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[54] **CRUCIBLES**

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[56] **References Cited**

UNITED STATES PATENTS

3,582,528 6/1971 Seale 13/27

3,461,215 8/1969 Reboux 13/27
3,520,980 7/1970 Sterling et al.....13/27

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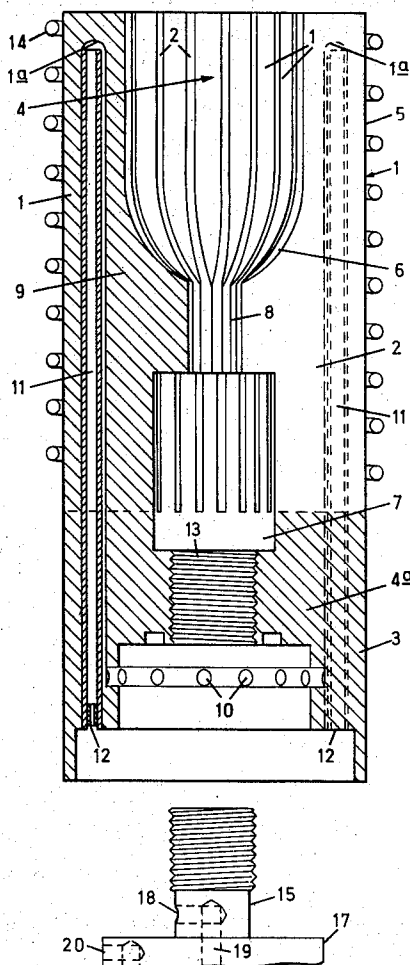
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[57]

ABSTRACT

The invention provides an improved design for a crucible for the melting of materials by means of radio frequency eddy currents induced in the materials. A segmented platform is located intermediate an open end of the crucible and a closed base at the opposite end, in a region where the crucible wall is segmented, thereby to separate a melt from the "cold spot" in the crucible caused by the electrical short circuit of the closed base end. The outer surface of the wall segments is curved and defines a single cylindrical surface to facilitate fitting within a primary induction coil.

7 Claims, 2 Drawing Figures



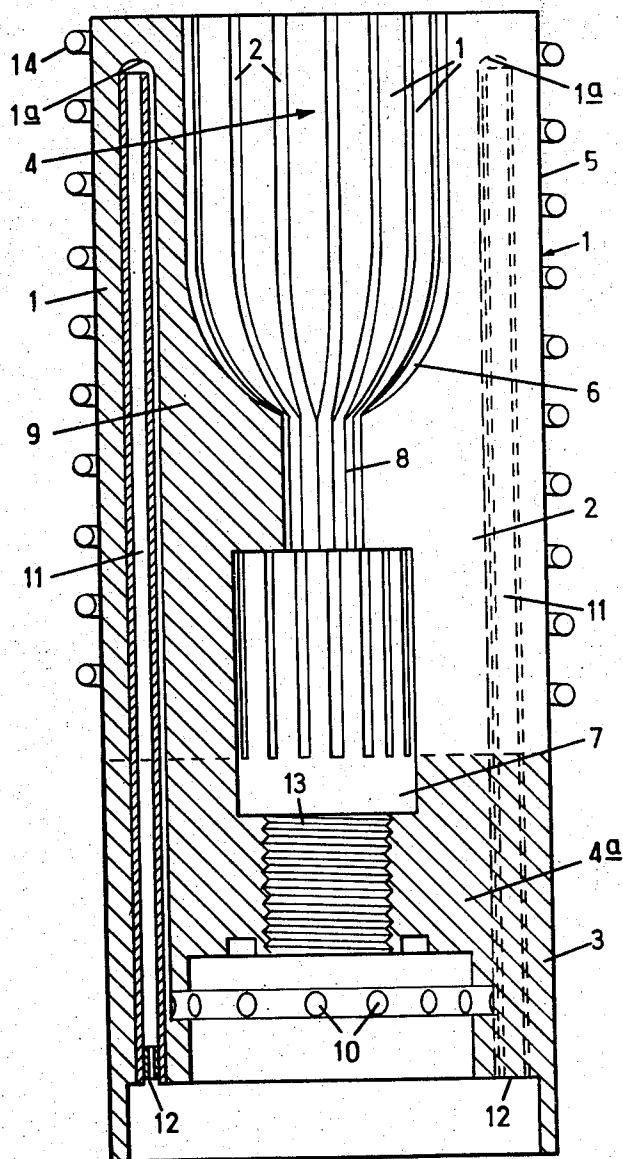
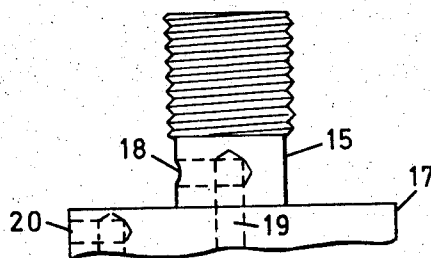


