

[54] METHOD AND APPARATUS FOR DETERMINING THE DEPTH OF SUBMERGED LANCES AND THE LIKE

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[58] Field of Search 73/302, 301; 266/34 L, 34 LM

[56] References Cited

UNITED STATES PATENTS

2,427,690	9/1947	Peterson	73/302
3,130,252	4/1964	Metz	266/34 L
2,213,485	9/1940	Conley	73/301
1,359,014	11/1920	Alexander	73/302

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[57]

ABSTRACT

Method and apparatus for determining the depth of a submerged article with the use of a pressure probe, and in particular the depth of a submerged lance used to deliver a gaseous reaction agent to a metallic bath. The probe is adjacent or within a conduit delivering the gaseous reaction agent to the bath. The pressure at the probe is compared with that above the bath, the difference between the two pressures being proportional to depth. The system can be used in installations where the pressure at the surface of the bath is atmospheric pressure or in cases where the space above the surface is evacuated as in vacuum decarburization of stainless steels and the like. In the former case, the probe is usually pressurized to prevent clogging of the tip. In the latter case, the ambient pressure at the tip of the probe is compared with that above the surface of the bath and the probe pulse-pressurized periodically to prevent clogging.

3 Claims, 6 Drawing Figures

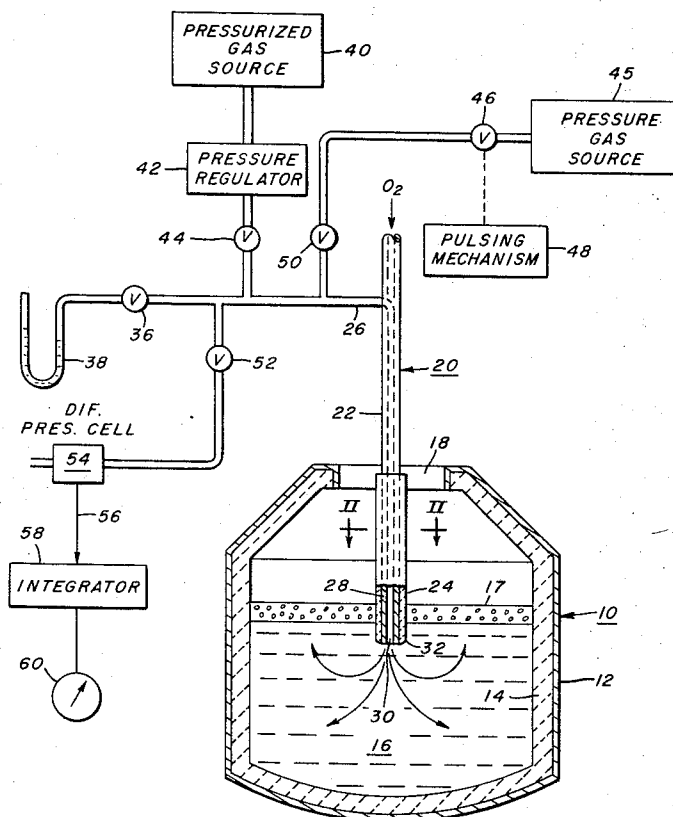


FIG. 1.

