May 1, 1945. R. K. HOPKINS 2,375,107

METHOD AND APPARATUS FOR THE CONTINUOUS PRODUCTION OF METAL

Filed June 26, 1941 3 Sheets-Sheet 1

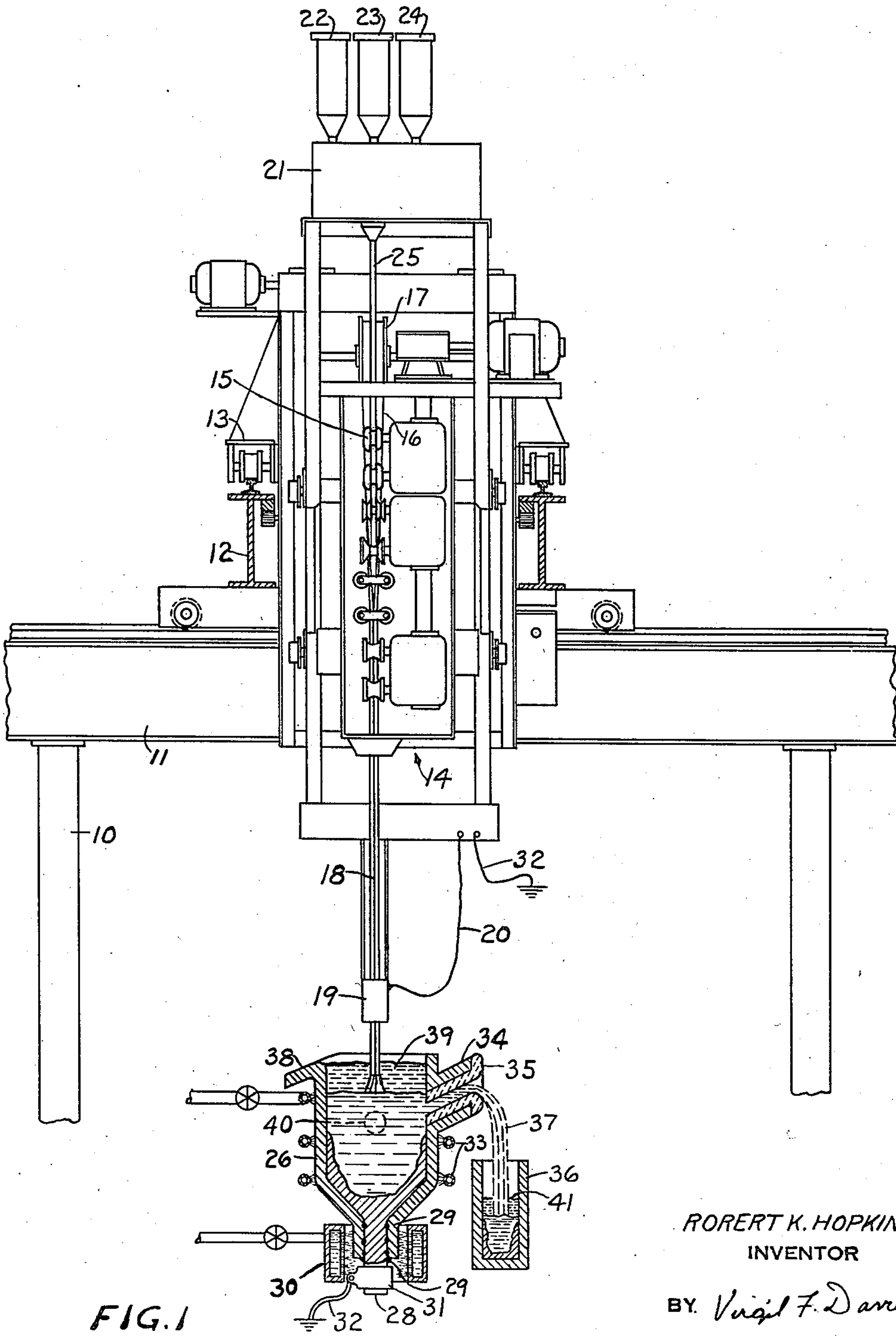

FIG. 1

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METHOD AND APPARATUS FOR THE CONTINUOUS PRODUCTION OF METAL

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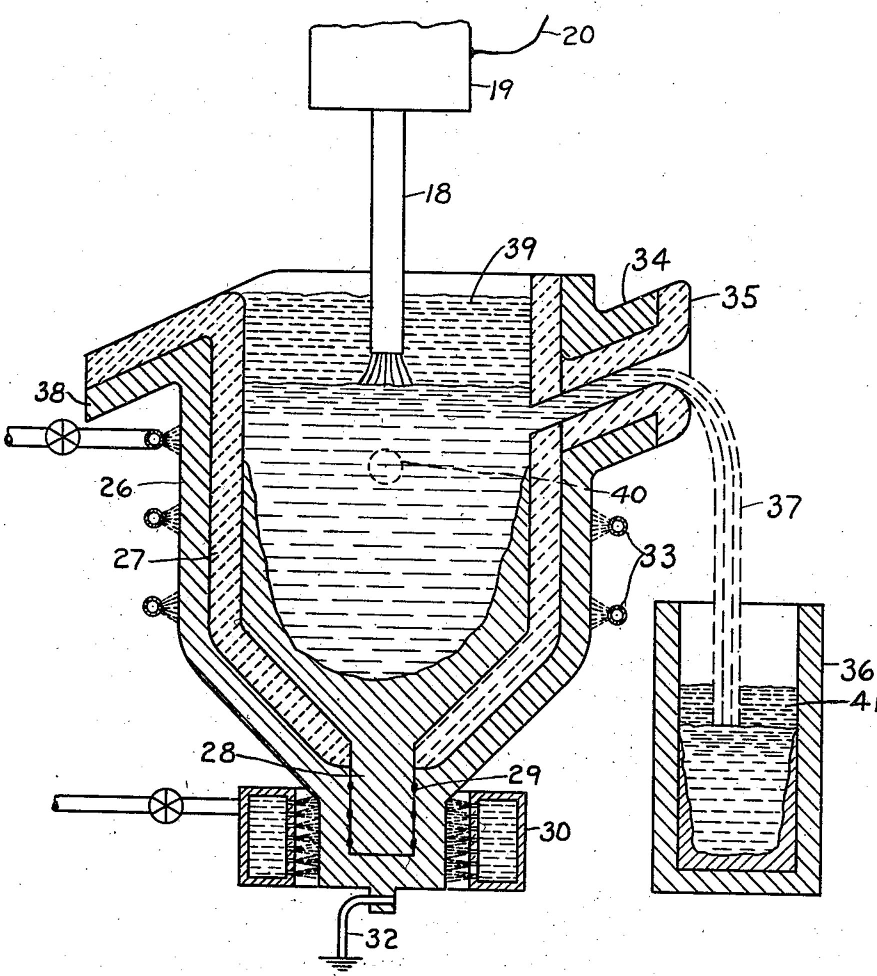

FIG. 2

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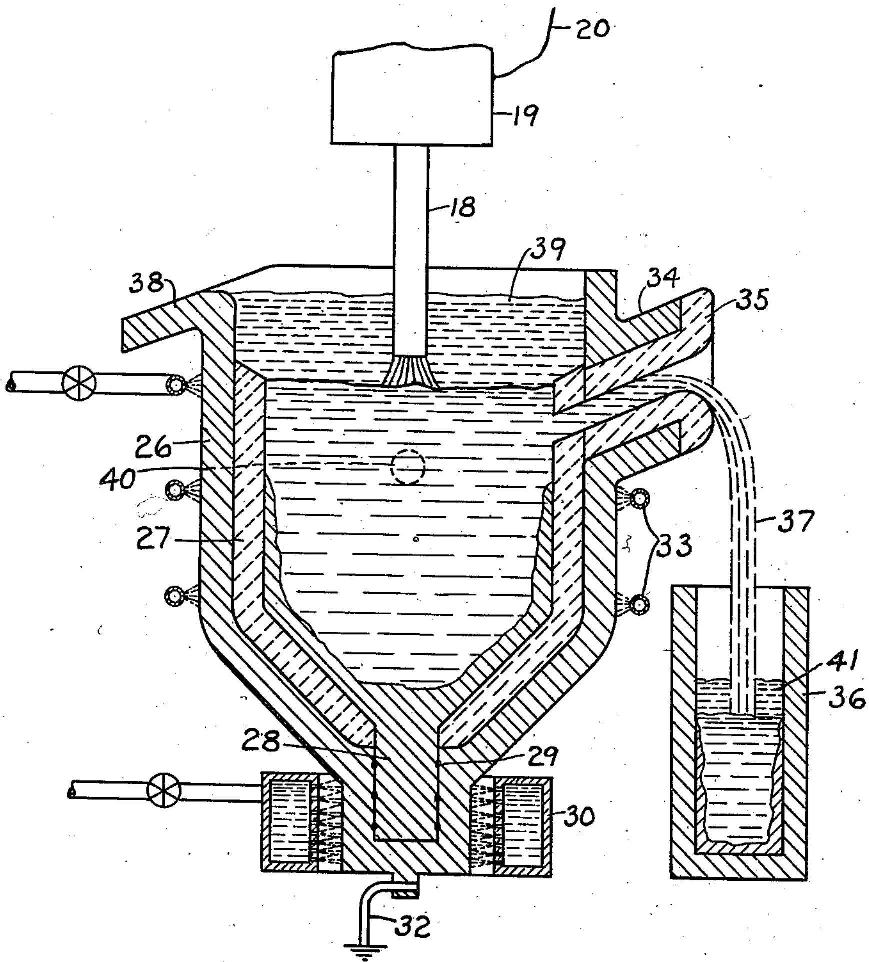

FIG. 3

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UNITED STATES PATENT OFFICE

2,375,107

METHOD AND APPARATUS FOR THE CONTINUOUS PRODUCTION OF METAL

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Application June 26, 1941, Serial No. 399,820

10 Claims. (Cl. 75—10)

This invention relates to the production of metal and in particular to the production of a continuous supply of molten metal.

