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METHOD AND APPARATUS FOR MELTING AND POURING TITANIUM

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Fig. 1

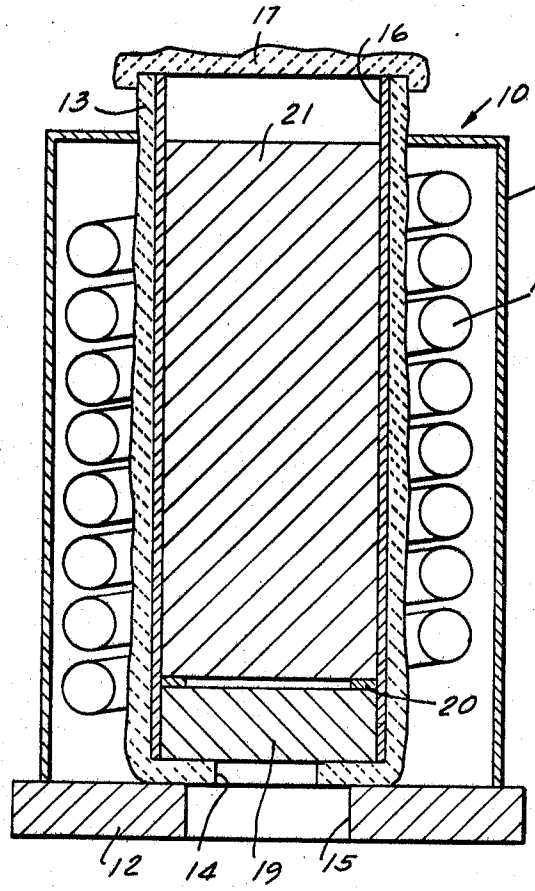
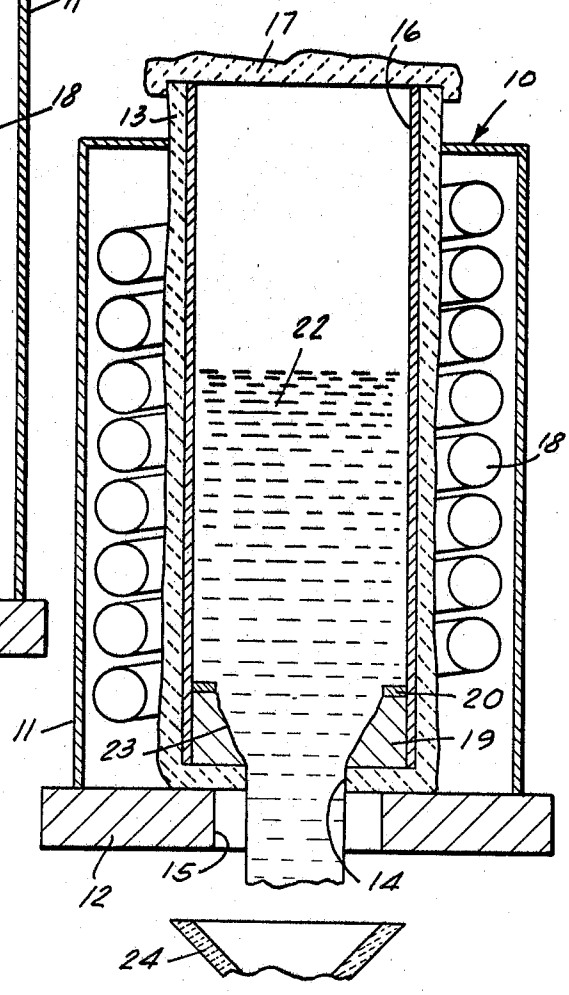


Fig. 2



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METHOD AND APPARATUS FOR MELTING AND POURING TITANIUM

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ABSTRACT OF THE DISCLOSURE

Melting of titanium to avoid contamination wherein a titanium alloy charge is rapidly melted by induction heating and the molten charge melts its way through a disc of titanium alloy to form its own pour hole, thereby avoiding contact with contaminants.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention is in the field of melting titanium alloys having high titanium contents (80% titanium and above) and is also applicable to the melting of substantially pure titanium (99+% titanium). The invention makes use of inductive heating of a titanium charge within an enclosure which preferably consists of a shell mold crucible, the charge being positioned above and in spaced relation to a disc of titanium alloy, whereby rapid melting of the charge without melting of the disc causes the molten, superheated titanium to melt through the disc and thereby form a pour hole for funneling the molten titanium out of the crucible.