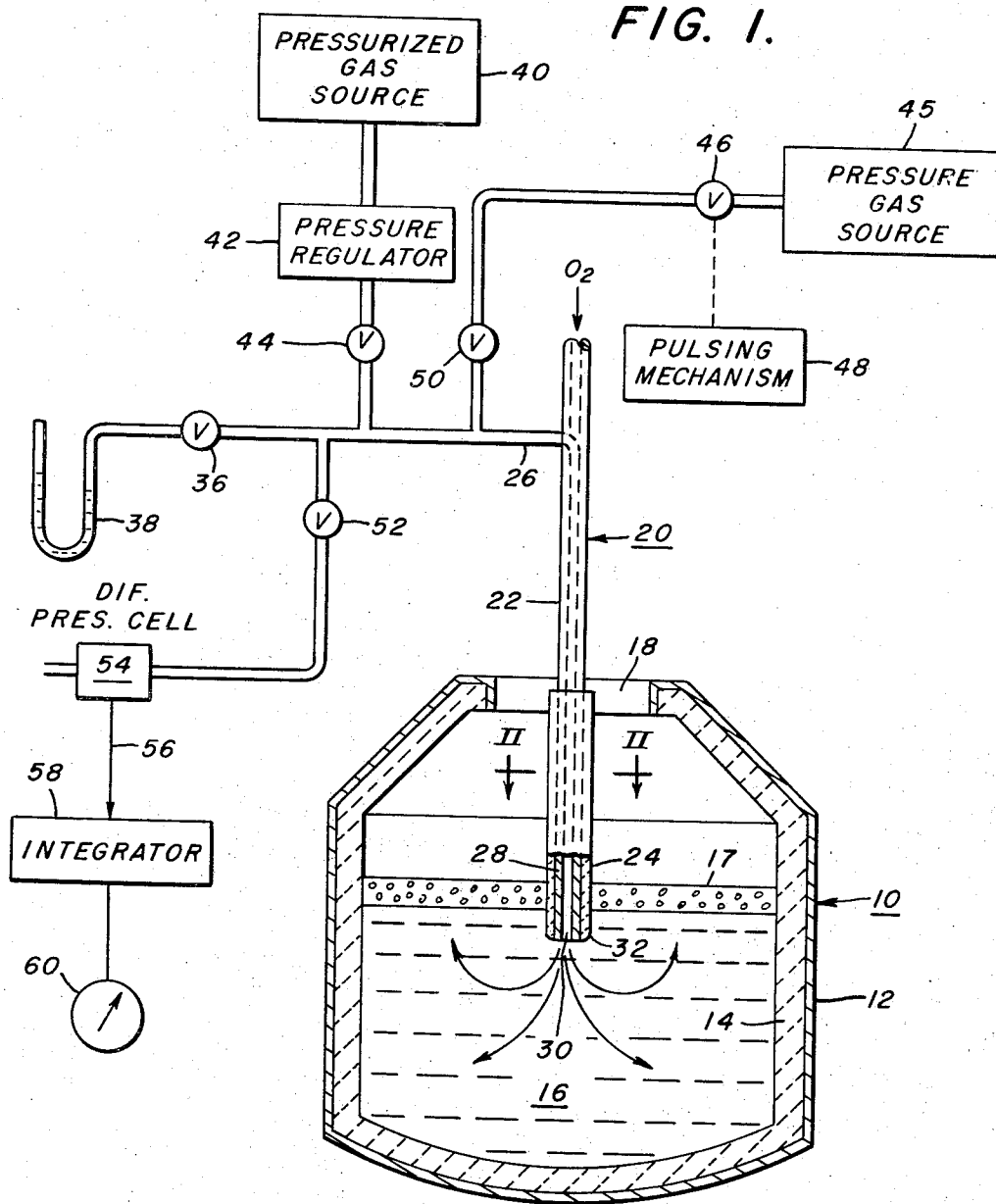


FIG. 2.

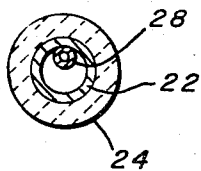


FIG. 3.

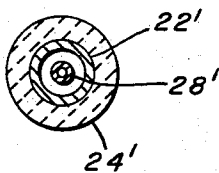


FIG. 4.

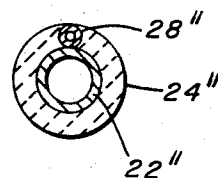


FIG. 6.

