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Metz

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

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[30] **Foreign Application Priority Data**

Feb. 4, 1971 Luxembourg 62545

[52] **U.S. Cl.** .... **266/34 T,** 75/51, 75/93

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

[58] **Field of Search** .... 75/49, 51, 52, 61, 93 R, 75/93 E; 266/34 R, 34 T, 34 V

[56] **References Cited**

UNITED STATES PATENTS

1,921,060	8/1933	Williams	266/34 V
3,033,550	5/1962	Harders	266/34 T
3,154,404	10/1964	Loreng	266/34 V
3,212,767	10/1965	Muller	266/34 V
3,215,423	11/1965	Taylor	266/34 V
3,367,396	2/1968	Sickbert et al.	266/34 V
3,618,924	11/1971	Messing	266/34 V
3,664,652	5/1972	Spire et al.	266/34 A

FOREIGN PATENTS OR APPLICATIONS

954,214	4/1964	Great Britain	266/34 V
1,224,375	2/1960	France	266/34 V

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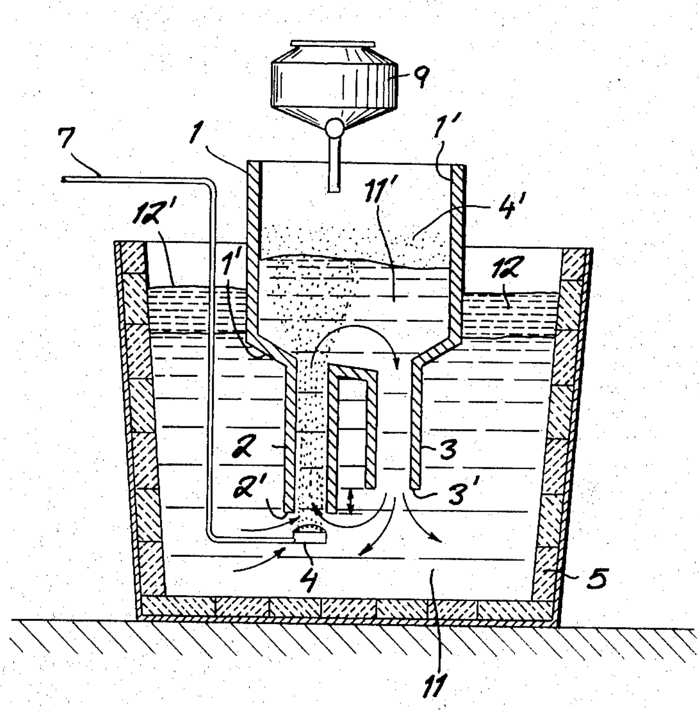
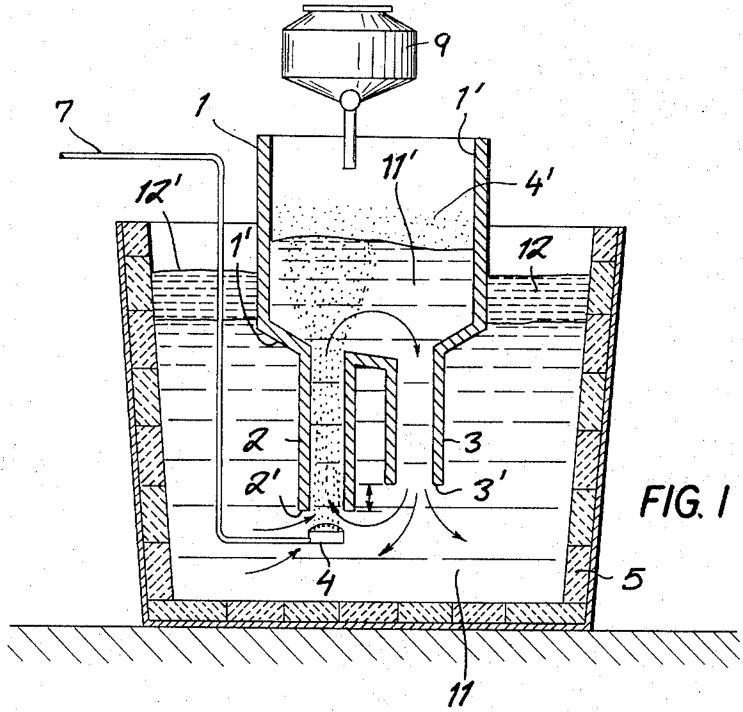
[57] **ABSTRACT**

