

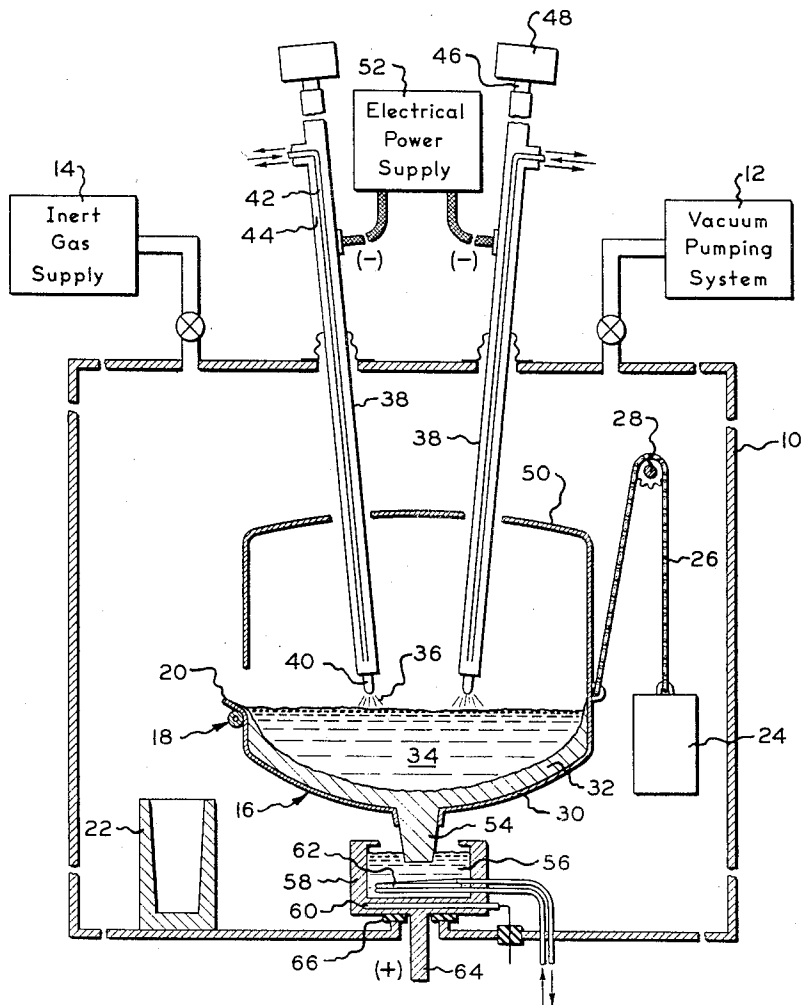
Nov. 1, 1960

N. BEECHER

2,958,719

PRODUCTION OF METAL

Filed Sept. 18, 1958



INVENTOR.

BY *Norman Beecher*

Oliver W. Hayes
ATTORNEY

1

2,958,719

PRODUCTION OF METAL

Norman Beecher, Concord, Mass., assignor to National Research Corporation, Cambridge, Mass., a corporation of Massachusetts

Filed Sept. 18, 1958, Ser. No. 761,707

7 Claims. (Cl. 13—31)

This invention relates to the production of metals and more particularly to arc melting furnaces which employ a "skull" of the metal to be melted.

A principal object of the present invention is to provide an improved skull melting furnace.

Another object of the invention is to provide a skull melting furnace of the above type with an improved ground return for the electrodes.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawing which is a diagrammatic view of one embodiment of the invention.

Skull melting is usually carried out under vacuum or inert gas conditions by subjecting the metal to be melted to an extremely hot electrical arc, while the molten metal is supported in a solid skull of the same metal. The metal to be melted serves as one of the electrodes for supporting an arc from one or more electrodes which can be either consumable, nonconsumable or both. The electrode is usually maintained at a negative potential while the skull and molten metal supported thereby is maintained at a positive potential. After sufficient melting, the molten metal is ready for pouring and casting.

