LABORATORY EVALUATION OF GRAPHITE CRUCIBLE COATINGS
FOR
VACUUM MELTING URANIUM

By

Orville R. Magoteaux
Delmer L. Elston
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AEC RESEARCH AND DEVELOPMENT REPORT

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of

TECHNICAL DIVISION
NATIONAL LEAD COMPANY OF OHIO

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ABSTRACT

Oxide and carbide coatings and methods of applying them to graphite crucibles were evaluated at the National Lead Company of Ohio on a laboratory scale. The objectives were to find a better crucible and mold coating than magnesia (MgO), which is currently used in the Metal Production Plant remelt operation, and a better method of application than brushing. The evaluation consisted of the vacuum-melting of slug uranium charges and derby uranium "as reduced" charges in graphite crucibles having different coatings, followed by studies of (1) the appearance of the coatings and (2) the metal quality (impurity levels) of the products.

Flame-sprayed magnesium zirconate ($MgZrO_3$) was determined to be the best coating evaluated. It limited the average carbon pickup to 73 ppm for derby uranium charges; with slug uranium, no pickup occurred. The flame-spray method provided a uniform coating thickness and virtually eliminated moisture and volatiles in the coatings. Studies showed that the flame-sprayed magnesium zirconate contains a very small amount of volatiles and is not hygroscopic, but that above $2500^{\circ}F$ it is reduced slightly by graphite and CO is released.

INTRODUCTION

Uranium ingots are produced at the National Lead Company of Ohio (NLO) by a vacuum remelt process consisting of the melting of uranium derbies, solid scrap (slugs and rod ends), and briquetted machine turnings.¹ A step of this process is the coating of the graphite crucibles and molds with a refractory to minimize the carbon pickup by preventing reactions between the molten metal and the graphite. A magnesia coating is presently used for this purpose. The magnesia is prepared as a slurry and is brushed on the crucible and mold. Before use, the coated crucibles and molds are treated differently to remove the excess moisture.

The magnesium oxide used at the National Lead Company of Ohio is not entirely satisfactory for use as a crucible coating, since the carbon content increases 300 ppm to 600 ppm during the melting of an all-derby charge, and from 200 ppm to 300 ppm during the melting of a 50 per cent derby - 50 per cent solid-scrap charge. Fedder, Chellew, and Rosen² showed that magnesium oxide is reduced by molten uranium metal to form urania (UO_2) and magnesium vapor. Studies at Battelle Memorial Institute³ on the magnesia used for the National Lead Company of Ohio crucible and mold coating showed that it is highly reactive (a calcined precipitate), and that it is reduced by molten uranium and graphite at 2500°F. Therefore, it provides minimum protection of the uranium from the graphite. In addition, preparation of the magnesia slurry allows hydration of magnesia. In order to remove the water of hydration, the magnesia should be heated in a vacuum to at least 1200°F for one hour.

During the course of this investigation, the crucible and mold coating materials and the methods of application used at Mallinckrodt Chemical Works (MCW) and Los Alamos Laboratories (LASL) were compared with those used at National Lead Company of Ohio (Appendix A). It was learned that there were differences among the three sites in the type of magnesia used, the method of preparing the slurry, and the method of applying the coatings to the crucibles and molds. It was believed that these differences accounted for the differences in remelt time-temperature cycles used in the remelt operations and the differences in product yields reported by these sites. Consequently, the study included an evaluation of the types of magnesia (chemically precipitated and electrically fused) used at three sites.

A laboratory investigation was undertaken to evaluate coating materials and methods of applying them to graphite. The materials and the methods of application to the crucible that could best control carbon pickup during vacuum remelting were to be determined.

PREPARATION OF COATINGS

Two sizes of graphite crucibles were made with Speers 7100-grade graphite: (1) 1 $\frac{7}{8}$ inches OD by 1 $\frac{1}{2}$ inches ID by 2 inches high, and (2) 3 $\frac{1}{4}$ inches OD by 2 $\frac{3}{4}$ inches ID by 3 $\frac{1}{4}$ inches high. The crucibles were coated by the methods described below.

1. Wash

An aqueous slurry was prepared and applied to the crucible with a brush. The coated crucible was dried in air for several hours to remove the free water.

2. Flame Spray

a. Metco Process

Refractory oxide powder was fed into a gun and sprayed onto the inside surface of the crucible in a semi-fused condition. A flame formed by oxygen-acetylene was used as the heating and carrier medium.

b. Rokide Process

Refractory oxide in the form of a rod was fed into a gun and was sprayed onto the inside surface of the crucible in a semi-fused condition.