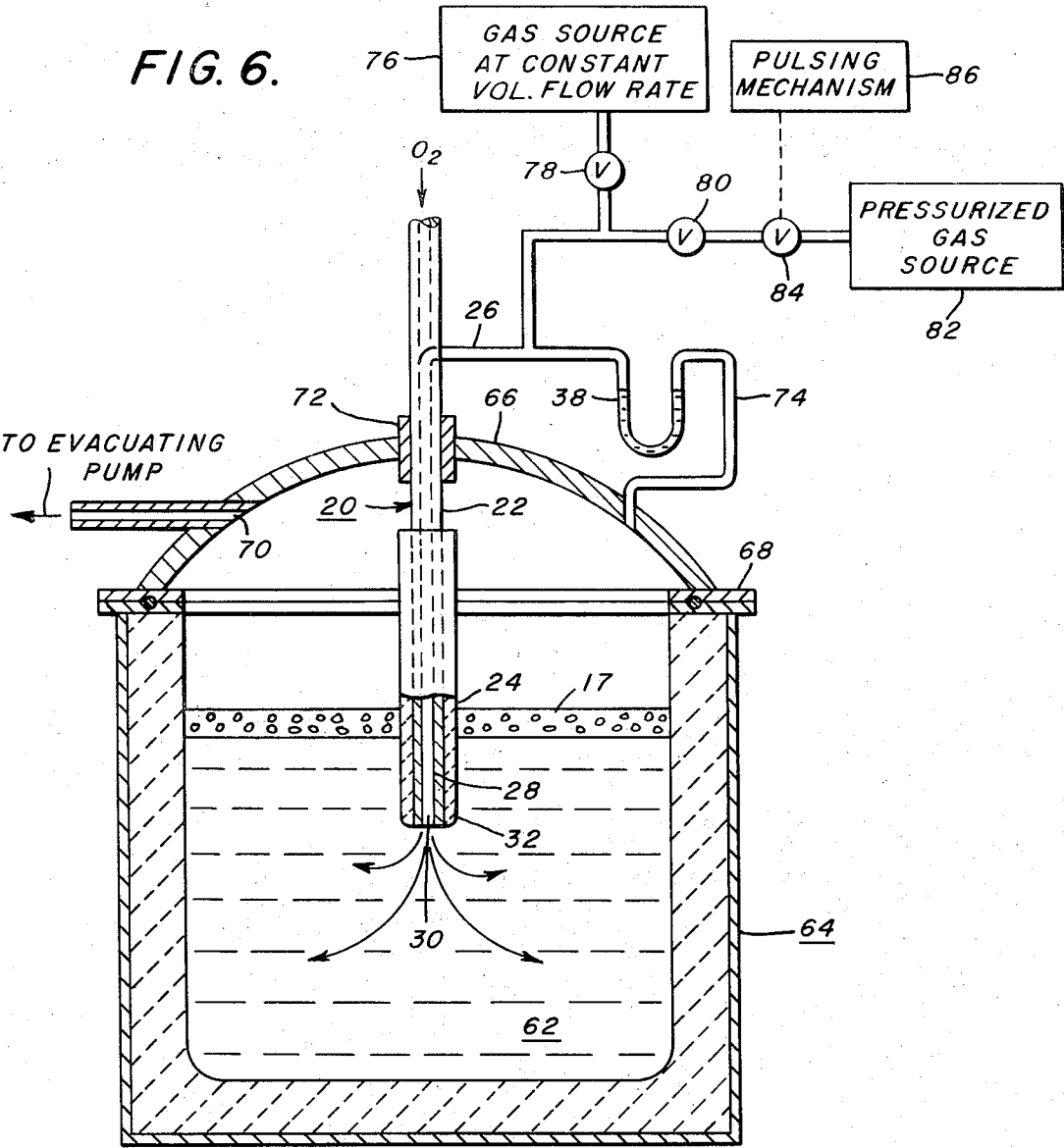
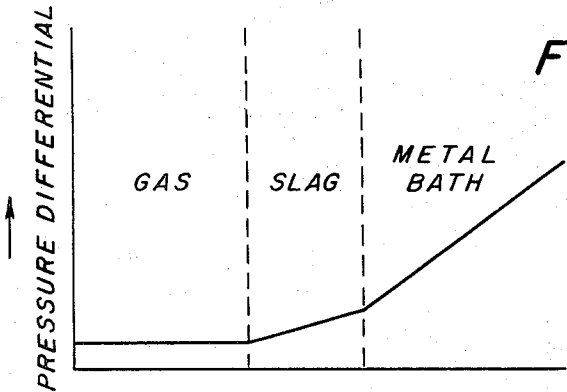


FIG. 5.



METHOD AND APPARATUS FOR DETERMINING THE DEPTH OF SUBMERGED LANCES AND THE LIKE

BACKGROUND OF THE INVENTION

As is known, many metallurgical processes require the introduction of a gas onto the surface or within a volume of molten metal for the purpose of reacting impurity elements in the melt with the gas phase to form volatile reaction products. Desiliconization, degassing and decarburization are some of the processes that employ such a technique. In the basic oxygen process (BOF), the refining oxygen is introduced in the form of a jet issuing from a lance positioned above the surface of the bath. The interaction of the oxygen jet with the liquid metal results in the oxidation of carbon and other elements capable of chemically reacting with the oxidizing gas. However, blowing oxygen or another gaseous reaction agent onto the surface of a molten metal bath results in considerable splashing and slopping of liquid in the vessel and undesirable oxidation of useful alloying elements.

