

[54] SKULL-MELTING CRUCIBLE

[75] Inventor: **John N. Turpin**, Oak Ridge, Tenn.

[73] Assignee: **The United States of America as
represented by the United States
Atomic Energy Commission,
Washington, D.C.**

[22] Filed: **Aug. 23, 1972**

[21] Appl. No.: 283,018

[52] U.S. Cl. 13/35, 263/48, 266/39

[51] Int. Cl.....F27d 1/12

[58] **Field of Search** 13/9, 35; 263/11,
263/14, 48; 266/39, 43

[56] **References Cited**

UNITED STATES PATENTS

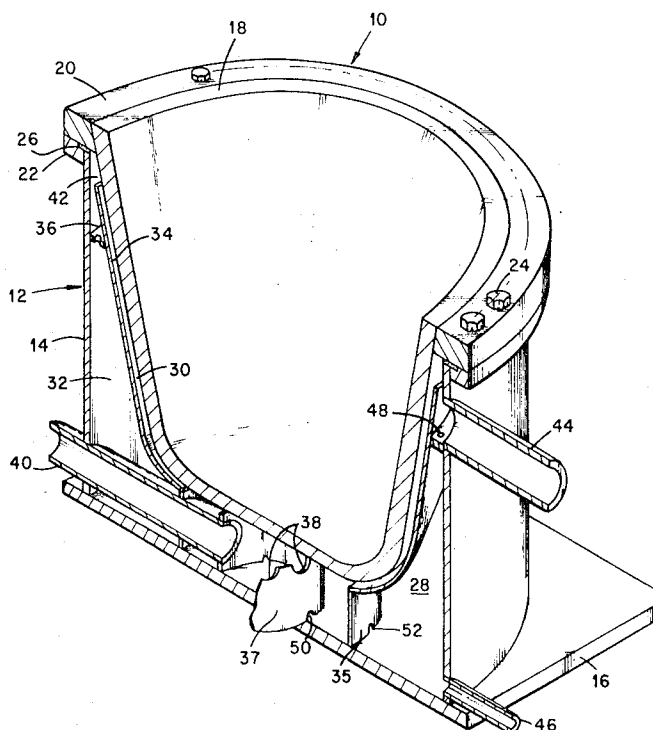
2,836,412	5/1958	Krieger.....	266/39
2,958,719	11/1960	Beecher.....	13/35 X

