

Feb. 27, 1945.

R. K. HOPKINS

2,370,467

METAL FUSING APPARATUS AND METHOD

Filed Jan. 15, 1942

2 Sheets-Sheet 1

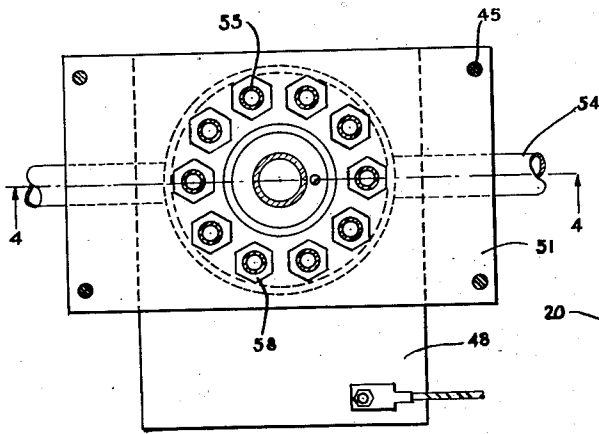


Fig. 3

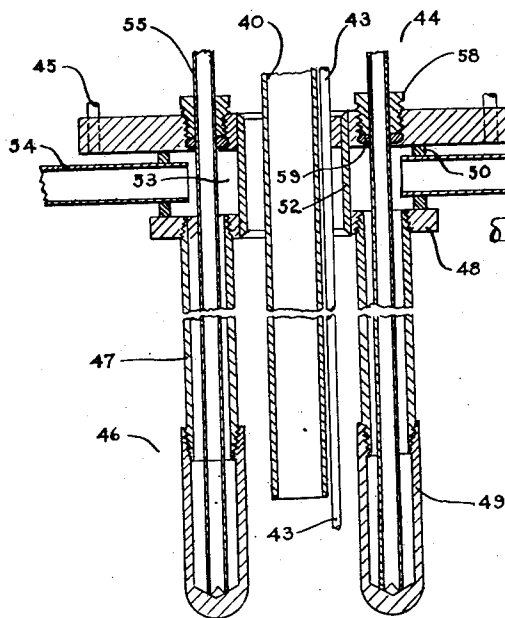


Fig. 4

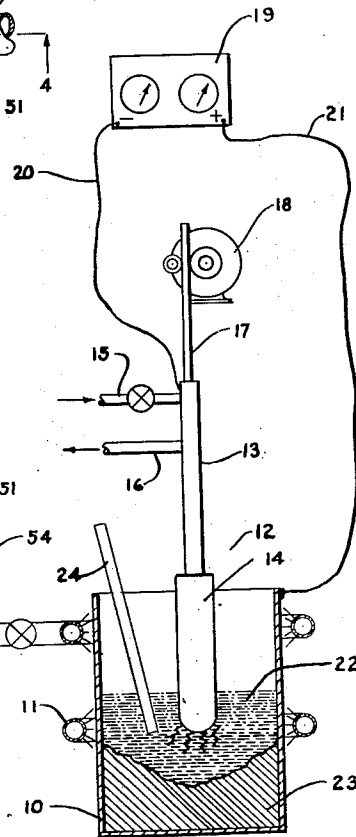


Fig. 1

ROBERT K. HOPKINS
INVENTOR

BY *Virgil F. Davies*
ATTORNEY

Feb. 27, 1945.

