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TECHNIQUES USED TO PRODUCE TONNAGE QUANTITIES OF URANIUM ALLOYS AT THE DOE'S FEED MATERIALS PRODUCTION CENTER

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FEED MATERIALS PRODUCTION CENTER

NATIONAL LEAD COMPANY OF OHIO

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by

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TECHNIQUES USED TO PRODUCE TONNAGE QUANTITIES OF URANIUM ALLOYS AT THE DOE'S FEED MATERIALS PRODUCTION CENTER

R. L. Schardt
NATIONAL LEAD COMPANY OF OHIO

The National Lead Company of Ohio (NLO) operates a large-scale integrated facility for the production of uranium ingots, fuel cores, and miscellaneous parts by chemical and metallurgical techniques. The plant, established in 1951 by the Atomic Energy Commission, started production casting of uranium ingots in 1952 and is still producing uranium for the government-owned reactors now operated by the U. S. Department of Energy.

This paper will (1) describe the melting and casting equipment at NLO, (2) show how this equipment is used to produce "dilute" uranium alloys, and (3) display the various geometries cast within these facilities.

REMELT EQUIPMENT

NLO currently has 36 production vacuum remelt furnaces ranging in capacity from 1400 pounds (636 kg) to 6000 pounds (2727 kg) - see Table 1. The various sizes (lengths to diameters) of the molds used for the bulk of the uranium production at NLO are shown in Figure 1. A majority of these furnaces are housed in the building shown in Figure 2.

TABLE 1

REMELT FURNACE CAPACITY AT NLO

No. of Furnaces	U-lb Capacity	Special Features
4	1400	H_2O cooled - no mold heating.
1	1400	NaK cooled - mold heating available.
28	1500	H_2O cooled - mold heating available.
2	2000	H_2O cooled - special H_2O detection system for use with higher enrichments - no mold heating.
1	6000	Very flexible. Contains most features described above.

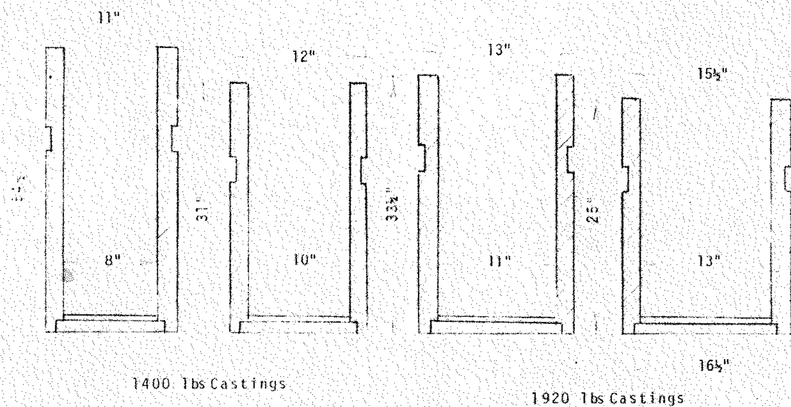

Figure 1. Relative sizes of the molds used for uranium alloy castings at NLO on a production basis.

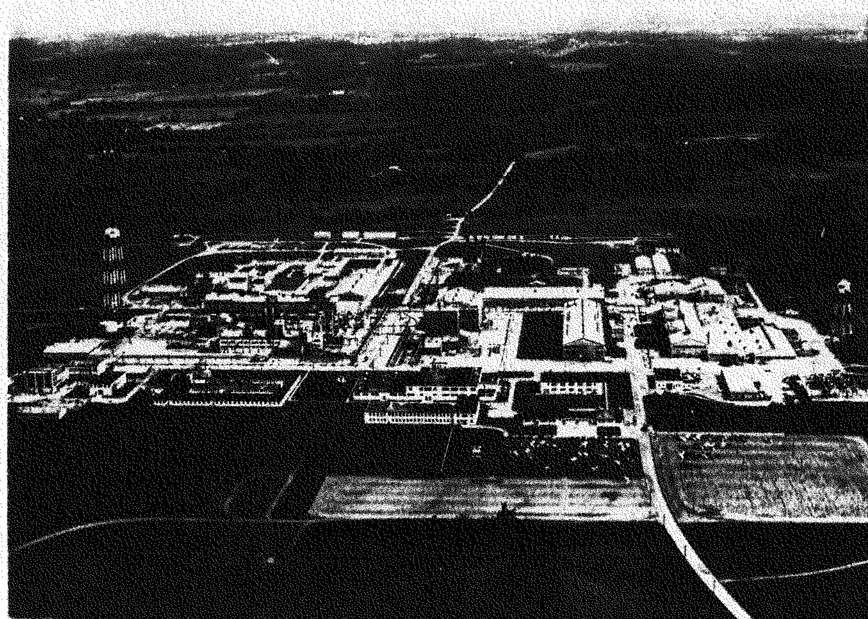

Figure 2. Aerial view of Fernald facility. Portions to right of center are the metals areas.

All the remelt furnaces at NLO consist of double-walled, water-cooled, vacuum-tight, stainless steel housings with copper, water-cooled, refractory-lined induction coils. The induction coils are powered by 3000 cps, 200 KW motor-generator sets. Those furnaces containing both crucible and mold heating coils share this 200 KW power source. The power between the two coils is adjusted through the use of a series of transformer tap settings. Some of these differences are illustrated in Figure 3.

