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(54) Title: METHODS AND APPARATUSES FOR ALUMINUM AND ZINC RECOVERY FROM DROSS AND METAL-RICH RESIDUES USING INDUCTION MELTING

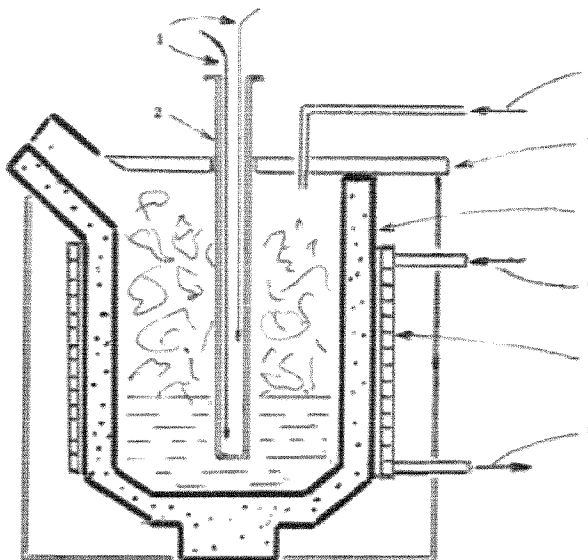


FIG. 1

(57) **Abrégé/Abstract:**

Methods and apparatuses for treating aluminum dross, zinc dross, or metal-rich residues. These methods comprise heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal

(57) **Abrégé(suite)/Abstract(continued):**

contained within the aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of the at least one metal for causing melting and agglomeration of the at least one metal at a bottom portion of the furnace; and removing the molten at least one metal from the furnace so as to separate the molten at least one metal from the aluminum dross, zinc dross or metal rich residues.

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(54) Title: METHODS AND APPARATUSES FOR ALUMINUM AND ZINC RECOVERY FROM DROSS AND METAL-RICH RESIDUES USING INDUCTION MELTING

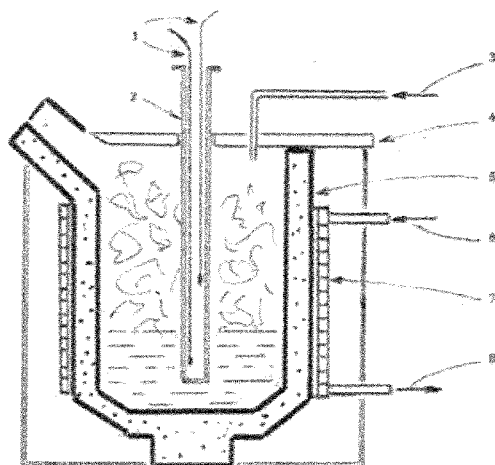


FIG. 1

(57) Abstract: Methods and apparatuses for treating aluminum dross, zinc dross, or metal-rich residues. These methods comprise heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal contained within the aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of the at least one metal for causing melting and agglomeration of the at least one metal at a bottom portion of the furnace; and removing the molten at least one metal from the furnace so as to separate the molten at least one metal from the aluminum dross, zinc dross or metal rich residues.



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METHODS AND APPARATUSES FOR ALUMINUM AND ZINC RECOVERY FROM DROSS AND METAL-RICH RESIDUES USING INDUCTION MELTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to US application No. 62/630,499 filed on February 14, 2018. This document is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to the field of treating aluminum dross, zinc dross and various metal-rich residues. More particularly, it relates to methods and apparatuses for recovering various metals from dross residues. For example, such methods can comprise recovering non-ferrous metals from dross such as aluminum, zinc etc. For example, such methods can be carried out in an induction furnace. For example, such methods can be carried without the use of salts i.e. salt-free methods.

BACKGROUND OF THE DISCLOSURE

[0003] In a typical aluminum or zinc production plant a lot metal-rich-plant residues are generated such as, metal dross, autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim and pot bottom

[0004] In the case of aluminum dross, which generally comprises metal oxides and a considerable quantity of free (unreacted) metal, for economic reasons it has been found desirable to extract the free metal before discarding the residues.

[0005] For this purpose, several furnaces have been devised and some are presently being used; such furnaces are normally heated with an external heat source, such as fuel- or gas-operated burners, plasma torches, or electric arcs.

[0006] Fuel or gas can be used for heating the dross in a dross treating furnace, in order to recover the aluminum contained therein. However, these processes have the major drawback of requiring the addition of salt fluxes such as NaCl or KCl, used to increase the percentage of aluminum recovery. In addition to the

fact that such salt fluxes increase the cost of the operation, they also lead to increased pollution.

[0007] Some proposals and small scale tests were made regarding the use of furnaces for treating hot dross but these technologies were not efficient for treating cold dross without the addition of an auxilliary heat source such as fuel- or gas-operated burners , plasma torches, or electric arcs.

[0008] Processes that comprise extraction of the liquid metal from dross by mechanical compression of the hot dross removed directly from a furnace have been proposed. Such processes were found to be only used with hot dross right away after its skimming from the liquid metal holding furnace. Moreover, metal recovery was very poor.

[0009] Other techniques involving an electric arc were proposed but comprised several drawbacks such as the controlled feeding of the graphite electrodes that required to maintain the arc, Such a technology has thus been found difficult to implement at an industrial level due to its mechanical complexity in a high electrical voltage environnement.

SUMMARY OF THE DISCLOSURE

[0010] It would thus be highly desirable to be provided with a device, system or method that would at least partially address the disadvantages of the existing technologies.

[0011] According to one aspect, there is provided a method for treating aluminum dross, zinc dross, or metal-rich residues the method comprising:

heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal contained within the aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of the at least one metal for causing melting and agglomeration of the at least one metal at a bottom portion of the furnace; and

removing the molten at least one metal from the furnace so as to separate the molten at least one metal from the aluminum dross, zinc dross or metal rich residues.

[0012] According to another aspect, there is provided a method for treating aluminum dross, zinc dross or metal-rich residues, the method comprising:

heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal contained within the aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of the at least one metal for causing melting, separation of a waste and the molten at least one metal, and agglomeration of the at least one metal at a bottom portion of the furnace;

removing from a furnace crucible the molten at least one metal;

transferring the recovered molten at least one metal to a holding furnace for pouring in the melt;

removing the waste remaining in the crucible; and

scraping the wall of the crucible.