R. K. HOPKINS

2,370,467

METAL FUSING APPARATUS AND METHOD

Filed Jan. 15, 1942

2 Sheets-Sheet 2

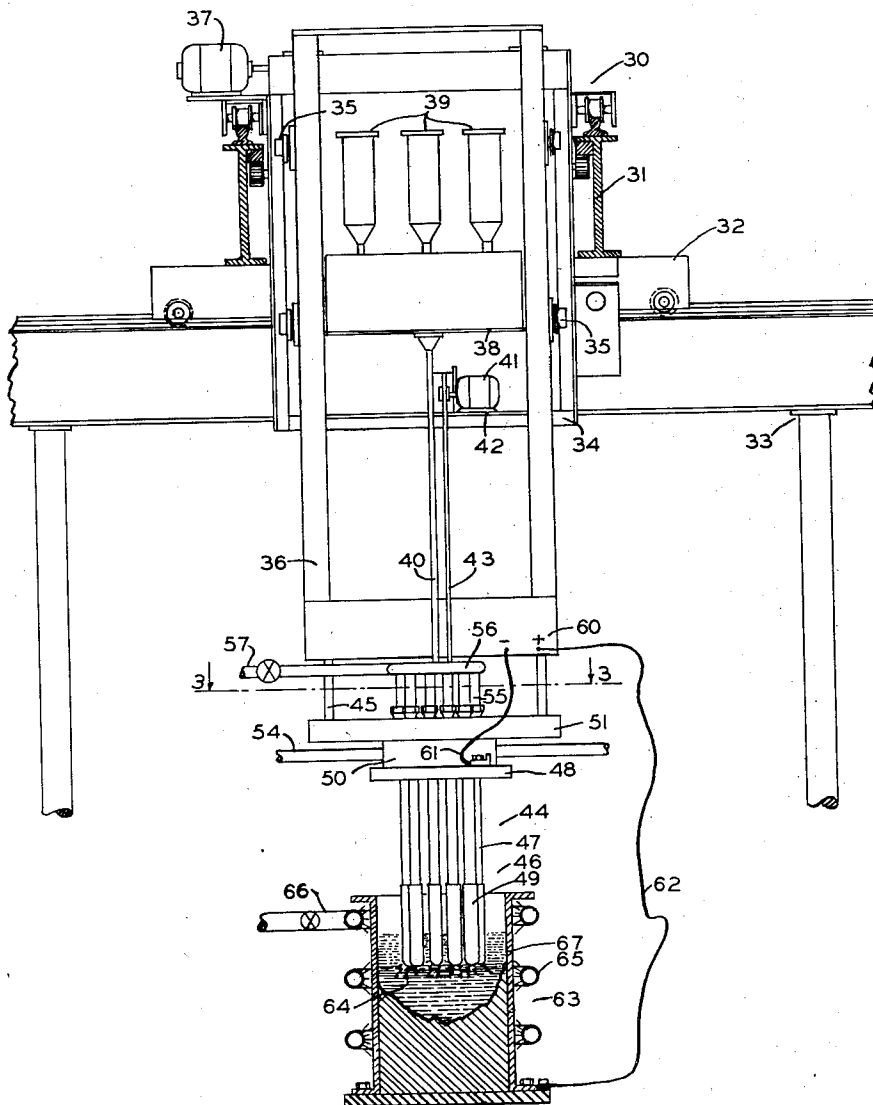


Fig. 2

ROBERT K. HOPKINS
INVENTOR

BY *Virgil F. Davis*
ATTORNEY

UNITED STATES PATENT OFFICE

2,370,467

METAL FUSING APPARATUS AND METHOD

Robert K. Hopkins, New York, N. Y., assignor to
The M. W. Kellogg Company, New York, N. Y.,
a corporation of Delaware

Application January 15, 1942, Serial No. 426,826

14 Claims. (Cl. 22—200)

This invention relates to the fusion of metal and particularly to the production of molten metal by the discharge of electric current from the ends of electrodes.

The discharge of electric current from the ends of electrodes is used in many arts, such as the electric furnace and electric welding arts, to supply the heat required to produce molten metal. The electrodes used may be of the consumable type, i. e., they may be made of metal either of the same analysis as the desired molten metal or of such an analysis that when intermixed with other metal fused during the operation the desired molten metal results; the electrodes used may also be of the so-called non-consumable type, i. e., they may be made of a material such as carbon, tungsten, etc., which is not readily fused or consumed by the electric current discharge. While the so-called non-consumable electrodes have a long life they are in fact consumable and must be replaced at regular intervals. The so-called non-consumable electrodes are generally quite expensive and their replacement cost is an appreciable item in any operation employing them. The so-called non-consumable electrodes have the further disadvantage that the materials that result from their consumption often have a deleterious effect on the desired molten metal.

The consumable metal electrodes while highly useful and desirable in many operations have the inherent disadvantage that by supplying substantial proportions of metal to the operation they impose limitations on the analysis of the metal that can be produced. This disadvantage is sometimes encountered in operations of the character disclosed in my prior Patents Nos. 2,191,479 and 2,191,481.

I have found that metal fusing operations, employing the electric arc discharge, can be easily and cheaply carried out without imposing any limitation on the analysis or the character of the final metal.

It is a primary object of this invention to provide a novel method for fusing metal by the electric arc discharge, and novel apparatus for carrying it out in practice, by means of which a desired metal may be produced whose analysis and characteristics are independent of and not deleteriously affected by the constituents of the electrode.

It is also a primary object of this invention to provide novel apparatus for fusing metal by the electric arc discharge which includes an electrode, or electrodes, that are substantially non-

consumable whereby the molten metal produced does not include constituents derived from the electrode, or electrodes.

It is also an important object of the invention to provide a novel method and novel apparatus for carrying it out in practice, for producing alloys of desired analysis, from materials containing their constituents, in which the materials are supplied at the rates required to produce the alloy of desired analysis to a fusion zone whereat they are fused and intermingled by the heat of the electric arc discharge to produce the alloy of desired analysis without addition of electrode constituents thereto.