Metals and alloys, both ferrous and non-ferrous, such as carbon steel, tool steel, the corrosion resistant alloys, etc., are at present produced commercially by batch operations. The production of metal by continuous operations has been proposed at various times but for one reason or another none of the proposals has been accepted commercially. A commercial process capable of continuously producing metal is highly desirable because of the inherently higher efficiency of the continuous processes as opposed to batch processes; also a continuous supply of molten metal makes it possible to carry out subsequent operations more efficiently and makes possible operations which the discontinuous molten metal supply of the batch processes renders difficult if not impossible.

I have found that metal can be produced economically and satisfactorily in a continuous manner in simple and efficient apparatus.

It is a primary object of this invention to provide a novel method, and novel apparatus for carrying it out in practice, for producing metal continuously; the novel method and novel apparatus being such that all essential conditions may be easily and accurately controlled whereby desired metal in the molten condition and of substantially uniform analysis and character is continuously available at a predetermined rate.

It is also one of the main objects of the invention to provide a novel method, and novel apparatus for carrying it out in practice, for producing metal continuously in which the raw materials employed to produce the desired metal are supplied to a fusion zone at controlled rates adjusted to supply the raw materials in the proportions required to constantly produce metal of the required analysis and molten metal is constantly withdrawn from the fusion zone at a rate substantially equal to that at which it is produced.

It is a further object of the invention to provide a novel method, and novel apparatus for carrying it out in practice, for producing metal continuously in which the raw materials employed to produce the desired metal are supplied to a fusion zone at controlled rates adjusted to supply the raw materials in the proportions required to constantly produce metal of the required analysis, molten metal is constantly withdrawn from the fusion zone at a rate substantially equal to that at which the metal is produced and the essential conditions of the operation are adjusted and controlled whereby the molten metal withdrawn is of substantially constant character and analysis.

The further objects and advantages of the invention will be readily appreciated and understood from a consideration of the following description of present preferred modes of carrying it out in practice taken with the accompanying drawings, in which

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

Figs. 2 and 3 are fragmentary views, partly in section, showing alternative forms of elements of the apparatus.

The invention is of general application and while it may be used to provide a continuous supply of molten metal without substantially altering the analysis of the metal fused, it is particularly adapted to the production of metals from their constituents to provide a continuous supply of molten metal of desired analysis. The invention may be successfully employed in the production of both ferrous and non-ferrous metals and alloys but it is particularly useful in the production of ferrous alloys, especially those containing substantial proportions of elements such as chromium, nickel, manganese, vanadium, silicon, tungsten, columbium, etc., either alone or in combination. Of the latter class of alloys, the corrosion resistant alloys such as the chromium steels and the chromium-nickel steels, and also the tool steels are particularly suited for production by the novel method.

In practicing the invention, the constituents of the desired molten metal, in readily available commercial forms, are supplied at constant rates to a fusion zone in the proportions required to produce the molten metal of desired analysis. The desired molten metal is formed in the fusion zone and is withdrawn therefrom at a rate substantially equal to the rate at which it is produced. The conditions at the fusion zone are adjusted to produce molten metal of the required character and these conditions are maintained so that throughout the operation the molten metal withdrawn is of substantially constant character and analysis.

The raw materials used to supply the constituents of the desired metal may all be metallic or some may be metallic and others non-metallic; the non-metallic materials should, however, be such that the constituent, or constituents, to be derived from them can be converted to the metallic form in the fusion zone. The materials used to supply the constituents of the desired metal may be supplied to the fusion zone in any convenient form but it has been found preferable to supply at least one of them in the form of a tube or hollow member and to supply others, or the remainder, of the materials in granular form through the tube or hollow member. Solid bars or rods may also be used in conjunction with the tube or hollow member. The hollow member may also be used as the conduit of supply of materials required for any necessary reactions in the production and refinement of the desired metal. When the operation is one in which a metal is fused to provide a continuous source of molten metal without substantial change in analysis of the metal, the metal to be fused is the sole raw material and it will usually be supplied in the form of a solid rod or bar.

The materials are preferably supplied to the fusion zone beneath the surface of a depth of slag, or flux, which protects the materials supplied and the molten metal produced from the atmosphere. The flux, as in the case where the operation is one wherein a molten metal supply is produced without substantial change in analysis, may be neutral or have only a limited chemical activity or, as in the case where the raw materials employed contain substantial proportions of impurities or one of the constituents is converted into the metallic form by chemical action, the flux may be of such a composition as to exercise the required smelting and refining action on the metal. In order to constantly produce molten metal of the same character and analysis the flux is preferably maintained at a substantially constant depth throughout the operation and is modified as by additions and withdrawals to maintain it at a substantially constant composition and activity.