[0013] According to another aspect, there is provided a method for treating aluminum dross, zinc dross or metal-rich residues, the method comprising:

heating in an induction furnace a molten metal heel to induce electrical current in the molten heel metal to keep the metal molten and contacting the molten metal heel with aluminum dross, zinc dross or metal-rich residues in order to heat the aluminum dross, zinc dross or metal-rich residues charged into a furnace crucible by conduction of heat from the molten metal heel surface, for causing melting, separation of a waste and the molten at least one metal, and agglomeration of the at least one metal at a bottom portion of the furnace;

removing the molten at least one metal from the furnace so as to separate the molten at least one metal from the waste, while maintaining the molten metal heel in the crucible at a predetermined level.

[0014] According to another aspect, there is provided an apparatus for treating aluminum dross, zinc dross or metal-rich residues, the apparatus comprising:

an induction furnace suitable for treating aluminum dross, zinc dross or metal-rich residues by heating the aluminum dross, zinc dross or metal-rich residues via an eddy electrical current induced, at a temperature above a melting point of at least one metal to be recovered therefrom, the furnace having an opening for passing material therethrough for charging and discharging a furnace crucible and a cover for closing the opening;

an injector for injecting an inert gas into the furnace; and

a temperature controlling device for monitoring and controlling temperature in the furnace.

BRIEF DESCRIPTION OF DRAWINGS

[0015] The following drawings represent non-limitative examples in which:

[0016] The following examples are presented in a non-limiting manner.

[0017] FIG. 1 is a side elevation view of a single coil induction furnace in accordance with the present disclosure;

[0018] FIG. 2 is a side elevation view of a double coil induction furnace in accordance with the present disclosure;

[0019] FIG. 3 is a side elevation view of a single-coil-continuous-tapping induction furnace in accordance with the present disclosure; and

[0020] FIG. 4 is a side elevation view of the furnace without the plunger used to illustrate the formation of a bridge well above the surface of the melt.

DESCRIPTION OF VARIOUS EMBODIMENTS

[0021] The following examples are presented in a non-limitative manner.

[0022] The word "a" or "an" when used in conjunction with the term "comprising" in the claims and/or the specification may mean "one", but it is also consistent with the meaning of "one or more", "at least one", and "one or more than one" unless the content clearly dictates otherwise. Similarly, the word "another" may mean at least a second or more unless the content clearly dictates otherwise.

[0023] In understanding the scope of the present disclosure, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including", "having" and their derivatives. The term "consisting" and its derivatives, as used herein, are intended to be closed terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The term "consisting essentially of", as used herein, is intended to specify the presence of the stated features, elements, components, groups, integers, and/or steps as well as those that do not materially affect the basic and novel characteristic(s) of features, elements, components, groups, integers, and/or steps.

[0024] Terms of degree such as "about" and "approximately" as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed. These terms of degree should be construed as including a deviation of at least $\pm 5\%$ or at least $\pm 10\%$ of the modified term if this deviation would not negate the meaning of the word it modifies.

[0025] For example, the heating can be carried out under an inert gas atmosphere.

[0026] For example, the inert gas is Ar or N₂.

- [0027] For example, the inert gas is injected at a controlled rate.
- [0028] For example, the molten at least one metal is removed from the furnace by means of a tap hole at a bottom portion of a furnace crucible.
- [0029] For example, the molten at least one metal is removed from the furnace by tilting the furnace and emptying the molten at least one metal by a furnace crucible spout.
- [0030] For example, the molten at least one metal is removed from the furnace by tilting the furnace and emptying the molten at least one metal by a furnace crucible spout while preventing, the flow of a solid waste floating at the surface of the melt.
- [0031] For example, the molten at least one metal is removed from the furnace by tilting the furnace and emptying the molten at least one metal by a furnace crucible spout while preventing, with a grid, the flow, with the molten at least one metal, of a solid waste floating at the surface of the melt.
- [0032] For example, the at least one metal is aluminum or zinc.
- [0033] For example, heating is stopped upon reaching the required temperature of the aluminum dross, zinc dross or metal-rich residues by induction of eddy current into the aluminum dross, zinc dross or metal-rich residues charged into the furnace crucible.
- [0034] For example, the at least one metal is aluminum or zinc.
- [0035] For example, the predetermined level of molten heel is a same level than before introducing the charge into the furnace.
- [0036] For example, the heating is stopped upon achieving the required temperature of the material by transfer of heat from the molten metal heel.
- [0037] For example, the method further comprises monitoring and controlling the temperature at different levels in the crucible to avoid overheating of the liquid at least one metal.
- [0038] For example, the eddy current is generated by electromagnetic induction produced by at least one coil surrounding the crucible.

- [0039] For example, the method comprises heating aluminum dross.
- [0040] For example, the method comprises heating metal rich residues from an aluminum plant
- [0041] For example, the waste comprises aluminum oxide.
- [0042] For example, the waste comprises at least 95, 96, 97, 98, 99 or 99.5 % of aluminum oxide.
- [0043] For example, the waste is recycled for use in an electrolytic cell.
- [0044] For example, the waste is recycled for use as a cover in an electrolytic cell.
- [0045] For example, the method comprises heating zinc dross.
- [0046] For example, the method comprises heating metal residues from a zinc plant.
- [0047] For example, the waste comprises zinc oxide.
- [0048] For example, the waste comprises at least 95, 96, 97, 98, 99 or 99.5 % of zinc oxide.
- [0049] For example, the waste is recycled for use in a zinc leaching step.
- [0050] For example, the method comprises heating metal-rich residues.
- [0051] For example, the metal-rich-plant residues are chosen from residues generated in operating aluminum and zinc plants, metal dross, autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim, pot bottom and mixtures thereof.
- [0052] For example, the crucible is dimensioned to operate with a molten metal heel of about 65 % to about 85 % of a capacity of the crucible.
- [0053] For example, the crucible is a non-conducting crucible.
- [0054] For example, the method further comprises monitoring and/or controlling the temperature at different levels in the crucible.

[0055] For example, the temperature monitoring and/or controlling is carried out by means of a temperature controlling device that is effective for monitoring and/or controlling temperature of a charge inside the crucible.

[0056] For example, the temperature controlling device comprises a plunger for inserting into the crucible, the plunger defining a hollow chamber for receiving at least one thermocouple for monitoring and/or controlling the temperature .

[0057] For example, the temperature controlling device comprises a plunger for inserting into the crucible and contacting the charge, the plunger defining a hollow chamber for receiving at least two thermocouples for monitoring and/or controlling the temperature at different levels inside the crucible.

