Sept. 18, 1945. R. K. HOPKINS 2,385,206

METHOD AND APPARATUS FOR PRODUCING METAL BODIES

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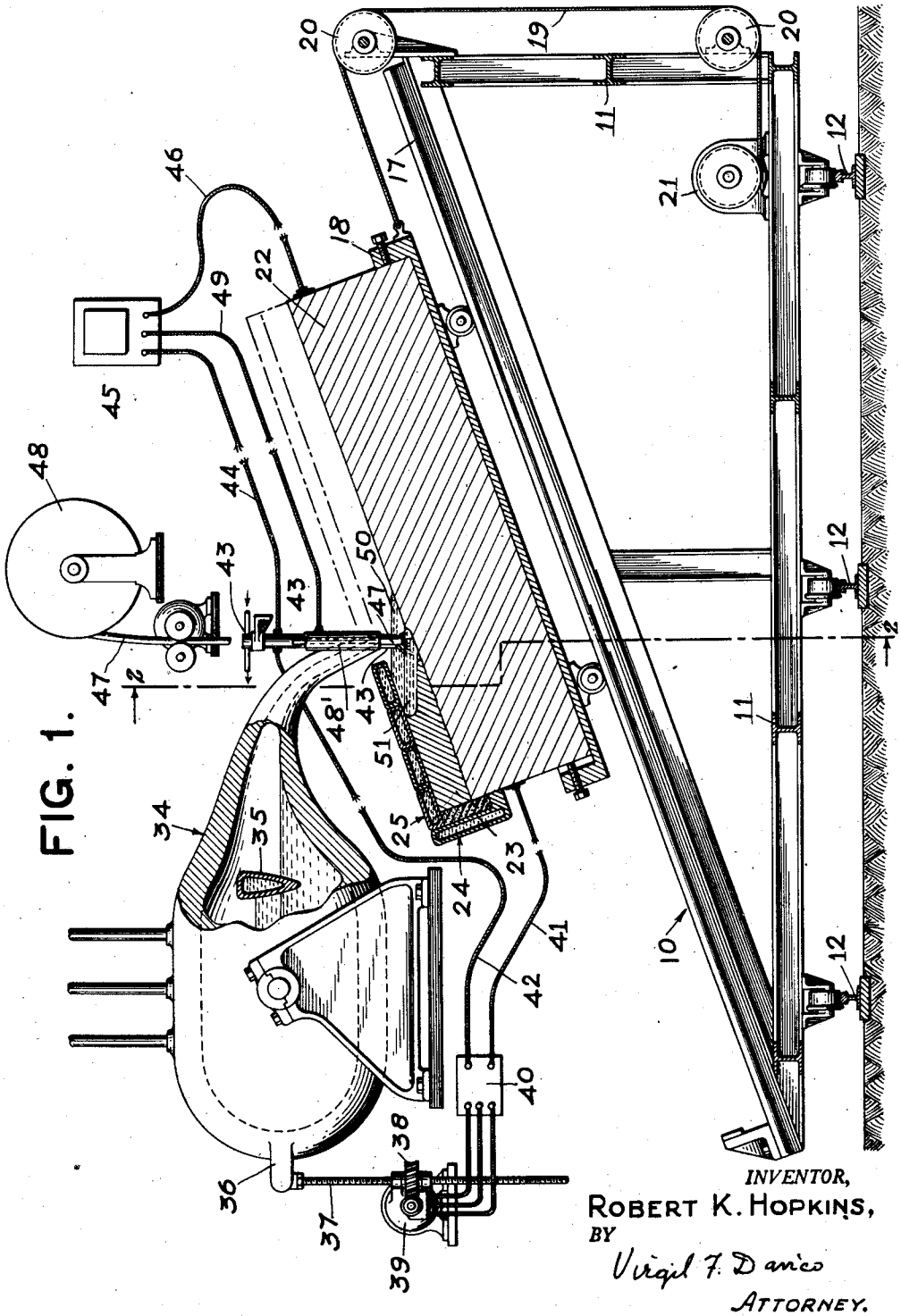