The maintenance of the skull and molten metal carried thereby at a positive potential and the conductance of the arc current away therefrom has heretofore been accomplished by employing large flexible lead means, or through the use of massive conductor blocks or bus-bars (usually copper) arranged to contact another massive cooling block. The use of flexible leads as shown in U.S. 2,789,150 is not satisfactory, since they readily deteriorate under such current loads and present insulation problems. Moreover they do not provide a satisfactory means for the removal of heat generated by electrical resistance or for the heat obtained by conductance from the skull. The use of massive conductor blocks, as shown in U.S. 2,789,152 is more effective than the use of flexible leads in the removal of heat. However, a high interfacial or contact resistance is present in the metal to metal contact required to complete the electrical circuit to the skull so that the current carrying capacity is considerably diminished. Moreover, the contacting surfaces must be kept exceptionally clean else detrimental pitting of the metal surfaces can occur. Also if the metal to metal contact is not as tight or firm as possible then arcing therebetween can result. In the present invention the ground return for the skull is such that the above difficulties are avoided.

The present arc furnace for skull melting a refractory

2

metal such as titanium and the like comprises a gas-tight housing and means for creating a substantially inert atmosphere within the housing. A first crucible for holding a mass of refractory metal within a solid skull of the same refractory metal, means for tilting the first crucible, and at least one electrode means for creating a metal-melting arc to the metal to be melted in the first crucible are provided within the gas-tight housing. The grounding means for the first crucible comprise a second crucible below the first crucible for holding a mass of low-melting metal and bus-bar means connected to the second crucible for conducting current therefrom. A substantially large metallic connector means extends from the bottom of the first crucible and skull therein into the low melting-metal in the second crucible, thereby providing good electrical connection therebetween when the first crucible is not in the tilted position. The second crucible is also provided with means for initially melting the low-melting metal and with means for cooling the low-melting metal therein.

In one embodiment of the invention, the low melting metal in the second crucible comprises a lead-bismuth alloy. In said embodiment of the invention, the metallic connector between the first crucible and the second crucible is comprised of the same refractory metal as the skull within the first crucible.

Referring now to the drawing, there is illustrated one preferred embodiment of the invention which will be discussed in connection with the melting of titanium to produce a large pool of molten titanium which can be poured into a suitable mold therefor. A gas-tight or vacuum-tight furnace chamber or housing 10 is provided, this housing being arranged to be evacuated to low free air pressures by a vacuum pumping system schematically indicated at 12. The housing is also preferably arranged to be subjected to a reduced pressure, or even an atmospheric pressure of an inert gas such as argon from a suitable supply 14. As used in the specification and claims "inert atmosphere" shall mean a vacuum or inert gas atmosphere. Inside of the furnace housing 10 there is provided a first crucible 16 arranged to be tilted on an axis 18 substantially about its lip 20 so as to permit the pouring of molten titanium into a mold schematically indicated at 22. The pivot 18 is affixed to the crucible and rotated by an external drive to tilt the crucible. To assist in tilting the crucible, a counterweight 24 is preferably included, this counterweight being provided with a chain 26 which is connected to the crucible 17 and passes over a pulley 28.

The crucible 16 is preferably a "skull" type crucible comprising an outer steel jacket 30 and a solid titanium skull 32. Between the outer jacket 30 and skull 32 there can also be a layer of refractory insulating material and/or an electrically conducting crucible such as graphite which are described and illustrated in U.S.P. 2,789,152. The skull 32 supports therewithin the mass of refractory metal to be melted which on melting forms a deep molten pool of titanium 34, which pool is maintained molten by means of one or more arcs 36. At least one, and preferably a plurality of electrodes 38 are provided for maintaining through electrode tips 40 of for example, tungsten arcs to the molten titanium pool. Consumable electrodes of the metal to be melted (such as described and illustrated in U.S.P. 2,825,641) can also be provided. Each electrode is provided with suitable fluid passage means to permit the flow of a cooling fluid such as an inert gas, e.g. helium under pressure therethrough. These passage means comprise a pipe 42 for permitting flow of cooling fluid downwardly to the bottom of the electrode 38, and a passage 44 for permitting the upwardly return of the cooling fluid. In order to achieve a substantial cooling effect with an