DESCRIPTION OF THE PRIOR ART

Titanium alloys used in forming shaped castings are usually skull melted in water-cooled, crucible arc melting units. The temperature control in this type of melting is difficult because the molten titanium is cooled rapidly by the water-cooled crucible when power from the arc is terminated. The resulting variation in pouring temperature may cause many casting defects. If the temperature is too high, dimensional and metallurgical problems result. If the pouring temperature is too low, the castings misrun and also contain metallurgical defects.

One of the most serious problems in melting and pouring titanium is the avoidance of contamination. Titanium has a strong affinity for hydrogen, nitrogen and oxygen. Excess absorbed hydrogen is removed from titanium alloys by expensive processing such as vacuum annealing. According to current specifications, the hydrogen content of titanium should be limited to about 125 to 200 parts per million. Above these limits, hydrogen embrittles most titanium alloys, and reduces their impact strength and notch tensile strength, causing brittel failure under sustained loads at low stresses.

Titanium alloys are also embrittled by contamination with oxygen, carbon and nitrogen. This embrittlement is usually manifested by the formation of a brittle surface layer which must be removed by pickling, grinding or machining.

Various arc melting furnaces for melting titanium will be found in the following references:

Maddex, U.S. Patent No. 2,564,337; "Journal of Metals," April 1950, article entitled, "Ductile Titanium", pages 634 to 640;

U.S. Air Force Project Rand, "Titanium and Titanium Base Alloys," pages 52 to 58, published Mar. 13, 1949

The melting apparatus described in these references is highly specialized and very expensive, so that ordinary

casting foundries are usually not equipped to handle titanium alloys.

SUMMARY OF THE INVENTION

The present invention is directed to the provision of equipment which can be installed and operated by investment casting foundries without substantial capital expenditures. The method imvolved in the operation of the equipment provides a much better control of the pouring rate and temperature than can be obtained with conventional arc melting furnaces. The cost of melting and pouring titanium by the method of the present invention is significantly less than the cost of melting titanium with a vacuum arc melting unit. In addition, the method involved provides a much safer melting procedure than now exists with water-cooled crucibles used in arc melting.

In the preferred form of the present invention, a solid disc of titanium alloy which is to be melted is placed in an enclosure, and the main charge of the same alloy to be melted is positioned above and in spaced relation to the disc. The main charge is positioned directly within the effective field of an induction heating coil, whereas the disc is located at or beyond the periphery of the coil so that it is not directly in the effective field of the electromagnetic energy produced in the coil. The main charge is rapidly heated by induction heating to above its melting temperature and to a controlled amount of superheat, while the disc is retained in solid form because of its position relative to the field of the coil. When the charge is melted, it flows onto the disc thereby melting an opening through the disc through which molten metal can be withdrawn from the enclosure and directed to a ladle or directly into a casting mold.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a somewhat schematic view of a melting and pouring assembly which can be used in accordance with the present invention, showing the disc and the charge positioned in the crucible before melting; and

FIGURE 2 is a view similar to FIGURE 1, but illustrating the condition where the main charge has been melted and has formed a pour hole through the disc.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is applicable to the melting and pouring of titanium alloys generally, where contamination is a problem. Typical titanium alloys now available, with which the present invention can be usefully employed, are listed in the following table:

TABLE I

Ti-6A1-4V
Ti-5A1-2.5Sn
Ti-2Fe-2Cr-2Mo
Ti-8Mn
Ti-5A1-1.5Fe-1.4Cr-1.2Mo
Ti-7A1-4Mo
Ti-4A1-4Mn
Ti-4A1-3Mo-1V
Ti-2.5A1-16V

In FIGURE 1, reference numeral **10** indicates generally a casting and pouring apparatus which can be used in accordance with the present invention. The apparatus **10** includes an outer casing **11** which rests on a support plate **12**. Disposed within the casing **11** is a crucible **13** which preferably takes the form of a relatively thin porous shell mold produced by the techniques presently employed in the well known shell mold process of precision investment casting. The crucible **13** has an aperture **14** at the base thereof, the aperture **14** communicating with an

aperture **15** of somewhat larger diameter in the support plate **12**.