3. Reaction-Bonded Coating

A slurry of a refractory oxide, such as zirconia, was applied to the graphite crucible. The crucible was then heated in a vacuum at high temperature, which caused a reaction between the oxide coating and the graphite. A metal carbide was thereby formed at the interface of the oxide and the graphite. The metal carbide became a bond between the refractory oxide slurry and the graphite.

4. Direct Reaction

A metal carbide coating was formed by placing a metal (such as zirconium) in a graphite crucible, and heating them in a vacuum until the metal became molten. A metal carbide was thereby formed at the interface as a result of a reaction between the graphite and the molten metal.

The slurry coatings consisted of beryllia (BeO), magnesia (MgO), magnesium zirconate (MgZrO₃), and urania (UO₂). The flame-sprayed coatings consisted of alumina (Al₂O₃), calcia-stabilized zirconia (CaO·ZrO₂), magnesia-alumina spinel (MgO·Al₂O₃), magnesia-stabilized zirconia (MgO·ZrO₂), and magnesium zirconate. The reaction-bonded coatings consisted of calcia-stabilized zirconia, magnesia-stabilized zirconia, and magnesium zirconate. The direct-reaction coatings consisted of titanium carbide (TiC) and zirconium carbide (ZrC).

VACUUM MELTING

Derby-uranium and slug-uranium charges were used for the vacuum melts. Before use, the uranium was cleaned with nitric acid and then was washed with water and acetone.

Some of the vacuum melts were made in the 1½-inch-ID by 2-inch-high crucibles inside a resistance-type vacuum furnace (Optical Film Engineering Company); some were made in the 2¾-inch-ID by 3¼-inch-high crucibles in a 50-kw vacuum induction furnace in the Pilot Plant.

The following operation conditions were used:

1. Maximum temperature: $2550^{\circ}\text{F} \pm 25^{\circ}\text{F}$
2. Furnace pressure: maximum of 400 microns
3. Rate of heating: $35^{\circ}\text{F}/\text{min}$
4. Time of melt: 40 minutes (from the time the uranium melted at 2066°F until it reached $2550^{\circ}\text{F} \pm 25^{\circ}\text{F}$)
5. Hold time of melt at 2550°F : 20 minutes
6. Leak rate into furnace: 20 microns per minute

Both the slug and derby melting stock and the products were sampled and analyzed for carbon, nitrogen, and metallic content. In some tests, samples of the products were taken from vertical slices through the center, and in other tests, samples of products were taken from the centers and edges. In some tests, the interface materials between the uranium and coatings were subjected to X-ray analysis.

DISCUSSION

The general appearance of the coating and the purity of the uranium after melting (as compared with the purity before melting) were used to determine the best coating materials.

All of the coatings, except magnesium zirconate and magnesia-alumina spinel (20 mole per cent magnesia) flame-sprayed by the Metco process, either failed or contaminated the uranium products with carbon (Fig. 1 to 6 and Tables I to IV). X-ray data on the interface material (Appendix B) confirmed the work of Fedder et al.

The flame-sprayed magnesium zirconate and the magnesia-alumina spinel were tested again. The coatings were observed, and samples were removed from vertical sections at the centers and the edges of the products. Metallographic studies were made for comparison of the average inclusion concentrations with those of standard slug and derby uranium.

In these tests, the magnesium zirconate (Fig. 7 and 8) and the spinel were not appreciably attacked when slug-uranium and derby-uranium charges were used, and the metal surfaces were clean and smooth.

There was no carbon pickup in the vacuum-melted slug uranium when the magnesium zirconate coating was used (Table V). When the magnesia-alumina spinel was used, the carbon increased 30 ppm and the aluminum content increased 46 ppm (Table VI). The nitrogen content was the same for both coatings. A carbon pickup of 73 ppm occurred in the melted "as reduced" derby uranium when the magnesium zirconate coating was used; when the magnesia-alumina spinel coating was used, the carbon content increased 108 ppm and the aluminum more than 48 ppm.

Metallographic studies of the vacuum-melted slug uranium showed that when the magnesium zirconate coating was used, the average inclusion concentration (Fig. 9) was similar to that found in typical slug uranium (Fig. 10). The average inclusion concentration in the vacuum-melted derby uranium (Fig. 11) was greater than that in typical "as reduced" derby uranium (Fig. 12).