The fusion zone is supplied with heat at the temperature level required by the particular operation. The heat may be supplied externally or internally as by a flame, the electric arc, electric induction heat, etc. It has been found preferable to supply the heat internally rather than externally as a better control of the heat input and a more uniform operation may be obtained. While both electric arc heating and electric induction heating are satisfactory for supplying heat internally, the electric arc is at present preferred as its heat input can be concentrated at the point of supply of the raw materials; also, with the electric arc the heat is available at much higher temperature levels so that any necessary reaction, such as converting constituents to the metallic form, refinement of the molten metal and intermingling of the constituents to provide homogeneous molten metal, can be carried out very rapidly.

The temperature conditions at the fusion zone, as well as the temperature of the molten metal withdrawn from the fusion zone, are controlled by controlling the quantity and temperature of the heat input as well as the rate of heat removal. These factors are adjusted as required to give the desired conditions and are maintained throughout the operation. Heat is preferably removed by means of a heat exchange medium which may be circulated at a proper rate through a jacket, or coils, around the fusion zone, or parts thereof at which predetermined temperature changes are desired; alternatively the heat exchange medium may be directly contacted, as by spraying, against the fusion zone or parts thereof.

Reference will now be made to the more specific aspects of the invention and particularly to the novel apparatus illustrated and the novel method as carried out in this apparatus.

The apparatus shown is designed to employ the electric arc, either A. C. or D. C. current, as the means for supplying the required heat; this showing is not to be taken as a limitation on the broad aspects of the invention for as stated heretofore other means may be employed to supply the required heat. The apparatus includes a support 10, formed of structural members, which is provided with horizontal members 11. A bridge 12 is mounted for movement on members 11 while a truck 13 is mounted for movement on bridge 12. The arrangement is such that truck 13 may be moved in any horizontal direction.

An electrode forming and feeding mechanism 14 is supported on truck 13 and is movable vertically, manually or by motor operated means, relative to truck 13. The mechanism 14 includes a plurality of rollers 15 which are adapted to form a flat strip 16, supplied from a coil 17 also supported on truck 13, into a hollow electrode 18. Rollers 15 are driven by a variable speed motor which is arc controlled, as is common in the electric welding and electric furnace art, to form and feed electrode 18 as required to maintain an electric discharge of constant characteristics from its end. In this way a substantially constant predetermined rate of fusion of electrode 18 may easily be obtained. If preferred for the same purpose electrode 18 may be fed at a constant rate, equal to the desired rate of burnoff, and the current supply adjusted to burn electrode 18 at the rate supplied.

Electrode 18 passes through a contact device 19 which is supported from mechanism 14. A cable 20 connects device 19 to one side of the electric current supply. Strip 16, out of which electrode 18 is formed, is made of one of the raw materials used to supply the constituents of the desired metal. When producing ferro-alloys whose major constituent is iron, strip 16 can conveniently be Armco iron or similar low carbon iron or steel. When the ferro-alloy is such that iron is only a minor constituent or large proportions of iron must be introduced with other constituents, strip 16 may be made of one, or more, of the other constituents.

A housing 21 is supported above coil 17 and in it are positioned a plurality of metering devices. The metering devices and housing 21 are movable with mechanism 14. Each of the metering devices is arranged to receive granular material from a hopper, such as hoppers 22, 23 and 24, and feed it at a constant but adjustable rate to a tube 25 that leads from housing 21 through rollers 15 into electrode 18. By this arrangement raw materials in the particle form that contain the constituents of the desired metal are supplied to the fusion zone through the hollow electrode 18. When the conditions of the operation make it desirable one or more of the metering devices may feed into a tube other than tube 25 so that some of the metered material may be led directly to the fusion zone without passing through hollow electrode 18. In operations wherein one or more of the constituents is derived from non-metallic raw materials, such raw materials either alone or intermixed in the proper proportions with material required for the conversion in the fusion zone are metered through one or more of the metering devices. Materials required for reactions in the fusion zone may also be metered separately through one or more of the metering devices. In operations wherein it is necessary to make additions to the flux in order to maintain its character uniform, such additions may be made by metering the materials to be added to the flux through one of the metering devices so that they will be supplied in the proper quantity and at a constant rate. These flux additions may be passed through the hollow electrode or otherwise conducted to the flux.