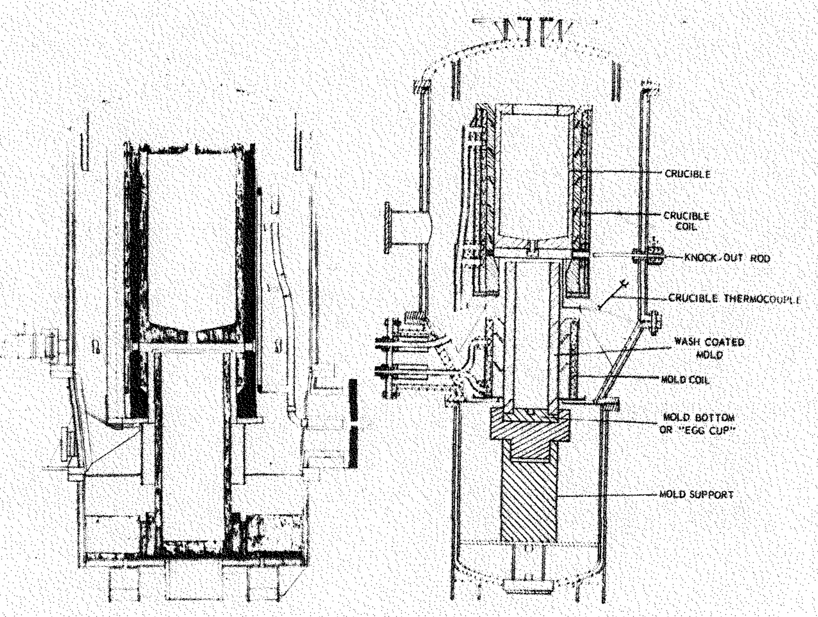

Figure 3. Comparison of the two basic remelt furnace designs used at the Fernald facility.

The vacuum systems consist of Dollinger pipeline filters, single-stage Roots Connersville blowers and oil-sealed, rotary piston, gas ballasted, mechanical backup pumps capable of maintaining pressures of less than one hundred microns on the molten pool.

The vacuum gauging system consists of a single Alphatron, with the detection tube located in the plane of the crucible bottom.

A considerable number of man-hours have been expended over the years to find suitable refractories for these furnaces. Those in use today - a combination of high alumina ring refractory linings and a ceramic felt (Kaowool or Cerafelt) insulator - give excellent life, good furnace coil protection, and consistent crucible-to-coil heat losses.[1] Some of these features can be seen in Figures 4 and 5.

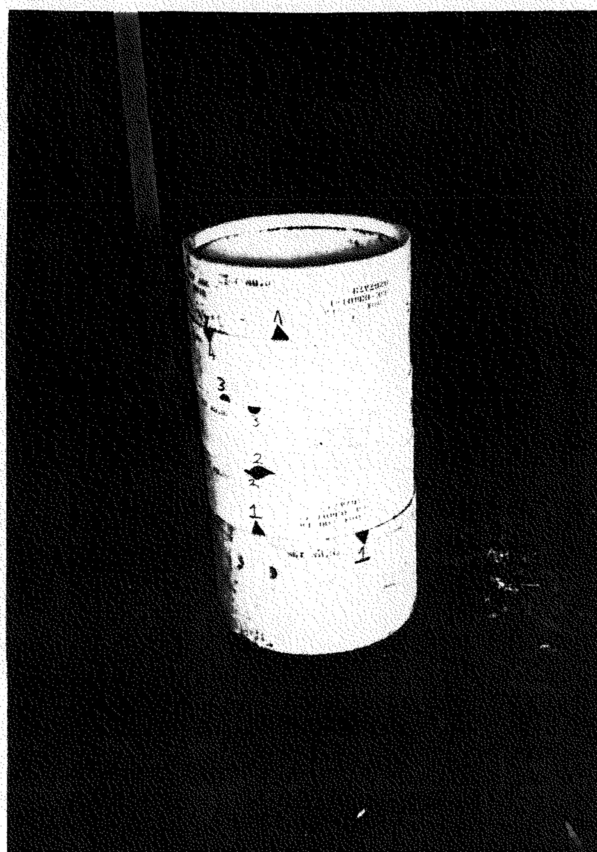

Figure 4. Set of alumina refractory rings used as inner coil liner. Kaowool insulation not shown.

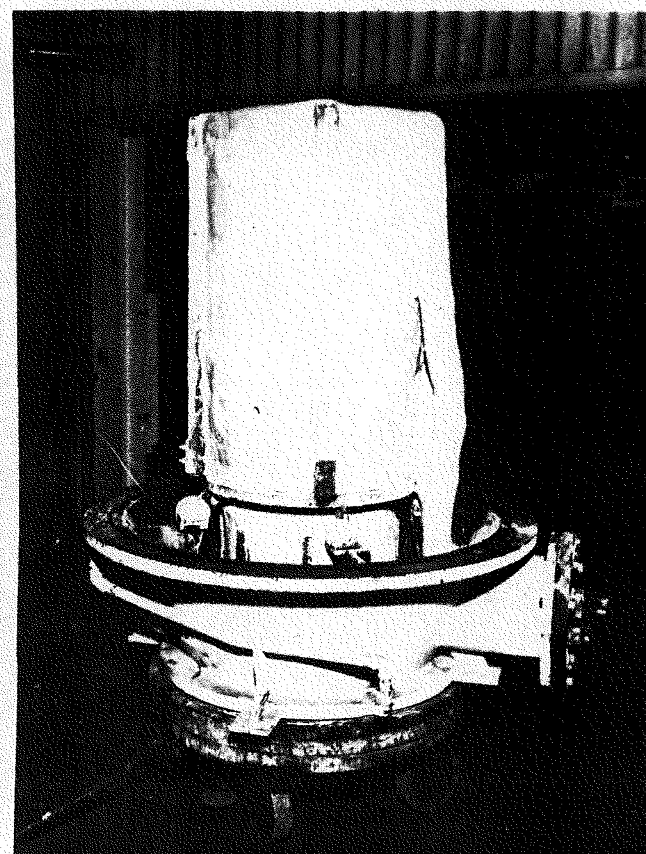

Figure 5. Completed remelt coil assembly. "Mud-like" ceramic grouting is used on outer diameter of coil for protection against spill metal. Note mold coil in lower section of tank.

Before describing the physical operation of these furnaces in casting dilute uranium alloys, a brief pictorial tour of the NLO casting areas is shown in the following series of photographs, Figures 6 through 11.