It is also an object of the invention to provide a novel method, and novel apparatus for carrying it out in practice, for producing metal bodies that are free from pipes and other shrinkage defects, in which heat is applied to the metal during the solidification thereof by the discharge of electric current, without addition of metal, at a rate less than that at which the heat is dissipated but sufficient to maintain molten metal until the solidification is substantially complete.

It is a further object of the invention to provide a method, and novel apparatus for carrying it out in practice, for filling shrinkage pipes, voids and other defects in metal bodies, in which the metal of the body surrounding the defect is fused and coalesced with filler metal by heat generated through the discharge of electric current, the addition of filler metal being discontinued when the void is filled to the desired extent and the electric current discharge being continued without addition of metal until substantially all of the metal has solidified, the heat of the arc being sufficient to maintain molten metal until solidification is substantially complete.

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

Fig. 1 is a front view, partly in section of a simple form of apparatus embodying the invention,

Fig. 2 is also a front view, partly in section, of a form of the apparatus embodying the invention especially adapted for the production of alloys from materials containing their constituents,

Fig. 3 is a sectional view taken on line 3—3 of Fig. 2, and

Fig. 4 is a sectional view taken on line 4-4 of Fig. 3.

The invention is of general application and may be used in carrying out a wide variety of operations in which metals or other materials are subjected to the heat of the electric arc discharge. For the purposes of this disclosure the invention will be described in connection with the manufacture of metal ingots.

The apparatus of Fig. 1 includes a fusion zone defined by ingot mold 10 which may be made of metal, or of refractory material, or it may in part be made of metal and in part of refractory material. In the manufacture of ingots of ferrous metals and alloys, molds made of a metal having a high heat conductivity, such as copper, are preferred. The metal molds are usually cooled as by circulating a cooling medium through a jacket or by jetting a cooling medium against them. A valve controlled coil 11 is shown for this purpose.

An electrode 12 projects into the fusion zone. Electrode 12 includes a tubular body portion 13 and a removable tubular tip 14 connected by a screw joint to the body portion. While body portion 13 may be made of any metal of a good heat conductivity, tip 14 is made of a metal having a high heat conductivity such as copper, brass, silver, etc. A tube 15 enters the top of electrode 12 and leads a cooling medium, water being the cooling medium generally employed, to the bottom of tip 14 whereat it jets against the walls of tip 14 to remove heat therefrom. The cooling medium flows up the inside of the electrode and exits through tube 16. A valve is provided to control the flow through tube 15.

To the top of electrode 12 is attached a rod or similar member 17 for raising or lowering the electrode by means of motor 18. Motor 18 is of the type found in electric arc welding heads for feeding welding electrodes; its operation is controlled by arc control arrangements, of the character usually employed in the electric furnace and electric arc welding arts, which will be considered as located in back of control panel 19. The arc control arrangements are cut into the electric current circuit of electrode 12 and control the rotation of motor 18 so that it will move electrode 12 as required to maintain a discharge of predetermined characteristics from its end. Since electrode 12 is not fused the control of the current discharge from its end is a simple matter and may be effected by hand.

In back of panel 19 is located the electric current source. This may be a generator or a connection to an outside supply. I have found that while the electrode described is useful with A. C. current it shows signs of appreciable wear and its life is not over long when such current is employed. However, if D. C. current is used and the electrode is connected to the minus lead, as by cable 20, and mold 10 connected to the positive lead, as by cable 21, the electrode is practically indestructible and shows a minimum of wear even after prolonged hard use.

Electrodes 12 constructed and electrically connected as above described, have been used for long periods of time without evidence of substantial wear. Thus, while the surface of tip 14 will occasionally show some pitting and change in contour it can be used indefinitely if sufficient cooling medium is circulated. Also, examination of the metal produced has not revealed the presence of the material out of which tip 14 is formed; nor has any of the metal examined exhibited inferior qualities and properties which were traceable to

the effect of the electrode. The tests conclusively show that electrode 12 not only is practically indestructible but that it has no measurable deleterious effect on the metal produced.

In producing a metal body, such as an ingot, in the apparatus above described, a body of metal or the equivalent, of sufficient thickness to prevent fusing the bottom of the metal mold is initially positioned in the bottom of mold 10. Electrode 12 is lowered until its end approaches the top surface of the metal body and a wad of steel wool or other arc starter interposed between them. The required quantity of protective flux 22 chosen as suitable for the operation, is then placed in the mold. The valves controlling the flow of cooling medium to coil 11 and tube 15 are opened. After the control arrangements for motor 18 have been set, the circuit of motor 18 and the arc circuit may be closed. The initial surge of current destroys the arc starter and establishes the arc. The arc length is maintained at the predetermined value by movement of electrode 12 through motor 18. The material out of which ingot metal 23 is formed is supplied to the arc by member 24.

