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Funck et al.

[11] **3,887,172**

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[54] **APPARATUS FOR THE TREATMENT OF A MOLTEN METAL BATH**

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[52] **U.S. Cl.** .... **266/34 A**

[51] **Int. Cl.** **C21c 7/00**

[58] **Field of Search** .... 75/45, 59, 60, 61, 93 E; 266/34 A, 34 T, 34 PT, 34 V, 34 PP

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[57] **ABSTRACT**

A molten-metal bath is treated by generating gas bubbles in a rising column of molten metal in a conduit which opens laterally below a slag layer, within this layer or somewhat above the slag layer to discharge the metal upon separation of the gas therefrom within the conduit. Treating agents may be supplied to the circulating metal within the duct.

8 Claims, 8 Drawing Figures

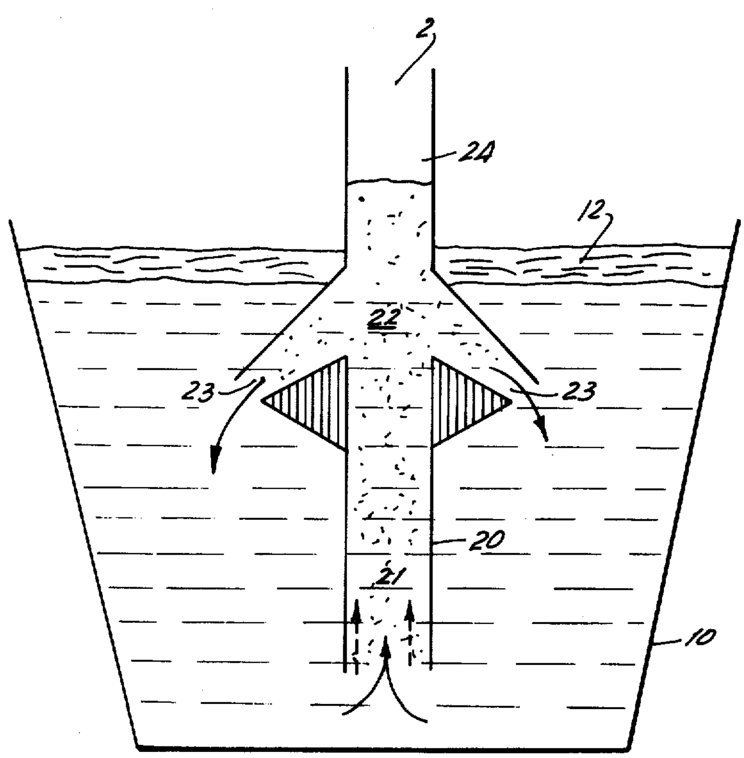
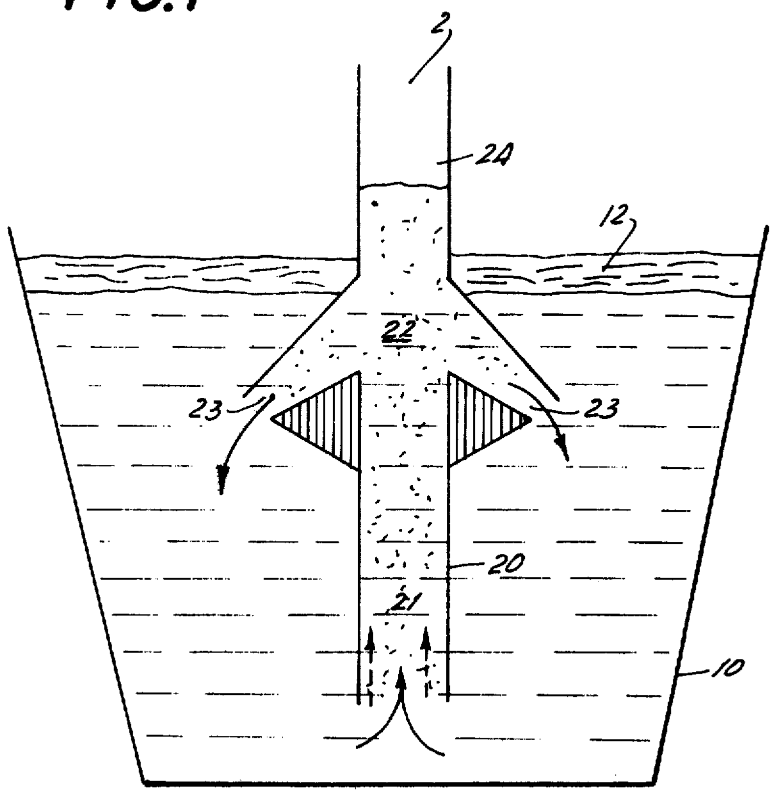