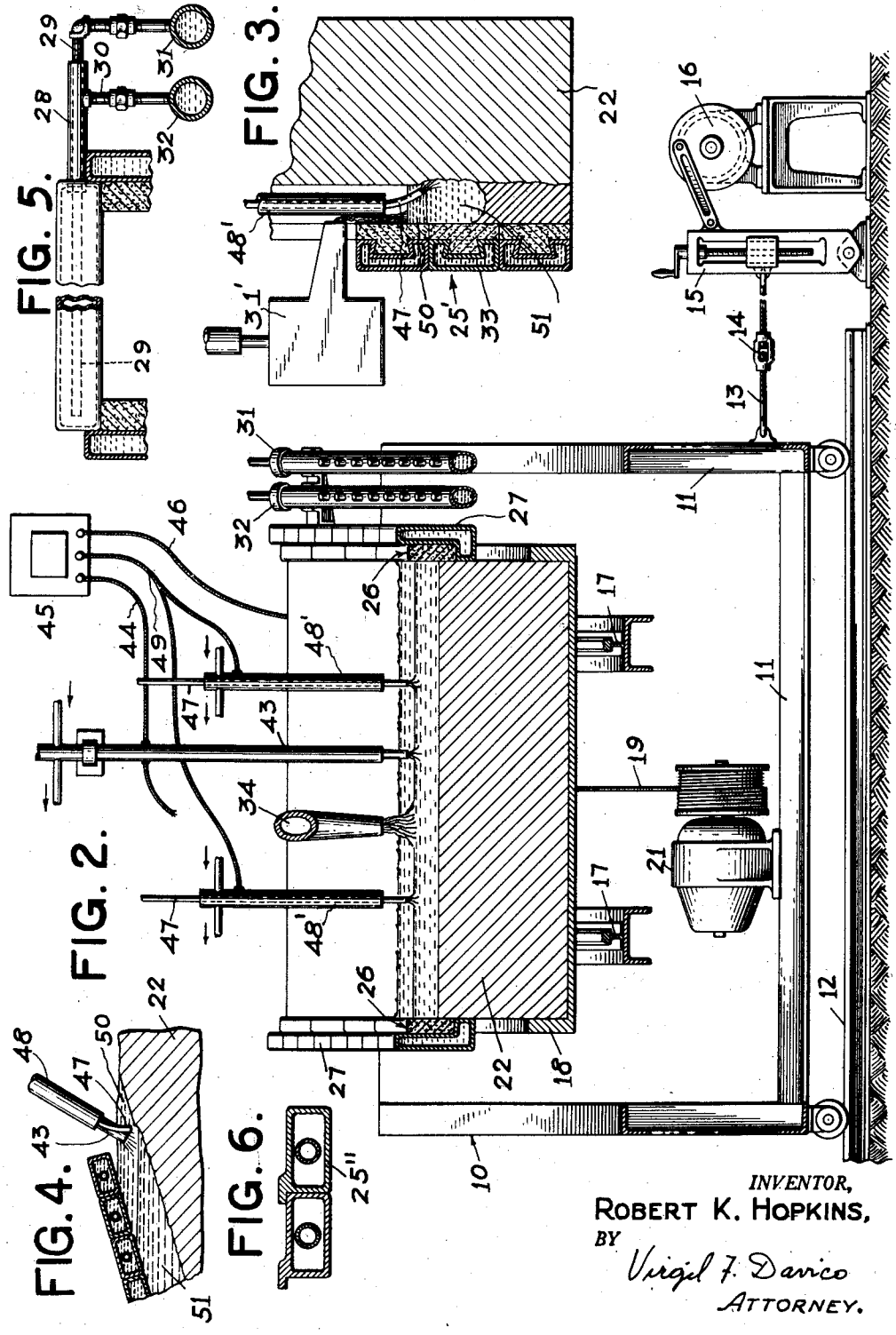
FIG. 1.

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METHOD AND APPARATUS FOR PRODUCING METAL BODIES

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The invention relates to the production of metal bodies by shaping operations in which molten metal is deposited in a shaping mold space over a prolonged period and the deposited metal is progressively solidified during the metal deposition.