Electrode 18 feeds into the fusion zone defined by crucible like member 26. Member 26 has been shown as cylindrical but it may be made of any desired shape. The walls of member 26 are preferably of metal, and, as shown in Fig. 1, these metal walls may be the walls of the fusion zone. When such is the case copper, because of its high heat conductivity, is preferably used. When the operation to be carried on makes it desirable, the metal walls of member 26 may be lined with a refractory lining 27, as shown in Figs. 2 and 3. In Fig. 2 lining 27 covers the whole surface of the metal walls whereas in Fig. 3 the metal walls are left exposed at substantially above the molten metal level; the purpose for this will be explained hereinafter.

The bottom of member 26 is reduced in diameter to provide a conical portion which has at its apex a cylindrical extension into which fits a rod or bar 28. The cylindrical extension may be open at its bottom, as shown in Fig. 1, so that rod 28 extends outwardly from member 26 or the bottom of the cylindrical extension may be closed, as shown in Figs. 2 and 3, with rod 28 entirely within member 26. Rod 28 is preferably of the same analysis as the desired metal. Rod 28 fits snugly in the cylindrical extension of member 26 so that electric current can flow from one to the other without undue heating. To assure good electrical flow it has been found preferable to weld, or braze, rod 28 to the walls of the cylindrical extension as at areas 29. The cylindrical extension of member 26 is surrounded by a hollow ring member 30 into which water or other cooling medium may be passed, as through a valve controlled line. The inner wall of member 30 is perforated to allow the water, or other cooling medium, to jet against the cylindrical extension of member 26. In Fig. 1 the extending end of rod 28 is encircled by a suitable clamp 31 to which is connected a cable 32. In Figs. 2 and 3, cable 32 is connected to the bottom of the cylindrical extension of member 26. Cable 32 may be directly connected to the other side of the electric current supply or, as shown, cable 32 may be connected to a ground and the other side of the electric current supply likewise grounded.

The cylindrical body-portion of member 26 is surrounded by a plurality of coils 33 which are supplied, as through a valve controlled line, with water or other heat exchange medium. Coils 33 are perforated to allow the water, or other heat exchange medium, to jet against the body portion of member 26. Coils 33 may be connected or they may be individual coils whose supply of water or other heat exchange medium may be individually controlled. While the jetting of water on the outside walls of member 26 is at present preferred, the coils 33 and ring 30 may be eliminated and a jacket through which the cooling medium is circulated used in their stead. Cooling coils 33 and ring 30, or their equivalents, are provided as an aid in controlling the temperatures within the fusion zone. These cooling means also serve to prevent the destruction of member 26 when as in Fig. 1 it is not provided with a refractory lining. When member 26 is lined, and the lining is of a sufficient thickness, coils 33 may be omitted and an outside insulation lining provided. In the latter case the temperature control is effected by controlling the heat input and the quantity of materials fused.

An inclined spout 34 projects from the body portion of member 26. The spout is preferably lined with a refractory member 35. Rapid wear of lining 35 is prevented by cooling at least a portion of the region at the juncture of member 26 and spout 34. The molten metal stream 37 flows out of spout 34 into a mold 36 or other container. An overflow lip 38 is formed at the top of member 26. The bottom of lip 38 and the highest point of lining 35 over which molten metal flows are so positioned that in operation the molten metal level will be above the opening in member 35 in communication with the fusion zone and the distance between the molten metal level and the bottom of lip 38 will be equal to the maximum depth desired for flux blanket 39. Thus, in operations wherein additions to the flux are made at a constant rate as well as in operations wherein materials not ultimately found in the molten metal are passed at constant rates to the fusion zone, the excess flux will overflow lip 38 and the height of the flux blanket 39 will remain constant.

Flux blanket 39 may be of any composition suitable to produce the results desired in the particular operation. Generally, the finishing slag used in the present batch processes for a particular alloy is suitable as material for blanket 39 if the alloy is produced from materials comparatively free from impurities. If the materials contain impurities which must be removed the finishing slag is modified as required. It has been found that some slags, or fluxes, have a pronounced solvent action on refractory lining 27. To prevent rapid deterioration of lining 27, as well as to prevent unwanted modification of flux blanket 39 when highly solvent fluxes are used, refractory lining 27 is extended only to about the liquid metal level, as shown in Fig. 3. With this arrangement the flux blanket 39 cannot penetrate into lining 27 below the level of the liquid metal. A depth of flux 41 may also be provided in mold 36 to serve as a protective blanket for a metal poured therein.

Member 26 may be supported in various ways as for instance by trunnions 40 so that it can be tilted to empty it at the end of the operation.