[0058] For example, the plunger is a steel plunger.

[0059] For example, the surface of the plunger is covered with a protective coating for protecting the plunger against molten aluminum.

[0060] For example, the protective coating comprises WC-Co.

[0061] For example, the method further comprises moving the plunger is movable upwardly, downwardly and/or laterally for stirring the charge.

[0062] For example, the method further comprises moving the plunger is movable upwardly, downwardly and/or laterally for stirring the charge, thereby breaking accumulation of solids on top on molten metal.

[0063] For example, the method further comprises further moving the plunger is movable upwardly, downwardly and/or laterally for stirring the charge, thereby breaking accumulation of solids bridging portion(s) of an internal wall of the crucible.

[0064] For example, the eddy current is generated by electromagnetic induction produced by at least one coil surrounding the crucible.

[0065] For example, the eddy current is generated by electromagnetic induction produced by at least two coils surrounding the crucible.

[0066] For example, the eddy current is generated by electromagnetic induction produced by a double coil surrounding the crucible.

[0067] For example, the furnace crucible comprises a tap hole for tapping at least one recovered molten metal.

[0068] For example, the furnace comprises a device for tilting the furnace.

[0069] For example, the apparatus further comprises a controller for controlling inert gas injection.

[0070] For example, the apparatus further comprises means for conveying the molten at least one metal into a holding furnace.

[0071] For example, the apparatus further comprises means for pouring recovered molten metal into the holding furnace.

[0072] For example, the apparatus further comprises a conveyor to charge the material in the furnace.

[0073] For example, the apparatus further comprises a vibratory conveyor suitable for charging in a heel melting operation.

[0074] For example, the apparatus further comprises a suitable container that is an insulating refractory lined ladle for transporting the recovered molten metal and for pouring the molten metal into a plant molten metal holding furnace.

[0075] For example, the temperature controlling device is effective for monitoring and controlling temperature of a charge inside the crucible.

[0076] For example, the temperature controlling device comprises a plunger for inserting into the crucible, the plunger defining a hollow chamber for receiving at least one thermocouple for monitoring the temperature .

[0077] For example, the temperature controlling device comprises a plunger for inserting into the crucible and contacting the charge, the plunger defining a hollow chamber for receiving at least two thermocouples for monitoring the temperature at different levels inside the crucible.

[0078] For example, the plunger is a steel plunger.

[0079] For example, the surface of the plunger is covered with a protective coating for protecting the plunger against molten aluminum.

[0080] For example, the protective coating comprises WC-Co.

[0081] For example, the plunger is movable upwardly, downwardly and laterally for stirring the charge.

[0082] For example, the metal-rich-plant residues are chosen from residues generated in operating aluminum and zinc plants, metal dross, autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim, pot bottom and mixtures thereof.

[0083] For example, the dross can be obtained from skimming of a metal holding furnace.

[0084] For example, the crucible can be a non-conductive crucible.

[0085] For example, a nonconductive crucible holding the charge of material to be heated, can be surrounded by a coil (for example of copper wire). An alternating current can flow through the coil. For example, the coil can create a rapidly reversing magnetic field that penetrates the metal present in the material. The magnetic field can induce eddy currents such as circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating. For example, once melted, the eddy currents can cause vigorous stirring of the melt, thereby assuring appropriate mixing.

[0086] For example, once melted, the eddy currents can cause vigorous stirring of the melt, assuring good mixing.

[0087] For example, the magnetic field can induce eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, can be flowing through the electrical resistance of the bulk metal, heat it by Joule heating. The current in the at least one coil can be fed and controlled independently in order to heat independently some section of the crucible in order, for example, not to overheat the bottom of the crucible when full with molten metal.

[0088] For example, it is possible to select a low frequency power supply to get more important stirring at the metal line, and at the same time the lower frequency, giving larger wave length, provided more penetration of the electromagnetic field into the charge, which will pass straight through the entrapped metal at the dross line and not superheat the entrapped metal.

[0089] For example, the methods can comprise

charging a batch of dross , resulting from skimming of a metal holding furnace in an aluminum plant, or of aluminum-rich-plant-residue into the nonconductive crucible of an induction furnace (for example to insure that the charge is thereby heated above the melting point of the metal to be recovered by electromagnetic induction of electrical eddy currents in the partially metallic charge). For example, the eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating.

providing an inert atmosphere in the furnace by filling the furnace with inert gas, such as Ar or N₂, for example to prevent oxidation of the metal during the process.

energising an electrical current in the induction coils surrounding the nonconductive crucible of the furnace (for example in order to induce a heating electrical eddy current in the charge to bring it to a temperature above the melting point of the recoverable metal), its separation from the waste also contained in the dross or residue and its agglomeration at the bottom of the furnace. For example, once melted, the eddy currents cause vigorous stirring of the melt, assuring good mixing.

removing from the furnace crucible the recoverable free metal (for example by tilting the crucible or by means of a tap hole at a bottom portion of a furnace crucible. The remaining waste can also be removed by tilting the crucible and by scraping the crucible walls if required.

charging into the furnace a new batch of material for recycling and repeating the process.

[0090] For example, the apparatus for recovering metal, such as aluminum or zinc, contained in a dross or a plant aluminum or zinc residues, comprising:

an induction furnace adapted for high temperature treatment of drosses and metal-rich-plant-residues, for example, the furnace comprises a nonconductive crucible holding the charge of material to be heated, surrounded by a coil (for example of copper wire). An alternating current flows through the wire. The coil creates a rapidly reversing magnetic field that penetrates the metal present in the material. The magnetic field induces eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating. The furnace can have an opening through which the material to be treated may be charged into the crucible and the recovered molten metal and the waste can be discharged from the crucible, as well as a cover for closing the opening during treatment of the charge.

optionally means for tilting the the furnace and lifting the furnace cover;

optionally means for injecting an inert gas into the furnace;

optionally means for monitoring the temperature of the charge inside the crucible. For this purpose, a plunger (for example made of steel) can be provided which is inserted through the furnace cover, for example axially and all the way down into the crucible; the plunger can be hollow in order to contain several thermocouples devices to be used for monitoring the temperature at different levels, inside the crucible; the external surface of the plunger can be covered with a protective coating (for example WC-Co), against the molten aluminum attacks. The steel plunger can also be equipped with means to move it slightly up and down and sideways in order to slightly stir the charge and break the possible formation of a solid cap or "bridge", above the melt;

optionally means for returning the recovered metal in the molten state to the holding furnace;

optionally means for pouring the recovered molten metal into the holding furnace;

optionally means for supplying the electrical current to the coil surrounding the crucible which, by electromagnetic induction, will generate the electrical eddy currents required for the Joule heating of the metallic charge contained in the crucible;

optionally means to water cool the coil surrounding the crucible; and

optionally means for the control of the operation and the recording and time display of the measured data such as the electrical power, furnace current, furnace frequency, capacitor voltage, ground leakage and charge temperature.

