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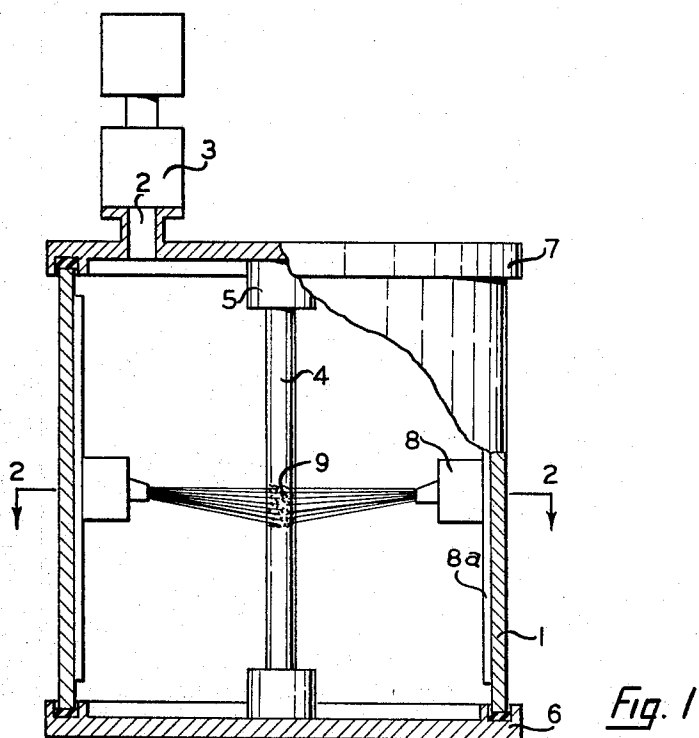
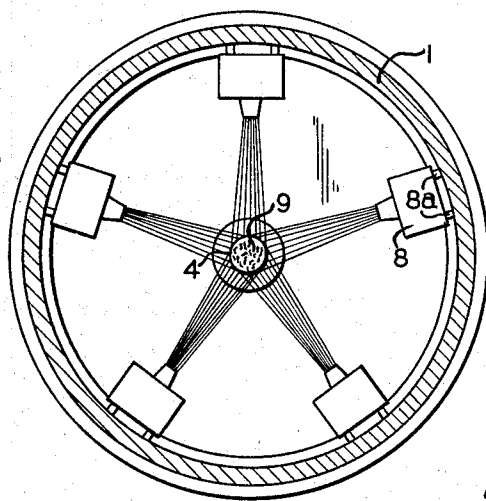
H. GRUBER ETAL

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APPARATUS FOR MELTING METALS UNDER HIGH VACUUM

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2 Sheets-Sheet 1



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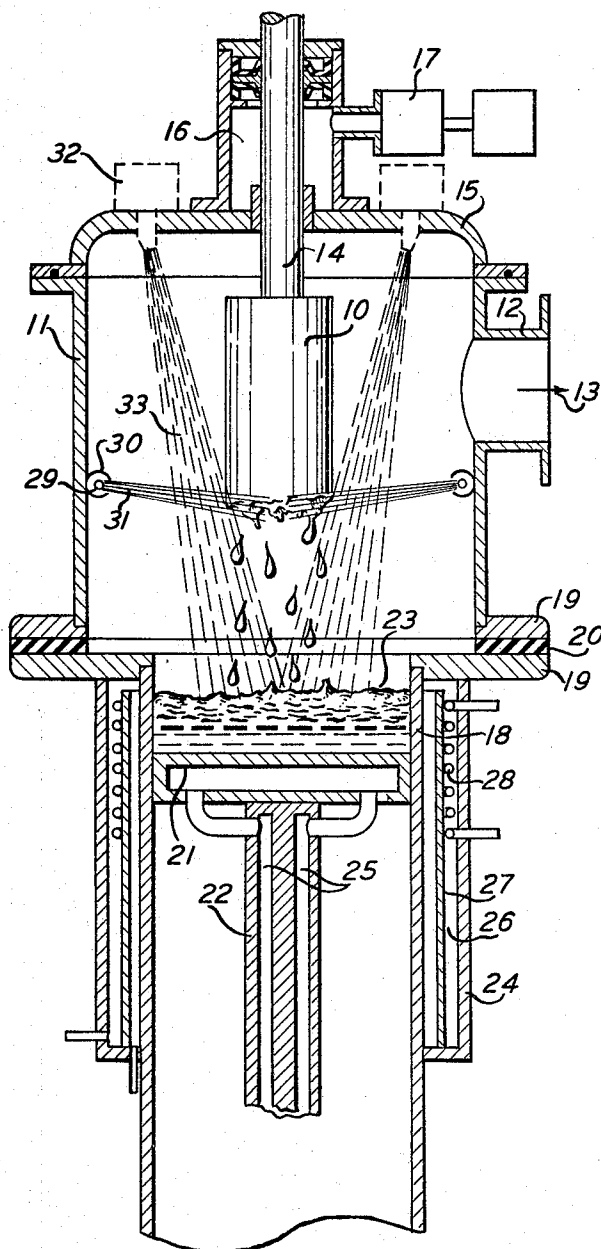