Member 24 may be a rod or a plurality of rods which contain the constituents of the desired metal. The constituents may be present in metallic form, or in non-metallic form, in the proportions required to produce the metal of desired analysis. In the latter case the materials necessary to convert the constituents to the metallic form are included in the proper proportions. Member 24 is fed to the arc, either manually or automatically as required to produce the metal of desired analysis. Member 24 may also be a tubular non-consumable member through which the constituents are supplied at rates metered to produce the metal of desired analysis. The metered constituents may be supplied in this way beneath the surface of flux 22, as shown, or they may be deposited on the surface of the flux and allowed to fall through the flux to the arc.

The intense heat of the arc rapidly fuses and thoroughly intermingles the constituents to form metal 23, the action is equally rapid and thorough when some of the constituents are introduced as non-metallic material. As the operation progresses metal 23 accumulates and its level rises in mold 10. The end of electrode 12 is automatically raised by motor 18 to maintain it at a substantially constant distance from the surface of the molten metal. The flow of the cooling medium is preferably so controlled that metal 23 solidifies progressively during the operation and yet there is at all times a sufficient body of molten metal present to assure complete intermixing of the constituents and homogeneity of product.

When the level of metal 23 has reached a predetermined level member 24 is removed so that no further constituents are added and no further metal is produced. However, the arc is allowed to continue and a pool of molten metal of constantly diminishing size is maintained until substantially all of metal 23 has solidified. By maintaining a pool of molten metal during the final solidification of metal 23 pipe cavities and other shrinkage defects are eliminated and the yield of useable metal is measurably increased. The heat input may be maintained as during the operation or it may be decreased stepwise or progressively. By proper control of the heat input during this final solidification period ingots have been produced which have no shrinkage

defects and show only a depression of insignificant size at the top of the ingot.

This procedure for preventing the formation of the shrinkage defects in ingots and the apparatus above described may also be used successfully in connection with ingots produced in the usual way. Thus, after an ingot mold has been filled in the usual manner the apparatus of the invention is placed over it and an arc struck from the end of electrode 12 to supply heat during the solidification of the poured metal at a rate less than that at which heat is removed from the mold but sufficient to maintain a pool of molten metal until substantially all of the ingot is solidified. In this type of operation it is preferred to use a blanket of protective flux 22. If the heat input is properly controlled and continued until only a small pool of molten metal is left the resulting ingot will be free of all pipes and voids and the sound metal yield will be a maximum. If this expedient is used the usual large hot-top may be eliminated entirely or the hot-top used need only be of a size sufficient to contain the metal required to compensate for shrinkage during solidification to a desired line of the ingot.

The apparatus and method can equally well be used to fill voids, pipes and repair defects in solid ingots and other solid metal bodies. In filling the pipe cavities in ingots, the apparatus is positioned over the ingot and electrode 12 moved into the primary pipe cavity until it closely approaches the bottom wall thereof. An arc is struck off the end of the electrode. It is preferable at the beginning of the operation to use a sufficiently high current to completely fuse the secondary pipe region. When this has been done filler metal is supplied to the electrode in any preferred way until the cavity is filled and the electrode is manipulated as required to fuse the walls of the cavity and unite the filler metal to them. After the cavity is filled the arc continues until substantially all of the metal is solidified. As before, the current input is adjusted to maintain a molten pool of metal of constantly diminishing size. The operation is preferably carried out under a blanket of protective flux.

The apparatus of Figs. 2, 3 and 4 includes the elements of the apparatus above described and is particularly adapted for alloy ingot manufacturing operations, of the general type described in my prior Patent No. 2,191,479.

The apparatus includes a truck 30 that is mounted for movement on rails carried by a bridge 31. Truck 32 supports bridge 31 and is mounted for movement on rails carried by supporting structure 33. Truck 30 has attached thereto a vertical frame 34 against which bear rollers 35 mounted on vertically movable frame 36. A motor 37 operates the arrangement for lifting and lowering frame 34, for instance, this arrangement may include a vertical elongated screw rotated by motor 37 in a nut fixed to frame 36. Motor 37 is controlled as will be explained hereinafter.

