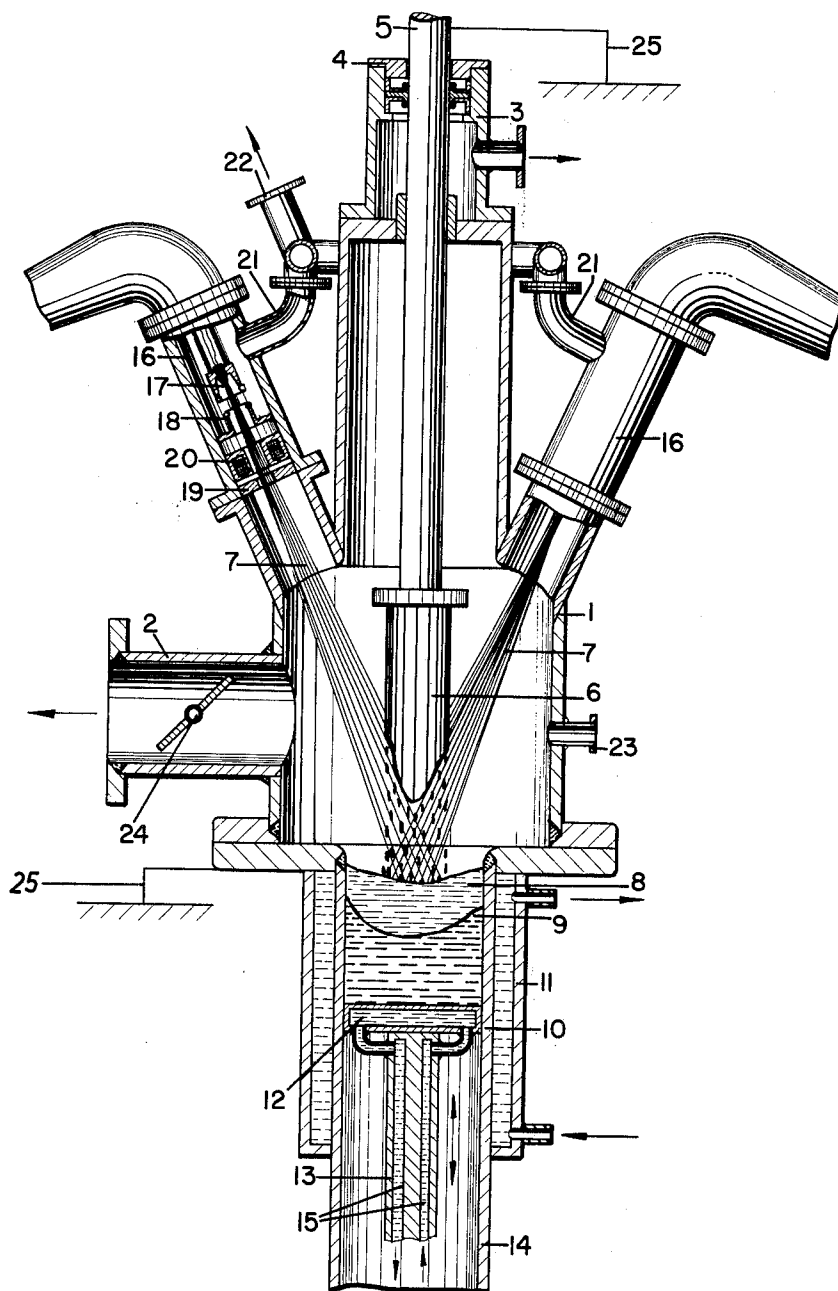


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METAL BLOCKS BY ELECTRON BEAMS
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1

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METHOD AND APPARATUS FOR PRODUCING
METAL BLOCKS BY ELECTRON BEAMS

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The present invention relates to a method and apparatus for producing metal blocks by melting the metal in a vacuum or inert atmosphere of reduced pressure by means of electron beams.

It has been known for a considerable length of time that electron rays could be applied for heating melting crucibles. This is generally done by directing the electron rays upon the outer side of the crucible so as first to heat the crucible and then, through the latter, the metal contained therein.