FIG. 1



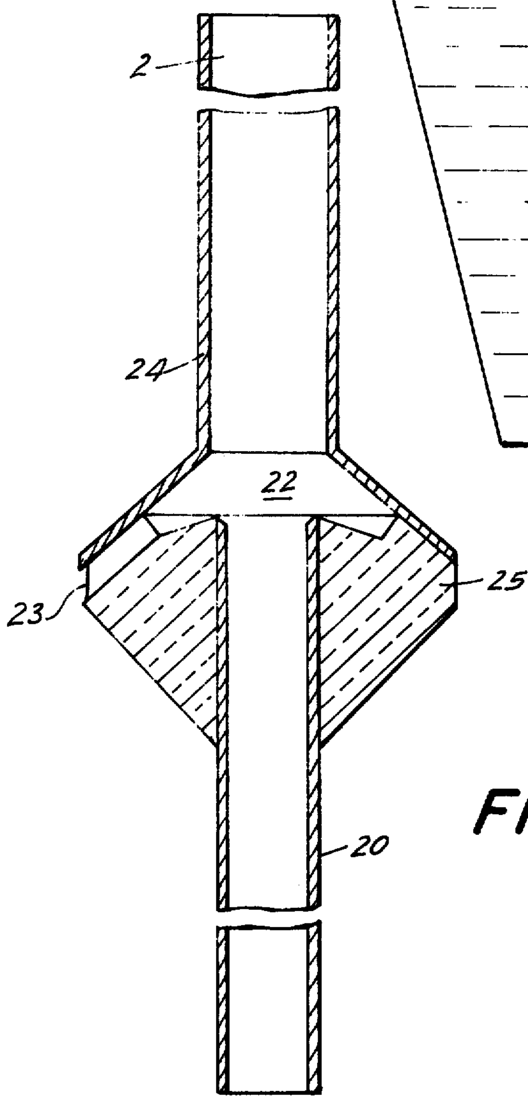
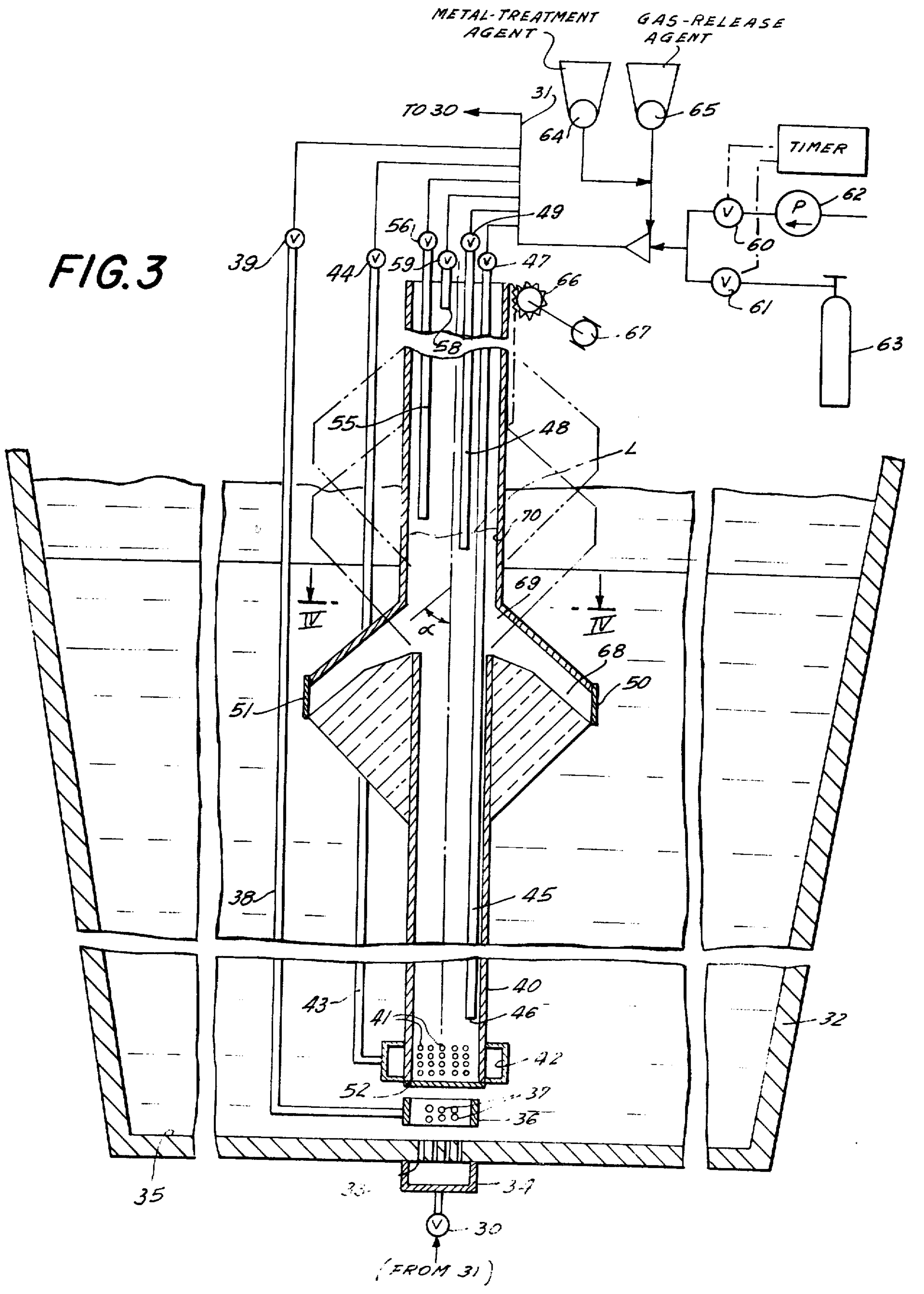