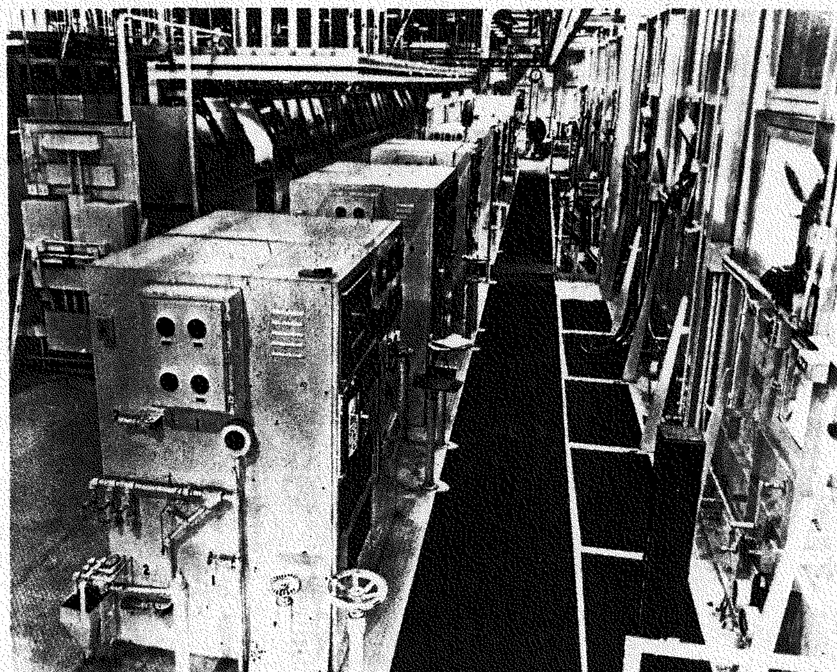

Figure 6. Upper floor of casting area. Note remote facilities for handling crucibles.

Figure 7. Close-up of furnace bulkhead. Operator is using a mechanical lever to knock-out bottom pour plug.

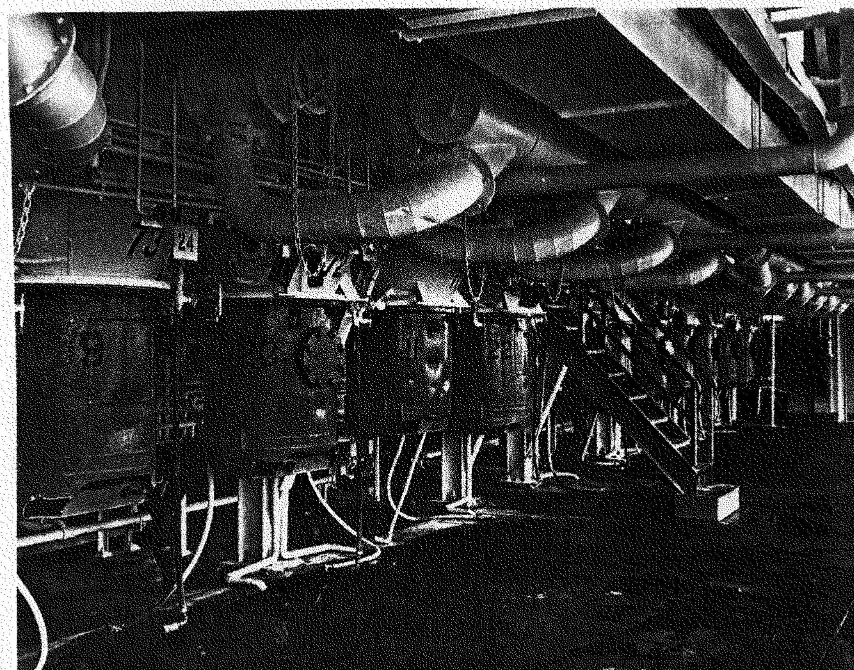

Figure 8. Lower remelt floor. All furnaces are double-shelled with water cooling.

Figure 9. Gun barrel mold with egg cup (right). Mold interior is coated with a zirconium silicate slurry for protection.

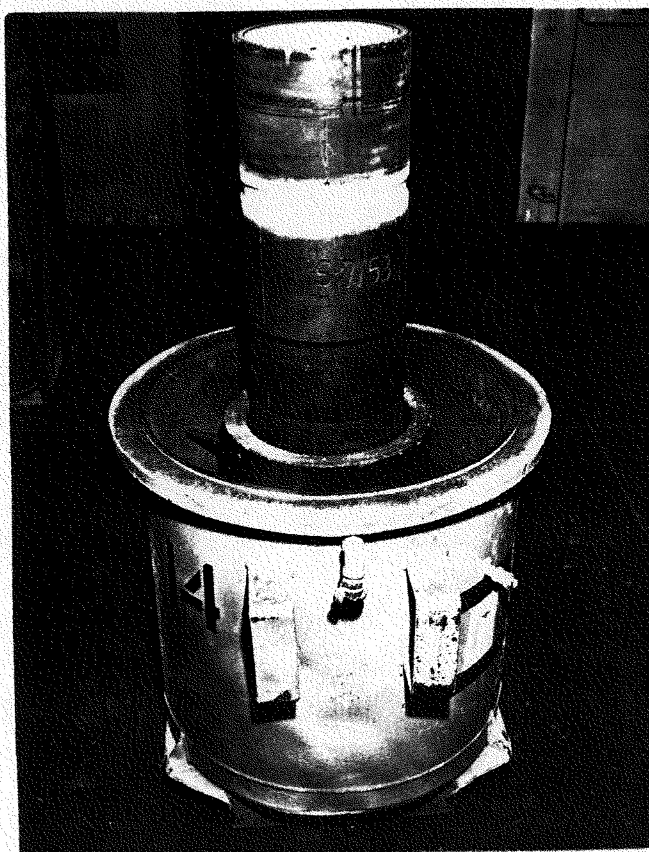

Figure 10. Assembled mold on graphite block ready for use.