It has also been known that electron rays could be applied directly for melting and vaporizing various materials. The concentrated, focused electron beam is then directed upon the material to be melted, whereupon this material will be heated locally to a very high temperature and thereby cause a limited part of the material to be melted. This method has also been applied for melting small amounts of pulverulent material into small balls. Its advantage consists primarily in the fact that the melting process may be carried out without a crucible so that the molten material will not react with the material of the crucible.

It has also been proposed prior to this invention to melt off the end of a rod or wire by means of electrons. This is usually done by providing a heating ring which forms an oxide or boride cathode and surrounds the end of the rod and is adjustable in the axial direction thereof. By a suitable voltage distribution, it is then possible to direct a large part of the electrons upon the end of the rod and thus to melt the same. The molten material may then drip into a pool. A part of the electrons may in such an apparatus also be utilized for keeping the pool of molten metal in a liquid condition. Due to the small distance between the electron source and the metal to be melted, this method of melting metals by means of an electron bombardment involves considerable difficulties which are primarily caused by the fact that during the melting operation considerable amounts of gases emerge from the treated material which may result in glow discharges between the electrodes. Such glow discharges, however, prevent the necessary concentration of electric energy upon the ends of the consumable electrodes to be melted off, result in a strong increase in the current, and especially consume a considerable amount of the electric energy within the plasma of the discharge so that the amount of energy required for melting is no longer available.

It is an object of the present invention to overcome the disadvantages of the above-mentioned methods and to melt greater amounts of metal by means of electrons by separately generating and forming electron beams and directing them by conventional electron-optical means so as to impinge only upon the end of a consumable electrode or simultaneously also upon the pool of molten metal which is then being formed.

In order to attain this object, the invention provides the electron generators in such a position that the electron beams will be passed at a downwardly inclined direction upon the lower end of a vertical consumable electrode in order to heat this end until it is melted in the form of drops which fall into the pool of molten metal below. Due to the fact that the rays of the electron beam

2

diverge, a considerable part of the electrons flow past the consumable electrode and impinge upon the pool. These electrons give up their energy to the pool and thereby keep the same in a liquid condition. In order to insure that a greater part of the pool will be kept liquid by the impinging electrodes, it is advisable not to concentrate the electron rays to form a too narrow beam but to give this beam a certain aperture angle by conventional electron-optical means. The size of this angle depends upon how strongly concentrated the electron rays have to be in order to melt off the end of the electrode and also upon the size of the pool. In actual practice, these two factors may be easily coordinated so that the electrode will be melted off continuously and the pool of metal will also be kept constantly in a liquid condition.

In order to melt off an electrode uniformly and at the same time to maintain a larger pool in a liquid condition, it is advisable to apply several (at least two) electron beams simultaneously. If several electron beams are applied, it is also possible to direct one or more beams only upon the consumable electrode and another or several other beams only upon the pool of metal. This has the advantage that the pool may then be heated independently of the melting process.

The method according to the invention is applicable particularly for melting larger blocks of metal and has the advantage that the electron source may be mounted at a considerable distance from the electrode to be melted and the molten material in the pool. It is thus possible to reduce the danger of the occurrence of glow discharges since the gases developing during the melting process may be pumped off in the vicinity of the melting point on the electrode and will therefore not reach the electron source. Furthermore, it is possible to make the distance between the end of the electrode and the surface of the pool relatively small.

If according to the invention the electron-generating chamber is additionally separated from the melting chamber by an apertured partition and is also kept by a separate pump unit at a very low pressure, it is impossible that glow discharges will reach the electron source. The generating chamber of the electrons which is shielded by a diaphragm will then always be under such a low pressure that the gas developed from the molten metal will not be able to exert any influence within that chamber. The pressure within the generating chamber of the electrons should then preferably amount to approximately 10^{-4} to 10^{-6} mm. Hg.

In the event that it is desirable that the melting process be carried out in an inert atmosphere of a reduced pressure, it is even possible according to the invention to conduct inert gases into the melting chamber without danger that interfering gas discharges might occur.

The above-mentioned as well as other objects, features, and advantages of the present invention will become further apparent from the following detailed description and the accompanying drawing of one preferred embodiment thereof which, however, is merely illustrative of the invention and may be modified considerably without departing from the scope of the invention.