When magnesia-alumina spinel was used in melting slug uranium, the product had an average inclusion concentration (Fig. 13) similar to that of the original charge of slug uranium (Fig. 10), but there was a slight increase in average inclusion concentration of the derby uranium after it was melted (Fig. 14), compared with typical "as reduced" derby uranium (Fig. 12).

CONCLUSIONS AND RECOMMENDATIONS

Refractory coatings were applied to small-scale graphite crucibles by brushing, flame-spraying, and by the reaction of oxides and metals. The oxide coatings prepared by flame-spraying a powder were found to be the best. Flame-sprayed magnesium zirconate (MgZrO_3) was found to limit carbon pickup in derby uranium to 73 ppm and to prevent carbon pickup in slug uranium charges. The flame-sprayed magnesium zirconate coating also adhered strongly to the graphite crucible after the uranium was cooled and removed, the graphite crucible surface being essentially intact. The other flame-sprayed oxides appeared to be favorable from a carbon pickup viewpoint, but because of their failure to adhere to the graphite during or after melting, they were not considered to be as promising as magnesium zirconate.

On the basis of this study, it is recommended that flame-sprayed magnesium zirconate be evaluated as a crucible and mold coating on production-size crucibles in the Pilot Plant using a standard crucible charge of 50 per cent derby and 50 per cent solid-scrap. Data obtained from a large-scale study will enable us to establish the use of the magnesium zirconate and the Metco flame-spray method. It will also permit a study of material consumption and optimum coating thickness, as well as economic evaluation of the flame-spray process.

ACKNOWLEDGMENTS

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APPENDIX A

MAGNESIA WASH TYPE REFRACTORY COATINGS FOR GRAPHITE CRUCIBLES AND MOLDS
USED IN THE VACUUM MELTING OF URANIUM METAL

Installation G

Installation	Grade of Magnesia	Chemical Specifications (Maximum Impurities)	Slurry Preparation	Application	Drying	Remarks
NLO*		Ammonium Hydroxide ppt 0.020% Barium (Ba) 0.005% Calcium (Ca) 0.05% Chloride (Cl) 0.010% Heavy Metals (as Pb) 0.003% Insoluble in HCl 0.020% Iron (Fe) 0.01% Loss on Ignition 2.0% Nitrate (NO ₃) 0.005% Silica (SiO ₂) 0.040% Soluble in Water 0.40% Sulfate and Sulfite (SO ₄) 0.005%	Magnesia Water (tap)	Hand brushed with 3" - 4" brush	Dried at 400°F - 500°F prior to load- ing with the Uranium Metal	Water is added to the mag- nesia until the slurry reaches the proper consis- tency. No definite per- centages are used.
1. Crucible	MCW Analytical Reagent					
2. Mold	Same	Same	Magnesia 400 g Zeogel 16 g Sodium Silicate 70 cc Water (tap) 740 cc Naccanal 10 cc	Same	1. One hour air-dried 2. One hour at 1000°F in an outgassing unit under 29 inches of vacuum	The Slurry is prepared 24 hours prior to use
MCW**						
1. Crucible	MCW Analytical Reagent	Same	Magnesia Water Aerosol (1.0% Sol.)	Sprayed on with a Banks Mfg. Co. Model 19 Spray Gun	Dried at 400°F prior to loading with metal	No definite percentage is available for the H ₂ O/MgO mixture. It is approximately the same as the mold slur- ry, with a slightly higher H ₂ O content which gives it a better texture for spraying
2. Mold	MCW USP Grade (fine particles)	CaO 1.5% Loss on Ignition 10.0% Alkali and Soluble Salts 2.0% Acid Insolubles 0.1% Fe 0.05% Heavy Metal 0.004% As 0.00125%	Magnesia 24.3% Sodium Silicate 0.7% Water 73.4% Bentonite 1.0% (Commercial Vol Clay 40% Solution, 40% Be) Aerosol (1.0% Sol.) 0.60%	Same	Coating was applied while the mold was at a temperature of 300°F - 500°F. No further drying was necessary	Preparation of Mold Prior to Use 1. Outgas at 1000°F under 200 microns (or less) of vacuum. 2. Cool to room temperature 3. Preheat to 300°F - 500°F prior to spraying
L.A.S.L.***						
1. Crucible	Norton Electrically Fused, Blend G(-200 mesh)	SiO ₂ 2.0% B 200 ppm Be 5 ppm Fe ₂ O ₃ 0.25% SiO ₂ /CaO 2/1 and 3/1	Magnesia - 100 parts by weight Magnesium Sulphate - 7 parts by weight (added as H ₂ O Solution, 1cc of which contained 0.2 g MgSO ₄)	Sprayed on with a Paasche Airbrush Model CUPS-2	Air dried	The slurry is prepared and allowed to stand for thirty minutes prior to use. Dur- ing this period, it is stirred several times by hand
2. Mold	Special mix- tures of clay and fused Alumina					
Type A1-7			Fused Alumina 1960 g Bentonite 10 g Tennessee #5 Clay 30 g Distilled H ₂ O 1250 cc	Same	Mold are preheated to ~700°C at the bot- tom and to ~1000°C at the top prior to casting	Milled for 11 hours prior to use
Type A1-4			Kentucky Ball Clay 240 g Georgia Kaolin 260 g Norton 800 Grade Alumina 1200 g Distilled H ₂ O 900 cc Sodium Carbonate 156 g	Same		Milled for 2 hours prior to use

