The starting material for this project was from a batch of high purity NpO_2 which had been purified previously[(1)] at Rocky Flats for the Isotopes Pool at ORNL. The 95 gram batch of NpO_2 was converted to metal and the metal button was cast into a feed ingot.

The first two castings were made at 820 to 830°C and produced five and four disks, respectively. The temperature was increased to the 840-850°C range for the subsequent castings which all produced ten disks. The average thickness of the best thirty disks varied from 0.0055 to 0.0067 inch with the spread in the thickness of the individual disks ranging from 0.0001 to 0.0005 inch.

One concern with the multiple disk casting technique was the potential contamination of the metal with CaF_2 mold coating or graphite scraped from the walls of the mold by the tantalum metal rod. Another possible contamination source was the tantalum rod itself. A sample of the central sprue from the last neptunium disk casting was analysed for impurities by spark source mass spectroscopy. The results of this analysis are shown in Table III along with the impurity analysis from the NpO_2 feed used for this project. The C, Ca, and Ta content of the metal was lower than in the oxide while the increase in the F content of

TABLE III

SPARK SOURCE MASS SPECTROGRAPHIC

IMPURITY ANALYSIS

Element[a]	Concentration in NpO_2 Feed	Concentration in Np Metal
	(μg/g Np)	(μg/g Np)
Al	16	28
C	300	130
Ca	38	23
Cl	130	1
Cr	1	14
Cu	4	1
F	5	12
Fe	4	47
In	13	< 0.2
K	12	< 0.08
Mg	5	< 0.06
Mn	< 1	6
N	7	N.A.
Na	55	< 0.04
Ni	< 1	70
O	N.A.	260
P	3	9
S	< 0.06	2
Se	5	< 0.3
Si	25	21
Ta	15	4
Ti	< 1	1
W	4	< 1
Zn	1	0.4
Zr	3	3
TOTAL	646	692

(a) Impurities not listed were not detected.

the metal was very small. The Fe, Ni, and Cr content of the metal was higher than in the oxide. This increase was attributed to pickup from the inconel and stainless steel equipment used in the conversion of the oxide to metal. The oxide contained a total of 646 ppm of detectable impurities. The metal sample contained 692 ppm total of detectable impurities, but if oxygen is excluded, the total impurity level is reduced to 432 ppm.

The multiple disk casting technique provides a method for preparing thin actinide metal disks without the problems associated with a rolling and punching process. This is especially important in the case of neptunium metal which is difficult to roll because of its very brittle nature. This technique is capable of producing disks with good dimensional tolerances and without adding objectional impurities to the metal.

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