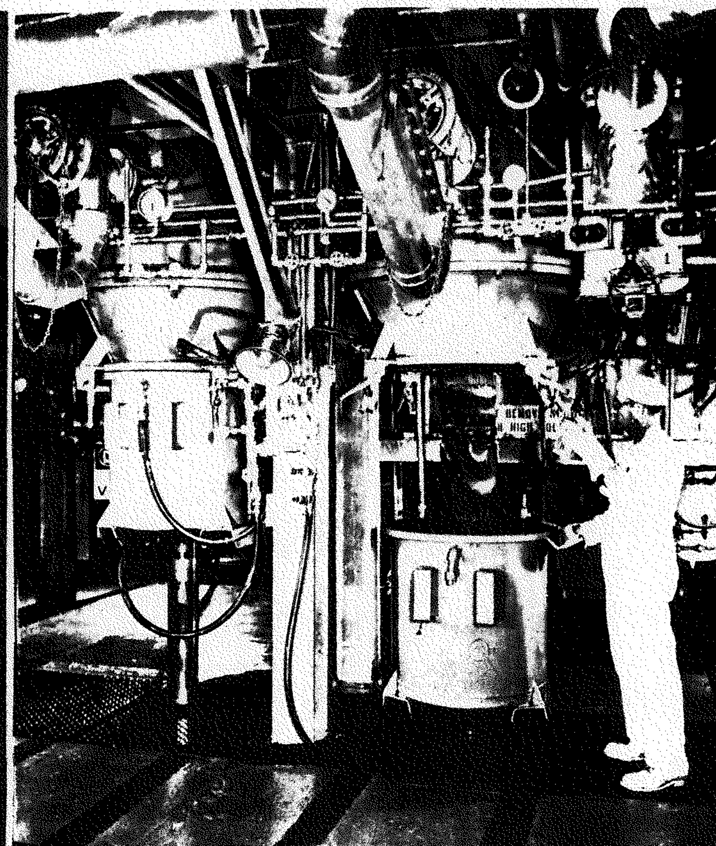

Figure 11. Final assembly procedure for vacuum remelt furnace.

REMELT TEMPERATURE CONTROL

Because molten uranium reacts with most materials, an indirect system for measuring the remelt temperature has been developed. This system consists of a vacuum operated device with a tungsten-rhenium thermocouple attached. See Figure 12. The thermocouple is automatically inserted into a slot in the crucible bottom when the furnace is placed under vacuum and automatically retracted when the vacuum is broken. When a new furnace (coil) is installed, and periodically throughout its life, the actual melt temperature is determined by immersing a graphite-clad thermocouple into the molten uranium. This is illustrated in Figure 13. The temperature obtained on the bottom thermocouple during this comparative operation is then used to control that furnace. This system has reduced the melt-to-melt temperature variations and is thought to be an intangible factor responsible for improved product quality.

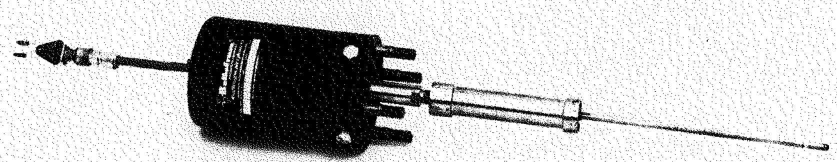

Figure 12. Vacuum operated retractable thermocouple. The thermocouple is tungsten-rhenium sheathed in niobium tubing.

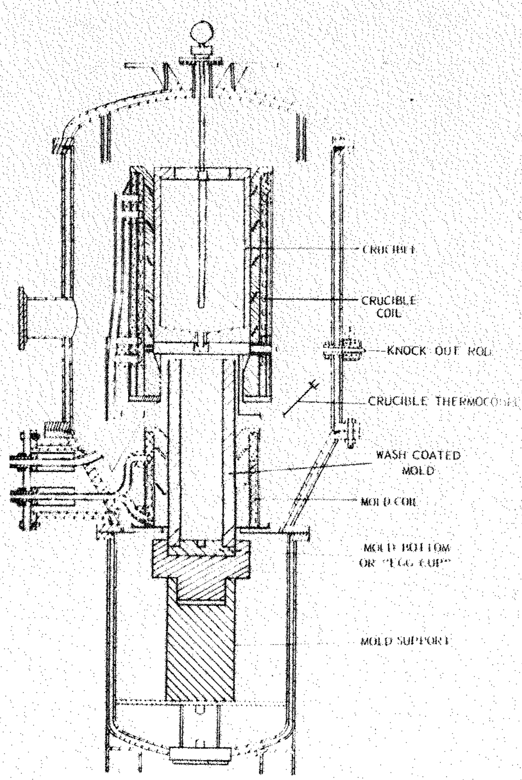

Figure 13. Schematic showing relative locations of immersion thermocouple versus bottom thermocouple.

CASTING OF ALLOYS

In recent years, considerations have changed from the original concept of producing "pure" uranium ingots to that of "dilute" alloys for improved properties. A number of different uranium-alloys have been cast recently including molybdenum, niobium, zirconium, and combinations of these elements; however, those cast in tonnage quantities on a sustained basis have been:

1) uranium - silicon and iron (125 to 225 ppm each),

2) uranium - titanium (nominal 0.75 w/o), and

3) uranium - aluminum (700 to 900 ppm) and iron (300 to 400 ppm).

Each alloy requires a slightly different furnacing technique to accomplish consistent results with a minimum of rejects. First, good control of all scrap and recycled materials is required to prevent crossovers from one alloy to the other. Second, records and identification of the alloy content are important. Breakdowns in these two areas are the prime source of chemical rejects.

URANIUM-IRON AND SILICON SYSTEM

The uranium-iron and silicon alloy is the simplest of the three systems from a furnacing standpoint; that is, the charges of virgin and recycle materials are made up, calculations of iron and silicon requirements determined, the additives weighed,* and their contents placed in paper envelopes which are charged directly to the crucible. Requirements on carbon are such that an uncoated (bare) graphite crucible can be used. The iron and silicon quite readily alloy with the uranium, thus negating any need for mechanical stirring. There are no significant segregations problems. See Figures 14, 15 and 16.