Frame 36 carries a platform 38 upon which are supported metering devices for metering the materials employed in producing the desired metal. These devices may be of any preferred type and construction; each material may be metered through a separate metering device or one metering device may be used to meter a known mixture of two or more materials. The materials are in the particle form and are stored in hoppers 39 from whence they pass to their respec-

tive metering devices. The metered materials are collected in a hopper and pass into pipe 40 which leads them to the fusion zone. The metering devices are so adjusted that the materials are constantly supplied into pipe 40 in the proportions required to produce the metal of required analysis. The constituents of the desired metal may all be obtained from granular material as just indicated or some of them may be obtained from granular material and others from solid shapes such as rods, bars, tubes, etc. In the latter case, the solid shapes required are fed at the proper rate by appropriate means to the fusion zone. One such means is motor 41 that is mounted on platform 42 carried by frame 36. Motor 41 is of the adjustable speed type and through suitable drive wheels drives wire 43 at a selected rate to the fusion zone. Wire 43 may be of any required analysis and may be kept on a reel also mounted on platform 42.

The electrode arrangement 44 is supported by members 45 attached to frame 36. The arrangement includes a plurality of electrodes 46 similar in character and construction to electrode 12 of Fig. 1. The electrodes are grouped in a circle or other closed or substantially closed shape. Each electrode 46 includes a body portion 47, formed of copper, brass, iron or other suitable metal, that is screwed into a hole tapped into bottom plate 48 and tip portion 49 threaded on the end of body portion 47. Tip 49 is preferably made of copper, brass, silver, or other metal, having a high heat conductivity. A ring 50 is united, as by welding, to bottom plate 48 and top plate 51. A tubular member 52 fits in aligned holes in plates 48 and 51 and is united, as by welding, to the walls thereof to complete annular heat exchange medium outlet chamber 53 and to provide a passage for tube 40 and wire 43. The heat exchange medium leaves chamber 53 through pipes 54 that are united, as by welding, to ring 50 and open into chamber 53. Tubes 55 depend from a manifold 56 which is supplied with the heat exchange medium, usually water, from a valved line 57. Tubes 55 pass through holes in plate 51 to enter chamber 53 and extend to the bottom of electrode 46. The ends of tubes 55 are notched as shown and contact the bottoms of tips 49. By making the notches of proper size the jetting of the heat exchange medium against the bottom wall of tip 49 which produces a maximum heat transfer rate may easily be secured. Glands 58 and packing 59 are provided for sealing the holes in plates 51 through which tubes 55 extend.

A panel board 60 is carried at the bottom end of frame 36. For the purposes of this disclosure the various instruments and controls necessary for the proper operation of the apparatus will be considered as located on or in back of this panel board. The current supply means or the connection to an outside current source is also located in back of panel board 60. The current whatever its supply is preferably D. C. current as only with D. C. current can the electrodes operate continuously without substantial wear and the full advantages of the invention be realized. The negative side of the current supply is connected by a cable 61 to bottom plate 48 while a cable 62 connects the positive side of the current supply to mold 63. It is essential that the electrodes and the mold be of the polarity stated if the electrodes are to be substantially indestructible. For proper operation it is necessary that a substantially constant distance

be maintained between the ends of the electrodes and the surface of the metal 64. For this purpose the operation of motor 37 is controlled by arc control arrangements cut into the electrode circuit. The arc control arrangements may be any of the types commonly found in the electric arc welding and electric furnace arts suitable for the purpose. These arrangements will be considered as located in back of panel board 80.

Mold 63 may be of metal or it may be of refractory material, or a combination of both, depending upon the operation carried out. When ferrous alloys are produced a metal mold of high heat conductivity, preferably copper, has been found satisfactory; such mold is cooled in order to prevent its destruction by jetting a heat exchange medium, usually water, against its sides. Coil 65 that receives the heat exchange medium from valved line 66 is provided for this purpose.

After the analysis of the metal required to be produced is established and the raw materials selected, the quantities of the raw materials required, per unit of time, to produce a predetermined weight, per unit of time, of the metal of the desired analysis is determined by simple calculation. When, as is usually preferred, the operation is carried out under a protective blanket of flux 67, little if any allowance need be made for loss of materials. The metering devices, if all of the raw materials are in particle form, or the metering devices and motor 61 or equivalent means, when some of the raw materials are in particle form and others are in the form of rods, wires or other shapes, are set to feed the raw materials at the proper rates. It may be stated here that while wire 43 is shown as passing to the fusion zone through the passageway provided by member 52, it has been shown thus for convenience only as wire 43, or its equivalent, might be passed through tube 40 as well or it might be passed to the fusion zone outside of electrodes 48.

The various settings having been made a body of metal, or the equivalent, of a thickness sufficient to prevent fusion of the bottom of the mold is placed in the bottom of the mold. The electrode arrangement 44 is then lowered until the tips 49 approach the metal body and wads of steel wool or other arc starters interposed between the tips 49 and the plug. A proper amount of the chosen flux 67 is placed in the mold. The valves in lines 54, 57 and 66 are then opened and the electric circuits closed to set the apparatus in full operation. The initial surge of current destroys the arc starter and establishes an arc between tips 49 and the metal body. The arc control arrangements control the operation of motor 37 so that frame 36 is moved to establish and maintain the arcs at the predetermined length.