[0091] For example, the apparatus for recovering metal, such as aluminum or zinc, contained in a dross or a plant aluminum or zinc residues or metal-rich residues, can comprise:

an induction furnace adapted for high temperature treatment of drosses and metal-rich-plant-residues, the furnace comprises of a nonconductive crucible holding the charge of material to be heated, surrounded by at least one or at least two independent coils (for example of copper wire). An alternating current flows through the coil wires. For example, the coils can create a rapidly reversing magnetic field that penetrates the metal present in the material. The magnetic field can induce eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, can be flowing through the electrical resistance of the bulk metal, heat it by Joule heating; the current in each coil can be fed and controlled independently in order to heat independently some section of the crucible in order, for example, not to overheat the bottom of the crucible when full with molten metal. In addition, the furnace can have an opening through which the material to be treated may be charged into the crucible and the recovered molten metal and the waste can be discharged from the crucible, as well as a cover for closing the opening during treatment of the charge;

optionally means for tilting the the furnace and lifting the furnace cover;

optionally means for injecting an inert gas into the furnace;

optionally means for monitoring the temperature of the charge inside the crucible. For example, a plunger (for example made of steel) can be provided which can be for example inserted through the furnace cover, for example, axially and all the way down into the crucible; the plunger can be hollow in order to contain several thermocouples devices to be used for monitoring the temperature at different levels, inside the crucible; the external surface of the steel plunger can be covered with a protective coating (such as WC-Co) against the molten aluminum attacks. The steel plunger can also be equipped with means to move it slightly up and down and sideways in order to slightly stir the charge and break the possible formation of a solid cap or "bridge", above the melt.

optionally means for returning the recovered metal in the molten state to the holding furnace;

optionally means for pouring the recovered molten metal into the holding furnace;

optionally means for supplying the electrical current to each coil surrounding the crucible which, by electromagnetic induction, will generate the electrical eddy currents required for the Joule heating of the metallic charge contained in the required section of the crucible;

optionally means for supplying the amount of electrical current in each of the coils as required to obtain the temperature profile in the crucible required for the metal recovery treatment of the material charged into the crucible;

optionally means to stop the induction heating of the material to prevent overheating of the charge;

optionally means to water cool the coils surrounding the crucible; and

optionally means for the control of the operation and the recording and time display of the measured data such as the electrical power, furnace current, furnace frequency, capacitor voltage, ground leakage and charge temperature.

[0092] For example, the apparatus for recovering metal, such as aluminum or zinc, contained in a dross or a plant aluminum or zinc residues or metal-rich residues, can comprise:

an induction furnace adapted for high temperature treatment of drosses and plant aluminum residues, the furnace comprises of a nonconductive crucible holding the charge of material to be heated, surrounded by a coil (for example a copper wire). An alternating current can flow through the wire. The coil can create a rapidly reversing magnetic field that penetrates the metal present in the material . The magnetic field can induces eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, can be flowing through the electrical resistance of the bulk metal, heat it by Joule heating. For example, the furnace can have an opening through which the material to be treated may be charged into the crucible and the waste can be discharged from the crucible, as well as a cover for closing the opening during treatment of the charge. A tap hole can be provided at the bottom of the furnace crucible for tapping of the molten metal;

optionally means for tilting the furnace and lifting the furnace cover;

optionally means for injecting an inert gas into the furnace;

optionally means for monitoring the temperature of the charge inside the crucible. For example, a plunger (for example comprising steel) can be provided which is inserted through the furnace cover, for example axially and all the way down into the crucible; the steel plunger can be hollow in order to contain several thermocouples devices to be used for monitoring the temperature at different levels, inside the crucible; the surface of the steel plunger can be covered with a protective coating such as WC-Co, against the molten aluminum attacks. The steel plunger can also be equipped with means to move it slightly up and down and sideways in order to slightly stir the charge and break the possible formation of a solid cap or 'bridge', above the melt;

optionally means for returning the recovered metal in the molten state to the holding furnace;

optionally means for pouring the recovered molten metal into the holding furnace;

optionally means for supplying the electrical current to the coil surrounding the crucible which, by electromagnetic induction, can generate the electrical eddy currents required for the Joule heating of the metallic charge contained in the crucible;

optionally means to water cool the coil surrounding the crucible; and

optionally means for the control of the operation and the recording and display of the measured data such as the electrical power, furnace current, furnace frequency, capacitor voltage, ground leakage and charge temperature.

[0093] For example, the apparatus for recovering metal, such as aluminum or zinc, contained in a dross or a plant aluminum or zinc residues or metal-rich residues, can comprise:

an induction furnace adapted for high temperature treatment of drosses and plant aluminum residues, the furnace consists of a nonconductive crucible holding the charge of metal to be melted, surrounded by a coil (for example comprising copper wire). An alternating current can flow through the wire. The coil can create a rapidly reversing magnetic field that penetrates the metal contained in the crucible. The magnetic field can induce eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, can be flowing through the electrical resistance of the metal, heat it by Joule heating. The induction heating, in this case, can be provided to heat the pure metal, (for example which can fill the crucible at about 60 to about 85% or at about 70 to about 80% of its capacity), thus forming what is called a Molten Metal Heel. The material to be treated, can be placed on the surface of the molten metal heel, and can be heated by heat transfer from the molten metal heel and also by induction. The amount of heat provided by the molten metal heel can be greater than the heat provided by the induction. The furnace can have an opening through which the material to be treated may be

charged into the crucible and the waste can be discharged from the crucible, as well as a cover for closing the opening during treatment of the charge.

optionally means for tilting the the furnace and lifting the furnace cover;

optionally means for injecting an inert gas into the furnace;

optionally means for monitoring the temperature of the charge inside the crucible. For this purpose, a plunger (for example comprising steel) can be provided which is inserted through the furnace cover, for example axially and all the way down into the crucible; the steel plunger is hollow in order to contain several thermocouples devices to be used for monitoring the temperature at different levels, inside the crucible; the surface of the steel plunger can be covered with a protective coating (for example such as WC-Co), against the molten aluminum attacks. The plunger can also equipped with means to move it slightly up and down and sideways in order to slightly stir the charge and break the possible formation of a solid cap or "bridge", above the melt.

optionally means for returning the recovered metal in the molten state to the holding furnace; and

optionally means for pouring the recovered molten metal into the holding furnace.

optionally means for supplying the electrical current to the coil surrounding the crucible which, by electromagnetic induction, will generate the electrical eddy currents required for the Joule heating of the metallic charge contained in the crucible.

optionally means to water cool the coil surrounding the crucible.

optionally means for the control of the operation and the recording and display of the measured data such as the electrical power, furnace current, furnace frequency, capacitor voltage, ground leakage and charge temperature.