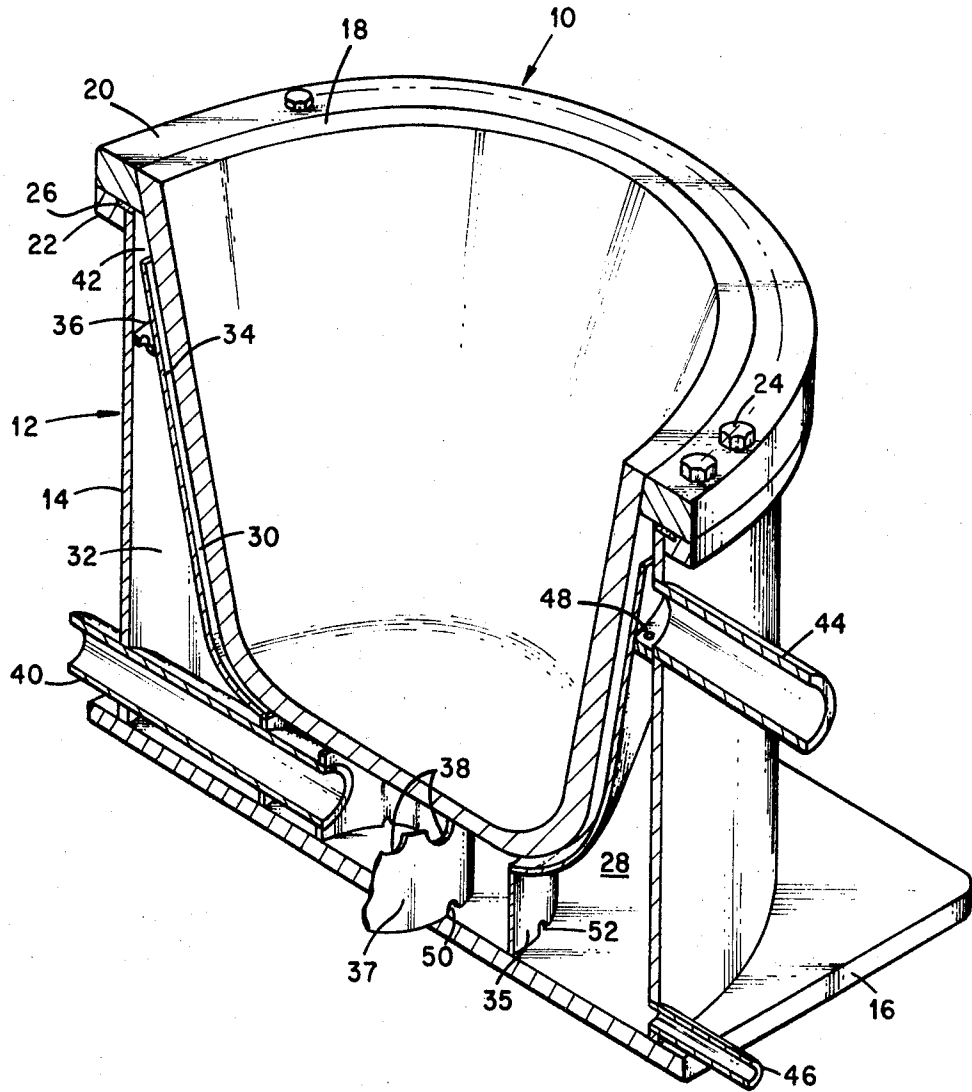
Primary Examiner—Roy N. Envall, Jr.
Attorney—Roland A. Anderson

[57] **ABSTRACT**

This invention is directed to an improved crucible for skull melting metals and alloys by employing consumable electrode arc melting procedures. The crucible is formed of a housing containing a removable, relatively thin, cup-shaped liner and a substantially conforming enclosed chambered volume through which liquid metal is channeled and circulated for uniformly cooling the liner.

6 Claims, 1 Drawing Figure





SKULL-MELTING CRUCIBLE BACKGROUND OF THE INVENTION

The present invention relates generally to a crucible in which metals and alloys are skull melted and cast by consumable electrode arc melting, and more particularly to such a crucible having an improved construction including a relatively-thin, removable liner which is uniformly cooled. This invention was made in the course of, or under, a contract with the U. S. Atomic Energy Commission.

Alloys and metals of high purity can be produced by melting the alloy forming metals or the metal to be purified in a crucible by employing well known electric arc-melting procedures. The crucibles used for such arc-melting procedures are often those which provide for a type of operation commonly known as skull melting and casting. These crucibles are formed of a good electrical and thermal conducting material such as copper and may be internally cooled with a liquid metal having good electrical conducting properties such as provided by a mixture of sodium and potassium (NaK). As the arc melting occurs, the molten metal contacting the relatively cool crucible wall cools and solidifies to form, in effect, a shell or skull for containing the subsequently melted metal. Ideally, the temperature difference between the cooled crucible wall and the molten metal prevents fusion of the latter with the crucible prior to forming the skull, but allows the accumulation of liquid metal within the skull. Thus, upon completion of the electrode melt and solidification of the metal skull the liquid metal contained therein may be removed by tilting the crucible.