The heat of the arcs fuses metal of the body and the flux and shortly after the action is started the raw materials work their way through the molten flux and are also fused. The desired metal thus produced forms a pool beneath the blanket of molten flux. The removal of heat through the sides of the mold is so controlled that a sufficient body of molten metal is present to assure thorough intermingling of the constituents and production of homogeneous metal. When the metal produced reaches a predetermined level in mold 63 the metering devices and any other devices used to supply the raw materials are shut

down while the discharge of electric current from the electrodes is continued at a reduced rate until substantially all of the metal is solidified. The electric current discharge during this period should be sufficient to maintain a pool of liquid metal of constantly diminishing size until substantially all of the metal is solidified. If this is done the solidified ingot will be free of all shrinkage defects.

Electrode tips 49 have been examined after long periods of use and aside from minor changes in contour little evidence of their wear has been found. A large number of ingots have been examined and their analyses reveal no ingredients derived from the electrode.

In this disclosure reference is made to striking an arc and maintaining the arc length; it is not to be inferred from these statements that applicant bases this disclosure on the theory that there is an arc between the end of the electrode and the molten metal. Applicant has given a factual disclosure and has used terms common in the art to describe it; he is not concerned with, and has no interest in, any particular theory as to the character of the electric current flow through the gap at the end of the electrode.

While the invention has been described in connection with the manufacture of ingots, it is not limited thereto but is of general application. Also, while the invention has been disclosed in connection with operations in which metal of desired analysis is continuously produced, it is also applicable to operations in which the desired metal is produced in batch operations.

I claim:

1. In apparatus for fusing materials, a metal electrode including a tubular body portion and tubular tip having one end removably united to one end of said body portion, the other end of said tip being closed, said tip being made of a metal of high heat conductivity, a tubular member positioned in said electrode concentrically therewith, said tubular member entering said body portion and extending to the closed end of said tip, portions of the walls of said tubular member adjacent said tip being removed to provide a passageway of predetermined area between the space within said tubular member and the space between said electrode and said tubular member, means for supplying a cooling medium to the entering end of said tubular member, and means for removing the cooling medium from said electrode.

2. In apparatus for producing metal, an electrode arrangement comprising members defining a closed chamber, said members including a top member, a bottom member and side members, said bottom member having a plurality of spaced holes therethrough positioned on the periphery of a substantially closed curve, a hollow metal electrode at each of said holes united to said bottom member and opening into said chamber, said electrodes having a closed discharge end, a like plurality of holes in said top member aligned with the holes in said bottom member, a tubular member positioned in each of said electrodes and having one end adjacent the inner wall of the closed discharge end of said electrodes, said tubular members extending through said chamber and through the hole in said top plate aligned with their respective electrodes, means for sealing the space between said tubular members and the walls of the holes in said top member, means for supplying a cooling medium to said tubular members, and cooling medium outlet

means united to the wall of said side member for evacuation of the cooling medium from said chamber.

3. In apparatus for producing metal; an electrode arrangement comprising members defining a closed chamber, said members including a top member, a bottom member, and side members, said bottom member having a plurality of spaced holes therethrough positioned on the periphery of a substantially closed curve; a hollow metal electrode at each of said holes; each of said electrodes including an open ended hollow body portion, one end of which opens into said chamber and is removably united to the wall of its hole, a hollow discharge tip portion made of a metal of high heat conductivity having its discharge end closed and its other end removably united to the other end of said body portion; a plurality of holes in said top member, each hole being aligned with a hole in said bottom member; a tubular member in each of said electrodes, said tubular members having one end adjacent the inner wall of the discharge end of said tip portion, said adjacent end being formed to provide a communicationway of predetermined area; said tubular members extending through said chamber and the holes in said top member corresponding to their respective electrodes; gland means sealing the spaces between said tubular members and the walls of the holes in said top member; means for supplying a cooling medium to the other ends of said tubular members; and means opening into said chamber for outlet of the cooling medium from said chamber.