Fig.1



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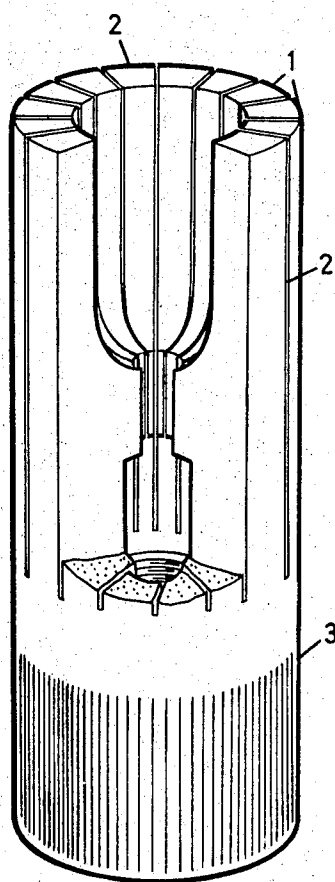


Fig. 2

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CRUCIBLES

The present invention relates to crucibles for the melting of materials by means of radio frequency eddy currents induced in the materials.

The melting of fusible materials in metal crucibles by means of radio frequency eddy currents induced within the materials is a well known technique which has wide applications in the fields of metallurgy and semiconductor technology. Conventionally, the eddy currents are generated by means of a primary, or work, coil surrounding the crucible, to which radio frequency power is supplied. Generally metal crucibles have been of segmented wall construction to reduce eddy current losses in the crucible walls. Thus a common crucible design consists of a generally cup-shaped array of tubes of circular cross-section positioned sufficiently closely together for molten material to be retained in the crucible by surface tension effects. The tubes are connected together at their ends to enable cooling fluid to be circulated through them. However, such crucibles suffer from the disadvantage that the manifolds connecting together the ends of the tubes short-circuit them, thus reducing the electric field in these regions so causing the ends of the crucible to be considerably colder than the central region. This can prevent the setting up of desired temperature conditions within the molten material, for example, if single crystal material is to be made from the molten material.

Furthermore the circular cross-section of the tubes does not permit very close electrical coupling of the work coil to the crucible and the crucible to its load. Thus, high power radio frequency generators are required to overcome the losses in the crucible.

It is an object of the present invention to provide an improved crucible in which "cold" regions thereof do not affect the temperature conditions within a melt and capable of close coupling to a primary induction coil.

According to the present invention a segmented hollow wall crucible open at one end to receive material for processing and closed at the other by a base which alone joins the wall segments, is provided with a segmented platform intermediate said open end and said base for supporting material remote from said base.

Preferably the platform segments are integral inwardly directed portions of the crucible wall segments.

In order to facilitate coupling with a primary induction coil the outer surfaces of the wall segments preferably all lie on a single cylindrical surface.

Conveniently the base includes a set of ports each communicating with the hollow interior of a wall segment and a second set of ports each communicating with one end of a tube fitted within each hollow wall segment and communicating with the remote end thereof. A central threaded opening is formed in the base by which it can be screwed onto a supporting spigot having a complementary thread profile and extending from a platform which cooperates with the underside of the base to form a cooling water reservoir.

It is envisaged that a crucible according to the invention will be fitted with a primary induction coil embracing at least that portion of the crucible between said open end and the platform.

The present invention thus provides a crucible comprising a series of hollow members of high electrical and thermal conductivity so shaped as to provide a ves-

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sel having a thick wall, the outer surface of which is in the form of at least part of a cylinder and which has an inner surface whose form is such as to provide at at least one end of the vessel a region of reduced cross-sectional area, the said wall being interrupted by a plurality of slots extending parallel to the axis of the cylinder, the said slots extending throughout and beyond the region or regions of reduced area, the arrangement also being such that cooling fluid can be circulated through the hollow members.

In a preferred embodiment of the invention the inner surface has a form such as to provide an enclosure in the shape of a cup with a tapering interior having a central aperture. The crucible is intended for use with a radio frequency heating coil arranged to extend beyond the platform formed by the region of reduced cross-sectional area forming the bottom of the cup. The interior projection which forms the bottom of the cup forms a concentrator for the radio frequency field, thus ensuring that the bottom of the crucible is not cooler than the remainder of the vessel.

Furthermore, the shape of the radio frequency field is made to be such that once the material is molten it is levitated slightly out of contact with the crucible and therefore cannot be contaminated by impurities dissolved from the metal forming the crucible. The fact that the slots extend beyond the end of the radio frequency heating coil means that effectively, so far as the radio frequency field is concerned, the individual members forming the walls of the crucible are not short-circuited together, each forming a separate transformer for the radio frequency currents.

Suitable materials for the crucible are high purity copper, or silver. The surfaces of the crucible may be plated with some reflective metal to reduce heat losses from the inside of the crucible.