In carrying out any particular operation, and after the raw materials to be used are selected, the rates of feed of the raw materials metered through the metering devices and the rate of feed of hollow electrode 18 are determined. For instance, if it is desired to produce an 18% chromium, 8% nickel alloy steel containing 1% manganese and a maximum of 0.04% carbon it will be necessary, if there are no losses in the operation, to supply per unit of time 18 weight units of chromium, 8 weight units of nickel, 1 weight unit of manganese and 73 weight units of iron. Commercial ferro-chrome containing 70% chromium and having a carbon content of 0.06% is a comparatively cheap material and is used as the raw material to supply the necessary chromium; 25.75 weight units of the ferro-chrome will supply the required 18 units of chromium, 7.75 weight units of iron and 0.0156 weight unit of carbon. Commercial ferro-manganese containing 80% manganese and 0.10% carbon is a satisfactory raw material for the required manganese. 1.25 weight units of this material will supply the required 1 weight unit of manganese and in addition, 0.25 weight unit of iron and 0.0014 weight unit of carbon. The nickel may be supplied by using commercial nickel shot containing 0.10% carbon. A low carbon iron such as the readily available Armco iron in strip form and containing 0.02% carbon, maximum, may be used as a source of iron. 65 weight units of Armco iron strip will supply the remainder of the iron and 0.0130 carbon. Knowing the metal producing capacity of the apparatus and the quantity of molten alloy required per unit time it is a simple matter to determine the settings of the metering devices and the electrode feed.

To initiate the operation electrode 18 is fed until it approaches the top of rod 28 when an arc starter, such as a wad of steel wool, is interposed between rod 28 and the electrode. A quantity of the flux, or the ingredients required to produce the flux, is passed to the bottom of member 26. After the proper settings have been made, the flow of water through coils 33 and ring 30 commenced, and the metering devices set in operation, the electric circuit of electrode 18 is closed. The initial surge of current destroys the arc starter and establishes an arc between the end of electrode 18 and rod 28. The heat generated by the arc fuses the metal at the end of electrode 18, the raw materials supplied in granular form through electrode 18, the flux, or flux constituents, and metal at the end of rod 28. The molten metals rapidly intermingle to form a molten metal pool which rises in the fusion zone and ultimately flows out through nozzle 34 as stream 37 into mold 36, or other place of use. The flux rises on the molten metal and when it is all fused forms a protective molten blanket which submerges the arc and protects the metal, as well as the arc, from the atmosphere. The molten flux readily absorbs impurities that float up through the molten metal and rapidly refines the molten metal. When the metal flows out of nozzle 34 it will have reached its highest level. The flux blanket 39, if originally deeper than desired, will overflow lip 38 to obtain the predetermined depth when the molten metal reaches its highest level. On the other hand, if an insufficient quantity of flux was initially placed within member 26 the flux blanket 39 will not reach the level of lip 38 and flux will be added until the desired level is obtained. In the specific operation above described the raw materials contain such small quantities of impurities that the flux changed very little in depth or character even when the operation was of long duration. In operations wherein flux changes occur additions may be made to the flux at a constant rate through electrode 18 as the above pointed out or the flux may be periodically modified by additions as its character begins to change. The additions will not change the depth of the flux blanket as any excess will overflow lip 38.

The temperature of the fusion zone is of importance and is controlled by proper selection and control of the characteristics of the electric current discharge and the rate at which heat is removed, and the rates at which the raw materials are supplied to the arc. By selection and control of the temperature conditions in the fusion zone alloys of high quality and of uniform analysis and character may easily be produced. The voltage of the electric current discharge is, within limits, of importance and, in general, the temperature of the operation, as indicated at the molten flux surface increases substantially directly with the voltage. There are variations in quality and properties of an alloy of a given analysis when produced at different temperatures. In general, there is an optimum temperature, or temperature range, for the production of each analysis. The optimum temperature, or temperature range, can in each case be determined by trial and can be duplicated at will by duplicating the adjustments. With a copper mold cooled as shown in the drawings good results, when ease of operation and quality of metal were balanced, were obtained with a voltage of about 40 volts in making the 18–8 alloy above described. Under these conditions the flux surface temperature was maintained at about 3600° F., the temperature of the metal was higher. At these temperature levels the molten metal intermixes extremely rapidly, also, any refining or smelting reactions take place at extremely rapid rates with the result that the metal produced is of uniformly high quality and of uniform analysis.

When the raw materials are all metallic and comparatively free from impurities the yield very closely approximates 100% if a proper flux is used. In the production of the 18–8 alloy above described, the yield was for all practical purposes 100% and the analysis of the metal produced was substantially identical with the analysis chosen for calculating the rates of feed of the raw materials to be used.

Comparable results have also been obtained in the production of ferro-alloys from raw materials some of which were non-metallic. Thus, in the production of a chromium-tungsten alloy tool steel containing from 3.50–4.0% tungsten, 0.40–0.60% chromium, 0.10–0.35% silicon, 0.20–0.40% manganese and 0.95–1.10% carbon with remainder iron and impurities, the required tungsten and the bulk of the manganese were supplied by using a non-metallic tungsten ore known as wolframite. The ore used contained 54.44% tungsten and 4.19% manganese with the remainder iron and impurities. The tungsten and manganese were considered to be present as oxides of these metals. Carbon in the form of graphite was employed to convert the tungsten and manganese oxides to metal in the reaction zone. The required silicon was supplied by a commercial ferro-silicon which contained 48.50% silicon, 0.50% carbon and remainder iron and impurities. The required chromium was supplied by a commercial ferro-chrome containing 70.0% chromium, 0.40% silicon, 0.40% manganese, 0.06% carbon with remainder iron and impurities. Graphite was used to complete the carbon required. The remainder of the iron required was supplied by forming the hollow electrode out of Armco iron containing in addition to iron 0.02% carbon, 0.04% manganese and 0.02% silicon.