4. In apparatus for producing metal; an electrode arrangement comprising members defining an annular closed chamber; said members including a top member, a bottom member, and inner and outer side members, said bottom member and said top member having a plurality of aligned holes therethrough spaced along the periphery of a substantially closed curve; a hollow metal electrode, having a closed discharge end, at each of the holes in said bottom member united to said bottom member and opening into said chamber; a tubular member positioned in each of said electrodes and having one end adjacent the inner wall of the discharge end thereof; said tubular members extending through said chamber and the holes in said top member; means for sealing the space between said tubular members and walls of the holes in said top member; means for supplying a cooling medium to said tubular members; means united to the wall of said outer side member for evacuation of the cooling medium from said chamber; and means passing through the central passageway defined by said inner member for conducting the raw materials used to produce the desired metal to the space encompassed by said electrodes.

5. In apparatus for producing metal; an electrode arrangement comprising members defining an annular closed chamber; said members including a top member, a bottom member, and inner and outer side members, said bottom member and said top member having a plurality of aligned holes therethrough spaced along the periphery of a substantially closed curve; a hollow metal electrode, having a closed discharge end, at each of the holes in said bottom member united to said bottom member and opening into said chamber; a tubular member positioned in each of said electrodes and having one end adjacent the inner wall of the discharge end thereof; said tubular members extending through

said chamber and the holes in said top member; means for sealing the space between said tubular members and walls of the holes in said top member; means for supplying a cooling medium to said tubular members; means united to the wall of said outer side member for evacuation of the cooling medium from said chamber; means passing through the central passageway defined by said inner member for conducting the raw material used to produce the desired metal to the space encompassed by said electrodes; a direct current supply; a mold including a conductive portion forming a surface of the mold space; means connecting the negative side of said current supply to said electrodes; means connecting said conductive portion to the positive side of said current supply; and means operatable for moving said electrode arrangement to maintain a substantially constant electric discharge between the surface of the metal produced and the discharge ends of said electrodes.

6. In the method of treating metalliferous material in a zone heated by the discharge of electric current through a gap, the steps comprising, establishing a heating zone by discharging electric current through a gap between a conductive body and a tubular metal electrode having a closed ended hollow discharge tip of metal of high heat conductivity, conducting a confined stream of liquid cooling medium through the electrode toward the bottom wall of the discharge tip and releasing the stream immediately adjacent said wall to sweep the surface of said wall while maintaining the closed end and a portion of the tip beneath the surface of a depth of flux capable of protecting the submerged portion of the tip from the atmosphere, and adjusting the flow of the cooling medium to remove heat from the discharge tip at a rate sufficient to prevent fusion thereof so that the electric current discharge may be continued substantially indefinitely without destruction of the discharge tip and without passage of substantial quantities of the metal thereof into the heating zone.

7. In the method of treating metalliferous material in a zone heated by the discharge of electric current through a gap, the steps comprising, establishing a heating zone by discharging electric current through a gap between a conductive body connected to the positive side of a source of direct current and a tubular metal electrode connected to the negative side of said source and having a hollow closed ended discharge tip of metal of high heat conductivity, conducting a confined stream of liquid cooling medium through the electrode toward the bottom wall of the discharge tip and releasing the stream immediately adjacent said wall to sweep the surface of said wall, controlling the electric current discharge to maintain it of substantially constant character, simultaneously with the discharge of the electric current and the flow of the cooling medium, maintaining at least the portion of the discharge tip directly effected by the current discharge and the discharge gap submerged beneath the surface of a blanket of flux capable of protecting them from the atmosphere, and adjusting the flow of the cooling medium to remove heat at a rate to prevent destruction of the tip and passage of metal of the tip into the heating zone.

8. The method of producing a melt of metalliferous materials comprising; discharging electric current through a gap between a conductive body in a furnace and a tubular metal electrode

having a hollow closed ended discharge tip of metal of high heat conductivity; conducting a confined stream of liquid cooling medium through the electrode toward the bottom wall of the discharge tip and releasing the stream immediately adjacent said wall to sweep the surface of said wall; simultaneously with the discharge of the electric current and the flow of the cooling medium, maintaining the portion of the discharge tip directly effected by the current discharge and the gap submerged beneath the surface of a depth of flux in the furnace, and adjusting the flow of the cooling medium to remove heat at a rate to prevent destruction of the tip and passage of metal of the tip to the region of the gap; and supplying metalliferous material at a controlled rate into the furnace to be fused by the heat generated at the gap beneath the depth of flux.

9. The method of making a metallic body comprising depositing molten metal in a mold; discharging electric current through a gap between the surface of the deposited metal and a tubular metal electrode having a hollow closed ended discharge tip of metal of high heat conductivity; conducting a confined stream of liquid cooling medium through the electrode toward the bottom wall of the discharge tip and releasing the stream immediately adjacent said wall to sweep the surface of said wall to remove heat therefrom; simultaneously with the discharge of the electric current and the flow of the cooling medium, maintaining a blanket of flux on the deposited metal of a sufficient depth to submerge the gap and at least the portion of the discharge tip directly effected by the current discharge, and adjusting the flow of the cooling medium to remove heat at a rate to prevent destruction of the tip and passage of metal of the tip to the deposited molten metal; and adjusting the electric current discharge to maintain the quantity of heat generated thereby less than the quantity of heat lost by the molten metal to progressively diminish the quantity of molten metal in the mold.