An apparatus for the treatment of molten metals, e.g., cast iron or steel in a vessel such as a furnace or ladle wherein an upwardly moving stream of the molten is induced by confining a column thereof and injecting a gas beneath this column into the melt. A treatment receptable is located above the column which, in turn, may be separated from any slag layer overlying the bath, the receptacle having a downwardly moving column returning the metal to the bath. The receptacle may be maintained at a pressure other than atmospheric or may be open to the atmosphere.

5 Claims, 7 Drawing Figures




9
7
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1'
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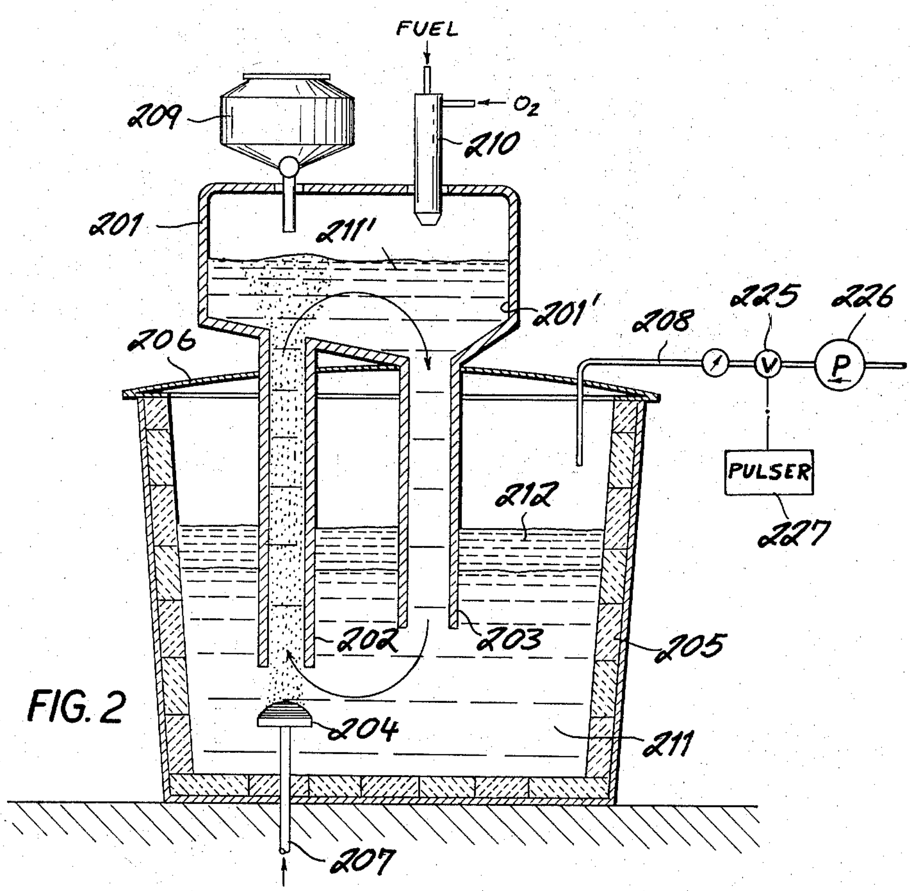
11

FIG. 1


FUEL
O2
209
210
201
211'
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204
211
207