It was found by calculation that with these raw materials an alloy within the allowable analysis range could be produced containing 3.75% tungsten, 0.50% chromium, 0.225% silicon, 0.30% manganese and 1.025% carbon. It was calculated that to produce this alloy the feed of the hollow electrode and the metering devices must be adjusted to supply the raw materials in the following proportions; graphite 1.00, ferro-silicon 0.421, ferro-chrome 0.714, tungsten ore 6.88 and the Armco iron hollow electrode 90.96, these figures indicate the weight units of each raw material that must be supplied per unit of time. The alloy produced contained 3.74% tungsten, 0.50% chromium, 0.225% silicon, 0.327% manganese and 1.024% carbon with remainer iron and impurities. These results indicate a duplication of the analysis aimed at within limits of allowable error and a complete conversion and recovery of the tungsten and manganese oxides.

I claim:

1. In the method of producing a continuous supply of molten metal of desired analysis, the steps comprising providing a fusion zone, depositing a depth of flux in said fusion zone, supplying an elongated hollow metal member made up of one or more of the constituents of the desired metal into said fusion zone at a substantially constant rate to submerge the end of said hollow member beneath the surface of said depth of flux, supplying further constituents of the desired metal at substantially constant rates into said fusion zone and beneath the surface of the flux therein through said hollow member, the rates of feed of said hollow member and said further constituents being adjusted to constantly supply the constituents as required by the desired analysis, discharging electric current from the end of said hollow member through a gap beneath the surface of said depth of flux to fuse, intermingle and superheat all of said constituents at the rates supplied and to superheat said depth of flux, accumulating a depth of molten metal in said fusion zone and then removing the molten metal at the rate produced to maintain said depth of molten metal substantially constant.

2. In the method of producing a continuous supply of molten metal of desired analysis, the steps comprising providing a fusion zone, depositing a depth of flux in said fusion zone, supplying an elongated hollow metal member made up of one or more constituents of the desired metal into said fusion zone at a substantially constant rate to submerge the end of said hollow member beneath the surface of said depth of flux, supplying raw materials containing the remainder of the constituents of the desired metal at substantially constant rates into said fusion zone beneath the surface of the flux therein through said hollow member, supplying flux material to said flux depth at a substantially constant rate, the rates of feed of said hollow member and said raw materials being adjusted to constantly supply the constituents as required by the desired analysis, discharging electric current from the end of said hollow member through a gap beneath the surface of said depth of flux to fuse, intermingle and superheat all of said constituents at the rates supplied and to superheat said flux depth and flux material, accumulating a depth of molten metal in said fusion zone and then removing the molten metal at the rate produced to maintain said depth of molten metal substantially constant, accumulating a desired depth of superheated flux above said depth of molten metal then removing flux to maintain the depth of flux substantially constant.

3. In the method of producing a continuous supply of molten metal of desired analysis, the steps comprising providing a fusion zone, depositing a depth of flux in said fusion zone, supplying an elongated hollow metal member made up of one or more of the constituents of the desired metal into said fusion zone at a substantially constant rate to submerge the end of said hollow member beneath the surface of said depth of flux, supplying raw materials containing the remainder of the constituents of the desired metal at substantially constant rates into said fusion zone beneath the surface of the flux therein through said hollow member, at least one of said raw materials being a non-metallic substance, supplying through said hollow electrode with said raw materials and at a constant rate a material capable of converting the constituent supplied by said non-metallic substance into metal, the rates of feed of said hollow member and said raw materials being adjusted to constantly supply the constituents as required by the desired analysis, discharging electric current through a gap beneath the surface of said depth of flux to convert the constituent supplied by said non-metallic substance into metal, to fuse, intermingle and superheat all of said constituents at the rates supplied and to superheat said depth of flux, accumulating a depth of molten metal in said fusion zone and then removing the molten metal at the rate produced.

4. In apparatus for producing molten metal, a metal crucible member containing within it a fusion zone wherein molten metal is produced by heat supplied through the discharge of electric current, said metal crucible member having a recess in its walls in the region of its bottom, a metal member in said recess extending into said fusion zone, said metal member being united by weld metal to the portion of the walls of said metal crucible member defining said recess, and means connecting said metal member and the walls of said crucible member defining said recess to one side of the electric current supply.