When metal bodies are produced by shaping operations in which molten metal is deposited in a shaping mold space over a prolonged period of time and the deposited metal is solidified progressively during the prolonged period of its deposition, the rate of deposition and the cooling rate must be adjusted in order to obtain the desired results. When the molten metal is produced directly in the mold space, for instance as disclosed in my prior Patent No. 2,191,479, issued February 27, 1940, no difficulty is experienced in obtaining the desired results, however, when the molten metal is obtained from a molten metal source external to the mold space, it is difficult to pour the metal at the required rate and nice control of the process conditions is not always possible. This is particularly true when producing composite metal bodies by the method in which one of the metals of the composite defines at least a part of the surface of the mold space and this surface defining metal is fused by means of one or more electrodes to present a fused surface to the rising molten metal. If the rising molten metal level is not kept fixed relative to the rising surface fusing electrodes the composite will evidence areas in which the component metals are not properly bonded.

When producing composite bodies, either by the method in which the molten metal is produced directly in the mold space or by the method in which the molten metal is obtained from a source external to the mold space, there is a limit as to the minimum width of the mold space that can be used. Consequently, there is a limit as to the minimum thickness of the deposited metal of the composite body. This limit is imposed by the size of the apparatus elements that must necessarily enter the mold space. When the solid metal bodies used to form the composites are very thick and work-deforming equipment capable of handling very thick bodies is available the limitation above pointed out may be of no consequence. However, when the solid metal bodies available for forming the composites are of ordinary thicknesses or only the more common work-deforming equipment is available the pointed out limitation is of great importance for because of it it is impossible to reduce the percentage of deposited metal in the composite as low as is often highly desirable.

I have found that these disadvantages can be overcome in a simple and efficient manner.

It is, therefore, one of the principal objects of this invention to provide a novel method and novel apparatus for producing metal bodies, composite metal bodies as well as metal bodies of a single analysis, in which the molten metal required is produced in a batch operation at a point external to the mold space and after its production is supplied to the shaping mold space at a rate required by predetermined conditions and said rate of supply adjusted to maintain said predetermined conditions.

It is also a principal object of this invention to provide a novel method and novel apparatus for producing composite metal bodies in which a mold space is provided, formed at least in part by a non-horizontal surface of a solid body of one of the metals of the desired composite, the molten metal required to fill the mold space is produced in a batch operation at a point external to the mold space, the surface of the solid body to be covered by the molten metal is fused across its full extent on a constantly rising level, the molten metal is poured into the mold so as to progressively cover the fused surface and the pouring rate of the molten metal is adjusted as necessary to maintain a fixed positional relation between the rising level of the molten metal and the level of fusion of the solid body whereby the rising molten metal constantly covers fused surface of the solid body and complete union of the metals is assured.

It is a further principal object of the invention to provide a novel method and apparatus for producing composite metal bodies by uniting molten metal to a fused surface of a solid body of metal forming a part of the shaping surface of a mold space, the molten metal being obtained from a molten metal source external to the mold space or being produced directly therein, in which the mold space is built up progressively as the molten metal rises therein to allow easy access to the defined portion of the mold space by the necessary surface fusing and metal depositing elements without entering the bulkier portions of these elements into the mold space whereby the width of the mold space may be substantially reduced and composite bodies produced with the percentage of deposited metal materially smaller than heretofore. It is also an important object of the invention to carry out this operation with the mold and solid body so inclined that still

easier access to the defined portion of the mold space may be had and the minimum thickness of deposited metal still further reduced.

The further objects and advantages of the invention will be apparent from a consideration of the following description taken with the accompanying drawings, in which,

Fig. 1 is a diagrammatic side view, partly in section, illustrating the method and apparatus of the invention,

Fig. 2 is a sectional view, taken on line 2—2 of Fig. 1,

Figs. 3 and 4 are side sectional views illustrating variations of the invention, and

Figs. 5 and 6 are views of details of the apparatus.

The method and apparatus of the present invention is of general use and application and can be successfully employed in the production of non-ferrous as well as ferrous metal bodies. For the purpose of this disclosure, the invention will be disclosed in connection with the production of ferrous metal bodies such as those made of the stainless alloys, tool steels, etc., these bodies being formed of metal of a single analysis, as for instance an ingot of tool steel, or formed of two or more metals of different analysis, as for instance, a carbon steel slab armored on one or more sides with a depth of stainless alloy, etc. Since the more specific aspects of the invention can be better disclosed in connection with the production of composite metal bodies, the invention will be specifically disclosed mainly in connection with the manufacture of composite metal bodies.