3

inert gas such as helium, the inert gas must be circulated through the electrode 38 at an appreciable pressure and at a sufficient velocity. When utilizing helium, pressures above about 100 p.s.i. are adequate. The use of an inert gas for electrode cooling is extremely advantageous, since it does not present the danger of disastrous explosions which have been known to occur when using water-cooled electrodes. Each electrode 38 is carried by a rod 46 connected to moving mechanism such as an air cylinder 48 which permits the raising and lowering of the electrode 38. This permits the electrodes 38 to clear a heat shield or hood 50 which is provided over the crucible 16 and also permits tilting of the crucible when it is desired to pour the charge of molten metal. The electrode tip 40 is maintained at a negative potential by means of leads 51 connected to a suitable electrical power supply indicated at 52. The molten titanium 34 is maintained at positive potential.

Since it is essential to maintain a solid titanium skull 32 to prevent contamination of the molten charge, it is highly desirable to provide a means for removing large quantities of heat from the bottom of the crucible and skull therein. Additionally such means must be capable of conducting large arc currents away from the crucible 16 without creating high resistances or undergoing deterioration. In a preferred embodiment of the invention, the skull 32 is provided with a downwardly extending stud or connector 54 which passes through the bottom of the crucible 16. This connector 54 is preferably of the same material, e.g. titanium, as the skull 32. The connector 54 dips into a mass of low melting metal 56 (here shown in the molten state) contained within the second crucible 58. Suitable low-melting metals which can be employed are gallium, indium, and alloys of lead and bismuth. Lead-bismuth alloys containing about 45 percent by weight lead with a melting point of about 125° C. are preferred. The low-melting metal 56 is initially melted by heating means 60. Cooling means 62 here shown as coils are also provided for removing heat from the low-melting metal 56. The crucible 58 is connected to bus-bar means 64 to complete the electrical return circuit. The crucible 58 is electrically insulated from housing 10 by suitable insulation means 66. The crucible 58, low-melting metal 56 therein, and bus-bar means 64 serve as the ground return for the electrodes.

A phenomenon which accompanies the passage of a heavy current through a liquid metal is the agitation and stirring of the liquid metal by the influence of the magnetic field of the heavy current on currents induced in the liquid metal. If such agitation becomes too violent, liquid metal may be ejected from the crucible 58 eventually interrupting the current path. Two preferred embodiments for reducing this agitation are (a) the crucible 58 and connector 54 are of elongated, rectangular shape with small clearances on the side so that the liquid metal meets substantial resistance in flowing around the connector 54 due to the narrow passage and long path of flow and (b) the second crucible 58 may have a lip or overhang on the inner side so that the liquid metal, if circulating violently, is directed back into the crucible 58 by this lip and is prevented from spilling over.

In the operation of the furnace described above, a charge of titanium to be melted is placed in the crucible 16. The heating means 60 is energized so as to melt a charge of, for example, a lead-bismuth alloy 56, in the crucible 58 and to cause the connector 54 to be substantially wetted thereby. The furnace is sealed and evacuated by pumping system 12. After evacuation, electrodes 38 are moved down into position and argon is introduced into the furnace housing 10 until a predetermined pressure has been attained. If consumable electrodes only are initially employed then vacuum operation is preferable. An arc is created between elec-

4

trode tips 40 and the titanium charge so as to melt the charge.

As the charge is being melted down by the arc, a large quantity of heat is generated. Substantial quantities of heat are transmitted down connector 54 into the low-melting metal 56. The heating means 60 can be shut off since the heat being conducted from the crucible 16 and skull 32 and transmitted through connector 54 will maintain the low-melting metal 56 molten. The heat thus transmitted to the low-melting metal 56 plus that generated by electrical resistance is removed therefrom by circulating a suitable cooling fluid, e.g. helium under pressure through cooling coils 62. The extraction of heat from low-melting metal 56 is controlled so that solidification of the metal is not achieved. Moreover the large arc currents are effectively conducted away from the crucible 16, since the electrical connection formed by the solid connector 54 melted by and in intimate contact with the molten metal 56 presents interfacial or contact resistance which is significantly less than that presented in the heretofore employed solid to solid electrical connection.