While skull casting by arc melting has proven to be a highly desirable technique of preparing alloys and purifying metal, several shortcomings and drawbacks are present in the previously known liquid-metal-cooled crucibles employed for skull casting. For example, the vessels of such previous liquid-metal-cooled crucibles are cast around the coolant channels which results in variable effective wall thicknesses typically in the range of 0.5 to 4 inches. These thickness variations in the walls of the cast crucible result in a concentration of thermal stresses and shocks which crack the inner surface and with such cracks penetrating through the vessel after a limited number of cycles. The coolant channel arrangement of the prior art makes it difficult, if not impossible, to thoroughly examine the thermodynamics of the heat exchange process during melting and also causes troublesome heterogeneity in the temperature profile of the vessel during melting and casting operations. Further, the inadequate and non-uniform cooling of the inner vessel surfaces often results in fusion of the arc-melted metal skull with the crucible, which condition significantly hampers the removal of the skull from the vessel so as to substantially detract from the value of the skull-casting procedure. Another drawback attendant with the previously known crucibles is that the inner surface is integral with the outer shell or housing so as to necessitate the removal of the entire heat exchange system to effect repairs on any part of the crucible. This structural design also limits the crucible to a fixed, definite size. Since optimum crucible size is related to electrode size and power input level, a crucible must be matched, dimensionally, to the particular melting operation. Further, such integral crucibles are difficult to repair, have a low melt capacity total weight ratio, produce a thick skull requiring more electrical

power for arc melting, and have a lower overall effective thermal efficiency.

SUMMARY OF THE INVENTION

It is the primary aim or objective of the present invention to obviate or substantially minimize the above and other shortcomings by providing an improved crucible for use in skull melting and casting operations employing arc melting. The improved crucible comprises a housing having an end wall and a tubulation laterally projecting therefrom, an open-ended substantially hemispherical liner disposed within said tubulation in spaced relation to said end wall and said tubulation and affixed to latter adjacent the end thereof remote to said end wall for defining an enclosed volume between said housing and said liner, volume dividing means disposed within said volume intermediate said liner and housing and encircling said liner for forming first and second radially spaced apart chambers in said volume, passageway means adjacent the end of tubulation remote to said end wall for placing said chambers in registry with one another, conduit means penetrating said housing and communicating with the first chamber as defined by the liner and the volume dividing means at a location intermediate said end wall and said liner for conveying coolant into said volume in a heat exchange relationship with said liner, and further conduit means penetrating the housing and communicating with the second chamber as defined by the tubulation and the volume dividing means for removing coolant from the volume.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for the purpose of illustration and description. The preferred embodiment illustrated is not intended to be exhaustive or to limit the invention to the precise form disclosed. It is chosen and described in order to best explain the principles of the invention and their application in practical use to thereby enable others skilled in the art to best utilize the invention in various embodiments and modifications as are best adapted to the particular use contemplated.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawing the FIGURE is a somewhat schematic, perspective view showing, in section, the improved crucible construction of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown, the crucible generally indicated at 10 comprises a housing 12 of stainless steel, or the like, and formed of an open-ended tubulation 14 having an end wall or base 16 closing one end thereof. A liner 18 of a generally hemispherical open-ended configuration for containing the melt is disposed within the housing in spaced relation to the end wall and the tubulation. The liner 18 may be formed of wrought or spun copper with an essentially uniform wall thickness in the range of about 0.5 to 1 inch. The liner is maintained within the housing by a flange 20 disposed about the bearing

against or affixed to the periphery of the liner at the uppermost or open end thereof. This flange is secured to a lateral projection or shoulder 22 on the tubulation 14 by a bolting arrangement such as generally indicated at 24. A gasket 26 of a suitable heat-resistant material such as asbestos may be disposed between the flange and the housing projection 22 for sealing the liner to the housing.