FIG. 2

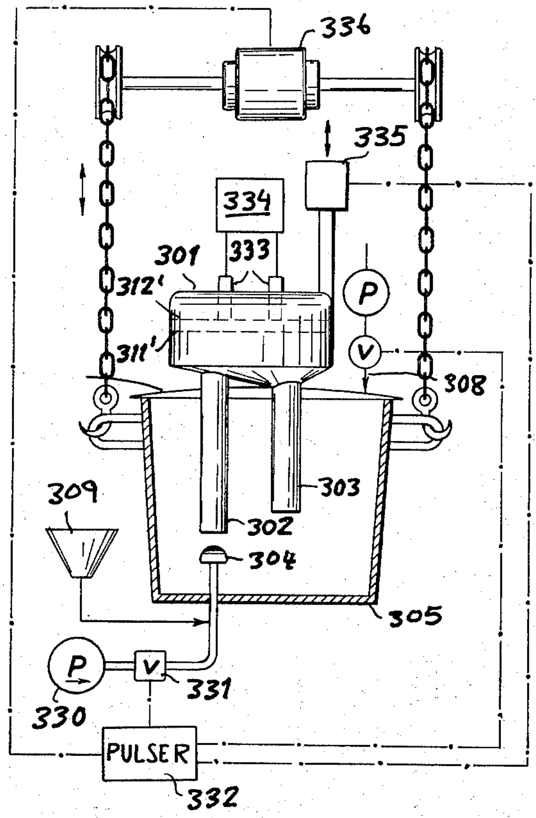

FIG. 5

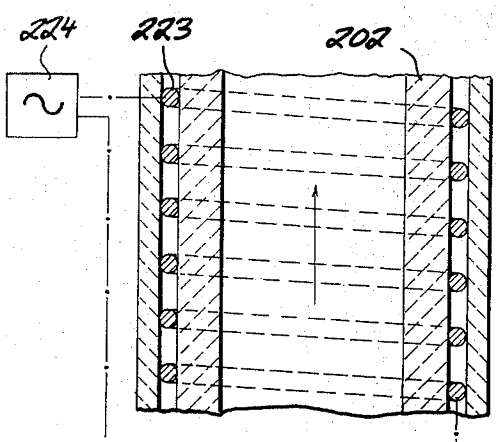

FIG. 4

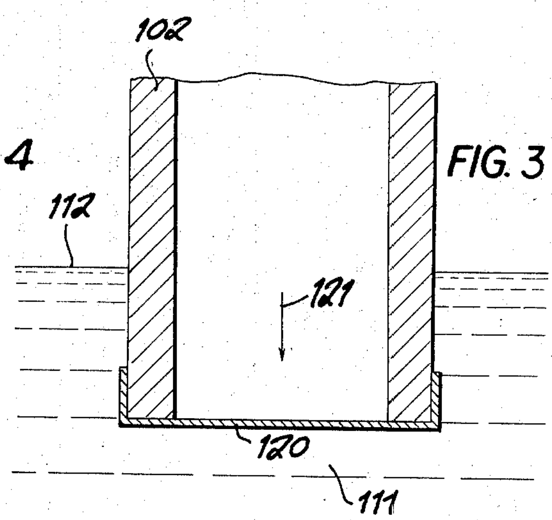

FIG. 3

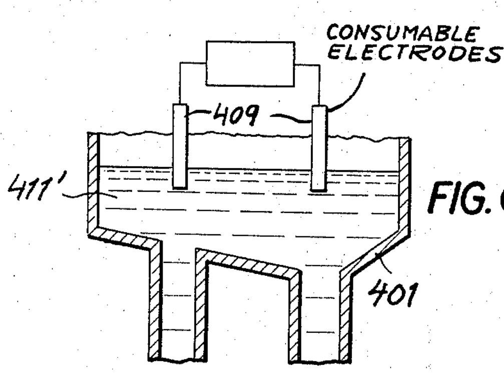

FIG. 6

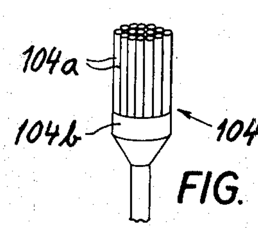

FIG. 7

APPARATUS FOR THE TREATMENT OF MOLTEN METAL

FIELD OF THE INVENTION

My present invention relates to the treatment of molten metals and, more particularly, to an apparatus for the treatment of cast iron, steel or like melts with reactive or alloying substances.