5. In apparatus for producing molten metal, a metal crucible member containing within it a fusion zone wherein molten metal is produced by heat supplied through the discharge of electric current, said metal crucible member having a hole through its walls in the region of its bottom, a metal member in said hole extending into said fusion zone, said metal member projecting outwardly of said metal crucible member, said metal member being united by weld metal to the portions of the walls of said metal crucible member defining said hole, means connecting the outwardly extending portion of said metal member to one side of the electric current supply, means for conducting a cooling medium to the region of said metal crucible member through which said metal member extends to remove heat from said metal member and said metal crucible member, and spout means opening into said fusion zone adapted to provide a passageway for molten metal from said fusion zone to a point of use, said spout means being arranged to prevent the level of molten metal in said fusion zone from rising above a predetermined point.

6. In apparatus for producing molten metal, a metal crucible member containing within it a fusion zone wherein molten metal is produced beneath a depth of molten flux by heat supplied through the discharge of electric current, said metal crucible member having a recess in its walls in the region of its bottom, a metal member in said recess extending into said fusion zone, means connecting said metal member and the walls of said crucible member defining said recess to one side of the electric current supply, means for controllably cooling portions of said metal crucible member, and spout means opening into said fusion zone adapted to provide a passageway for molten metal from said fusion zone to a point of use, said spout means being arranged to prevent the level of molten metal in said fusion zone from rising above a predetermined point in said fusion zone, said spout means opening into said

fusion zone below said predetermined point, the wall of said metal crucible member being internally lined with refractory material substantially to said predetermined point whereby contact between the molten flux above and the molten metal and the refractory lining of said metal crucible member is reduced to a minimum.

7. In apparatus for producing molten metal, a metal crucible member containing within it a fusion zone wherein molten metal is produced by heat supplied through the discharge of electric current, said metal crucible member having a recess in its walls in the region of its bottom, a metal member in said recess extending into said fusion zone, means connecting said metal member and the walls of said crucible member defining said recess to one side of the electric current supply, spout means opening into said fusion zone adapted to provide a passageway for molten metal from said fusion zone to a point of use, said spout means being lined with refractory material, and means for controllably cooling portions of said metal crucible member, said cooling means being arranged to cool the portion of said metal crucible member from which said spout means projects.

8. In apparatus for the continuous production of molten metal, a metal crucible member containing within it a fusion zone for the production therein of the desired molten metal under a depth of molten flux, metal electrode means extending into said fusion zone through the bottom portion of said metal crucible member, means connecting said metal electrode means to one side of a source of electric current, a hollow metal electrode formed of one, or more, constituents of the desired molten metal, means connecting said hollow metal electrode to the other side of said source of electric current, means for feeding said hollow electrode into said fusion zone to fuse said electrode at a substantially constant rate beneath the surface of the depth of flux, means for feeding a plurality of materials containing the remainder of the constituents of the desired molten metal at substantially constant and independently controlled rates into said hollow electrode to be subjected to the heat of the electric discharge beneath the surface of said depth of flux, controllable means for removing heat from said fusion zone, means for utilizing the molten metal, and means for continuously flowing molten metal from said fusion zone to said molten metal utilizing means, said molten metal flowing means being arranged to maintain a predetermined level of molten metal in said fusion zone.

9. In the method of producing a continuous supply of molten metal of desired analysis, the steps comprising providing a fusion zone, depositing a depth of flux in said fusion zone, introducing a hollow electrode arrangement into said fusion zone to submerge the end of said electrode arrangement beneath the surface of said depth of flux, supplying constituents of the desired metal into said fusion zone and beneath the surface of the flux therein through said hollow electrode arrangement, the rates of feed of said constituents being adjusted to constantly supply them as required by the desired analysis, discharging electric current from the end of said hollow electrode arrangement through a gap beneath the surface of said depth of flux to fuse, intermingle and superheat all of said constituents at the rates supplied and to superheat said depth of flux, accumulating a depth of molten metal in said fusion zone and then removing the molten metal at the rate produced to maintain said depth of molten metal substantially constant.

10. In the method of producing a continuous supply of molten metal of desired analysis, the steps comprising providing a fusion zone, depositing a depth of flux in said fusion zone, introducing a hollow electrode arrangement into said fusion zone to submerge the end thereof beneath the surface of said depth of flux, supplying raw materials containing constituents of the desired metal at substantially constant rates into said fusion zone beneath the surface of the flux therein, at least one of said raw materials being a non-metallic substance, supplying with said raw materials and at a constant rate a material capable of converting the constituent supplied by said non-metallic substance into metal, the rates of feed of said raw materials being adjusted to constantly supply said constituents as required by the desired analysis, discharging electric current from the end of said hollow electrode arrangement through a gap beneath the surface of said depth of flux to convert the constituent supplied by said non-metallic substance into metal, to fuse, intermingle and superheat all of said constituents at the rates supplied and to superheat said depth of flux, accumulating a depth of molten metal in said fusion zone and then removing the molten metal at the rate produced.

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