For minimum splashing, the lance tip of a gas injection lance should be immersed in the metal bath. Furthermore, the depth of immersion is critical. When the lance is one inch or more above the bath or is immersed 10 inches or more, splashing and slopping of the metal bath are noticeably increased. Furthermore, when the lance tip is immersed more than six inches below the liquid level of the metal bath, severe erosion of the lance occurs. The desired depth of the lance tip is preferably no greater than two inches.

SUMMARY OF THE INVENTION

In accordance with the present invention, a method and apparatus are provided for determining the depth of the bottom of a gas lance in a molten metal bath by providing a conduit or probe having a tip terminating at the bottom of the lance and by measuring the pressure difference between that in the probe and the pressure above the surface of the molten metal bath. Specifically, there is provided a conduit having a lower tip essentially coincident with the bottom of a gas-issuing lance in a molten metal bath and manometer means for comparing the pressure in the conduit with the pressure of the atmosphere above the surface of the bath whereby the depth of the lower tip and the bottom of the lance can be determined from a consideration of the difference in pressures in the conduit and above the surface of the bath. The pressure differential is the true measure of the depth of immersion of the bottom of the lance since the pressure within the aforesaid conduit adjacent the lance varies as a function of the hydrostatic pressure of the molten metal at the tip of the conduit or probe.

It may happen that the tip of the probe, while the lance is immersed, will become clogged because of solidification of molten metal in the tip. This can be alleviated by pressurizing the probe itself; and this is entirely acceptable in a case where the gas above the level of the molten metal bath is air at atmospheric pressure. However, in a vacuum decarburization process wherein the space above the molten metal bath is evacuated, it has been found that the pressure within the evacuated space will vary, possibly due to the fact that there is an uneven evolution of gases from the melt. For this reason, it is necessary to pressurize the probe at a constant

volumetric flow rate or otherwise pulse-pressurize the probe periodically in order to prevent clogging of the probe tip. While the depth reading will be disrupted during the pulse-pressurization, the system will immediately return to steady-state conditions after each pulse in order that the depth can be determined.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification, and in which:

FIG. 1 is a schematic illustration of one embodiment of the invention wherein the gas above the surface of a metallic bath is at atmospheric pressure;

FIG. 2 is a cross-sectional view of the lance shown in FIG. 1, taken substantially along line II—II of FIG. 1;

FIGS. 3 and 4 are cross-sectional views, similar to that of FIG. 2, showing alternative embodiments of the lance construction of the invention;

FIG. 5 is a plot showing the manner in which pressure differential varies as depth increases; and

FIG. 6 is a schematic illustration of an embodiment of the invention as applied to vacuum decarburization apparatus.

With reference now to the drawings, and particularly to FIG. 1, there is shown a reaction vessel 10 comprising an outer metallic lining 12 provided on its interior surface with a refractory lining 14. Within the vessel 10 is a bath 16 of molten metal, such as steel, covered with a slag layer 17. The vessel 10 has an open upper end 18 which receives a gas-delivery lance 20. As shown, the lance 20 comprises a metallic pipe or tube 22, the lower portion of which is surrounded by a refractory jacket 24. Passing through the wall of the pipe 22 is a second conduit 26 connected to or integral with a probe 28 which extends downwardly through the pipe 22 and has a lower tip 30 coplanar with and terminating at the bottom 32 of the lance 20. If the lance 20 is consumable, the probe 28 should be made of similar material as the consuming portion so that the probe consumes at about the same rate. If the lance is non-consumable, the probe should also be non-consumable. Normally, both the pipe 22 and the probe 28 will be formed from steel. It has been found from actual trials that the probe is preferably positioned adjacent and in abutment with the inside wall of the pipe 22 as shown in FIG. 2. With this arrangement, the pipe 22 will burn back or be consumed at about the same rate as the probe 28, thereby insuring that the bottom or tip of the probe 28 will be coplanar with the bottom of the lance 20 at all times.

Alternative embodiments of the lance 20, while not preferred, are shown in FIGS. 3 and 4. In FIG. 3, the probe 28' is concentric with the pipe 22' which is surrounded by a refractory jacket 24'. In FIG. 4, the probe 28'' is imbedded within the refractory jacket 24'' surrounding the main gas delivery pipe 22''. The arrangements of FIGS. 3 and 4, while workable, are not considered to be as reliable as the arrangement shown in FIG. 2 for insuring that the probe will burn back or be consumed at the same rate as the main gas delivery conduit, such as pipe 22.