The invention will be further described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a longitudinal section of an embodiment of the invention, and

FIG. 2 is a perspective view, partly cut-away, of the embodiment of FIG. 1.

Referring to the drawings, a crucible for use as a so-called cold crucible for the radio frequency melting of materials, consists of a number of elements 1 of trapezoidal cross-section separated by gaps 2 which are formed by cutting radial slots in a solid bar of high-conductivity copper 3 of some 2 ¼ inch diameter. A bore 4 of 1 ¼ inch diameter and having a hemispherical bottom is formed in the copper bar 3 at one end, resulting in a crucible having walls of some ½ inch thickness, a cylindrical external surface 5 and a cup-shaped internal surface 6. In the other end of the bar 3 is a counterbore 7 of somewhat less diameter than the cup-shaped bore 4. Beyond the counterbore 7 the solid metal forms a base 4a. Where the slots meet at the bottom of the cup-shaped bore 4 a hole 8 is formed of some ¼ inch diameter in a region 9 of the vessel. The size of the hole 8 is not critical and is in fact controlled by the width of the slots, the narrower the slots the smaller the hole 8. The region of the side wall between the upper and lower bores 4 and 7, respectively, acts as a concentrator for the radio frequency field ensuring that the bottom of the crucible is at least as hot as the major part of the

side wall. The region 9 also shapes the radio frequency field so that the material is levitated in the crucible. Each of the elements 1 forming the wall of the crucible is bored longitudinally, each bore 1a connects via a port 10 of a first manifold, and has a tube 11 inserted in it which connects via a port 12 in a second manifold formed in the bar 3 to enable cooling water to be circulated throughout the wall segments of the crucible. A screw thread 13 enables the crucible to be screwed on to a spigot 15 of supporting stand 17, which can be utilized to form part of the cooling system. To this end the spigot includes bores 18, 19 for communicating between a water supply and the first manifold ports 10 and the stand has bores 20, 21 for communicating between the water supply and the second manifold ports 12. The crucible is used in conjunction with a primary coil 14 which is arranged to extend from the top of the crucible to a point somewhat below the beginning of the counterbore 7. Thus each segment 1 is electrically isolated from its neighbors in the region of the radio frequency field and functions independently as a transformer, and the elements 1 form a cup-shaped crucible which is closely coupled to a charge within it over virtually the whole of its surface, including the bottom, and is closely coupled to the primary coil. The large numbers of elements 1, (16 in all), and the symmetrical shape of the crucible give a stable melt even though a low frequency ripple may be present on the high tension supply to the primary coil.

The fact that the crucible is supported by the stand in a vertical position means that there is no obstruction at the open end of the crucible to interfere with the installation of ancillary equipment such as radiation shields, receivers for the vacuum distillation of metals from the crucible; or equipment for the pulling of single crystals from a melt contained in the crucible.

The merits of the invention are illustrated by the facts that using the above described crucible a radio frequency power input of some 15 kW sufficed to completely melt in air a charge of 120 gm. of platinum and a charge of 60 gm. of lanthanum was completely melted in vacuo by 6 kW of radio frequency power.

I claim:

1. A crucible having a generally cylindrical body including a plurality of elongated slots extending longitudinally in the body and circumferentially spaced about

the longitudinal axis of the body to define a plurality of elongated wall segments of the body, the body being hollow to provide a melt chamber surrounded and defined by said wall segments, said wall segments terminating in free extremities spaced from each other at one end of the body, said slots and wall segments defined thereby terminating intermediate the ends of the body with the portion of said body between the wall segments and other end of the body constituting a base integral with said wall segments, an induction coil mounted about said body in surrounding relation to said wall segments, the cross-section of said wall segments gradually and uniformly increasing in thickness in the transverse direction of the body at a region opposite the free extremities of said wall segments to define a segmented platform extending transversely of the body intermediate the ends thereof to concentrate a radio frequency field on said region while also shaping the radio frequency field at said region, said induction coil extending from adjacent said one end of the body to said region.

2. A crucible as set forth in claim 1 in which the outer surfaces of the wall segments all lie on a single cylindrical surface to facilitate location of a primary induction coil therearound.

3. A crucible as set forth in claim 3 in which the radially innermost ends of the platform segments all lie on a coaxial cylindrical surface.

4. A crucible as set forth in claim 1 in which the base is cut away to define a first set of ports each communicating with the hollow interior of a wall segment and a second set of ports each communicating with one end of a tube fitted within each hollow wall segment and communicating with the remote end thereof.

5. A crucible as set forth in claim 1 in which the base is cut away to form a central threaded opening by which it can be screwed onto a supporting spigot having a complementary thread profile.

6. A crucible as set forth in claim 5 in combination with a supporting platform having an upstanding externally threaded spigot for engagement in the threaded opening in the base.

7. A crucible and platform combination as set forth in claim 6 wherein the platform cooperates with the underside of the base to form a cooling water reservoir.

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