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*35 to 65 grams each of iron and silicon are generally required.

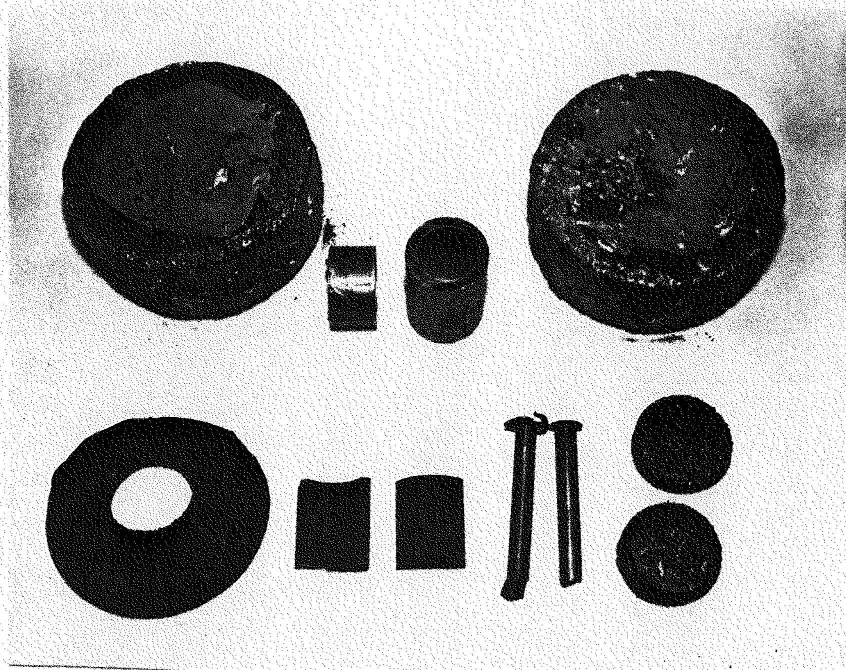

Figure 14. Various forms of uranium feed materials charged to crucible - derbies, reject fuel cores, extrusion scrap and briquetted machine turnings.

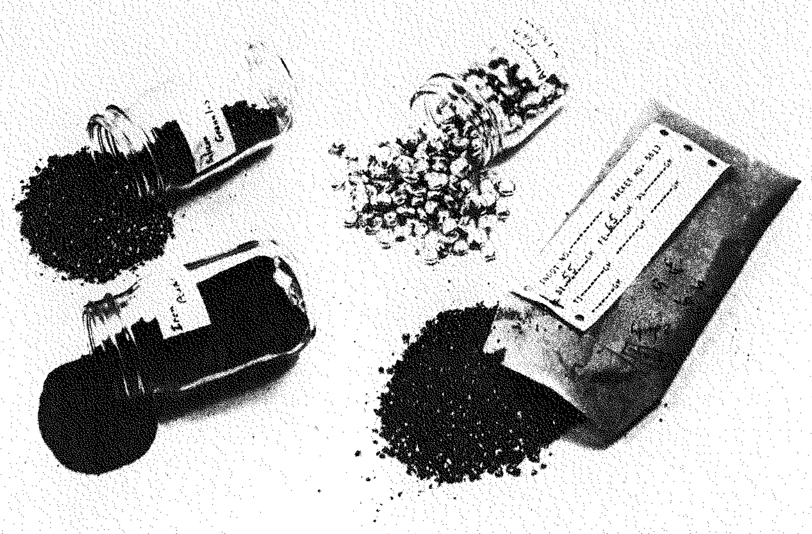

Figure 15. Examples of alloying agents added to crucible and/or mold.

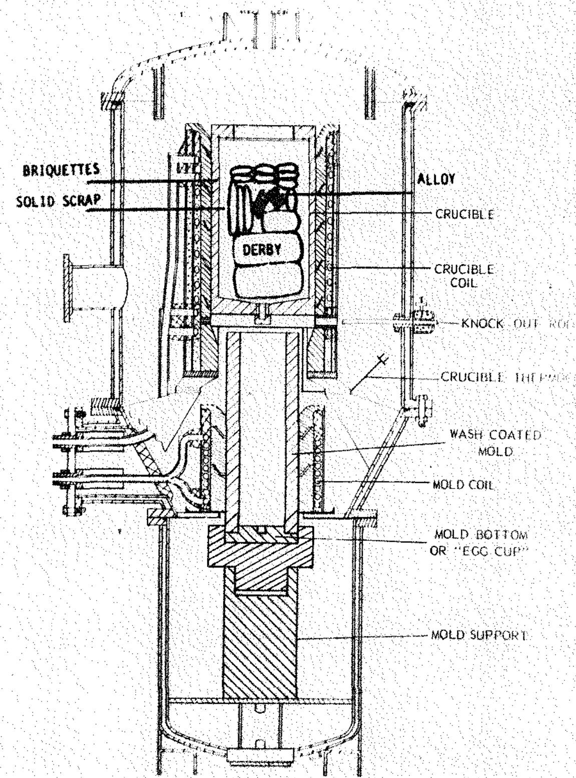

Figure 16. Remelt charge configuration for making dilute iron and silicon alloys.

URANIUM-IRON AND ALUMINUM SYSTEM (Figure 17)

This system is slightly more complex because of the aluminum additive. The charges for this system are made up in the same manner described above including the iron packet. In this case, however, the aluminum is added to the mold with the alloying occurring as the metal pours into the mold. This technique was adopted when unpredictable aluminum recoveries were obtained by adding the aluminum directly to the crucible. It is speculated that the following crucible reactions occur resulting in variable aluminum recovery. The MgF_2 residue (slag) is from the previous operation and is carried into the crucible with the derbies.

$$4\,Al + 3\,C \longrightarrow Al_4C_3$$

$$2\,MgF_2 + Al_4C_3 + 3\,U \longrightarrow$$

$$4\,AlF\uparrow + 2\,Mg\uparrow + 3\,UC$$

Approximately one pound of aluminum is required for each new casting to compensate for the crucible losses in the solid remelt (60% recovery expected) plus the unalloyed virgin (derby) portions of the charge. This technique works well and results in excellent homogeneity.