The upper end of the main gas delivery pipe 22 is connected to a source of gas under pressure. For purposes of illustration, it will be assumed that this gas is oxygen which is used to burn out carbon and other impurities within the melt 16. For maximum effective-

ness, the lance tip or bottom 32 should be immersed within the molten metal bath 16; however the depth of immersion is critical. Rapid erosion of the lance occurs when the tip is six inches or more beneath the level of the bath. Minimum splashing and slopping occur without incurring excessive erosion when the lance is no more than about two inches beneath the surface.

It is, of course, necessary to provide some means for determining when the bottom of the lance is at the desired depth; and this is complicated by the fact that the lance will erode as mentioned above. Accordingly, the probe 28 within the pipe 22 is connected through conduit 26 and valve 36 to one side of a manometer 38. The other side of the manometer 38 is open to the atmosphere. Consequently, it is at the same pressure as the air above the surface of the molten metal bath 16.

Notwithstanding the fact that a violent chemical reaction occurs beneath the bottom of the lance 20 when oxygen is delivered into the molten metal bath 16, and notwithstanding the fact that the pressure at the lower end of the probe 28 is that of the oxygen passing through the pipe 22, it has been found that the difference between the pressure at the probe tip 30 and atmospheric pressure is an indication of the depth of the bottom of the lance 20. Thus, by observing the differential levels in the manometer 38, the depth of the bottom of the lance can be determined.

In the preceding discussion, it was assumed that the probe 28 was not connected to an external source of pressure and that the pressure within the probe was that at the bottom of the pipe 22. When the probe is not pressurized in this way, it is possible for molten metal to cling to the probe tip 30 and possibly solidify, in which case the probe will be blocked. In order to prevent this condition, the probe itself can be pressurized. Thus, a pressurized gas source 40 can be connected through a pressure regulator 42 and valve 44 to the conduit 26. The gas from source 40 is preferably an inert gas; however air or even oxygen can be used. With the probe pressurized, the differential pressure reading observed with the manometer 38 will be greater than in the case where the probe is not pressurized; however the pressure differential is still proportional to the depth of the bottom of the lance; and the manometer 38 can be calibrated to show this depth.

Instead of constantly pressurizing the probe, it is also possible to pulse-pressurize it. In this latter case, a pressurized gas source 45 is connected through a valve 46 to the probe 28, the valve 46 being intermittently opened and closed by means of a pulsing mechanism 48. The pulsed gas can then be made to flow into the conduit 26 through valve 50, with valve 44 closed and valve 36 open. In this case, the pressure differential observed on the manometer 38 will be that between the pressure within the pipe 22 and atmospheric pressure, except when a pulse of pressurized gas is introduced via valve 50. A pulse will be applied to the probe, for example, only once every minute such that a reading on the manometer 38 between pulses can be determined.

Instead of using the manometer 38, it is possible to close valve 36 and open valve 52, in which case the conduit 26 is connected to a differential pressure cell 54 which produces an output signal on lead 56 proportional to the difference in pressure between that in probe 28 and atmospheric pressure. As will be understood, splashing and slopping of the molten metal bath will cause a variation in pressure within the probe 28.

This results in a more or less continual movement of the mercury in the manometer 38, assuming that valve 36 is open. However, even with this continual movement, it is possible to obtain a positive indication of the immersed depth of the lance by obtaining an average scale reading on the manometer. This average scale reading can be obtained automatically by applying the output of the differential pressure cell 54 to an integrator 58, the output of the integrator 58 being fed to a meter 60 which indicates depth directly. In many cases, it is desirable to use both the manometer and the electrical differential pressure cell. The differential pressure cell can be used to generate an electrical signal whose average magnitude represents depth as indicated on the meter 60, for example, while the movement of the mercury in the manometer 38 acts as an excellent indicator of the splashing and slopping of the bath during injection. Since the manometer 38 and differential pressure cell can be used interchangeably, the term "manometer means" as used in the claims herein means either.

A plot of pressure differential versus depth immersion is shown in FIG. 5. Thus, when the end of the lance is in the gaseous atmosphere above the level of the molten metal bath, the pressure differential is relatively low. When the bottom of the lance enters and passes through the slag layer 17, the pressure increases along a straight line. Finally, when the tip or bottom of the lance is immersed in the metal bath, the pressure differential rises linearly as depth increases, but at a much higher rate than when passing through slag, which is of lower density.