FIG. 2

FIG.3


METAL-TREATMENT AGENT
GAS-RELEASE AGENT
TO 30
31
64
65
TIMER
62
P
49
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59
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61
58
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IV
68
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(FROM 31)

FIG.4

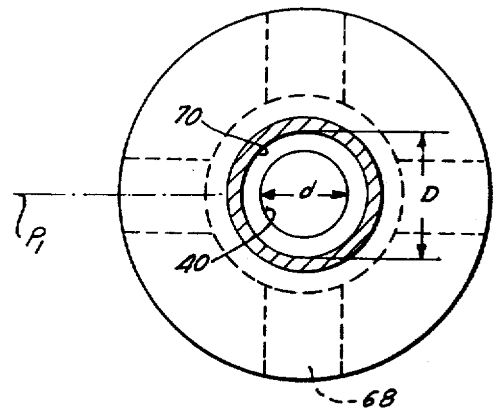


FIG.5

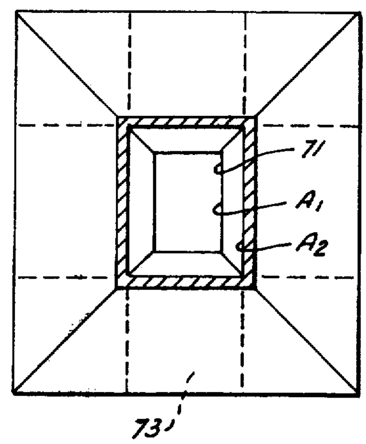
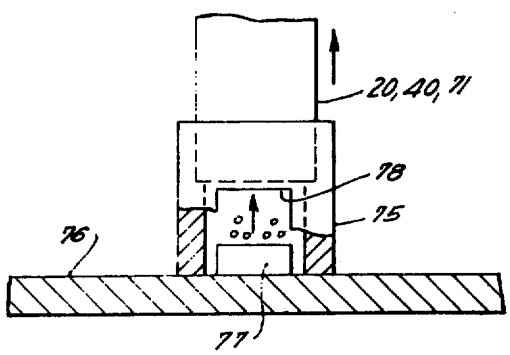