Lining the inner wall of the crucible **13** is a thin walled, high density graphite sleeve **16**. An insulating cover **17** is placed over the top of the crucible to reduce heat loss from the top of the crucible.

An induction heating coil **18** is mounted on a frame (not shown) set on the support plate **12**. The coil **18** is tightly wound to give a maximum power density and to provide an excellent electrical match with the charge introduced into the crucible **13**.

Positioned at the bottom of the crucible **13** is a disc **19** having the same chemical composition as the charge to be melted. A graphite spacer **20** separates the disc **19** from the main charge **21** of the titanium alloy being melted. At the beginning of the melting cycle, full power is applied to the coil **18**, thereby heating and melting the main charge. It is important that this charge be melted rapidly in order to prevent possible contamination. Our studies have indicated that the average heating rate for the charge should be at least about 14° F. per second. When the main charge **21** is molten to provide a superheated liquid **22** as shown in FIGURE 2, the molten charge melts through the disc **19**, thereby forming a generally conical-shaped funnel portion **23** in the disc **19**. This melting is accentuated by the electromagnetic stirring which results in the charge due to the presence of the inductive heating field The result of this action is the provision of a ring of titanium alloy from the disc **19** through which the molten titanium alloy flows. As illustrated in FIGURE 2, the molten titanium **22** can be delivered directly to the casting mold as schematically illustrated at reference numeral **24**.

The thickness of the disc **19** and its position relative to the bottom turn of the coil **18** determines the degree of superheat in the titanium metal. For some power densities and pouring superheat, no disc is required. In that case, a ring of graphite can be substituted for the disc **19** directly under the main metal charge **21** to prevent the reaction of the charge with the ceramic crucible. In cases where a higher level of contamination is allowable, a carbon impregnated ceramic crucible can be used in place of the separate graphite liner **16**.

The following specific example illustrates the method involved more completely.

EXAMPLE

A charge of titanium measuring 4.5 inches in diameter and weighing 7 pounds was set into a 4.6 inch diameter graphite liner having a 1/16 inch wall. The charge and the liner were inserted into a shell mold crucible. The charge was spaced from the melt out disc by a 0.1 inch thick graphite washer. Varying amounts of power were applied to the induction coil to produce different melting cycles. The metal was tapped into a steel pipe and carbon contamination of the titanium was measured.

At a melting time of about 120 seconds, the carbon pickup was only 0.01%. At a 160 seconds melting, the carbon pickup was about 0.04%. At about 190 seconds, the carbon pickup was 0.15%. At 240 seconds, the carbon pickup was about 0.24%, while at 320 seconds it was about 0.36%. Thus, by varying the melting time, a product can be produced which has carbon contents within desired specifications.

It should be evident that various modifications can be made to the described embodiments without departing from the scope of the present invention.

We claim as our invention:

1. The method of melting a titanium alloy which comprises providing a refractory ceramic crucible having a bottom opening therein, positioning an electrically conductive sleeve within said crucible, positioning a titanium alloy disc at the base of said sleeve and extending completely across said bottom opening, positioning a charge of the alloy to be melted within said sleeve and in spaced relation to said disc, and rapidly inductively heating such charge above its melting point without similarly melting said disc to thereby provide a pool of molten metal flowing onto said disc and thereby melt an opening through said disc.

2. The method of claim **1** in which said charge is heated at an average rate of at least 14° F. per second.

3. A melting assembly for melting titanium alloys comprising a refractory ceramic crucible having a reduced diameter bottom opening therein, a graphite sleeve lining the interior of said crucible, a titanium alloy disc positioned at the bottom of said sleeve and extending completely across and beyond said opening in said crucible, a titanium alloy charge located within said sleeve and supported in spaced relation to said disc, and an induction heating coil disposed about said crucible, said charge being positioned directly within the field of said coil and said disc being positioned substantially outside the direct field of said coil.

4. The assembly of claim **3** which includes an annular spacer between said charge and said disc.

5. The assembly of claim **3** in which said disc is composed of the same titanium alloy as said charge.

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