Fig. 3

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APPARATUS FOR MELTING METALS UNDER HIGH VACUUM

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2 Claims. (Cl. 22—57.2)

The present invention relates to an apparatus for melting metals in a high vacuum by means of electron beams.

The general idea of employing electron beams for melting metals either directly or indirectly in a high vacuum is already known. According to the indirect method of melting, the electron beams are employed for heating a crucible containing the metal to be melted, while in the direct method, concentrically focussed electron beams are directed upon the metal itself so as to heat the metal locally to a very high temperature and thus to melt it.

It has also already been proposed to melt the end of a metal rod forming a consumable electrode by directing separately generated electron beams by conventional electron-optical means so as to strike only upon the lower end of the consumable electrode or also upon the surface of the molten pool of metal. In the latter case, the electron beams are directed from above at a slight angle upon the lower end of the consumable electrode. Due to the divergence of the electron beams, some of the electrons then also fly past the consumable electrode and hit upon the surface of the pool of molten metal which is thus kept in a liquid condition. Although this melting method has the advantage over the conventional arrangement in which the metal rod to be melted is surrounded by an annular heated cathode that it avoids the luminous current discharges which occur very frequently in such an arrangement because of the small distance between the electron source and the metal rod, this advantage unfortunately also involves a certain disadvantage that, due to the glancing incidence of the electron beams upon the metal rod, a considerable portion of the electrons which is dependent upon their energy and upon the angle of incidence is deflected or scattered, and that consequently the electron bombardment has to be carried out for a considerable length of time until a sufficient amount of energy is supplied to the metal rod to melt it off locally.

It is an object of the present invention to provide a new apparatus for performing a method of melting metals in a high-vacuum melting furnace in a manner so as to overcome the disadvantages of the previous methods. This is possible by a new and very simple arrangement of the electron sources within the evacuated furnace chamber. According to the invention, the metal is melted by means of several conventional electron generators which are arranged in a substantially annular formation and within a substantially circular plane around the zone of a metal rod which is to be melted or refined, and by moving either the metal rod relative to the electron generators or the electron generators relative to the metal rod. The electron beams emitted from the generators are focussed by conventional electron-optical means so as to impinge almost vertically upon the outer surface of the metal rod, whereby the reflection of the electrons is reduced to a minimum so that a considerable amount of energy may be saved and the required length of time for carrying out the melting process will be considerably reduced.

According to the invention it has further been found advisable not to concentrate the electron beams to a very tight bundle but to emit each beam with a certain aperture angle. According to a preferred embodiment of the invention the electron sources are arranged at a greater distance from the metal to be melted, which has the ad-

vantage that luminous discharges between the electron sources and the metal rod will be completely or at least substantially avoided.

The number of electron generators which may be arranged within an annular formation is limited only by the amount of space required by them. If a completely symmetrical annular arrangement of the electron source is desired, an annular heated cathode may be employed in place of the individual electron generators. Such an annular cathode should also be spaced at a considerable distance from the metal rod so as to avoid luminous discharges. The heated annular cathode is preferably enclosed by a toroidal Wehnelt cylinder which is slotted at the side facing toward the metal rod to be melted and serves as a focussing device.

The high-vacuum melting apparatus for performing a method according to the invention may be applied either for zone melting or refining of a metal rod or for continuously melting off the lower end of a metal rod. Although it has been found preferable in both cases to mount the electron sources in a stationary position and to provide a mechanism for moving the metal rod relative thereto, the reverse procedure is obviously also possible. When treating a metal rod by zone melting, the melting zone is continuously or intermittently shifted from one end of the rod to the other by a suitable control mechanism. When employing the method of completely melting a metal rod, the lower end of the rod is melted off continuously and the molten metal is collected in a cooled crucible. The pool of metal is maintained in a liquid condition for a certain length of time since independently of the electron sources which are required for the melting process additional electron generators are provided, the electron beams of which are likewise not very closely bundled and are directed upon the surface of the metal pool in the crucible.