FIG.7



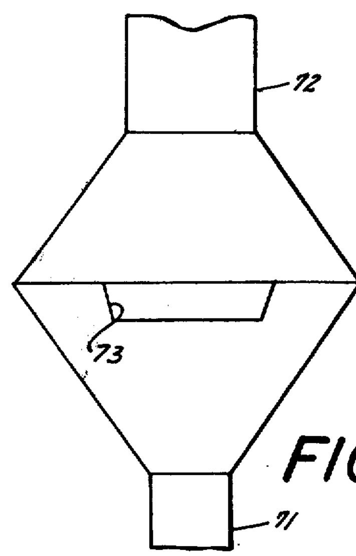
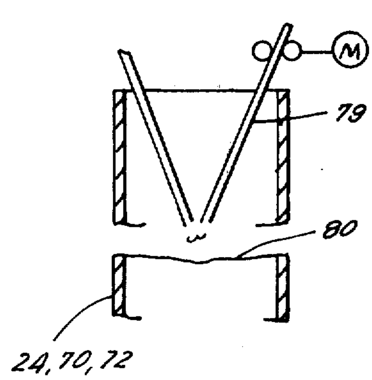


FIG.6

FIG.8



APPARATUS FOR THE TREATMENT OF A MOLTEN METAL BATH

FIELD OF THE INVENTION

Our present invention relates to an apparatus for the treatment of molten metals and, more particularly, to a system for inducing circulation in a molten-metal bath without some of the deficiencies which have hitherto plagued metal treatments of this type.

BACKGROUND OF THE INVENTION

The treatment of molten metals in baths thereof in a casting ladle or other metallurgical receptacle may be carried out for a variety of reasons. In general, the molten metal is covered by a slag which has a lower specific gravity and, at least in some cases, is not to be dispersed in the melt. Generally metal treatment includes the addition of a reactive substance, e.g. a desulfurizing or acid slag to the melt, the admixture of an alloying agent therewith and/or the circulation or agitation of the mold to achieve degasification.

Numerous techniques may be applied for metal treatment in this manner. For example, the additive may be cast directly onto the bath in a metallurgical receptacle, this having the disadvantage that the additive is frequently intercepted by the slag layer and does not come into intimate contact with the molten metal.

Alternatively, a finely divided additive, e.g. a treating substance as described or an alloying agent, may be blown into the melt by entrainment with a gas through a lance or the like reaching below the slag layer. In many cases, the additive has a low specific gravity so that it rapidly rises into the slag layer without prolonged contact with the molten metal. In other instances, the agitation of the entire bath produced by injecting the additive in a gas stream, entrains portions of the slag layer into undesirable contact with the heart of the melt.

It is also known to avoid the disruption of the slag layer by inducing a column of metal upwardly through a riser reaching below the slag layer and terminating above the latter in a treatment chamber in which the melt is subjected to treatment or in which additives are supplied. The molten metal is either returned to the bath or delivered to another vessel in which homogenization is effected. The disadvantage of this system is that the apparatus required is relatively complex and the volume of metal received in the receptacle is usually so great that a slag layer forms thereon to interfere with incorporation of an additive in the melt and also to introduce the danger of slag entrainment.

It should also be noted that the problem of distribution of an additive in a melt, especially a melt of pig or cast iron or steel, and the homogenization of the distributed additive in the melt may be avoided by carrying out the addition at one location and transferring the mixture of the melt and the additive to another location at which homogenization is effected. Obviously the apparatus required for this purpose is complex and expensive.

OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide an improved method of treating a bath of molten metal whereby the aforementioned disadvantages can be obviated.

It is another object of the invention to provide a simplified apparatus for the treatment of molten metal wholly within a metallurgical receptacle.

Still another object of the invention is to provide a system for the introduction of additives into a molten-metal bath and/or for the circulation of a molten metal in which slag entrainment from an overlying layer is minimized unless such slag entrainment is deemed to be advantageous.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, in a system for treating a molten-metal melt, especially iron (e.g. cast-iron) and steel, in a bath containing the molten metal surmounted by a slag layer, to add a metal-treating (reactive or alloying) ingredient thereto or simply to cause circulation of the metal, which comprises generating an upwardly moving stream of molten metal segregated from the remainder of the melt by injecting a gas into the molten metal of the rising column, separating the gas from the molten metal at a location above that at which the molten metal is drawn into the column, and discharging the molten metal laterally from the column in the region at which the gas is separated from the molten metal and wholly without the ladle or metallurgical receptacle.