[0094] In Figs. 1-3, the numbers identify the following components:

(1) Thermocouples

- (2) Steel Plunger
- (3) Argon inert gas injection pipe
- (4) Furnace cover
- (5) Non-conductive crucible
- (6) Coil cooling water in pipe
- (7) Copper induction coil
- (8) Cooling water out pipe
- (9) Coil cooling water in pipe for second coil
- (10) Copper induction second coil
- (11) Coil cooling water out pipe for second coil
- (12) Crucible taphole and plug

[0095] FIG. 4 is a side elevation view of the furnace without the plunger used to illustrate the formation of a bridge well above the surface of the melt. As shown, a solid cap or bridge (a) is formed at the top of the furnace which prevents the fall of the charge on the molten metal and as the void (b), between the two, acts as an insulator the molten metal (c) will superheat and its temperature will rise rapidly therefore there is a need to monitor the temperature to stop the process if needed to avoid equipment damage.

[0096] For example, the processing of the dross can be carried out under inert atmosphere, such as Argon gas, in order to prevent oxidation of the recoverable metal;

[0097] For example, in order to avoid dross build up at the molten metal line and superheating of entrapped metal at the same level, it is possible to select a low frequency power supply to get more important stirring at the metal line, and at the same time the lower frequency, giving larger wave length, provided more penetration of the electromagnetic field into the charge, which will pass straight through the entrapped metal at the dross line and not superheat the entrapped metal.

[0098] As indicated, for example, by Tabatabaei and Turner, (<http://www.foundrymag.com/feature/molten-metal-splash-and-furnace-refractory-safety>) and as illustrated in FIG. 4:

“When charge material in the top portion of the furnace is not in contact with the molten metal below it, the dangerous condition known as bridging exists. When bridging occurs, charge material is no longer serving to moderate the temperature of the bath during the melting cycle. Also, the air gap between the molten metal and the bridge can act as an insulator. The molten metal below the bridge, under the impact of full melting power, will superheat.”

[0099] It is precisely to prevent bridging to occur that, in accordance with the present disclosure and as illustrated in FIG. 1, 2 and 3, it is proposed to use a plunger equipped with several thermocouples for a continuous monitoring of the temperature at different levels in the crucible, thus avoiding the superheating of the melt.

[00100] Melting in a large heel of molten metal has the advantage that the power supply see always approximately the same load and therefore the efficiency is maximized. The furnace as shown FIG. 1 could be operated in this manner.

[00101] In addition, by keeping a high metal line in the furnace after tapping, can allow the operator easier access to scrape the walls at the metal line, keeping dross from building up.

[00102] It is also possible to avoid superheating of the melt, by using a furnace with two induction coils, as shown FIG.2, or more induction coils in order to be able to adjust the induction heat delivered in different levels of the furnace as required to obtain uniform temperature.

[00103] The furnace illustrated in FIG. 3 can be operated for stack melting with continuous feeding and tapping. The temperature monitoring, made by the plunger, can be used to adjust the tapping flow, ensuring that the level of the melt remain the same in the furnace.

OPERATION PROCEDURE REVIEW

[00104] In industrial operation safety issues can require possible charging of hot dross and discharging of both the molten metal and the hot waste at high temperatures have to be addressed as well as issues of protection of the environment, non-discharge of greenhouse gas and great attention to energy savings. Furthermore, recovery of the metal can be achieved without any use of salt fluxes and with a significantly reduced off-gas generation requiring much smaller gas cleaning equipment. For example, the process for recovery of the valuable metal, contained in the dross and the plant residues described earlier, can comprise :

injecting an inert gas, such as Ar or N₂, to fill the crucible in order to avoid any oxydation of the metal contained in the charge;

charging the material to be treated using an appropriate conveyor (for example a vibratory conveyor especially in the case of heel melting operation where the amount of feed has to be monitored to avoid splashing). Heel melting can also require drying of the feed prior to charging;

inserting the plunger, if required, to continuously monitor the temperature at different level in the crucible;

energysing the induction coil in order to heat the charge using a Melting Control System which calculates the energy required to melt the charge as a function of the charge weight and of the estimated metal content in the charge and the heat content required to heat and melt it. . A slight flow, in the crucible, of inert gas, such as Argon, can be maintained during that operation in order to prevent oxidation of molten metal; and

for added control of the operation the plunger thermocouples can be connected to an alarm and to the Melting Control System to interrupt the heating operation in case of charge overheating;

[00105] Once all the energy required for the operation or once the thermocouples of the plunger indicate that the required temperatures have been reached, the tapping of the molten metal can be done by tilting the furnace. Use can be made of a special metal grid placed in the crucible, just in front of the furnace spout, to prevent the flow, with the liquid metal, of the waste floating at the surface of the melt.

[00106] Once all the liquid metal has been tapped, the crucible is scrapped to remove all the waste and specially the dross stuck on the crucible wall.

[00107] A slight overpressure of inert gas, such as argon or dinitrogen, can be used during the processes described hereinabove, to prevent any air inflow into the furnace crucible which otherwise would oxidize some of the metal during the steps of charging, in the case of hot dross, and processing or discharging from the furnace.

RECOVERY OF METAL FROM DROSS AND WASTE FEASIBILITY STUDY

[00108] Three series of induction melting tests were conducted at the CANMET facility, Hamilton Canada, to determine the feasibility of recovering aluminum metal from dross and from metal-rich-plant-residues including autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim and pot

bottom, in a conventional induction furnaces and without the use of any salt addition to the charge material.