Referring now to the drawings. A truck 10, formed of structural members 11, is mounted for back-and-forth movement on a track-way made up by rails 12. For this purpose an arrangement is employed which includes rod 13, turnbuckle 14, length of stroke changer 15 and drive motor 16. By means of the length of stroke changer 15 the length of the back-and-forth movement may be adjusted as desired, and by means of turnbuckle 14 the mid-point of the movement may be positioned, within limits, as desired. Truck 10 supports a pair of rails 17 that provide an inclined track-way upon which carriage 18 is adapted to move.

Carriage 18 is moved up or down its track-way by a hoist arrangement that includes cable 19, sheaves 20 and hoist motor 21. Motor 21 is such that it will raise carriage 18 at a comparatively rapid rate and lower it at a much slower rate. The lowering rate is maintained substantially constant and the motor 21 includes the usual brake mechanisms that prevent the load falling freely or at a rate faster than the predetermined rate. The motor 21 may be adjustable so as to provide for a range of rates, or gear reducing arrangements may be provided for the same purpose.

A solid body of metal 22 is positioned in carriage 18. Body 22 is a component of the desired composite metal body and may be in the form of a slab, billet or ingot. Body 22 is usually the base metal of the composite and generally will be of carbon steel. To the bottom of body 22, adjacent the top surface thereof is attached, as by welding, a metal bar 23 upon which the operation may be begun. When the inclination of body 22 is sufficient to permit the operation to be begun directly on the surface of body 22, bar 23 may be substituted by an elongated slab of fire-brick or similar ceramic material. A hollow L-shaped member 24 is held against body 22 in any suitable way to partly enclose bar 23 and to provide with bar 23 a step into which may be positioned the lower edge of the bottom mold-front section 25. Water or other cooling medium is circulated through member 24. At each side of body 22 is positioned an elongated slab 26 of fire-brick or similar ceramic material. Hollow L-shaped members 27 are held against the sides of body 22, in any suitable way, to partly enclose slabs 26 and to provide therewith steps upon which the ends of the mold-front sections 25 may be positioned. If desired, members 24 and 27 may be supported from carriage 18.

Mold-front sections 25 are made of a convenient width to enable the operation to be carried out as will be hereinafter explained. Sections 25 may be of metal, or of fire-brick, or similar ceramic material. When made of metal they are preferably hollow and are provided for circulation of a cooling medium therethrough, as best shown in Fig. 5. When made of fire-brick and the like they preferably include a metal backing 33, as shown in Fig. 3, which is preferably hollow so that a cooling medium may be circulated therethrough. As shown in Fig. 5 sections 25 each includes a fitting 28 at one end through which extends an inlet tube 29 that leads the cooling medium to the opposite end of the section. Fitting 28 is also provided with a tube 30 for evacuation of the cooling medium. Inlet tube 29 and outlet tube 30 are provided with unions or similar devices at their ends so that they may quickly be coupled to appropriate tubes that extend from inlet header 31 and outlet header 32. Headers 31 and 32 are supported from carriage 18, as by suitable brackets, to be movable therewith. Headers 31 and 32 are connected respectively to the source of the cooling medium and the place of disposal thereof by flexible conduits. Members 24 and 27 are also connected through suitable tubing not shown to headers 31 and 32.

Section 25 may have a simple rectangular cross-section, as shown in Fig. 1, or as shown in Fig. 6, sections 25'' may include projections along their external lower edges to aid in sealing the space between the sections as well as to facilitate the assembly. Sections 25' of Fig. 3 each includes a hollow metal backing member 33 provided for circulation of a heating medium therethrough and shaped to retain the fire-brick, or other ceramic material, portion that defines the mold surface.