With reference now to FIG. 6, another embodiment of the invention is shown as applied to vacuum decarburization. A molten metal bath 62 is again positioned within a refractory-lined vessel 64. However, in this case, the vessel 64 is provided with a dome-shaped cover 66 connected to the vessel 64 through an annular sealing arrangement 68. The dome-shaped cover 66, in turn, is connected through conduit 70 to an evacuating pump, not shown, such that the space above the liquid metal bath 62 will be evacuated. Vacuum decarburization of this type is employed in certain cases, particularly with stainless steels and the like, since the activity of carbon (i.e., the rate at which it combines with oxygen to form carbon monoxide) is inversely proportional to the pressure above the bath. Hence, by evacuating the area above the bath, the refining oxygen passing through the lance 20 preferentially combines with carbon rather than with chromium or other desired alloying constituents.

The lance in the embodiment of FIG. 6 is essentially the same as that shown in FIG. 1 and, accordingly, elements of FIG. 6 which correspond to those of FIG. 1 are identified by like reference numerals. In this case, however, the pipe 22 passes upwardly through a seal 72 in the dome-shaped cover 66. The conduit 26 is again connected to one end of a manometer 38; however in this case the other side of the manometer is connected through conduit 74 to the evacuated space above the bath 62.

Unlike atmospheric pressure, the pressure above the bath 62 in the embodiment of FIG. 6 will vary due to the evolution of gases and/or splashing and slopping of the metal bath. If the probe 28 is to be constantly pressurized, therefore, it will be necessary to supply it with a source of gas 76 at a constant volumetric flow rate.

This source of gas can be connected to conduit 26, for example, through valve 78. Alternatively, it is possible to use the pulsing technique explained above in connection with FIG. 1. In this latter case, valve 80 will be open and valve 78 closed. Pressurized gas from gas source 82 then passes through pulsing valve 84 connected to pulsing mechanism 86 and thence through valve 80 to the conduit 26. Again, the probe need be pulsed only about once every minute. Thus, an average reading of the manometer 38 can be derived to determine the depth of the lance. Alternatively, the differential pressure cell 54 of FIG. 1 can be used together with an averaging or integrating circuit in a direct read-out meter, such as meter 60.

Although the invention has been shown in connection with certain specific embodiments, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

We claim as our invention:

1. In combination, a gas-issuing lance immersed in a molten metal bath, means for forcing a gas through said lance and into the molten metal bath, a conduit having a lower tip essentially coincident with the bottom of said lance when immersed in a molten metal bath and subjected to the pressure of the gas passing through the lance at the tip of the lance when it is so immersed, a source of gas under pressure, means for intermittently connecting said source of gas under pressure to said conduit whereby the conduit is continually pulse-pressurized, and manometer means for comparing the pressure in said conduit with the pressure of gas above the surface of said bath while said conduit is continually pulse-pressurized whereby the depth of said lower tip and the bottom of said lance can be determined from a consideration of the difference in pressures in the conduit and above the surface of the bath.

2. In combination, a gas-issuing lance immersed in a

molten metal bath, means for forcing a gas through said lance and into the molten metal bath, a conduit having a lower tip essentially coincident with the bottom of said lance when immersed in a molten metal bath and subjected to the pressure of the gas passing through the lance at the tip of the lance when it is so immersed, manometer means for comparing the pressure in said conduit with the pressure of gas above the surface of said bath whereby the depth of said lower tip and the bottom of said lance can be determined from a consideration of the difference in pressures in the conduit and above the surface of the bath, said manometer means including a differential pressure cell for producing an electrical output signal proportional to the difference in pressure between that in said conduit and the pressure above said surface of the bath, means for integrating said electrical signal, and meter means connected to said integrating means for indicating said difference in pressure.

3. In combination, a gas-issuing lance immersed in a molten metal bath, means for forcing a gas through said lance and into the molten metal bath, a conduit having a lower tip essentially coincident with the bottom of said lance when immersed in a molten metal bath and subjected to the pressure of the gas passing through the lance at the tip of the lance when it is so immersed, said lance and said conduit both being consumable in the molten metal bath, the conduit being positioned adjacent and in abutment with the inside wall of said lance whereby the conduit and lance will be consumed in the molten metal bath at substantially the same rate, and manometer means for comparing the pressure in said conduit with the pressure of gas above the surface of said bath whereby the depth of said lower tip and the bottom of said lance can be determined from a consideration of the difference in pressures in the conduit and above the surface of the bath.

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