In the drawing, which shows a diagrammatic side view, largely in cross section, of a melting furnace which is specially designed to carry out the method according to the invention, and which illustrates the use of two electron beams to carry out the melting process, the main furnace chamber 1 is provided with a suction outlet 2 leading to an evacuating pump, not shown, and a furnace head 3 which contains suitable sealing means 4 for a vacuum-tight insertion and vertical sliding movement of an electrode supporting rod 5 which carries on its lower end a consumable electrode 6. These sealing means 4 may be

of any conventional type and may consist of a suitable packing or may, as indicated, also include one or more intermediate suction stages which may be connected to a suitable evacuating pump, not shown, by means of an outlet 4'. The electrode 6 is to be gradually melted at its lower end by two or more electron beams 7, and the melting metal then drops downwardly into a pool 8 of molten metal which gradually builds up a metal block 9 within a crucible 10 which is surrounded by a water jacket 11 through which cooling water is circulated. Crucible 10 has a slidable hollow bottom 12 and is mounted on a bar 13 by means of which it is adapted to be raised and lowered by a suitable mechanical or hydraulic elevating mechanism, not shown, which is preferably disposed under a vacuum within the lower extension 14 of crucible 10. The elevating bar 13 contains water conduits 15 which are connected to the hollow bottom 12 to circulate cooling water therethrough, and the other parts of the elevating mechanism which are contained in the crucible extension 14 may also be water-cooled. This elevating mechanism is designed to maintain the surface of the pool at all times at the same level and to lower the metal block 9 gradually within crucible 10 as it is being formed therein by the molten metal dripping from electrode 6 and subsequently solidifying under the cooling action of the walls and the slidable bottom 12 of the crucible.

The electron beams 7 are produced by two or more electron generators or guns 16, each of which consists of a cathode 17, focusing means 18, and a diaphragm 19 with an aperture therein. The electron beam may be further controlled, for example, by magnetic coils 20. The two or more generators 16 are provided with separate evacuating conduits 21 which lead to a common outlet 22 which is preferably connected to a pump unit separate from the pump or pumps for evacuating the other parts of the apparatus. The electron generators 16 are mounted on furnace chamber 1 so that the diverging electron beams 7 will be directed at a downwardly inclined angle and their centers intersect with the central axis of furnace chamber 1 at a certain distance from the lower end of crucible 10.

The method according to the invention as previously described may be carried out by means of such an apparatus as follows:

At the beginning of the operation, the consumable electrode 6 is connected to the supporting rod 5 and the latter is drawn upwardly to such an extent that the lower end of electrode 6 will be disposed at a level above that which will be reached subsequently by the electron beams 7. The furnace is then hermetically closed and evacuated. Thereupon, the electron generators or guns 16 are started and electrode 6 is lowered until electron beams 7 will melt the lower end of the electrode. The molten metal dripping downwardly from electrode 6 will then form a crucible 10 a pool 8 of molten metal. Since electron beams 7 are not sharply focused upon the end of electrode 6, the diverging rays of the beams will impinge upon the surface of pool 8 and keep the same in a liquid condition.

In accordance with the amount of metal melted from electrode 6 and collected in pool 8, the bottom 12 of the crucible is lowered so that the surface of the pool will always remain at substantially the same level.

The downward feed of electrode 6 by feeding means, which are not shown since they may be of any suitable known design, is preferably controlled automatically so that the lower end of electrode 6, while being consumed during the melting process, will always be disposed at substantially the same level within the range of intersection of the diverging electron beams 7.

If the material to be treated is to be melted in an inert atmosphere, it is possible to conduct a suitable gas, for example, helium or argon, through an inlet 23 into the furnace chamber 1. In order to prevent such a gas from being immediately pumped out of chamber 1, it is advisable to provide a suitable damper or throttle 24 in the

suction outlet socket 2 to permit the latter to be at least partly closed.