On a platform not shown, positioned so as not to interfere with the movement of carriage 18 and the arrangement carried thereby, are supported the remainder of the apparatus elements. These include a holder 34 which may be an electric furnace or ladle or the like, in which is adapted to be produced, or held, a batch of molten metal of the analysis required to produce the desired deposit. Metal holder 34 may be provided with a plurality of electrodes, for maintaining the molten metal at a required pouring temperature, and a skimmer 35 to prevent slag from moving to the outlet as the holder is tilted. Holder 34 is mounted on trunnions so that it may be easily tilted. Lug 36 extends from holder 34 and includes a slot in which is adapted to move a member pivoted to the end of screw 37. Screw 37 is driven through worm and wheel assembly 38 from motor 39. Motor 39 is preferably reversible and its operation is controlled from an arrangement included in box 40. The trunnion arrangement of holder 34, as well as motor 39

and the elements connecting it to holder 34, are preferably mounted on a truck, or other means, movable on the supporting platform. Such truck, or the like, is also preferably provided with arrangements for raising and lowering it relative to the platform. By providing such a truck, or its equivalent, holder 34 may be moved, horizontally and vertically, as necessary to maintain the discharge end of its spout, or runner, in substantially fixed position while holder 34 is tilted.

The arrangement in box 40 is of the type commonly used in the electric welding and electric furnace arts to control the feed of electrodes and is connected through cable 41 to body 22 and through cable 42 to the non-consumable electrode 43.

Electrode 43 includes a hollow body portion and a discharge tip, preferably of copper, or other metal of high heat conductivity. Water, or other heat exchange medium, conducted and removed by suitable tubing, is circulated through electrode 43 to cool the discharge tip thereof. Electrode 43 is connected to the negative side of a direct current source shown as located in back of panel 45 by cable 44. The positive side of this current source is connected to body 22 through cable 46. If desired, the positive side of the direct current source may be grounded. A plurality of electrodes 47 are provided and these so spaced that as carriage 18 is oscillated beneath them they will fuse the surface of body 22 for the full width thereof. Electrodes 47 may be supplied in the form of wire as from reels 48 and their feed controlled, as by any of the electrode control arrangements common in the arc welding and electric furnace arts, to maintain a predetermined discharge from their ends. Suitable contact nozzles 48' are provided, which may be water cooled, and are connected through cables 49 to one side of a source of electric current. The other side of the electric current source may be connected to body 22 through cable 46 or may be grounded.

Electrodes 43 and 47 may be vertically positioned as shown in Fig. 1 or they may be inclined to the vertical as shown in Fig. 4. In either case the bulkier elements, electrode nozzles 48' and the spout or runner of holder 34, do not enter the mold space at all. By tilting the electrodes, it is possible to use bulkier nozzles and yet not increase the width of the mold space. It is to be noted that with the inclined electrodes mold sections 25 may be made wider than is possible when using the vertically disposed electrodes.

With body 22 tilted to the vertical, the width of the molten surface of deposited metal 51 always exceeds the ultimate depth of the deposited metal 51, as measured on a line at right angles to the surface of metal body 22, and thus a greater work area is provided than when body 22 is vertically disposed. By building up the outside face of the mold space progressively, by means of sections 25, advantage is taken of this fact, and a deposit of metal 51 can be produced which may be one-half, or less, as thick as the deposit produced when body 22 is maintained vertical. Thus, with a set of surface fusing electrodes having contact nozzles of approximately an inch in diameter a deposit of about two inches thick is the minimum that has been produced with the body 22 in the vertical position. With these same electrodes and nozzles but with body 22 tilted as shown, deposits of something less than an inch thick have been successfully produced. As is apparent the angle of tilt of body 22 can be varied considerably; as the angle flattens the width of the surface of the molten deposit increases. There is a limit, however, as to the flatness of the angle that can be successfully used for the greater the width of the surface of the molten deposit the more difficult it will be to maintain this whole surface molten and to prevent "cold shuts" etc.