With the liner disposed within the housing a volume 28 is formed between the liner and the housing for holding the liquid metal coolant, as will be described below. This volume 28 is, in turn, divided into chambers 30 and 32 by an annular partition or baffle 34 which is positioned adjacent to the liner and has a shape generally conforming to the configuration of the liner so as to provide the chamber 30 with dimensions suitable for uniformly cooling the entire periphery of the liner as will be described in greater detail below. The partition 34 may be supported in position within the housing by a ring 35 in contact with the base 16 and carrying the partition and by an annulus 36 disposed near the top of the partition and contacting the tubulation 14. The partition 34 has an aperture therein adjacent the base 16 for receiving a centrally disposed cylinder 37 which provides support for the liner as well as a manifoldlike structure for distributing the coolant into the chamber 30. The communication between the cylinder 37 and the chamber 30 may be provided by suitable passageways or openings 38 in the cylinder 37 which place the interior of the cylinder in registry with the chamber 30. A coolant inlet conduit 40 projects into the housing and into the interior of cylinder 37 for conveying the coolant into the housing from a suitable source (not shown). The partition 34 terminates at a location near the flange 20 on the liner 18 so as to define a passageway 42 between chambers 30 and 32 whereby the coolant flowing within the chamber 30 can be diverted from the latter and the housing through a suitable outlet once its cooling function is completed. While the communication or passageway between chambers 30 and 32 is shown as being provided by the space between the flange 20 and the top of the partition 34, it is to be understood that such communication may readily be provided by openings in the partition similar to the openings 38 in the cylinder 37. The coolant is removed from the housing by an outlet conduit 44 which penetrates the housing and is in registry with the chamber 32. In order to divert the coolant from chamber 32 into the outlet conduit 44 the annulus or ring 36 is disposed about the partition 34 at a location contiguous with the lower end of the outlet conduit 44. The metal coolant in the volume 28 and chambers 30 and 32 may be removed by a drainage pipe 46 which communicates with the volume 28 at a location near the base 16. Openings 48 in the ring 36 and openings 50 and 52 in the cylinder 37 and ring 35, respectively, provide relatively small passageways for the coolant into the drain pipe 46. During the melting operation, metal coolant is continually flowing through these openings but the quantity of this flow represents only a minor portion of the total coolant flow and is readily compensated for to assure adequate cooling of the liner. The width of chamber 30 between the partition 34 and the liner 18 is gradually decreased with respect to the axial direction of coolant flow by the position of the partition 34 so as to provide the chamber 30 with uniform cross-sectional area over the axial length thereof. This de-

creasing width of the chamber 30 increases the velocity of the coolant as it flows through the chamber 30 to insure uniform cooling of the liner.

In a typical skull-casting operation employing the crucible constructed in accordance with the teachings of the present invention uranium alloy can be prepared from scrap material with the resulting casting having a weight in the range of about 100 kg to 1,000 kg. To initiate the skull-casting operation the liner 18 is preferably thoroughly cleaned and dried. Loose pieces of the desired alloy material having a thickness of about one inch are then placed in the crucible for forming a surface against which the electric arc may be struck. Normally, for the large castings about 150 kg of the scrap material may be employed for forming the crucible skull and adequately provides a surface for the initial arc strike of the consumable electrode. Of course, if a smaller or larger casting is desired, less or more loose charge material may be used. For a 1,000-kg melt, the consumable electrode may be prepared by welding together pieces of melt stock material totaling about 1,000 kg. The electrode is connected to a suitable high current and low voltage electric power source through a movable ram. After the inner shell of the crucible is charged with loose pieces of metal and the consumable electrode prepared, the vacuum arc-melting furnace is subjected to an inert (argon) atmosphere at a pressure less than atmospheric, e.g., about 10 microns absolute pressure. The crucible is then cooled with a NaK mixture with the coolant flowing through the crucible coolant channels at a rate of about 150 gallons per minute to maintain the surface temperature of the crucible inner liner below about 200°C. To start melting the electrode, an arc is established between the metal charge and the consumable electrode with a current of 10,000 amperes and 50 volts. Then, the current is increased to 25,000 amperes and 60 volts which rapidly melts the charge metal. As the molten metal contacts the cooled liner, the molten metal contracts and solidifies to form a thin crust or skull. The temperature of the inner shell is maintained at 200°C. or less whereas the molten metal contained in the skull is about 1,600°C. The consumable electrode of scrap alloy is melted in the crust or skull at a rate of about 40 kg/min. Upon completion of the melt the molten metal in the skull is poured into a mold, cooled, and then removed from the mold and cleaned.

