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Title: -DEVELOPMENT OF A FURNACE FOR MELTING
AND CASTING URANIUM METAL.

Paper written by: - Robert J. Anicetti

Work done by: - Robert J. Anicetti

Contribution of: - Massachusetts Institute of Technology,

Cambridge, Massachusetts, and Metal

Hydrides Incorporated, Beverly,

Massachusetts.

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I. INTRODUCTION

At the start of the uranium project, it became necessary to design and construct a furnace suitable for melting and casting uranium powder into massive form. Early experiments showed that pressed and sintered compacts of uranium powder were inferior to the cast metal. Since the metal powder is quite pyrophoric, such casting would have to be done in an inert atmosphere or in vacuum. Preliminary investigations indicated that the powder could be melted in vacuum induction furnace. Facilities were then engaged in the Department of Metallurgy at the Massachusetts Institute of Technology for developing a vacuum induction furnace to melt and cast uranium on a large scale.

II. DISCUSSION

Early in 1942, a fund was created at the Massachusetts Institute of Technology to finance the development work on metal casting. For this purpose, the shell of an old furnace previously described by J. C. Chipman in Transactions of the American Institute of Mining and Metallurgical Engineers for 1940 was used. This furnace consisted essentially of a vacuum-tight shell enclosing an induction coil and a crucible inside this coil to be used for melting of metals. The old crucible used for steel melting was removed and

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replaced with a graphite crucible. Within the coil a fused silica tube lined with K-30 insulating bricks insulated the crucible from the coil. A removable water-cooled copper dome with sight glass fitted on the outer cylinder. The unit was firmly bolted to the bottom plate of a standard Ajax-Northrup furnace frame so the furnace could be tilted and a heat poured into a vacuum tight mold attached to the domed cover.

Preliminary heats were in alundum crucibles surrounded by a graphite shield with no attempt made to cast the metal. The powder melted down into a sound ingot topped with an oxide crust. There was little or no attack upon the crucible by the molten metal, and pressures in the order of 500-3000 microns were attained.

Several heats were poured into a graphite mold by tilting the furnace. Results were not too satisfactory since the metal tended to solidify on the crucible lip and the rate of pour could not be too well controlled. Cold shuts were present on the casting. The furnace was then modified so that the metal could be bottom poured into a mold. This included the following elements:

1. A base made of K-28 insulating brick
2. A fused silica tube which fitted loosely inside the inductor coil.
3. A graphite mold resting on the K-28 brick and surrounded by brick of the same material.
4. The support made of insulating brick and of alundum brick resting on the mold and designed to support the crucible. These pieces contained a hole through which the metal flowed from the crucible into the mold.
5. A graphite crucible resting on the alumina brick which served as the heating element.
6. An alumina crucible inside the graphite crucible.
7. A stopper rod made of an alundum tube which closed the hole in the bottom of the alumina crucible and extended upward to a hole in the graphite cover.
8. A steel rod attached to the alundum tube and extending through the furnace cover.
9. A vacuum seal in the furnace cover through which the steel rod extended. For this purpose, the so-called Wilson seal was used.

The entire furnace was evacuated down to a few millimeters of mercury. The crucible was heated by high frequency current applied to the induction coil and after the charge had melted, the stopper rod was raised thus allowing the molten metal to flow from the crucible into the mold. This method produced sound castings with good surface.

Design work which had started on a production furnace similar to that of the National Bureau of Standards was discontinued in favor of a bottom pour furnace. The first unit constructed was essentially an expanded model of the experimental furnace and was capable of holding an 8" diameter crucible. A removable bottom plate enabled one to lower this plate and remove the cast ingot. Numerous castings were successfully made with this furnace.

The next step in development led to the construction of a fused silica tube furnace and the use of graphite crucibles. A number of small melts had been made at the University of Chicago in graphite crucibles with no adverse effect upon the metal though a literature survey had pointed to the formation of a carbide. A 12" I.D. fused silica tube 36" long was placed inside an induction coil and set upon a water-cooled furnace base with removable bottom-plate to permit lowering of the casting from the bottom. Provisions were made in the water-cooled top cover plate for a vacuum tight seal and a sight glass. A graphite stopper rod replaced the alundum rod, and K-30 insulating bricks were used as furnace lining.