After the charge has been melted down and any alloying additions made, the electrodes 38 are retracted above the heat shield 50 so as to be free of the crucible 16 during its tilt. The crucible is then tilted (connector 54 being removed from contact with molten metal 56) so as to pour the charge of molten titanium or alloy into a mold 22. If desired, an additional charge of titanium may then be added to the emptied crucible and the filled mold can be replaced with an empty mold by means such as those shown in U.S. Patent 2,625,719. This has the advantage that it is not necessary to cool the crucible before an additional charge of titanium is added thereto or to open the furnace.

Since certain changes may be made in the above apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description, or shown in the accompanying drawing, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An arc furnace for skull melting a refractory metal such as titanium and the like which comprises a gas-tight housing, means for creating a substantially inert atmosphere within said housing, a first crucible for holding a mass of refractory metal within a solid skull of said refractory metal, means for tilting said first crucible, at least one electrode means for creating a metal-melting arc to the metal to be melted in said first crucible, grounding means for said first crucible comprising a second crucible below said first crucible for holding a mass of low-melting metal, bus-bar means connected to said second crucible for conducting current therefrom, means for initially heating said second crucible, means for cooling said mass of low-melting metal, and a substantially large metallic connector means extending from the bottom of said first crucible and skull therein into said low-melting metal in said second crucible, thereby providing good electrical connection therebetween when said first crucible is not in the tilted position.

2. An arc furnace for skull melting a refractory metal such as titanium and the like which comprises a gas-tight housing, means for creating a predetermined pressure of an inert gas within said housing, a first crucible for holding a mass of refractory metal within a solid skull of said refractory metal, means for tilting said first crucible, at least one electrode, means for feeding power to said electrode for creating a metal-melting arc to the metal to be melted in said first crucible, grounding means for said first crucible comprising a second crucible below first crucible for holding a mass of low-melting metal, bus-bar means connected to said second crucible for conducting current therefrom, means for initially melting said mass of low-melting metal in said second crucible,

5

means for cooling said mass of low-melting metal, and a substantially large connector of said refractory metal extending from the bottom of said first crucible and refractory metal skull therein into said low-melting metal in said second crucible, thereby providing a good electrical connection therebetween when said first crucible is not in the tilted position.

3. The arc furnace of claim 2 wherein said low-melting metal comprises a lead-bismuth alloy.

4. The arc furnace of claim 3 wherein the lead-bismuth alloy comprises about 45 percent by weight of lead.

5. The arc furnace of claim 2 wherein said low-melting metal comprises gallium.

6. The arc furnace of claim 2 wherein said low-melting metal comprises indium.

7. An arc furnace for skull melting a refractory metal such as titanium and the like which comprises a vacuum-tight housing means for evacuating said housing, a first crucible for holding a mass of refractory metal within solid skull of said refractory metal, means for tilting said first crucible, at least one electrode, means for feeding power to said electrode for creating a metal-melting arc to the metal to be melted in said first crucible, means for lowering and retracting said electrode, means for

6

tilting said first crucible, grounding means for said first crucible comprising a second crucible below said first crucible for holding a mass of low-melting metal, bus-bar means connected to said second crucible for conducting current therefrom, means for initially melting said mass of low-melting metal in said second crucible, means for cooling said mass of low-melting metal, and a substantially large connector of said refractory metal extending from the bottom of said first crucible and refractory metal skull therein into said low-melting metal in said second crucible, thereby providing a good electrical connection therebetween when said first crucible is not in the tilted position.

References Cited in the file of this patent

UNITED STATES PATENTS

2,371,278	Berghaus et al. -----	Mar. 13, 1945
2,625,719	Moore -----	Jan. 20, 1953
2,789,150	Clough et al. -----	Apr. 16, 1957
2,789,152	Ham et al. -----	Apr. 16, 1957
2,796,452	Krall -----	June 18, 1957
2,825,641	Beall et al. -----	Mar. 4, 1958