With the afore-described construction the liner 18 may be readily removed and replaced without necessitating the extensive expenses heretofore required such as described above. Further, with this construction, internal resistances can be designed so that the coolant flow about the liner is at all times essentially uniform and controlled so as to negate the aforementioned hot spots and thermal stresses. The relatively thin liner and the uniform cooling of the latter provide uniform heat removal during melting operations to prevent a build-up of thermal stress and shock so as to eliminate premature fractures and cracks in the liner as heretofore suffered.

This coolant is preferably a liquid metal such as the NaK mixture mentioned above which may be formed of 22 weight per cent sodium and 78 weight per cent potassium for providing a melting point of about -12°C.

The improved crucible generates a thin skull which increases melting efficiency of the crucible by lowering

the required amount of electrical power. Further, the high chill rate of the liner immediately shrinks the molten metal in contact therewith which effectively inhibits adhesion of the skull to the inner surface of the crucible. This absence of adhesion limits the heat transfer from the skull to the wall to insure a thin skull and provides for relatively easy skull removal. Also, the absence of skull weldments has prevented the contamination of the melt metal by the crucible wall metal.

What is claimed is:

1. An improved crucible within which metal can be skull melted and cast by electric arc melting, comprising a housing having an end wall and a tubulation laterally projecting therefrom, an open-ended substantially hemispherical liner disposed within said tubulation in spaced relation to said end wall and said tubulation and affixed to latter adjacent the end thereof remote to said end wall for defining an enclosed volume between said housing and said liner, volume dividing means disposed within said volume intermediate said liner and housing and encircling said liner for forming first and second radially spaced apart chambers in said volume, passageway means through said volume dividing means at a location adjacent the end of tubulation remote to said end wall for placing said chambers in registry with one another, conduit means penetrating said housing and communicating with said first chamber as defined by the liner and the volume dividing means at a location intermediate said end wall and said liner for conveying a coolant into said volume in a heat exchange relationship with said liner, and further conduit means penetrating the housing and communicating with said second chamber as defined by the tubulation and the volume dividing means for removing coolant from the volume.

2. The improved crucible claimed in claim 1, wherein said volume dividing means comprises an annular parti-

tion having a configuration generally corresponding to the configuration of said liner and disposed about and spaced from the latter for providing said first chamber uniform cross-sectional area over the axial length thereof with respect to the direction of coolant flow for uniformly cooling the entire periphery of the liner encompassed by the partition, and wherein support means are disposed in said volume for maintaining said partition in position about said liner.

3. The improved crucible claimed in claim 2, wherein a cylinder is disposed in said volume in a contacting relationship with said end wall and said liner and projecting through said partition at a central location thereof, the first mentioned conduit means in registry with the interior of said cylinder, and wherein passageways in said cylinder provide the communication between the first mentioned conduit means and said first chamber.

4. The improved crucible claimed in claim 3, wherein a portion of said support means is provided by an annulus disposed in said volume at a location adjacent to said passageway means and separated from the latter by said further conduit means and in a contacting relationship with said partition and said tubulation for defining therewith said second chamber.

5. The improved crucible claimed in claim 4, wherein drain means penetrate said housing and communicate with said volume for draining coolant from the latter, and wherein said cylinder and said annulus have apertures therethrough for placing said chambers in registry with said drain means.

6. The improved crucible claimed in claim 1, wherein the liner is formed of wrought copper, the liner is of an essentially uniform thickness in the range of 0.5 to 1 inch, and wherein the coolant is a liquid metal consisting of a mixture of sodium and potassium.

* * * * *

40

45

50

55

60

65