BACKGROUND OF THE INVENTION

Numerous techniques have been proposed for treating molten metals with reactive and alloying substances and, in fact, the treatment materials may be supplied to the treatment vessel before the melt is charged into it, during the charging of the melt, or subsequent to the filling of the vessel with molten metal. The means for introducing the reactive substance or the alloying ingredient material include a lance for injecting the treatment material below the level of the bath and beneath any slag layer overlying same, can include means for charging the treatment substance into a moving stream of the molten metal, e.g., as it is introduced into the receptacle, or may simply deposit or blow the treatment substance onto the top of the melt. To obtain a homogeneous distribution of the treatment agent within the melt and to prevent the slag layer from either trapping the treatment agent or reacting with it to the inclusion of the metal, it has been proposed to agitate the melt, either with mechanical stirrers or by oscillation, electrical inductive stirring, magnetic means or the like operating on the melt in bulk. There have been attempts to stir a melt or bath by injecting gases into it although, for the most part, the ebullition of the melt was insufficient to ensure uniform distribution of the treatment agent throughout the bath. These stirring methods, including the mechanical techniques described, also have the disadvantage that the slag may in part be drawn into the body of the melt and introduce problems.

In summary, therefore, the treatment of molten metals, especially molten cast iron or molten steel, has been handicapped by the presence of the slag layer upon the bath, by the inability to aboid entrainment of a portion of the slag into the body of the melt during treatment, and by difficulties with respect to distribution of the treatment agent throughout the melt.

OBJECTS OF THE INVENTION

It is, therefore, the principal object of the present invention to provide an improved apparatus for treating molten metals, even in the presence of a slag layer overlying the melt, whereby the aforementioned disadvantages can be obviated.

Another object of the invention is to provide an apparatus for treating molten metal, e.g., cast iron or steel, whereby the distribution of the treatment agent can be rendered more homogeneous and satisfactory.

It is also an object of the invention to provide an apparatus for treating molten metals whereby the entrainment of slag into the body of the melt during such treatment is avoided or limited.

Still another object of the invention is to provide an apparatus for treating molten metal with a minimum of expense and with maximum efficiency.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, with a method of treating molten metal which comprises withdrawing the molten metal from a bath thereof at a location beneath the surface of the bath and beneath a slag or dross layer, preferably in a column rising through the slag layer but uncontaminated thereby, into a treatment vessel, treating the molten metal with a treating agent in this vessel and returning the treated metal to the molten-metal bath at a point beneath the slag layer without contamination of the returning metal, the treated portion of the metal being circulated substantially continuously from the molten metal bath through the treatment vessel. According to a specific feature of this invention, the withdrawn portion of the molten metal is lifted by a gas-lift pump or the like, preferably by injecting into the molten metal beneath an upright tube, a mass of small gas bubbles to create an emulsion of the molten metal of relatively low density, the low-density gas/metal emulsion rising autogenously in the upright tube to the treatment vessel in which a certain quantity of the metal can be maintained during circulation. The gas separates from the molten metal within this vessel to increase the density of the treated portion which descends through a further upright tube to return to the bath below the slag layer or dross overlying same.

The molten metal of the bath to be treated, generally cast-iron or steel, may be contained in any of the usual receptacles, e.g., ladle, crucible, converter or furnace, into which the two upright tubes of the treatment apparatus depend through the slag layer. The treatment apparatus thus comprises a vessel having a volume determined by the desired quantity of metal retained or stored in the treatment cell along the recirculating path and a apir of tubes depending from this cell and opening into the bottom thereof. Optimum circulation and distribution of the treated molten metal within the bath has been obtained with a system in which one of the tubes extends to a lower level within the bath than the other. Preferably the riser tube extends further into the bath than the return tube.

According to another important feature of the invention, the treatment of the molten metal within the cell or treatment vessel is effected under atmospheric pressure, i.e., the treatment vessel is not sealed above the molten metal therein from the atmosphere to the extent that a pressure different from that of atmosphere pressure is applied to the molten metal within the treatment vessel. It has been found to be advantageous to provide the treatment vessel such that the base of its cell, inclined downwardly toward the return tube, lies above the surface of the metal or slag in the bath to be treated, although less heating is required where the base of the treatment vessel is immersed in the bath, i.e., the major part of the metal to be treated and lying within the treatment cell, is disposed beneath the level of the bath from which the molten metal is withdrawn, although segregated therefrom by the wall of the treatment vessel.

It has been found to be advantageous to control the level of the molten metal within the treatment vessel and for this purpose I may provide means for raising and lowering the treatment vessel relative to the ladle or other receptacle for the molten-metal bath, for raising and lowering the latter receptacle, or for applying a subatmospheric pressure to the top of the bath of the receptacle to control thereby the position of the surface of the treated melt within the treatment vessel. Furthermore, it has been found to be advantageous, in distributing the treating agent within the circulating metal of the treatment vessel to periodically raise and lower the level of the metal in the treatment cell, e.g., by pulsing the pressure applied to the top of the molten-metal bath, pulsing the injection of gas in the gas-lift-pump arrangement, alternately raising and lowering the treatment vessel and/or alternately raising and lowering the receptacle.