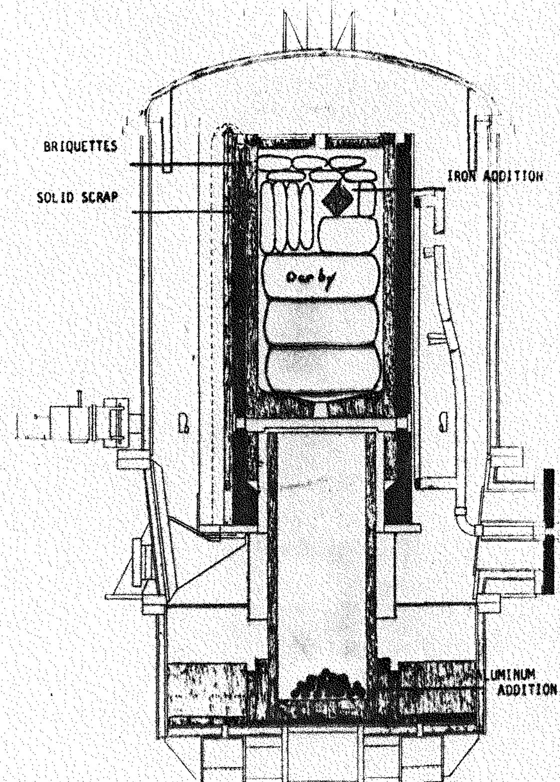

Figure 17. Remelt charge configuration for making dilute iron-aluminum alloys.

URANIUM-TITANIUM SYSTEM

This system requires more variations from our traditional melting practices than the previous two cases. The specifications call for a high purity product, that is, one with less than 100 ppm carbon; thus, a coated crucible is required. NLO has chosen to use a plasma applied calcia stabilized zirconium oxide coating for this operation.* See Figures 18 and 19. Some of the other changes can be more clearly seen in Figure 20.

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*Other DOE sites are having equal success with a Yttria wash coating.

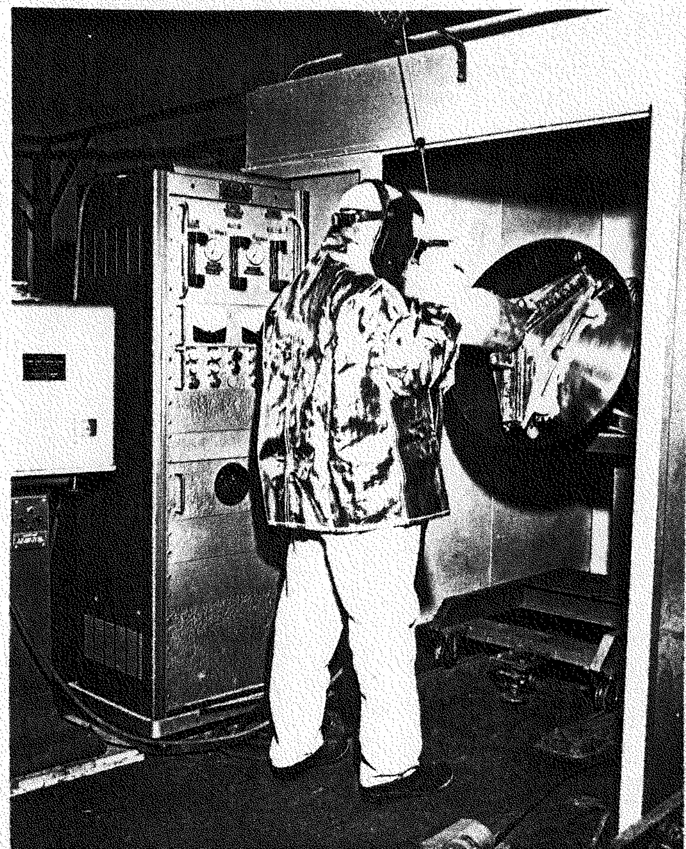

Figure 18. Plasma spraying of refractory coating onto graphite base.

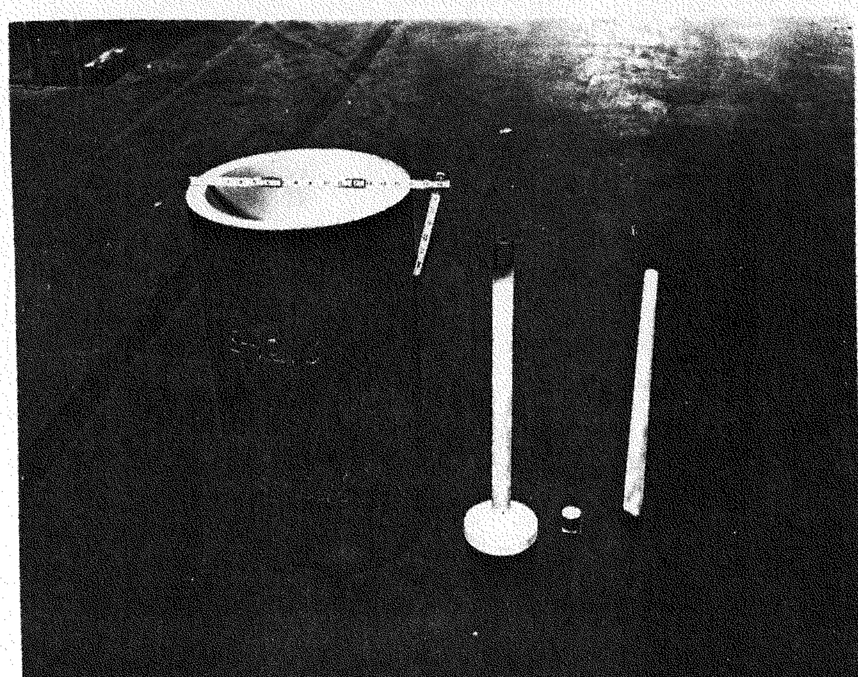

Figure 19. Plasma coated crucible, plunger and thermocouple well.