The above-mentioned and further objects, features, and advantages of the present invention will become more clearly apparent from the following detailed description thereof, particularly when the same is read with reference to the accompanying drawings, in which:

FIGURE 1 shows diagrammatically a longitudinal section of a zone melting apparatus according to the invention, in which the electron sources consist of electron generators;

FIGURE 2 shows a cross section taken along line A-B of FIGURE 3; while

FIGURE 3 shows diagrammatically a longitudinal section of a melting furnace according to the invention for continuously melting off the lower end of a metal rod and in which the electron source consists of an annular heated cathode.

Referring to FIGURES 1 and 2 of the drawings, the zone melting or refining apparatus according to the invention comprises a furnace chamber 1 which may be highly evacuated through a pump connection 2 by a pump unit 3, as merely indicated diagrammatically. The metal rod 4 which is to be melted or refined is mounted at both ends by clamping means 5 which are secured on the bottom 6 and the cover part 7 of the furnace chamber 1. For the zone melting operation, several conventional electron generators 8 are employed which are movable, simultaneously upwardly and downwardly in the furnace chamber 1, for example, along rails 8a, and are spaced at a sufficiently great distance from the metal rod 4 to prevent luminous discharges. During the entire melting process the electron generators 8 are located within a substantially circular plane in an annular arrangement around metal rod 4. The electron beams emitted from the electron generators 8 are directed upon the zone 9 of the metal rod which is to be melted or refined. This

melting zone moves upwardly and downwardly along the entire length of metal rod 4 at a speed of the electron generators as controlled by a mechanism, not shown.

As illustrated in FIGURE 2, the electron generators 8 are preferably distributed around the inner periphery of furnace chamber 1 in such a manner that none of them are disposed diametrically opposite to each other.

As already described, the continuously moving melting zone 9 on the metal rod 4 may also be attained by mounting the electron generators 8 in a fixed position and by continuously moving the metal rod upwardly and downwardly within the furnace chamber within the zone of intersection of the electron beams.

The zone melting apparatus according to FIGURES 1 and 2 may also be employed for carrying out sintering processes. In this event, care must be taken that the temperature to which the metal rod 4 will be heated by the electron bombardment will not reach the melting point of the metal rod.

The melting apparatus according to the modification of the invention as illustrated in FIGURE 3 is designed for continuously melting off the lower end of a metal rod 10 in the form of a consumable electrode in the furnace chamber 11 which is evacuated through a pipe 12 by a vacuum pump 13, as indicated by an arrow. The metal rod 10 is secured to the lower end of a supporting rod 14 which passes from the outside into furnace chamber 11 through the cover part 15 thereof and through suitable sealing means on this cover part, for example, in the form of one or more vacuum stages 16 which are either connected to the main vacuum pump 13 or to a separate pump unit 17. On its open lower end, furnace chamber 11 carries a tubular crucible 18 to which it is connected by flanges 19 between which one or more sealing gaskets 20 are provided. The hollow bottom 21 of crucible 18 is slidable within the tubular wall of the latter on a plunger 22 which is adapted to be lowered by suitable elevating means, not shown, in accordance with the amount of molten metal collected in a pool 23 in crucible 18 so that the surface of this pool remains at all times during the melting operation at substantially the same level. Plunger 22 and preferably also the mentioned elevating means are contained within the lower extension 24 of the wall of crucible 18 which is also maintained under reduced pressure. Plunger 22 contains channels 25 through which cooling water may be passed to and from the crucible bottom 21 to cool the latter. At least the upper part of crucible 18 is enclosed by a cooling chamber 26 through which cooling water may be circulated and in which a partition 27 is provided which carries a field coil 28 for exerting a stirring effect upon the molten metal.

For continuously melting off the lower end of the metal rod 10 which is gradually lowered within the furnace chamber by suitable elevating means to which the supporting rod 14 is connected at the outside of the furnace, an electron source is provided on the inner wall of furnace chamber 11. This electron source may again consist of a plurality of electron generators as shown in FIGURES 1 and 2 or, as shown in FIGURE 3, of an annular heated cathode 29 which is surrounded by a toroidal focussing device 30 which is slotted at the side facing in the direction of the metal rod to define a focusing aperture located in the space between cathode 29 and metal rod 10 and substantially in a horizontal plane through the lower end portion of metal rod 10 so that the electron rays 31 are concentrated onto the end portion of metal rod 10.