Since the gas which is injected in the form of fine bubbles in the gas-lift pump according to the present invention, forms a protective atmosphere upon separation above the molten metal in the treatment vessel, I prefer to make use of inert or reducing gases or mixtures thereof for the treatment. A typical inert gas for the purposes of the present invention is argon, while a suitable reducing gas may be a mixture of carbon monoxide and hydrogen. Mixtures of inert and reducing gases may also be used. Of course, it is possible to treat the molten metal with a reactive gas simultaneously if desired. It will be apparent that the major advantage of the present invention is that it allows a treatment of the molten metal in the bath free from entrainment of slag and contamination thereby, while permitting the slag layer to overlie the molten metal of the principal bath. Furthermore, the treatment may be effected at any given time with a relatively small quantity of molten metal so that, if it is necessary to avoid a fall in temperature of the treated metal, the additional heat applied to the latter during treatment may be minimal.

According to another feature of the invention, the treatment vessel with its descending tubes is inserted into the receptacle containing the bath to be treated, the tubes penetrating below and through the slag layer and being so provided as to prevent the introduction of slag into these tubes. More particularly, the mouth of the tubes may be covered with consumable members or may be maintained under pressure to exclude the introduction of slag as the vessel is lowered into the receptacle. The circulation of the treated metal free from slag improves the homogeneity of distribution of the treatment agent throughout the body of the melt and eliminates the need for mechanical agitators. The interaction of the treating agent with the circulated portion of the melt, moreover, provides a constantly renewed surface contact between the additive into the molten metal. In addition, the treatment portion of the metl is returned to the body of the latter well within the interior and without interference or with the slag.

Substantially any of the metallurgical additives introduced into the steel melt or a cast-iron melt may be used according to the invention and I may mention carbon, alloying ingredients such as nickel, chromium, cobalt, manganese, tungsten, and reactive ingredients such as aluminum, manganese and compounds thereof. The additives may be applied in powder or granular form, or even as consumable electrodes which may penetrate into the treated portion of the melt and are decomposed by the passage of an electric current therethrough. The electroheating afforded in this manner may supply the sole additional heat required at the treatment vessel. While, in general, the gas/lift-pump arrangement suffices to control the flow of molten metal through the treatment vessel and no other flow-control means is required, e.g., at the return pump, I may provide an electromagnetic or induction apparatus to increase the circulating rate or augment the gas lift.

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 a metallurgical treatment apparatus according to the invention;

FIG. **2** is a vertical cross-sectional view similar to FIG. **1**, but illustrating another embodiment of the invention;

FIG. **3** is an enlarged axial cross-sectional view representing a detail of a tube of FIG. **1** or FIG. **2** as it is introduced into the molten-metal bath;

FIG. **4** is a fragmentary, axial, cross-sectional view showing another upright tube according to the invention;

FIG. **5** is a diagrammaric cross-section illustrating other features of the invention;

FIG. **6** is a fragmentary cross-sectional view showing still another feature of the invention; and

FIG. **7** is a somewhat perspective view showing the gas-injector of a gas-lift pump according to the invention.

SPECIFIC DESCRIPTION

In FIG. **1** of the drawing, I have shown a ladle or other metal-bath receptacle **5** containing a bath **11** of molten metal, e.g. steel or cast iron, which is to be treated. The main bath of molten metal is overlain by a slag or dross layer **12** which generally interferes with the introduction of additives to the melt from above in conventional systems.

According to the present invention, there is provided a treatment vessel represented generally at **1** and comprising an upwardly open cell **1'**, the bottom **1''** of which is located below the level **12'** of the molten substances within the receptacle **5** so that loss of heat is low. The treatment vessel **1** is provided with two upright tubes **2** and **3** which depend from the cell **1'** in spaced-apart parallel relationship, the mouth **3'** of tube **3** terminating above the mouth **2'** of tube **2** by a distance D ensuring the circulation of a portion of molten metal as well as distribution thereof is represented by the arrows.