[00109] Two induction furnaces of different capacity were used:

- a small 100 kW , 2500 Hz induction furnace , 10" ID, 15" deep
- a larger 2 500 kW, 1000Hz tilting induction furnace, 15" ID, 23 "deep

The total amount of material tested was 385 kg,

[00110] The following Table 1, gives the total amount tested for each kind of residue , in kg, the corresponding amount of metal recovered and the corresponding percentage of recovery.

TABLE 1

KiIND OF WASTE	AMOUNTCharged	METAL recovered	% RECOVERY
Pit Scrap	44.5 kg	38.8 kg	87 %
Borings	66.8 kg	65.5 kg	98 %
Mill Residues	30 kg	11.15	37.2 %
Dross	244 kg	168.4	69 %

[00111] In the case of the tests performed with a dross charge two melting methods were investigated : a start from a 100% solid charge and a start with 50% molten metal heel with solid dross samples added.

[00112] The test results indicate that aluminum dross and aluminum-rich-plant-residues are suitable charge materials for treatment in an induction furnace. The results indicate also that metal recovery is comparable to that obtained with other treatment technologies.

[00113] It will be appreciated that, for simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements or steps. In addition, numerous specific details are set forth in order to provide a thorough understanding of the exemplary embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein may be practiced without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the embodiments described herein. Furthermore, this description is not to be considered as limiting the scope of the embodiments described herein in any way but rather as merely describing the implementation of the various embodiments described herein.

CLAIMS:

1. A method for treating aluminum dross, zinc dross, or metal-rich residues said method comprising:

heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal contained within said aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of said at least one metal for causing melting and agglomeration of said at least one metal at a bottom portion of the furnace; and

removing said molten at least one metal from said furnace so as to separate said molten at least one metal from said aluminum dross, zinc dross or metal rich residues.

2. A method for treating aluminum dross, zinc dross or metal-rich residues, said method comprising:

heating aluminum dross, zinc dross or metal-rich residues in an induction furnace to induce electrical current in at least one metal contained within said aluminum dross, zinc dross or metal-rich residues and heat the at least one metal at a temperature above the melting point of said at least one metal for causing melting, separation of a waste and said molten at least one metal, and agglomeration of said at least one metal at a bottom portion of the furnace;

removing from a furnace crucible the molten at least one metal;

transferring the recovered molten at least one metal to a molten metal holding furnace for pouring in the melt;

removing the waste remaining in the crucible; and

scraping the wall of the crucible.

3. A method for treating aluminum dross, zinc dross or metal-rich residues, said method comprising:

heating in an induction furnace a molten metal heel to induce electrical current in said molten metal heel to keep said metal molten and contacting said molten metal heel with aluminum dross, zinc dross or metal-rich residues or metal rich residues in order to heat said aluminum dross, zinc dross or metal-rich residues charged into a furnace crucible by conduction of heat from the molten metal heel surface, for causing melting, separation of a waste and said molten at least one metal, and agglomeration of said at least one metal at a bottom portion of the furnace;

removing said molten at least one metal from said furnace so as to separate said molten at least one metal from said waste, while maintaining the molten metal heel in the crucible at a predetermined level.

4. The method of any one of claims 1 to 3, wherein said heating is carried out under an inert gas atmosphere.
5. The method of any one of claims 1 to 4, wherein the inert gas is Ar or N₂.
6. The method of claim 4 or 5, wherein the inert gas is injected at a controlled rate.
7. The method of any one of claims 1 to 6, wherein the molten at least one metal is removed from said furnace by means of a tap hole at a bottom portion of a furnace crucible.
8. The method of any one of claims 1 to 6, wherein the molten at least one metal is removed from said furnace by tilting the furnace and emptying the molten at least one metal by a furnace crucible spout.
9. The method of any one of claims 1 to 6, wherein the molten at least one metal is removed from said furnace by tilting the furnace and emptying the molten at least one metal by a furnace crucible spout while preventing, the flow of a solid waste floating at the surface of the melt.
10. The method of any one of claims 1 to 6, wherein the molten at least one metal is removed from said furnace by tilting the furnace and emptying the molten at least one

metal by a furnace crucible spout while preventing, with a grid, the flow, with the molten at least one metal, of a solid waste floating at the surface of the melt.

11. The method of any one of claims 1 to 10, wherein the at least one metal is aluminum or zinc.

12. The method of any one of claims 1 to 10, wherein heating is stopped upon reaching the required temperature of the aluminum dross, zinc dross or metal-rich residues by induction of eddy current into said aluminum dross, zinc dross or metal-rich residues charged into the furnace crucible.

13. The method of any one of claims 1 to 12, wherein the at least one metal is aluminum or zinc.

14. The method of claim 3, wherein the predetermined level of the molten metal heel is a same level than before introducing said charge into said furnace.

15. The method of claim 3, wherein the heating is stopped upon achieving the required temperature of the material by transfer of heat from the molten metal heel.

16. The method of any one of claims 1 to 15, further comprising monitoring and controlling the temperature at different levels in the crucible to avoid overheating of the liquid at least one metal.

17. The method of any one of claims 1 to 16, wherein the eddy current is generated by electromagnetic induction produced by at least one coil surrounding the crucible.

18. The method of any one of claims 1 to 17, wherein said method comprises heating aluminum dross.

19. The method of any one of claims 1 to 17, wherein said method comprises heating metal rich residues from an aluminum plant

20. The method of claim 3, wherein said waste comprises aluminum oxide.

21. The method of claim 20, wherein said waste comprises at least 95, 96, 97, 98, 99 or 99.5 % of aluminum oxide.
22. The method of claim 20, wherein said waste is recycled for use in an electrolytic cell.
23. The method of claim 20, wherein said waste is recycled for use as a cover in an electrolytic cell.
24. The method of any one of claims 1 to 17, wherein said method comprises heating zinc dross.
25. The method of any one of claims 1 to 17, wherein said method comprises heating metal residues from a zinc plant.
26. The method of claim 3, wherein said waste comprises zinc oxide.
27. The method of claim 26, wherein said waste comprises at least 95, 96, 97, 98, 99 or 99.5 % of zinc oxide.
28. The method of claim 26, wherein said waste is recycled for use in a zinc leaching step.
29. The method of any one of claims 1 to 17, wherein said method comprises heating metal-rich residues.
30. The method of claim 29, wherein the metal-rich-plant residues are chosen from residues generated in operating aluminum and zinc plants, metal dross, autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim, pot bottom and mixtures thereof.
31. The method of any one of claims 1 to 30, wherein said crucible is dimensioned to operate with a molten metal heel of about 65 % to about 85 % of a capacity of said crucible.
32. The method of any one of claims 1 to 31, wherein the crucible is a non-conducting crucible.