* National Lead Company of Ohio ** Mallinckrodt Chemical Works *** Los Alamos Scientific Laboratory

APPENDIX B

X-RAY DATA ON INTERFACE MATERIAL BETWEEN THE URANIUM AND CRUCIBLE

Material	Method of Application	Location of Sample	Compounds Identified As The Interface Material
Magnesium Oxide*	Brushing Slurry	Bottom	MgO, UO ₂ , UC
Magnesium Oxide** (100 parts) and Magnesium Sulfate (7 parts)	Brushing Slurry	Bottom & Sidewall	MgO, UO ₂ (trace)
Uranium Dioxide	Brushing Slurry	Bottom	UO ₂ , UC
Magnesium Zirconate	Brushing Slurry	Bottom	ZrO ₂ , trace of unidentified constituent
Beryllia†	Brushing Slurry	Bottom	BeO, UO ₂
Alumina	Flame-Spraying Powder (Rokide Process)	Bottom & Sidewall	UO ₂ , Al ₂ O ₃
Zirconia	Flame-Spraying Powder (Rokide Process)	Bottom & Sidewall	ZrO ₂ , UO ₂
Alumina (low grade, thin coat)	Flame-spraying Powder (Metco Process)	Bottom	UO ₂ , UC
Alumina (low grade, thick coat)	Flame-Spraying Powder (Metco Process)	Sidewall	UO ₂ , UC, trace amount of another compound
Alumina (high grade, thin coat)	Flame-Spraying Powder (Metco Process)	Bottom & Sidewall	UO ₂ , UC
Alumina (high grade, thick coat)	Flame-Spraying Powder (Metco Process)	Bottom & Sidewall	UO ₂ , UC
Calcia-stabilized Zirconia (thin coat)	Flame-Spraying Powder (Metco Process)	Bottom	ZrO ₂ , small amount of UO ₂
Calcia-stabilized Zirconia (thick coat)	Flame-Spraying Powder (Metco Process)	Bottom	ZrO ₂ , small amount of second phase

* Analytical reagent MgO, prepared by the National Lead Company of Ohio method

** Electrically fused MgO, prepared by the Los Alamos method

*** Titanium Alloy Manufacturing (TAM) magnesium zirconate slurry, "as received"

† "Ames" high purity beryllia procured through the AEC

APPENDIX C
TABLES AND FIGURES

TABLE I

ANALYSES OF SLUG AND DERBY URANIUM BEFORE AND AFTER VACUUM
MELTING IN GRAPHITE CRUCIBLES COATED WITH SLURRIES

Type of Coating	Type of Uranium	Impurities Before (b) and After (a) Melting (ppm)													
		C		N		Al		B		Cr		Fe		SiO ₂	
		b	a	b	a	b	a	b	a	b	a	b	a	b	a
National Lead Company of Ohio - type Magnesia	Slug	625	895	65	40	L4	6	L0.2	G1.2	11	15	75	62	20	80
	Derby	20	500	20	35	20	18	L.2	0.4	20	18	66	80	80	140
Los Alamos - type Magnesia	Slug	625	635	65	55	L4	6	L0.2	1.2	11	18	75	89	20	60
	Derby	15	625	35	25	15	L4	L0.2	0.3	20	18	99	83	80	60
TAM - type Magnesium Zirconate	Slug	530	650	45	25	10	L4	L.2	2.5	25	25	94	84	70	150
	Derby	20	245	20	15	20	100	L0.2	0.3	20	18	66	114	80	160
Ames - type Beryllia	Slug	530	—	45	—	Not Analyzed									
	Derby	15	240	35	15	25	100	L0.2	L0.2	20	18	99	95	80	130
Uranium Dioxide	Slug	530	—	45	—	Not Analysed									
90% Magnesia, 10% Magnesium Zirconate	Derby	40	230	10	10	10	100	L0.2	0.4	20	13	89	83	80	120