The apparatus, for this purpose, comprises a riser reaching downwardly into the metallurgical receptacle or vessel containing the molten-metal bath, e.g. a casting ladle, the riser being provided with an inlet close to the bottom of the vessel and one or more lateral outlets at a location spaced above the inlet.

Means is provided to inject a gas under pressure at this base of this column and, in the region of the lateral outlet, a decanting or separating chamber is formed for enabling the gas to separate from the metal gas column of low specific gravity ascending the column. The gas thus acts in a manner similar to the compressed air in an air-lift pump to raise the molten metal in a confined column in the form of a emulsion whose apparent density is less than that of the surrounding metal bath. The buoyant force therefore causes the emulsion to rise with a dynamic effect similar to that of pumping to enable a continuous circulation to be maintained between the bottom of the bath and an upper location at which the lateral outlets discharge the molten metal.

Generally, the lateral outlets will be disposed below the layer of slag overlying the bath and means may be provided for introducing the treating ingredient (reactive agent or alloying component) to the column prior to its discharge from the lateral outlet. The slag layer thus does not interfere with the introduction of the additive and a dispersion of the latter into the body of the melt without interfering with the slag layer, or interference thereby. Of course, if it is desired that the slag be agitated in the metal, the lateral outlets can be disposed in or slightly above the slag layer, whereupon the discharged metal will entrain the slag into the body of the melt. This latter system may be used for effecting treatment of the molten metal with a reactive slag. Similarly, when it is desirable that the treating agent contact both the molten metal and the slag, it may be added when the lateral openings are disposed above the slag/metal interface.

Advantageously, the lateral outlets are constituted as nozzles directing jets of the molten metal generally obliquely toward the base of the vessel, i.e. diverting the rising column through an obtuse angle downwardly into the melt, the nozzle or jet including an acute angle preferably between 30° and 55°, with the vertical axis of the column or riser.

The additive may be simply dispensed on top of the metal in the column or may be introduced into the latter at the base thereof, the additive being injected in a carrier gas, e.g. the gas used to levitate the molten metal.

The riser may be provided directly (unitarily) with means for injecting gas under pressure into the column at the base thereof or else the gas-injecting means may be provided on the floor of the vessel or may be formed directly in the floor in vertical alignment with the riser. Alternatively, a separate assembly may be provided between the floor of the vessel and the mouth of the riser for injecting gas under pressure into the molten metal. In each of these cases, the gas-injecting means may be a chamber or pipe provided with a multiplicity of perforations or a bundle of small tubes. Preferably, the gas injector and/or riser are interchangeably fixed on the bottom of the treatment vessel.

The lateral outlets are preferably provided in diametrically opposite pairs at the aforementioned upper location of the riser and may have passages which begin at overflow passages or weirs within the treatment device. When an odd number of outlets is provided, each outlet may lie along a radius of the device, preferably with an outlet axis in an axial plane thereof, the outlets being angularly equispaced about the riser.

Advantageously the device is disposed centrally in the metallurgical receptacle and is maintained stationary during the operating treatment. No mechanical pumping operation utilizing the riser is intended. However, it has been found to be advantageous to vary the pumping rate (rate of flow or circulation of the melt) by varying the gas-supply rate and/or pressure substantially periodically.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a diagrammatic vertical cross-sectional view through an apparatus for carrying out the process of the present invention;

FIG. 2 is a vertical section through a metal-circulating device according to another embodiment thereof;

FIG. 3 is a somewhat more detailed diagrammatic vertical section through an apparatus for carrying out the process of the present invention;

FIG. 4 is a cross-sectional view taken along the line IV — IV of FIG. 3, the various ducts being omitted;

FIG. 5 is a view similar to FIG. 4 of another embodiment of the invention;

FIG. 6 is an elevational view of a portion of the latter embodiment;

FIG. 7 is an elevational view, partly broken away, showing a recirculating device replaceably mounted on the floor of a metallurgical receptacle; and

FIG. 8 is a diagrammatic vertical section showing another technique for introducing a treating agent into the molten metal.