33. The method of any one of claims 1 to 17, further comprising monitoring and/or controlling the temperature at different levels in the crucible.
34. The method of claim 33, wherein the temperature monitoring and/or controlling is carried out by means of a temperature controlling device that is effective for monitoring and/or controlling temperature of a charge inside the crucible.
35. The method of claim 34, wherein the temperature controlling device comprises a plunger for inserting into the crucible, the plunger defining a hollow chamber for receiving at least one thermocouple for monitoring and/or controlling the temperature .
36. The method of claim 34, wherein the temperature controlling device comprises a plunger for inserting into the crucible and contacting the charge, the plunger defining a hollow chamber for receiving at least two thermocouples for monitoring and/or controlling the temperature at different levels inside the crucible.
37. The method of claim 35 or 36, wherein said plunger is a steel plunger.
38. The method of any one of claims 35 to 37, wherein the surface of the plunger is covered with a protective coating for protecting said plunger against molten aluminum.
39. The method of claim 38, wherein said protective coating comprises WC-Co.
40. The method of any one of claims 35 to 39, further moving said plunger is movable upwardly, downwardly and/or laterally for stirring the charge.
41. The method of any one of claims 35 to 39, further moving said plunger is movable upwardly, downwardly and/or laterally for stirring the charge, thereby breaking accumulation of solids on top on molten metal.
42. The method of any one of claims 35 to 39, further moving said plunger is movable upwardly, downwardly and/or laterally for stirring the charge, thereby breaking accumulation of solids bridging portion(s) of an internal wall of the crucible.

43. An apparatus for treating aluminum dross, zinc dross or metal-rich residues, said apparatus comprising:

an induction furnace suitable for treating aluminum dross, zinc dross or metal-rich residues by heating said aluminum dross, zinc dross or metal-rich residues via an eddy electrical current induced, at a temperature above a melting point of at least one metal to be recovered therefrom, said furnace having an opening for passing material therethrough for charging and discharging a furnace crucible and a cover for closing said opening;

an injector for injecting an inert gas into said furnace; and

a temperature controlling device for monitoring and controlling temperature in said furnace.

44. The apparatus of claim 43, wherein the eddy current is generated by electromagnetic induction produced by at least one coil surrounding the crucible.

45. The apparatus of claim 43, wherein the eddy current is generated by electromagnetic induction produced by at least two coils surrounding the crucible.

46. The apparatus of claim 43, wherein the eddy current is generated by electromagnetic induction produced by a double coils surrounding the crucible.

47. The apparatus of any one of claims 43 to 46, wherein said furnace crucible comprises a tap hole for tapping at least one recovered molten metal.

48. The apparatus of any one of claims 43 to 47, wherein said furnace comprises a device for tilting said furnace.

49. The apparatus of any one of claims 43 to 48, further comprising a controller for controlling inert gas injection.

50. The apparatus of any one of claims 43 to 49, further comprising means for conveying said molten at least one metal into a holding furnace.

51. The apparatus of claim 50, further comprising means for pouring recovered molten metal into the molten metal holding furnace.
52. The apparatus of any one of claims 43 to 51, further comprising a conveyor to charge the material in the said furnace.
53. The apparatus of any one of claims 43 to 52, further comprising a vibratory conveyor suitable for charging in a heel melting operation.
54. The apparatus of any one of claims 43 to 53, further comprising a suitable container that is an insulating refractory lined ladle for transporting the recovered molten metal and for pouring said molten metal into a plant molten metal holding furnace.
55. The apparatus according to any one of claims 43 to 54, wherein the temperature controlling device is effective for monitoring and controlling temperature of a charge inside the crucible.
56. The apparatus of claim 55, wherein the temperature controlling device comprises a plunger for inserting into the crucible, the plunger defining a hollow chamber for receiving at least one thermocouple for monitoring the temperature .
57. The apparatus of claim 56, wherein the temperature controlling device comprises a plunger for inserting into the crucible and contacting the charge, the plunger defining a hollow chamber for receiving at least two thermocouples for monitoring the temperature at different levels inside the crucible.
58. The apparatus of claim 56 or 57 wherein said plunger is a steel plunger.
59. The apparatus of any one of claims 56 to 58, wherein the surface of the plunger is covered with a protective coating for protecting said plunger against molten aluminum.
60. The apparatus of claim 59, wherein said protective coating comprises WC-Co.
61. The apparatus of any one of claims 56 to 60, wherein said plunger is movable upwardly, downwardly and laterally for stirring the charge.

62. The apparatus of any one of claims 43 to 61, wherein the metal-rich-plant residues are chosen from residues generated in operating aluminum and zinc plants, metal dross, autogenous mill residues, crucible cleaning residues, pit scrap, borings, pig bottom, mold machine skim, pot bottom and mixtures thereof.

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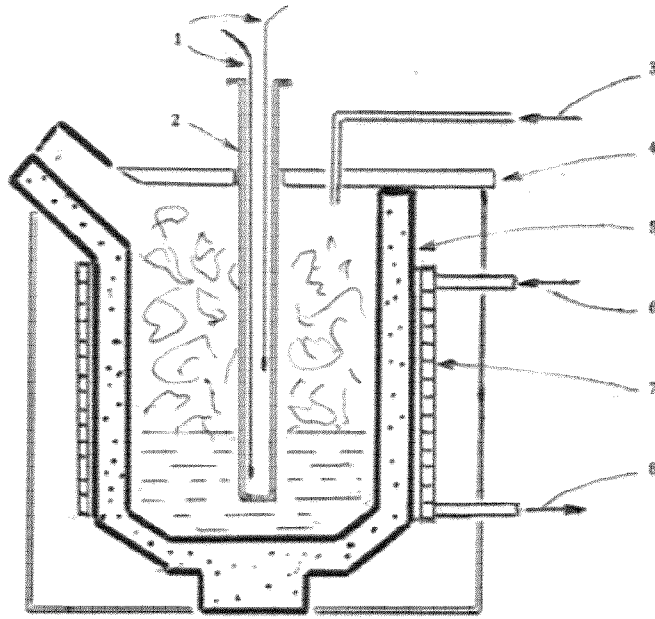