In carrying out the operation, using the apparatus of Figs. 1 and 2, after metal body 22 is positioned in carriage 18 and members 23, 24, 26, and 27 of the mold structure have been properly assembled, the stroke of the means for moving truck 10 is adjusted as required to have electrodes 47 fuse the full width of the face of body 22, and carriage 22 is raised to its starting position, electrodes 47 are fed until they closely approach the surface of body 22. Arc starters, wads of steel wool, etc., are then interposed between body 22 and the ends of electrodes 47 and the quantity of flux 50 necessary to protect the operation from the atmosphere placed in the space defined by the surface of body 22 and members 23 and 26. Flux blanket 50 is preferably of the kind and character disclosed in my prior Patent No. 2,191,479. The circuit of electrodes 47 is then closed and motor 16 set in operation. The circuit of electrode 43 and motor 39 are then closed with the result that motor 39 will rotate screw 37 to tilt holder 34 and cause molten metal to fall through the blanket of flux 50 onto the fused surface of body 22. The circuit of hoist motor 21 will then be closed to lower carriage 18 at the constant selected rate.

As the liquid metal level rises it will contact the end of electrode 43 to initiate the discharge of electric current therefrom. Controls in box 40 will then function to control the operation of motor 39 as required to so adjust the pouring rate of the molten metal as to maintain a predetermined electric current discharge from the end of electrode 43. The voltage of the predetermined discharge is so chosen that the level of the liquid metal 51 is maintained in such a position, relative to the discharge ends of electrodes 47, that said electrodes 47 discharge electric current at substantially the line of contact between the surface of body 22 and the surface of molten metal 51 so that the rising molten metal level constantly rises against freshly fused surface of body 22 and a complete union of the metals is assured. As the level of the molten flux approaches the top edge of member 23 the bottom section 25 of the mold front is positioned and connected to manifolds 31 and 32. The deposition is continued and sections 25 added until the molten flux 50 reaches the top edge of body 22. As the operation proceeds holder 34 is raised and moved to maintain the discharge end of its spout or runner in substantially the same position.

The tilting control feature of the invention is also applicable to the production of ingots or other metal bodies of a single analysis. To produce such bodies electrodes 47, truck 10 and carriage 18 are eliminated. A mold of suitable character is provided. The mold may be fixed in position, in which case electrode 43 is raised at the rate required to give the desired pouring rate, or electrode 43 may be fixed in position and the mold lowered at the rate required to give the desired pouring rate. In either case, electrode 43 through controls in box 40 will control the functioning of motor 39 and metal holder 34

will be tilted as required to constantly pour the molten metal into the mold at the chosen rate.

The progressive formation of the inclined mold space feature of the invention can be successfully used in the production of composite metal bodies regardless of the source of the molten metal. Thus, in place of tiltable holder 34 the metal producing arrangement shown in my prior Patent No. 2,279,990 may be employed or that shown in my prior Patent No. 2,310,635 may be employed. In either case, electrode 43 and the control arrangements in box 40 are preferably used to control the functioning of hoist motor 21 so that by controlling the rate at which carriage 18 is lowered, so as to maintain a predetermined discharge of constant characteristics from the end of electrode 43, the level of the deposited molten metal 51 is kept in fixed positional relationship with the surface fusing electrodes 47. As in the operation described in connection with the apparatus of Fig. 1 electrode 43 is positioned so that the surface fusing electrodes 47 discharge substantially at the intersection of the surface of metal body 22 and the molten surface of deposited metal 51. In either of these operations by progressively building up the inclined mold space a wider space is available for the fusion of the surface of body 22 and the deposition of the molten metal so that the elements for effecting these results may easily be kept out of the mold space and metal deposits of less depth than heretofore can be produced. Also, when molten metal produced externally is supplied into the mold space, the drop of the molten metal is kept to a minimum and the operation more easily controlled and a better product produced.

The progressive building up of the mold space feature of the invention may also be used in connection with the production of composite metal bodies when the mold space is vertically disposed, as shown in Fig. 3. In this figure contact nozzles 48' are arranged to curve surface fusing electrodes 47 toward the surface of metal body 22. Alternatively nozzles 48' may be at an angle to the vertical and entirely outside of the mold space. Metal container 34' may be of the same type as that described in connection with Fig. 1. In such case carriage 18 will be mounted to be vertically movable and electrode 43 and the arrangements in box 40 will function to control the pouring rate of the molten metal.

Container 34' may, however, also be of the type, disclosed in my prior Patent No. 2,310,635, which is adapted to produce molten metal at a selected rate. In such case, electrode 43 and the arrangements in box 40 may be employed to control the functioning of the hoist motor 21 to lower carriage 18, vertically, as required to maintain a fixed positional relation between the surface of the rising molten metal and the discharge ends of electrodes 47.