In the operation of the melting apparatus according to the invention, as illustrated in FIGURE 3, the electron rays which only impinge upon the lower end of the metal rod 10 will melt the latter. The molten metal then drops into crucible 18 and forms therein the deepening pool 23 which when cooled forms a solid metal block. The melting process for attaining this metal block is carried out continuously by continuously lowering the supporting

rod 14 with the metal rod 10 thereon at a speed which is regulated in accordance with the speed at which the lower end of the metal rod is melted off, while at the same time the bottom 21 of crucible 18 is continuously lowered at a speed so that the upper surface of the metal pool 23 remains at substantially the same level until the entire metal rod 10 is melted and the current for the electron source is switched off.

If the melting apparatus according to FIGURE 3 is provided with a plurality of electron generators similarly as shown at 8 in FIGURES 1 and 2, rather than with an annular heated cathode 29, as shown in FIGURE 3, it is also in this case advisable to distribute these electron generators uniformly around the inner wall of furnace chamber 11. Aside from thus heating the lower end of the metal rod uniformly from all sides, this arrangement has the advantage that additional electron generators 32 may then be provided above the electron generators 8 and their electron beams 33 are directed upon the surface of the metal pool 23 in the crucible 18. These additional generators 32 are preferably mounted on the cover part 15 of furnace chamber 10 in a staggered relation to the lower electron generators 8 so that each of their electron beams 33 which are not too closely focussed is directed centrally through the angular space which is formed between two adjacent electron beams from the lower generators 8 which, in turn, are arranged as illustrated, for example, in FIGURE 2, so as not to be diametrically opposite to each other. By this arrangement the possibility of any interference between the various electron beams will be reduced to a minimum.

The electron generators 8 in the embodiment according to FIGURES 1 and 2 may, of course, also be replaced by an annular heated cathode which is provided with a toroidal focussing device, as shown in FIGURE 3.

Although our invention has been illustrated and described with reference to the preferred embodiments thereof, we wish to have it understood that it is in no way limited to the details of such embodiments, but is capable of numerous modifications within the scope of the appended claims.

Having thus fully disclosed our invention, what we claim is:

1. An apparatus for melting metals, comprising a furnace chamber, means for evacuating the furnace chamber, means for vertically suspending within the furnace chamber a rod of the metal to be melted, at least one first electron source mounted in the furnace chamber in an annular horizontal arrangement around and spaced from the metal rod, means for maintaining the lower end of the metal rod substantially at the horizontal level of the first electron source, electron focusing means associated with the first electron source and defining a focusing aperture located in the space between the first electron source and the metal rod and substantially in a horizontal plane through the lower end of the metal rod for concentrating substantially all of the electrons emitted by the first electron source onto the lower end of the metal rod to cause metal to melt at and drip off from the lower end of the metal rod, a crucible located within the furnace chamber and below the metal rod for collecting the molten metal dripping off the lower end of the metal rod and forming a pool of the molten metal, means for maintaining the upper surface of the pool of molten metal at a predetermined level, and at least one second electron source arranged above the first electron source for projecting electrons through the furnace chamber and onto the pool of molten metal to maintain the metal in the pool in a molten condition.

2. An apparatus for melting metals, comprising a furnace chamber, means for evacuating the furnace chamber, means for vertically suspending within the furnace chamber a rod of the metal to be melted, a plurality of first electron sources mounted in the furnace chamber and arranged in mutually spaced relationship in an annular hori-

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zontal arrangement around and spaced from the metal rod to emit mutually spaced beams of electrons substantially horizontally in the direction of the metal rod, means for maintaining the lower end of the metal rod substantially at the horizontal level of the first electron sources to cause metal to melt at and drip off from the lower end of the metal rod by action of the electron beams emitted by the first electron sources, a crucible located within the furnace chamber and below the metal rod for collecting the molten metal dripping off the lower end of the metal rod and forming a pool of the molten metal, means for maintaining the upper surface of the pool of molten metal at a predetermined level, and a plurality of mutually spaced second electron sources arranged above the first electron sources in a staggered relation to the first electron sources for projecting electrons through the furnace chamber and past the electron beams emitted by the first electron sources onto the pool of molten metal in the crucible to maintain the metal in the pool in a molten condition.

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