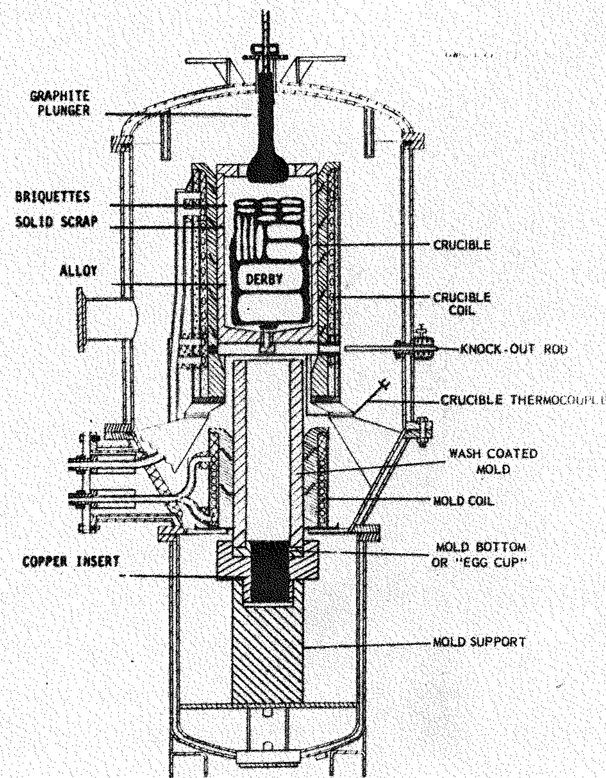

Figure 20. Remelt charge configuration for making dilute titanium alloys.

Briefly, this procedure differs from the previous two in that:

—A small U-metal wafer is placed over the pour hole to prevent the alloying material from sifting into the hole.

—The alloy is added around the periphery of the crucible.

—A plunger or stirring device is inserted through the lid before the melting process commences.

NLO consumes process scrap by briquetting chips, remelting machining rejects, rolling mill crops, etc. These materials are all from a closed stream of high purity, low carbon materials. There are no crossovers between any of the three production streams.

Typical analyses and/or specification ranges of all three NLO alloy production streams are shown in Table 2.

TABLE 2

TYPICAL ANALYSES OF NLO CAST PRODUCT

	ppm							Density
	Carbon	Al	Fe	Si	H_2	O	Ti	(g/cc)
Unalloyed (High Purity)	<70	10	45	45	<2.0	<25	<10	18.92
0.75 w/o Titanium	<30	<20	<40	<70	<2.0	<25	0.75* ±0.1	18.64
Fe-Si Alloy	350-500	<10	125-225	125-225	<2.5	60	<10	18.86
Fe-Al Alloy	450-650	700-900	300-400	100	<2.0	60	<10	18.82

*Weight percent

PIECE GEOMETRIES

The basic casting at the National Lead Company over the years has been the right circular cylinder illustrated in Figure 21. These are currently made in 7, 8, 10, 11 and 13-inch diameters for fabrication into reactor target and fuel cores.

More recently, NLO has cast custom sizes and geometries for other DOE sites and government agencies. Several of these geometries are shown in Figures 22, 23 and 24.

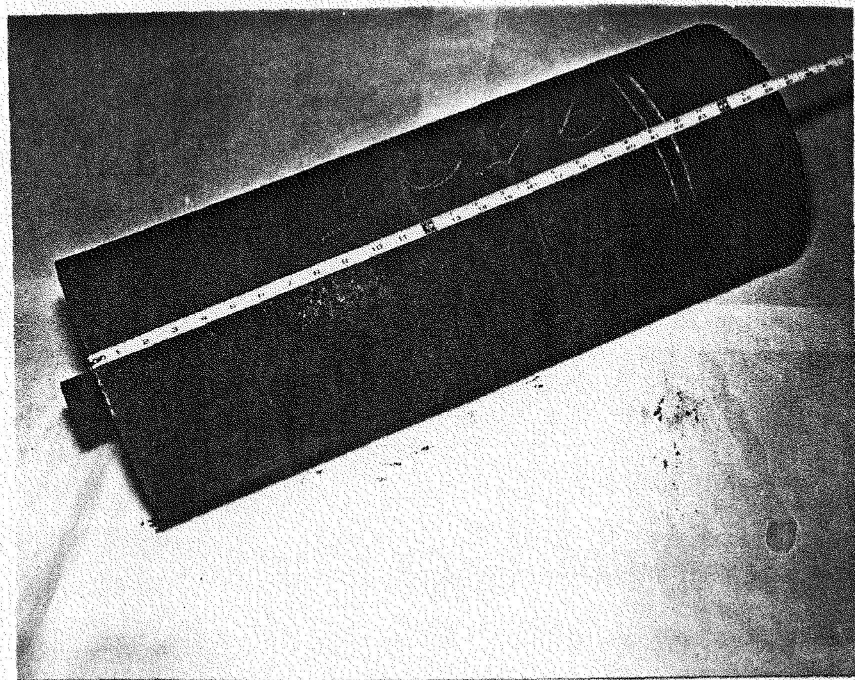

Figure 21. Basic right cylinder cast at NLO. These are made in 7, 8, 9, 10, 11, and 13-inch diameters.