Also, when container 34' is of the type disclosed in my prior Patent No. 2,310,635, body 22 and the mold structure may be immovable and electrode 43 employed to control the raising of electrodes 47 to maintain the desired positional relation between the surface of the molten metal and the discharge end of the surface fusing electrodes 47. Container 34' will then be raised constantly or in step as required for the positioning of the mold sections 25'.

In all of the cases mentioned in connection with Fig. 3, by building up the mold space progressively the spout of holder 34' can be kept at a comparatively short distance from the surface of the molten metal in the mold space. This results in a short and compact metal stream which is easily directed and controlled and which is not unduly exposed to the atmosphere.

I claim:

1. In apparatus for producing metal bodies, a mold including a mold space, a container for molten metal tiltably supported for pouring molten metal into the mold space, an electrode device adapted to discharge electric current through a gap between its end and the surface of the molten metal in the mold space, means for effecting relative vertical movement between the mold and the electrode device, means for tilting said container, and means in the electric circuit of said electrode device to control the operation of said tilting means to adjust the pouring rate of the molten metal as required to maintain an electric discharge of substantially constant characteristics through said gap.

2. In apparatus for producing composite metal bodies, a mold including a mold space defined at least in part by surface of a solid metal body which is to form an integral part of the desired composite metal body, a container for molten metal tiltably supported for pouring molten metal into the mold space, an electrode device adapted to discharge electric current through a gap between its end and the surface of the molten metal in the mold space, means fixedly positioned relative to the discharge end of said electrode for fusing the surface of the metal body defining the mold space, means for effecting relative vertical movement between the mold and the electrode device and the surface fusing means, means for tilting said container, and means in the electric current circuit of said electrode device to control the operation of said tilting means to adjust the pouring rate of the molten metal as required to maintain a substantially fixed positional relation between the surface of the molten metal and the surface fusing means.

3. In apparatus for producing composite metal bodies, a mold including a mold space defined at least in part by surface of a solid metal body, a container for molten metal tiltably supported for pouring molten metal into the mold space, an electrode device adapted to discharge electric current through a gap between its end and the surface of the molten metal in the mold space, electrode means fixedly positioned relative to the discharge end of the electrode device for fusing the surface of the metal body defining the mold space, means for effecting relative horizontal movement between the surface fusing electrode means and the mold, and means for effecting relative vertical movement between the mold and the electrode device and the surface fusing electrode means, and means in the electric circuit of the electrode device to control the operation of the tilting means to adjust the pouring rate of the molten metal as required to maintain a substantially fixed positional relation between the surface of the molten metal and the surface fusing electrode means.

4. In apparatus for producing composite metal bodies, an inclined pathway, support means movable in either direction along said pathway, a solid metal body adapted to form part of the desired composite metal body supported by said support means, means framing all but the top edge of the upper surface of said metal body adapted to form with said metal body a mold space having an open top and an open side, means

adapted to enter through said open side for fusing said upper surface of said metal body, means also passing through said open side for depositing molten metal into said mold space, means for lowering said support means along said pathway to progress said fusing and said depositing means along the open side of said mold space, and sequentially positionable means positionable on said framing means to progressively close the open side of the mold space.

5. In apparatus for producing composite metal bodies, an inclined pathway, carriage means movable in either direction along said pathway, a solid metal body adapted to form part of the desired composite metal body supported in said carriage for movement therewith and having a generally rectangular upper surface, mold forming elements positioned against the side and bottom edges of said surface to define with said body a mold space having an open side exposing said surface, means fixed against vertical movement for fusing said surface, means for depositing molten metal into said mold space, means for lowering said carriage along said pathway at a constant selected rate, means for adjusting the rate of deposition of the molten metal to maintain a fixed positional relation between said surface fusing means and the level of the molten metal, and means sequentially positionable on said mold forming elements to close the open side of the mold space downwardly of said fusing means.