The riser tube **2** is located directly above and registers with an injector **4** of gas under pressure, the injector being constituted as a hollow ceramic body provided with closely spaced apertures from which small bubbles of gas are dispensed upwardly to form an emulsion rising in tube **2** and separating in the cell **1'** into a gas phase **4'** and the molten metal **11'**. Since the vessel **1** is open to the atmosphere, the gas is employed for this purpose, is preferably any inert or reducing gas. As the molten metal **11'** separates from the phase, the density of the metal stream increases and the molten metal descends in tube **3**, as shown by the arrows. The treatment agent can be cast directly onto the surface of the metal **11'** within the vessel **1**, e.g., from a hopper **9**, in accordance with conventional techniques.

To enable the vessel **1** to be lowered through the slag layer **12** without contamination of the tubes, the lower end of each tube, e.g., as shown for the tube **102** in FIG. **3**, is provided with a consumable cap **120** of sheet metal or cardboard. When the tube **102** is thrust rapidly downwardly through the slag layer **112** into the molten metal layer **111** in the direction of arrow **121**, the cover prevents the slag from penetrating into the tube but rapidly melts away or is burned up to leave the mouth of the tube free for treatment.

The low density of the gas/metal emulsion within tube **2** produces an upward or buoyancy force causing the molten metal to rise into the vessel **1** to a level determined by the gas-flow rate and the cross-sections of tubes **2** and **3**, this level being slightly above the level of the bath **11, 12** when both the surface of the bath and the surface of the melt within vessel **1** are at atmospheric pressure. The treated metal, whose density is greater than that of the emulsion rising in column **2**, returns to the bath through tube **3** and is distributed within the latter.

In place of the perforated ceramic body **4**, which is carried by a tube **7** immersed from above into the bath, the gas bubbles may be injected by a body **104** consisting of a bundle of tubes **104***a* supplied by a manifold **104***b* as illustrated in FIG. **7**. The injector **4** is spaced below the mouth of tube **2** and may be inserted in the bath as described in FIG. **1** or permanently mounted in the floor of the receptacle (FIG. **2**) or can be formed directly on the vessel **1**.

In the system of FIG. **2**, the treatment vessel **201** is shown to comprise a cell **201'** disposed well above the level of the slag layer **212** and the molten metal **211** within the receptacle **205**. In this case, the receptacle **205** is closed hermetically by a cover **206** and is charged, above the level of the melt therein, via a duct **208**, with a gas under pressure, causing the molten metal **211'** to ride up into the cell **201'** and enabling the molten metal **211'** to ride up into the cell **201'** and enabling the molten metal to be supported there. The upper surface of the treated portion of the metal is exposed to atmospheric pressure. In this embodiment as well, as gas injector **204** produces an emulsion of the molten metal which rises in tube **202**, separates in cell **201'** and gives rise to a more dense stream which descends in tube **203**. A duct **207** supplies gas to the injector **204**. In the embodiment of FIG. **2**, I may increase the flow rate by the electromotor effect of an electromagnetic pump, here shown as an induction coil **223** surrounding the tube **202** and energized by an induction-current source **224**. The electromagnetic pump in this case works together with the gas-lift pump to circulate the molten metal. It should be noted that the pressurization of the surface of the melt **211, 212** allows adjustment of the quantity of metal maintained within the cell **201'** without regulating the effective cross-section of the tube **203** and independent of the circulating rate of the gas-lift pump.

The homogeneity of the distribution of the circulating stream of metal into the body of the melt and the homogenization of the molten metal within the treatment vessel **1, 201,** can be increased by varying the level of the bath in the receptable **5, 205** and/or in the treatment vessel **1, 201**. This variation in level, i.e., rise and drop in the surface, can be produced in the system of FIG. **2** by pulsing a valve **225** between the pressure source **226** of duct **208** and the receptacle **205**. A pulser, e.g., a timer **227** is employed to trigger the valve. The treatment agent may be introduced via the dosing and feed device **209** while the burner **210** is provided to heat the circulating stream of molten metal within the vessel **201**.