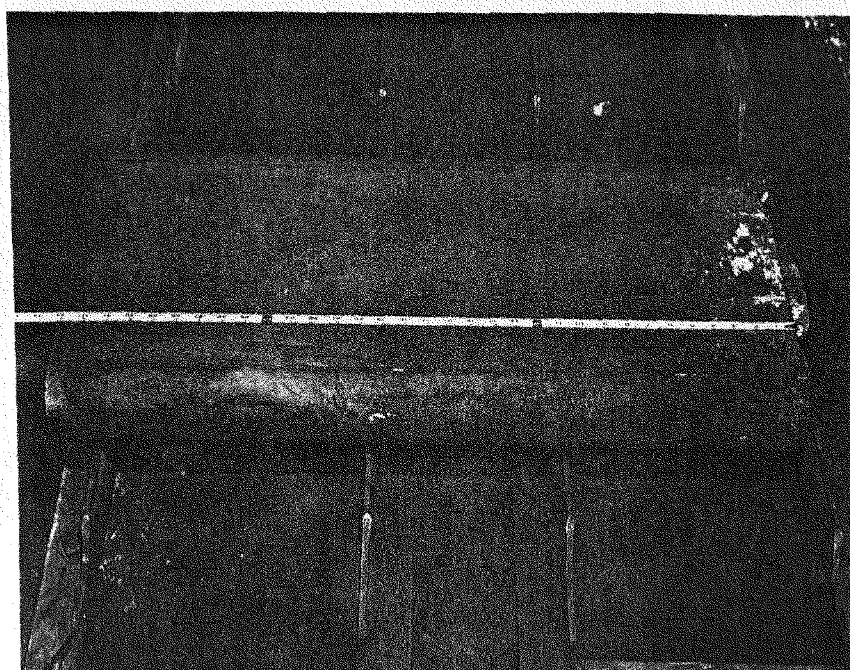

Figure 22. Four inch by thirty-three inch cast slab.

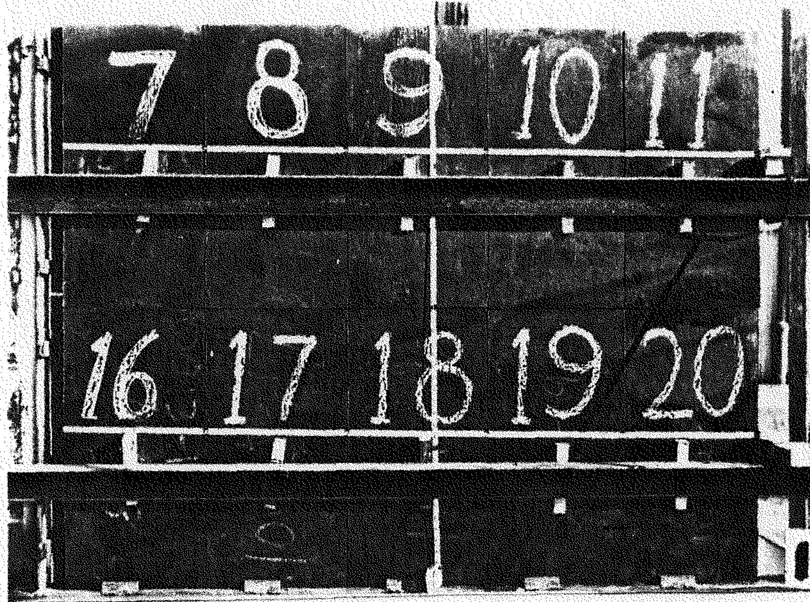

Figure 23. Cast tongue and groove slab wall used for shielding at Battelle Northwest Laboratories

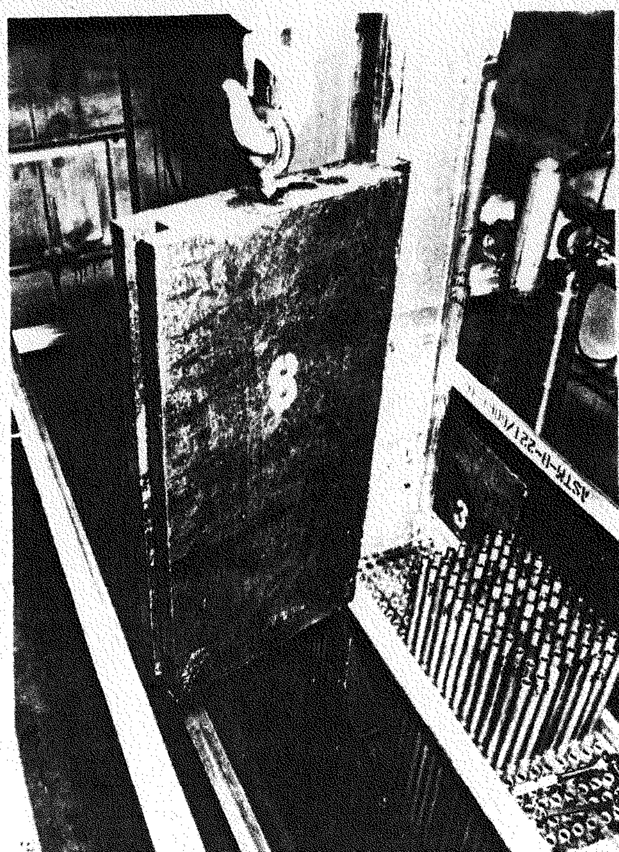

Figure 24. Section of above shielding wall being place in position at BNL.

SUMMARY

On this the twenty-fifth anniversary of this society organized to discuss vacuum metallurgy in the USA, NLO, through the Department of Energy, is pleased to have been chosen as a participant. Twenty-five years ago while many were still exploring vacuum operations as a laboratory curiosity, NLO was already producing a reactive metal in tonnage quantities. During the interim, new concepts and improved technologies have been developed with vacuum techniques spreading into many different metal fields. Many have considerably more modern equipment than NLO; however, with periodic updating, additions, and replacement of parts, the basic furnaces installed at the Fernald site 27 years ago are still producing a quality product on a daily basis. Furnaces originally designed to produce 500 lb, 5-inch diameter round ingots are now producing high quality 1500 lb rounds, slabs and other miscellaneous geometries.

REFERENCE

1/ Vacuum Metallurgy Conference, 1964, "*An Improved Production Furnace Coil Assembly for Uranium*" by Shera and Lusky, page 222.

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