The superiority of the method according to the invention over the known method is particularly impressive when the melting furnace is filled out by a gaseous component. In the prior apparatus for carrying out the known method, the cathode for producing the electron rays was disposed at the inside of the melting furnace in the near vicinity of the consumable electrode to be melted. If the gas pressure in such a furnace increases only slightly, gas discharges will occur with the result that the energy of the electron rays will no longer be concentrated upon the end of the electrode but be scattered around the inside of the furnace in the form of a plasma. According to the method and apparatus according to the invention, however, the electrode 6 as well as the pool of molten metal are grounded by electrical conductors 25, and the electrons are produced within the electron generators 16 which are shielded from the furnace chamber 1 and are supplied with the necessary voltages through suitable insulators and conductors. Since the electron generators 16 are also evacuated separately from the furnace chamber, there is practically no possibility for the occurrence of any glow discharges.

Although our invention has been illustrated and described with reference to the preferred embodiment thereof, we wish to have it understood that it is in no way limited to the details of such embodiment, 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 electron beam melting furnace comprising a vacuum furnace chamber having a container for molten metal, means for feeding a consumable electrode to be melted into said chamber above said container, at least one electron gun having an apertured diaphragm connected to said furnace chamber for directing a focused electron beam through said apertured diaphragm into said furnace chamber against an electrode fed by said means for feeding to thereby melt material from the electrode to drop into said container to form a molten pool, and to direct a focused electron beam into said container to heat the molten pool, and means for separately evacuating said chamber and said electron gun on opposite sides of said apertured diaphragm whereby said furnace chamber may be evacuated to a low pressure and said electron gun may be separately evacuated to a lower pressure.

2. An electron beam melting furnace according to claim 1, in which said electron gun is connected to said furnace chamber to direct an electron beam against the electrode at an oblique angle and there-past into said container.

3. An electron beam melting furnace according to claim 2, in which said means for feeding a consumable electrode to be melted is means for feeding the consumable electrode vertically downwardly above said container and in which said electron gun is directed obliquely downwardly so that an electron beam therefrom is partially directed against the tip of a consumable electrode being fed by said means for feeding and there-past into said container.

4. An electron beam melting furnace according to claim 3, including a multiple number of electron guns positioned about the axis of a consumable electrode being fed by said means for feeding each directed obliquely downwardly to intersect at said axis so that an electron beam therefrom is partially directed against the tip of a consumable electrode being fed by said means for feeding and there-past into said container.

5. An electron beam melting furnace according to claim 1, including means for supplying an inert gas to said furnace chamber and means for throttling said evacuating means of said chamber to prevent said inert gas from being immediately evacuated from said chamber.

5

6. An electron beam melting furnace according to claim 1 in which said container is in the form of a cooled mold having a slidable bottom.

7. An electron beam melting furnace according to claim 1 including at least two electron guns having apertured diaphragms connected to said furnace, one of said guns being positioned for directing a focused electron beam through its apertured diaphragm into said furnace chamber against an electrode fed by said means for feeding and other of said electron guns being positioned to direct a focused electron beam through its apertured diaphragm into said furnace chamber into said container.

8. A method of melting metal which comprises directing a focused beam of electrons from an electron gun through an apertured diaphragm into a vacuum furnace chamber against the tip of a consumable electrode in the chamber, melting metal from the electrode with said beam to thereby form a molten pool of metal below the electrode, directing a focused beam of electron from an electron gun through an apertured diaphragm into the furnace chamber against said molten pool evacuating said chamber to a low pressure and separately evacuating said gun on the inlet side of said aperture diaphragm to a lower pressure.

9. Method according to claim 8 in which said electron beam is directed against the tip of said consumable electrode and there-past against said pool of molten metal.

10. Method according to claim 9, in which the consumable electrode is fed vertically downwardly into said chamber and which includes directing electron beams

6

obliquely downwardly against the tip of said electrode and there-past against said molten pool from a multiple number of electron guns distributed about the axis of said electrode and directed to intersect at said axis.

11. Method according to claim 10 which includes feeding the electrode at a rate equal to the melting rate and thereby maintain the tip spatially positioned at a substantially fixed point in the chamber.

12. Method according to claim 8 in which the molten pool is formed in a cooled mold having a slidable bottom and which includes slidably lowering the bottom at a rate to maintain the surface of the pool at a substantially constant level.

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