SPECIFIC DESCRIPTION AND EXAMPLE

The recirculating device 2 shown in FIG. 1 consists essentially of a riser tube 20, a decanting chamber 22 and a pair of lateral downwardly opening outlets 23. The device functions in conjunction with a pressurized-gas injector 21 which is diagrammatically illustrated in FIG. 1 and can be fixed to the lower end of tube 20 or independent therefrom.

The device 2 is immersed vertically in a casting ladle 10 containing a bath 11 of a molten metal (cast iron or steel) covered by a layer 12 of slag. The passages of the outlets 23 are inclined toward the base of the vessel and lie below the surface of the metal bath.

As will be apparent from FIG. 3, the device 2 is immersed in the ladle 10 by covering the openings with a consumable cap or cover of thin sheet metal or cardboard. While it is in contact with the molten metal, it is maintained stationary and the consumable covers decompose at the temperature of the melt to permit access of molten metal to the riser and the discharge passages while preventing entry of slag during immersion.

The pressurized gas produces small bubbles within the molten metal at the base of the riser thereby forming an emulsion and lifting the liquid metal upwardly within the column toward the top thereof. In the decanting chamber 22 the bubbles of gas are separated from the molten metal and the gas emerges from the upwardly open duct 24 above the decanting chamber. The molten metal passes laterally through the overflow outlets 23 and returns to the melt within the bath. As a consequence, a circulation of molten metal is established through the device. In the heart of the bath, therefore, there is a rising column of molten metal and descending currents are formed as represented by the arrows in FIG. 1 throughout the remainder of the bath. The additive is supplied to the molten metal within the column and hence the slag layer does not interfere with such addition and the circulation is free from entrainment of slag. It should be noted that the overflow discharge of the molten metal ensures that the molten metal leaving the outlet will be in laminar flow, thereby minimizing the entrainment of slag.

The additives are preferably introduced in the form of powders, granules, electroeroded portions of a consumable electrode or in any other form facilitating dispersion in the metal of the column. The additives may have a density less than that of the metal since they are entrained by the circulating stream thereof and may be added by blowing them, in a carrier gas, into the column of metal. The additive may thus be introduced by a lance extending downwardly coaxially through the riser.

When it is desirable to bring about a reaction between the slag and the circulating metal, the device may be raised so that its outlets lie within the layer or above the layer of slag. Preferably the flow of metal is varied periodically by varying the flow of gas to the pumping outlets in a similar manner.

The decanting chamber preferably has a frustoconical or frustophramidal configuration and it has been found that the configuration of the decanting chamber shown in FIG. 2 is particularly advantageous for the separation of gas from the molten metal. The extension 24 of this chamber advantageously has a cross-section which is greater than that of the riser 20 to decelerate the circulating stream. The cross-sectional area of the extension may be in a ratio to that of the riser of 3:1 to 1:1.

Below the decanting chamber, the device has a downwardly converging configuration at **25** to facilitate the insertion of the device into the bath and to weight down the device. It has also been found to facilitate rotation of the device when such rotation may be desirable. The gas injector may be incorporated in the tube or disposed below the base thereof, or may be composed of porous refractory brick or bundles of tubes disposed on the floor of the vessel or upon a ledge having a face confronting the mouth of the tube. An injection lance extending axially through the tube may also be employed.

The recirculating gas is advantageously an inert gas although reactive gases may be employed for oxidizing and reducing purposes. A suitable inert gas is argon and, when increased nitrogen content is required, the gas may be nitrogen. The gas required for lifting the column of metal may also be obtained in situ by introducing a thermally decomposable material in a gas stream, the material such as a carbonate decomposing to increase the volume of gas. The system has been used effectively for the reduction of the silicon level of ferrous metals and for the desulfurization, dephosphorization and de-oxidation thereof. It has been found to be effective also for adding alloying ingredients, for thermally or chemically homogenizing the melt or for the degasing thereof. Highly reproducible results are obtained thereby.