Early in January 1943 the foundry constructed at Metal Hydrides Incorporated was ready to go into production and casting operations were transferred to that place. Since that time a number of improvements were made upon the original furnaces and operating technique.

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A new type furnace base was developed with a self-looking bottom plate eliminating the use of a bolted on plate. Insulation was reduced so that a larger crucible could be accommodated.

Casting yields from uranium powder were about 85% in an effort to increase the yield varying amounts of calcium hydride were added to the powder with the expectation of reducing the oxide film formed on the surface of each particle, and thus decrease the "hold-up" effect of the oxide upon the metal. There was no definite improvement upon casting yield but one beneficial result was noted. The boron impurity was in many cases lowered.

It was noted that casting yields did not vary greatly with pressures from 500 microns to 3000 microns. With lower pressures of about 50 microns yields tended to increase. Later work by Mallinckrodt Company confirmed this observation. However, vacuums of this order were difficult to maintain without excessive maintenance work. In an attempt to prevent oxidation a series of heats were made in an atmosphere of argon and of helium. There was no apparent increase in yield and the surfaces of the billets were poorer. Billets cast in helium were more pitted and had a generally poorer surface than billets cast in argon. Billet tops were swelled and porous. Commercial grades of argon and helium were used and nitrogen, present as an impurity, may have been the major factor in producing the poor surfaces. However, in view of the fact that billets cast in helium were worse than those cast in argon, it was believed that helium was soluble to some extent in the molten metal.

In crucible manufacture a method was devised whereby a center core was cut from the graphite cylinder leaving a sleeve which formed the walls of the crucible. A plug was then tightly fitted into one end to form the finished crucible. The center core was of such size that a mold for billets could be machined from it.

On a number of occasions the stopper rod became cemented to the crucible or broke so that the metal could not be poured. To eliminate such difficulties a 3/4 inch hole was drilled in the bottom center of the crucible and plugged with a short graphite rod. Whenever a heat could not be cast in the normal manner the furnace was filled with argon, the cover plate removed, and the emergency plug pushed out with a long graphite rod. The plug always floated to the top of the billet.

Operating schedules were arranged so that a heat could be made every half hour. The crucible side wall temperatures was brought rapidly to 1550 - 1600°C and maintained there until a metal temperature of 1400 - 1450°C (optical pyrometer) was reached. At first crucible life was shortened but by raising the crucible bottom 1" - 2" above the bottom of the induction coil no more cracking of crucibles was experienced. Contrary to the experience of others best casting yields were obtained with a pouring temperature of 1400 - 1450°C. Temperatures of 1500°C were found to be best when recasting heels from extruded billets. Casting yields from rejected rods and eggs averaged 97%, whereas yields from heels varied from 82% to 90% depending upon the surface oxidation of the metal.

A number of billets were cut to determine if any internal pipes were present. No billets were found to contain such internal voids. The crucible was intentionally set on the mold so that the

metal after pouring came to about 1" from the bottom of the crucible. In this manner a good hot-top was maintained and little or no piping occurred. Billets four or more inches from the bottom of the crucible all had fairly long pipes.

At these high operating temperatures, there was considerable sticking and pitting of the graphite mold. Several washes of zirconia, zinc oxide, alumina, and U_3O_8 were tried. Of these a thick slurry of U_3O_8 minus 100 mesh suspended in carbon tetrachloride was found to be best. Recently a high temperature "Zirconite" mold wash consisting of zircon sand and clay was very successful. The wash can be easily applied with a brush and air sets quickly to a hard surface. Mold life was considerably lengthened and surface appearance of the billets greatly improved.

III. SUMMARY

Design and development over a period of several years of a furnace for casting uranium metal led to the present type furnace shown in Fig. I.

The use of calcium hydride to increase casting yield was not successful but boron content was lowered through use of the hydride

Melting in an atmosphere of argon or of helium did not prove to be superior to vacuum casting.

FIG.

TWELVE INCH QUARTZ TUBE FURNACE

Scale: $1/8" = 1"$

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