L - Less than

G - Greater than

TABLE II

ANALYSES OF URANIUM BEFORE AND AFTER VACUUM MELTING
IN GRAPHITE CRUCIBLES COATED BY DIRECT REACTION

Type of Coating	Type of Uranium	Impurities Before (b) and After (a) Melting (ppm)													
		C		N		Al		B		Cr		Fe		Si	
		b	a	b	a	b	a	b	a	b	a	b	a	b	a
Titanium Carbide	Slug	500	535	95	30	4	70	L.2	L.2	15	18	55	59	24	30
	Derby	30	400	15	15	6	100	L.2	L.2	20	20	86	115	70	140
Zirconium Carbide	Slug	500	605	95	10	4	G100	L.2	L.2	15	20	55	84	24	36
	Derby	30	495	15	55	6	G100	L.2	L.2	20	18	86	119	70	100

L - Less than

G - Greater than

TABLE III

ANALYSES OF URANIUM BEFORE AND AFTER VACUUM MELTING
IN GRAPHITE CRUCIBLES TEST COATED BY REACTION BONDING

Type of Coating	Type of Uranium	Impurities Before (b) and After (a) Melting (ppm)													
		C		N		Al		B		Cr		Fe		Si	
		b	a	b	a	b	a	b	a	b	a	b	a	b	a
Magnesia-Stabilized Zirconia	Slug	520	545	50	20	L4	12	L.2	L.2	20	18	92	120	40	30
	Derby	20	380	15	35	4	10	L.2	L.2	15	18	69	120	36	50
Magnesium Zirconate	Slug	520	555	50	70	L4	12	L.2	L.2	20	18	92	89	40	36
	Derby	20	90	10	20	6	L4	L.2	L.2	20	18	108	62	36	30
Calcium-Stabilized Zirconia	Slug	520	580	50	10	L4	12	L.2	L.2	20	18	92	113	40	36
	Derby	25	165	10	20	8	6	L.2	L.2	25	25	127	102	36	70

L - Less than

G - Greater than

TABLE IV

ANALYSES OF URANIUM BEFORE AND AFTER VACUUM MELTING
IN GRAPHITE CRUCIBLES COATED BY FLAME SPRAYING

Coating Method	Type of Impurity	Alumina				Calcia-Stabilized Zirconia				Magnesia-Stabilized Zirconia				Magnesium Zirconate				Magnesia-Alumina Spinel			
		Slug Metal		Derby Metal		Slug Metal		Derby Metal		Slug Metal		Derby Metal		Slug Metal		Derby Metal		Slug Metal		Derby Metal	
		b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a
Norton Company (Rokide)	C					625	600	L5	425												
	N					65	25	20	15												
	Al					L4	25	L4	G100												
	B					L0.2	1.9	L0.2	0.3												
	Cr					11	25	20	20												
	Fe					75	73	95	70												
	Mg					10	9	15	12												
	N ₁					18	22	35	31												
	SiO ₂					20	80	30	40												
Metallizing Engineering Company (Metco)	C	500	530	L5	138	500	235	L5	75	520	1065	10	325	520	490	25	145	520	600	10	110
	N	95	40	20	25	95	50	20	30	50	10	15	10	50	25	10	25	50	10	15	15
	Al	4	G100	L4	G100	4	8	4	25	L4	12	6	8	L4	10	8	10	L4	70	6	60
	B	L0.2	0.4	L0.2	L0.2	L0.2	0.2	L0.2	0.5	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2
	Cr	15	20	20	25	15	10	15	25	20	18	20	18	20	20	25	18	20	20	20	20
	Fe	50	76	95	80	55	44	55	75	92	113	104	120	92	75	127	114	92	102	104	116
	Mg	15	9	15	12	15	2	15	12	3	4	15	2	3	3	15	4	3	8	15	8
	N ₁	20	25	35	37	20	29	20	23	36	36	15	22	36	35	15	13	36	31	15	16
	SiO ₂	24	40	30	30	24	30	24	30	40	36	36	60	40	36	36	80	40	36	36	40
Amour Research Foundation	C	500	570	25	305																
	N	95	10	20	25																
	Al	4	75	L4	G100																
	B	L0.2	0.2	L0.2	0.25																
	Cr	15	18	20	12																
	Fe	50	64	101	120																
	Mg	15	6	8	6																
	N ₁	20	41	21	14																
	SiO ₂	24	36	60	160																