6. In apparatus for producing composite metal bodies, an inclined pathway, carriage means movable in either direction along said pathway, a solid metal body adapted to form part of the desired composite metal body supported in said carriage for movement therewith and having a generally rectangular upper surface, mold forming elements positioned against the side and bottom edges of said surface to define with said body a mold space having an open side exposing said surface, means fixed against vertical movement for fusing said surface, a tiltable container for molten metal adapted to pour molten metal into said mold space, means for tilting said container, means for lowering said carriage along said pathway at a constant selected rate, means for controlling the operation of said tilting means to adjust the pouring rate of the molten metal as required to maintain a fixed positional relation between the surface of the molten metal and said fusing means, and means sequentially positionable on said mold forming elements to close the open side of the mold space downwardly of said fusing means to continuously present a mold space closed on all sides to the molten metal.

7. In apparatus for producing composite metal bodies, an inclined pathway, carriage means movable in either direction along said pathway, a solid metal body adapted to form part of the desired composite metal body supported in said carriage for movement therewith and having a generally rectangular upper surface, mold forming elements positioned against the side and bottom edges of said surface to define with said body a mold space having an open side exposing said surface, one or more electrodes extending through said open side and fixed against vertical movement adapted to discharge electric current to fuse said surface, a tiltable container for molten metal positioned to pour molten metal through said open side into said mold space, means for tilting said container, a further electrode extending through said open side and fixed against vertical movement adapted to discharge electric current through a gap between its end and the surface of the deposited molten metal, means for lowering said carriage along said pathway at a controlled selected rate, means in the circuit of said further electrode adapted to control the operation of said tilting means to adjust the pouring rate of the molten metal as required to maintain an electric current discharge from the end of said further electrode of substantially constant characteristics, and means sequentially positionable on said mold forming elements to close the open side of the mold space downwardly of said electrode to continuously present a mold space closed on all sides to the molten metal.

8. In a method for producing composite metal bodies, the steps comprising, providing a mold space defined at least in part by the surface of a solid metal body that is to form a part of the desired composite metal body and having an open side exposing said surface of the solid metal body, disposing said mold space and said body with said surface and said open side inclined to the horizontal, depositing molten metal into said mold space through said open side, entering said open side to fuse metal of said body at the level of the deposited molten metal, the inclination of said mold space and said body being such that the depth of said mold space measured in a horizontal plane is substantially greater than the depth of said mold space measured in a plane normal to said surface of said body, and progressively closing said open side to constantly present a mold space closed on all sides to the rising molten metal.

9. In a method for producing composite metal bodies, the steps comprising, providing a mold space defined at least in part by the surface of a solid metal body that is to form a part of the desired composite metal body and having an open side exposing said surface of the solid metal body, disposing said mold space and said body with said surface and said open side inclined to the horizontal, depositing molten metal into said mold space through said open side from a molten metal source external to said mold space, discharging electric current from the ends of electrodes passing through said open side to fuse metal of said surface, the inclination of said mold space and said body being such that the depth of said mold space measured in a horizontal plane is substantially greater than the depth of said mold space measured in a plane normal to said surface of said body, moving said body and mold space relative to said electrodes to fuse the full length of said surface, adjusting the pouring rate of the molten metal to maintain a fixed positional relation between the surface of the molten metal and the surface fusing electrodes, and progressively closing said open side to constantly present a mold space closed on all sides to the rising molten metal.

10. In a method for producing composite metal bodies, the steps comprising, providing a metal shaping mold space defined at least in part by the surface of a solid metal body that is to form a part of the desired composite metal body and having an open side exposing said surface of the solid metal body, disposing said mold space and said body with said surface and said open side inclined to the horizontal, depositing molten metal into said mold space, fusing a substantially horizontal band of the metal of said surface, the inclination of said mold space and said body be-

ing such that the depth of said mold space measured in a horizontal plane is substantially greater than the depth of said mold space measured in a plane normal to said surface of said body, moving the means employed to fuse said band and said mold space relative to each other at a constant rate to raise the top of said fused band, discharging electric current through a gap between the end of an electrode which projects through said open side and the surface of the molten metal, raising said electrode relative to said body with said band, adjusting the pouring rate of the molten metal to maintain a discharge of substantially constant characteristics from the end of said electrode, and progressively closing said open side to continuously present a mold space closed on all sides to the rising molten metal.

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