FIG. 1

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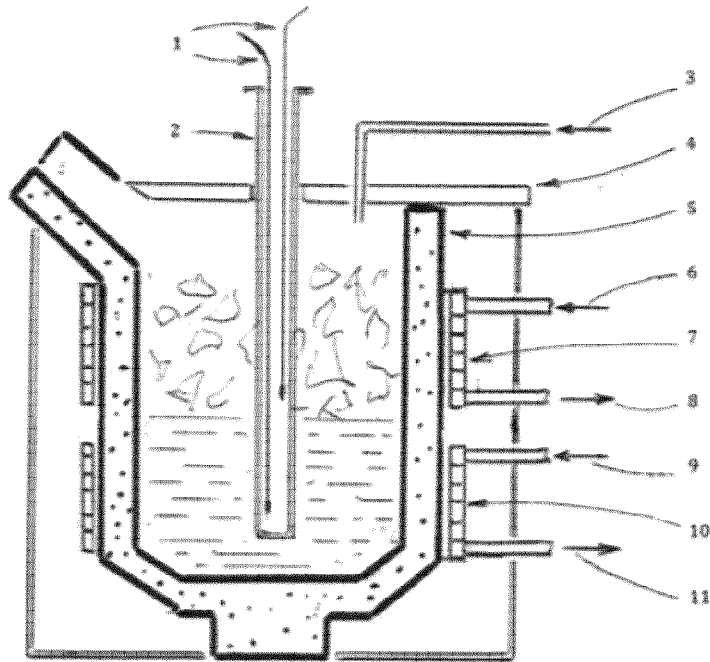


FIG. 2

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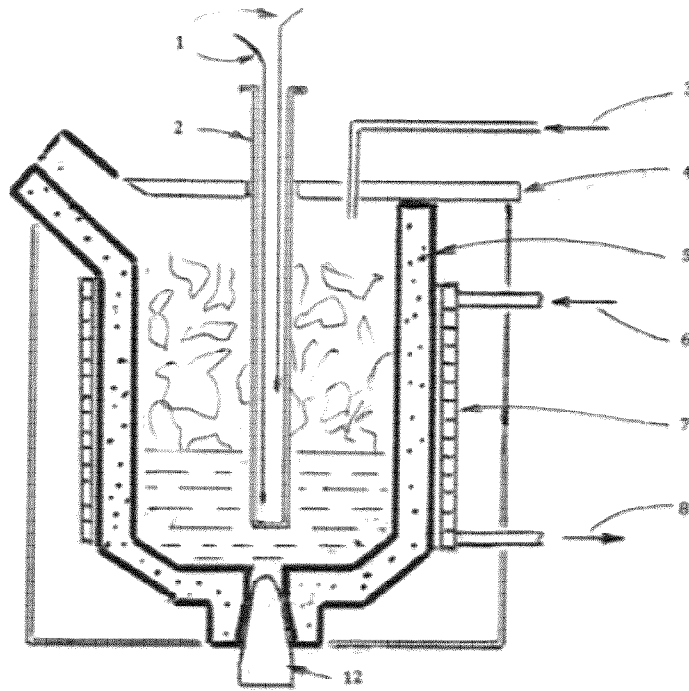


FIG. 3

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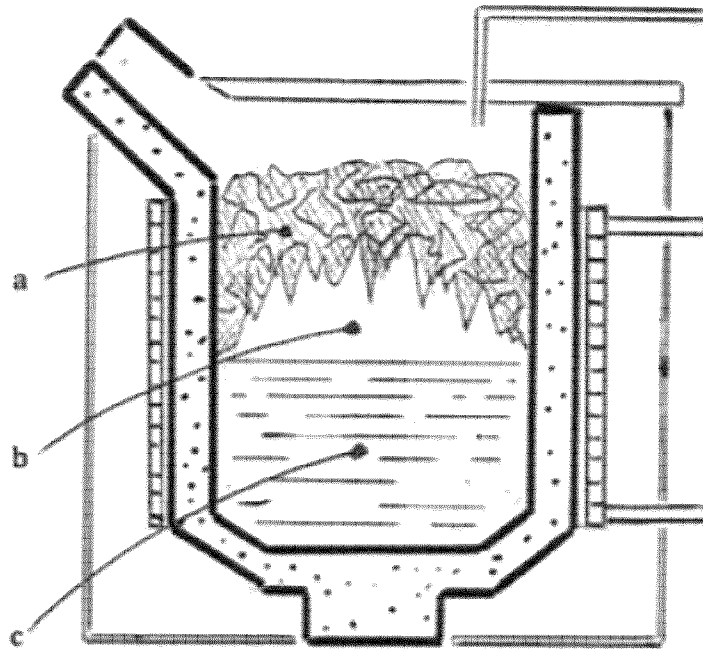


FIG. 4

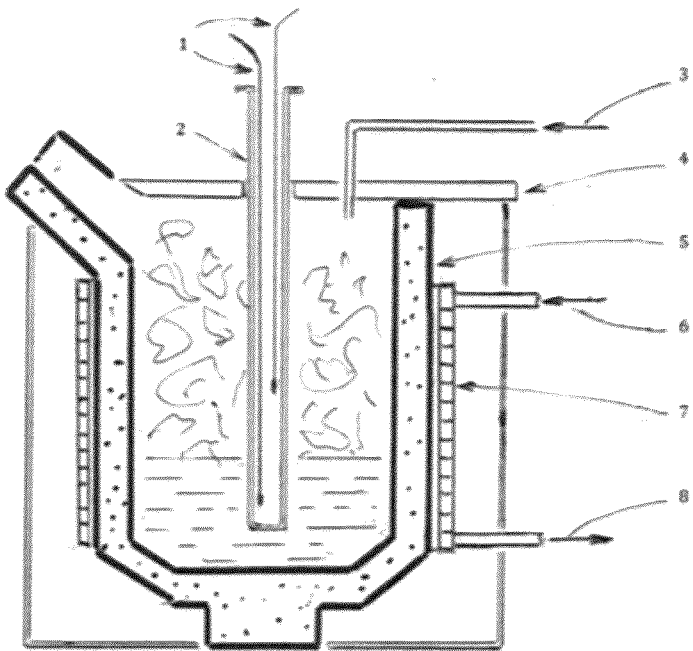


FIG. 1