L - Less than
G - Greater than
b - Before Melting
a - After Melting

TABLE V

ANALYSES OF URANIUM SLUG METAL BEFORE AND AFTER MELTING
IN COATED GRAPHITE CRUCIBLES

Impurities	Before Melting	Analytical Results (ppm)								
		After Melting				Before Melting	After Melting			
		Calcia-Stabilized Zirconia		Magnesia-Stabilized Zirconia			Magnesium Zirconate		Magnesia-alumina Spinel	
		Edge	Center	Edge	Center		Edge	Center	Edge	Center
Aluminum	L4	8	8	L4	L4	L4	L4	L4	50	50
Boron	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Chromium	18	18	18	18	18	15	15	15	18	18
Iron	56	66	55	50	58	67	35	49	64	58
Silica	50	50	60	50	60	50	40	50	50	50
Carbon	365	310	365	350	385	390	355	320	405	435
Nitrogen	25	15	20	20	35	15	85	15	45	40

L - Less than
G - Greater than

TABLE VI

ANALYSES OF URANIUM DERBY METAL BEFORE AND AFTER MELTING
IN COATED GRAPHITE CRUCIBLES

Impurities	Before Melting	Analytical Results (ppm)						
		After Melting				Before Melting	After Melting In A Crucible Coated With Calcium-Stabilized Zirconia	
		Magnesia-Alumina Spinel		Magnesium Zirconate				
		Edge	Center	Edge	Center			
Al	12	G60	G60	L6	L6	8	8	15
Boron	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2
Chromium	L4	9	9	L10	L10	L4	L10	L10
Iron	44	53	51	38	32	44	51	38
Silica	L20	52	44	36	30	L20	38	30
Carbon	20	110	145	85	100	25	95	105
Nitrogen	40	15	20	20	25	30	25	25

L - Less than
G - Greater than

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FIGURE 1 Vacuum Melts Made With Derby Uranium in National Lead Company of Ohio - Type Magnesia (left) and LA - Type Magnesia (right).

FIGURE 2 Vacuum Melt Made With Derby Uranium in Magnesium Zirconate Washed Crucible

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FIGURE 3 Vacuum Melt Made With Derby Uranium in Beryllia Washed Crucible

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FIGURE 4 Vacuum Melt Made With Derby Uranium in 90 Per Cent MgO - 10 Per Cent MgZrO_3 Washed Crucible

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FIGURE 5 Vacuum Melt Made With Derby Uranium in Flame-Sprayed Alumina (Metco Process) Crucible

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FIGURE 6 Vacuum Melt Made With Derby Uranium in Flame-Sprayed Calcia-Stabilized Zirconia (Rokide Process) Crucible

FIGURE 7 Graphite Crucible Flame-Spray-Coated With Magnesium Zirconate Before the Vacuum Melting of Uranium Slug

FIGURE 8 Graphite Crucible Flame-Spray Coated With Magnesium Zirconate; The Metal Product (After the Vacuum Melting of Uranium Slug).

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FIGURE 9 Uranium Slug Metal Showing Average Inclusion Concentration After Vacuum Melting In Graphite Flame-Sprayed With Magnesium Zirconate (100X).

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FIGURE 10 Uranium Slug Metal Showing Average Inclusion Concentration Before Vacuum Melting in a Coated Graphite Crucible (100X).

FIGURE 11 Uranium Derby Metal Showing Average Inclusion Concentration After Vacuum Melting in a Graphite Crucible Flame-Sprayed With Magnesium Zirconate (100X).

FIGURE 12 Uranium Derby Metal "As Reduced" Showing Average Inclusion Concentration Before Vacuum Melting in a Coated Graphite Crucible (100X).

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FIGURE 13 Uranium Slug Metal Showing Average Inclusion Concentration After Vacuum Melting in a Graphite Crucible Flame-Sprayed With Magnesia - Alumina Spinel Containing 20 Mole Per Cent MgO. (100X).

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FIGURE 14 Uranium Derby Metal Showing Average Inclusion Concentration After Vacuum Melting in a Graphite Crucible Flame-Sprayed With Magnesia - Alumina Spinel Containing 20 Mole Per Cent MgO (100X).