Independently of the pressurization of the bath **211, 212,** or conjointly therewith, the molten-metal level may be varied by modifying the rate of flow of gas to the injector. In FIG. **5**, for example, there is shown an arrangement in which the injector **304** is supplied with the inert or reducing gas by a pump **330** through a valve **331** which is pulsed by a timer or pulser **332**. I prefer to use a fairly rapid pulse frequency to increase the stirring and agitation of the melt within the ladle **5**. The pule period may range from 0.1 second to 1 minute, the gas "on" time being generally between **50** and **90%** of the pulse period. The pulsing and/or gas injection to circulate the molten metal is, in any event, maintained subsequent to termination of the addition of the alloying ingredients or reagents, for a period sufficient to ensure complete distribution of the treated metal within the main body of the melt. This latter period should be sufficient for at least one complete circulation of molten metal within the ladle. Hence, if the ladle holds 25 tons of molten metal and the latter is circulated at the rate of 1 tone per minute, the circulation should be maintained for a minimum of 25 minutes after termination of the treatment or where the circulation rate is 25 tons/minute, the post-treatment period can be about 1 minute.

As is also apparent from FIG. **5**, the surface of the molten metal **311'** within the treatment vessel **301** can be covered with a protective slag layer **312'** which remains in place during circulation. This slag, which may be an electroslag remelting flux, can conduct electric current between a pair of electrodes **333** conducted to an electric current source **344** to supply the additional heat necessary for electroslag heating this temperature may be well above the melt temperature. When an aparopriate seal is provided between the cover **306** and the vessel **301**, the level of the melt in the latter and in the receptacle **305** may be adjusted by raising or lowering the vessel **301**, e.g., via a motor **335** at the frequency produced by the pulser **332**. Furthermore, the ladle **305** itself may be suspended from a winch arrangement **336** which is likewise pulsed as may be the gas supply **308** to the receptacle **305**. The additives may be provided, moreover, in the form of granules or powder blown from a hopper **309** into the bath through the injector **304** at the base of the riser tube **302**. In this case, the additives are supplied in suspension in the gas of the pumping arrangement. As can be seen from FIG. **6**, another method of incorporating the additive into the molten metal **411'** within the vessel **401** is to constitute such material as consumable electrodes **409** and decompose these electrodes while heating the circulating stream. Induction heating can be provided, e.g., at the same time as electromagnetic pumping, as described in connection with FIG. **4**, or resistive heating elements may be incorporated in the vessel **1, 201, 301,** etc. The heating of the treated metal stream often suffices in the case of steel melts so that reheating of the latter may not be necessary. It should be noted, moreover, that the introduction of substances with a low boiling point or sensitivity to oxidation may require the closing of the treatment vessel to prevent loss of treatment agent or to control noxious fumes which may be generated. This is the case when magnesium is to be incorporated in a melt in order to produce a metal containing spheroidal graphite or where lead or sulfur are to be introduced.

I claim:

1. An apparatus for the treatment of molten metal, comprising:

a receptacle for a unitary bath of molten metal overlain by a layer of slag or dross;

a treatment vessel comprising a treatment cell of a relatively large horizontal cross-section adapted to receive a quantity of molten metal to be treated, and a pair of upright tubes of horizontal cross-sections smaller than that of said cell leading downwardly from said cell and terminating below said layer in said bath, both said tubes communicating with the interior of said cell and being immersed in said bath at spaced-apart locations within said receptacle;

means for injecting fine bubbles of a gas into the molten metal below one of said tubes to induce a flow of molten metal upwardly through said one of said tubes, through said cell and downwardly through the other of said tubes whereby molten metal may be treated in said cell without intervention of said layer;

means for treating the molten metal in said cell, said one of said tubes having a mouth opening into said bath at a location below the mouth of said other tube in said bath, said cell having a floor sloping downwardly from said one of said tubes toward said other of said tubes, said vessel being open to the atmosphere; and

means for pressurizing the gas above said layer to support molten metal in said tubes and said vessel.

2. The apparatus defined in claim 1, further comprising an electromagnetic pump for augmenting the circulation of molten metal through said vessel.

3. The apparatus defined in claim 1, further comprising means for heating the molten metal in said vessel.

4. The apparatus defined in claim 1, further comprising means for pulsing the flow rate of gas injected into said molten metal at a rapid frequency.

5. The apparatus defined in claim 1, further comprising means for intermittently varying the molten metal level in one of said cell and said receptacle.

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