10. The method of making a metallic body comprising discharging electric current through a gap between a conductive body in a mold and a tubular metal electrode having a hollow closed ended discharge tip of metal of high heat conductivity while maintaining the conductive body at a positive polarity and the electrode at a negative polarity; conducting a confined stream of liquid cooling medium through the electrode toward the bottom wall of the discharge tip and releasing the stream immediately adjacent said wall to sweep the surface of said wall to remove heat therefrom; simultaneously with the discharge of the electric current and the flow of the cooling medium, maintaining the portion of the discharge tip directly effected by the current discharge and the gap submerged beneath the surface of a depth of flux in the mold, and adjusting the flow of the cooling medium to remove heat at a rate to prevent destruction of the tip and passage of metal of the tip to the region of the gap; supplying constituents of the desired metal body to the gap to be converted into molten metal; discontinuing the supply of the constituents when the molten metal has risen to a predetermined level in the mold; and after the supply of the constituents is discontinued adjusting the electric current discharge to maintain the quantity of heat generated thereby less than the quantity of heat lost by the molten metal to progressively

diminish the quantity of molten metal in the mold.

11. The method of treating metalliferous material which comprises, establishing a heating zone in a furnace by discharging electric current through gaps between a conductive body connected to one side of a source of electric current and a plurality of spaced tubular metallic electrodes, each having a discharge tip of metal of high heat conductivity at its lower end, positioning the electrodes within the furnace in such spaced relation to each other and to the walls defining the furnace to supply heat uniformly through said heating zone and to prevent destruction of said walls when the current is applied, connecting the electrodes in parallel to the other side of the electric current source and causing electric current to discharge through said gaps, conducting a confined stream of liquid cooling medium through each of the electrodes toward the bottom walls of the respective discharge tips and releasing the stream immediately adjacent said walls to sweep the surfaces of said walls to remove heat therefrom, maintaining a blanket of flux in said furnace to submerge said conductive body and the portions of said tips effected by the electric current discharge, adjusting the flow of the cooling medium to remove heat at a rate to prevent destruction of said tips, and supplying metalliferous material into said zone.

12. In apparatus for fusing metalliferous materials, a tubular metal electrode including a closed ended tubular discharge tip, said tip being made of metal of high heat conductivity, a tubular member positioned in said electrode and extending to the closed end of said tip, portions of the walls of said tubular member adjacent said tip being removed to provide a passageway of predetermined area between the space within said tubular member and the space between said tip and said tubular member, means for supplying a cooling medium to said tubular member, and means for removing the cooling medium from the electrode.

13. An apparatus for fusing metalliferous materials, a heating zone defining member having a conductive portion, said member being adapted to receive a blanket of protective flux therein, a tubular electrode having a closed ended current discharge tip of metal of high heat conductivity adapted to extend into said member with at least the portion of said tip from which current is discharged submerged beneath the surface of said blanket of flux, a source of direct current, means connecting said conductive portion to the positive side of said current supply, means connecting said electrode to the negative side of said current supply, means for maintaining a current discharge of predetermined characteristics through a gap beneath the surface of the flux blanket between said discharge tip and said conductive portion, tubular means within said electrode and extending to the closed end of said tip having portions of its walls removed to provide a passageway of predetermined area between the space within said tubular means and the space between said tubular means and said tip for conducting a cooling medium through said electrode directly to said closed end to remove heat therefrom, while the portion of said tip from which the current is discharged is maintained beneath the surface of the blanket of flux, at a rate to prevent destruction of said tip and passage of substantial quantities of the metal thereof into the heating

zone, and means for removing the cooling medium from the electrode.

14. In apparatus for fusing metalliferous materials, a frame, a plurality of spaced tubular electrodes supported by said frame, each of said electrodes having a closed ended discharge tip of metal of high heat conductivity, a tubular member within each of said electrodes extending to the closed end of the discharge tip of its electrode for conducting a cooling medium through its electrode directly to said inner wall, portions of the walls of said tubular member adjacent said

tip being removed to provide a passageway of predetermined area between the space within said tubular member and the space between said tip and said tubular member, means for supplying a cooling medium through said tubular members to said inner walls to jet directly thereagainst and pass upwardly in said electrodes, means for removing the cooling medium from said electrodes, and means for discharging electric current from said tips for the purposes stated.

ROBERT K. HOPKINS.