In FIGS. **3** and **4**, we show a modified system in which the ladle **32** is formed at its base with a tube bundle **33** opening upwardly and communicating with a chamber **34** connected by valve **30** to a manifold **31.** Above the floor **35** of this ladle is disposed a gas injector **36** in the form of a ring having perforations **37** communicating with a duct **38** connected by a valve **39** to the manifold **31.** The riser **40** of the recirculating device may be provided directly with gas-injecting perforations **41** along the bottom of this riser, the perforations communicating with a chamber **42** connected by a duct **43** to a valve **44** leading to the manifold **31.**

A lance **45,** shown to be offset to one side of the recirculating device but preferably disposed coaxially therein, opens at **46** at the bottom of the riser **40** and communicates at its upper end with a valve **47** connected with the manifold **31.** Another lance **48,** likewise connected by a valve **49** to the manifold **31,** is immersed below the level L to which the molten metal is carried in the recirculator when the sheet-metal caps **50, 51** and **52** covering the openings are destroyed in situ. Still another lance **55** may be provided with an outlet trained on the surface L of the melt within the column and is connected by a valve **56** to the manifold **31.** When it is desired simply to discharge the additive into the top of the column, a tube **58** is employed, this tube being connected by a valve **59** to the manifold.

Depending upon which of a pair of valves **60** and **61** is opened, a compressor **62** or a tank **63** of pressurized gas is connected to the manifold and one of the valves **30, 39, 44** and **47** is opened to produce the gas-lift action described above. The metering devices **64** and **65** may also be selectively operated to introduce the additive at any desired level within the column.

The column is vertically positioned by a rack-pinion arrangement **66,** operated by the motor **67,** to locate the outlets within the slag layer as shown by dot-dash lines or above the slag layer as represented by double-dot-dash lines.

As can be seen from FIG. **4,** the riser **40** has a diameter *d* which is substantially less than the diameter D of the extension **70** of the decanting chamber **69** while the outlets **68** lie in axial planes P_1, are diametrically opposite, and extend along radii of the device.

In FIGS. **5** and **6,** the riser **71** has a rectangular cross-section and an area A_1 while the extension **72** has an area A_2 which is substantially greater. In this case, the outlets **73** are provided in a frustopyramidal structure.

FIG. **7** shows that the riser **20, 40, 71,** may be removably mounted in a pedestal **75** at the floor **76** of the ladle, a porous-brick gas discharge device **77** being provided within the pedestal an opening of which is illustrated at **78** to permit entry of molten metal to the bottom of the riser. FIG. **8** shows that a consumable electrode **79** may be provided to react with the molten metal **80** in the extension **24, 70, 72** to introduce the alloying ingredient into the melt.

We claim:

1. An apparatus for the treatment of molten metal in a bath thereof, comprising a receptacle receiving said bath of molten metal overlain by a slag layer; a circular-cross-section riser immersed in the molten metal and open at the bottom thereof; gas-injector means at the bottom of said riser for injecting gas into the molten metal and inducing an upward flow of a gas/metal mixture therein; a generally frustoconical decanting chamber on said riser at a location spaced above the bottom thereof and provided with a plurality of downwardly and outwardly trained radially extending nozzles for discharging molten metal into the melt upon separation of gas from the molten metal, said nozzles including angles of 30° to 55° with the axis of said riser; and a circular cross-section extension of said chamber extending through said layer and opening upwardly thereabove for discharging the gas separated from said mixture, the cross-section of said extension being greater than that of said riser.

2. The apparatus defined in claim **1** wherein the gas-injector means is fixed to said riser.

3. The apparatus defined in claim **1** wherein the gas-injector means is fixed to the bottom of said receptacle.

4. The apparatus defined in claim **1,** further comprising means for replaceably mounting said riser on the bottom of said receptacle.

5. The apparatus defined in claim **1** wherein said nozzles are located diametrically opposite one another.

6. The apparatus defined in claim **1,** further comprising downwardly converging wall means between said outlet and said riser for facilitating introduction of said riser and said chamber into said melt.

7. The apparatus defined in claim **1** wherein said outlet and the bottom of said riser are closed by consumable members upon insertion of the riser into said melt.

8. The apparatus defined in claim **1** wherein the ratio between the cross-section of said riser and the cross-section of said extension ranges between 1:1 and 1:3.

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