Jan. 1, 1963 C. W. FINKL 3,071,458

METHOD OF ADDING CHARGE MATERIAL TO MOLTEN METAL UNDER VACUUM

Filed May 9, 1960 2 Sheets-Sheet 1

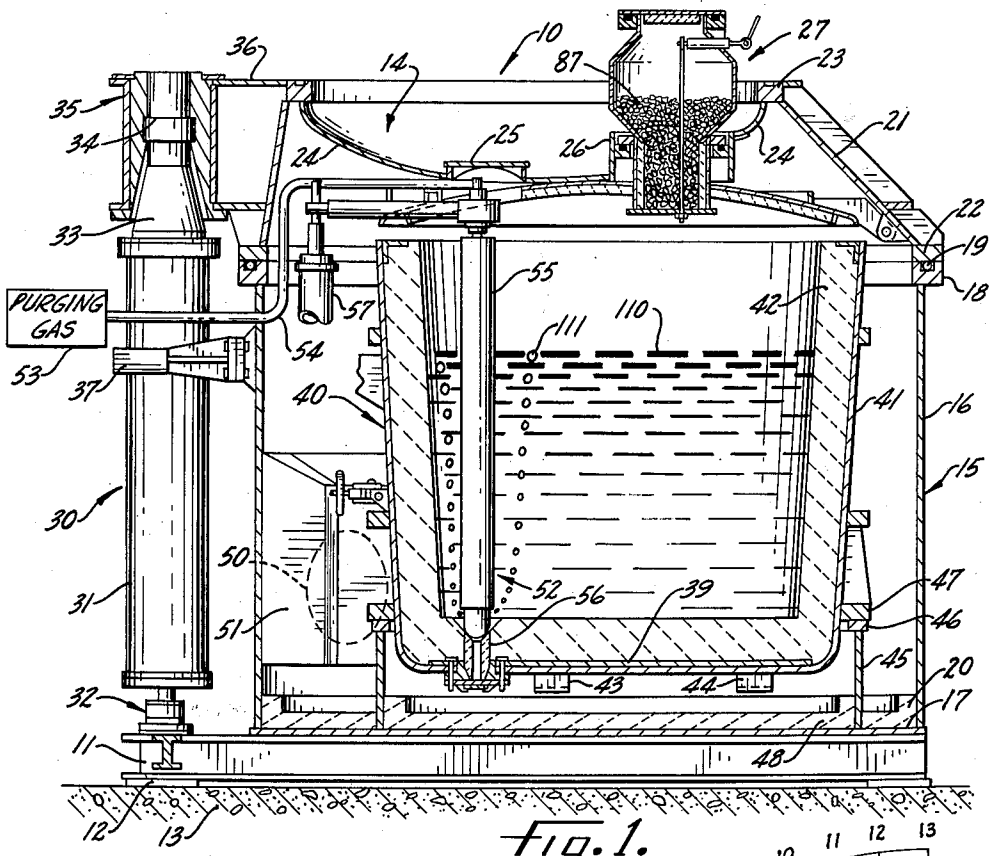

Fig. 1.

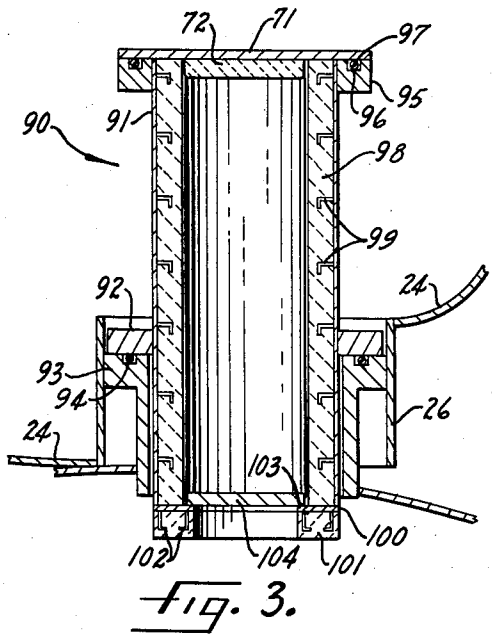

Fig. 3.

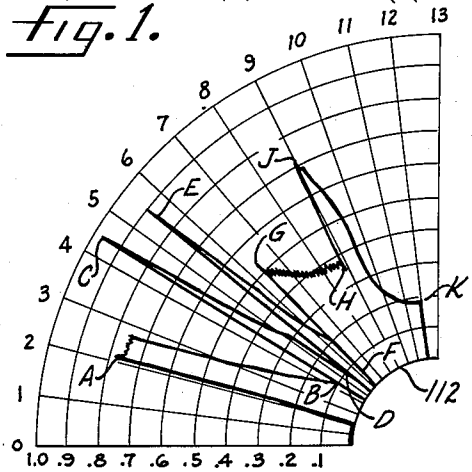

Fig. 4.

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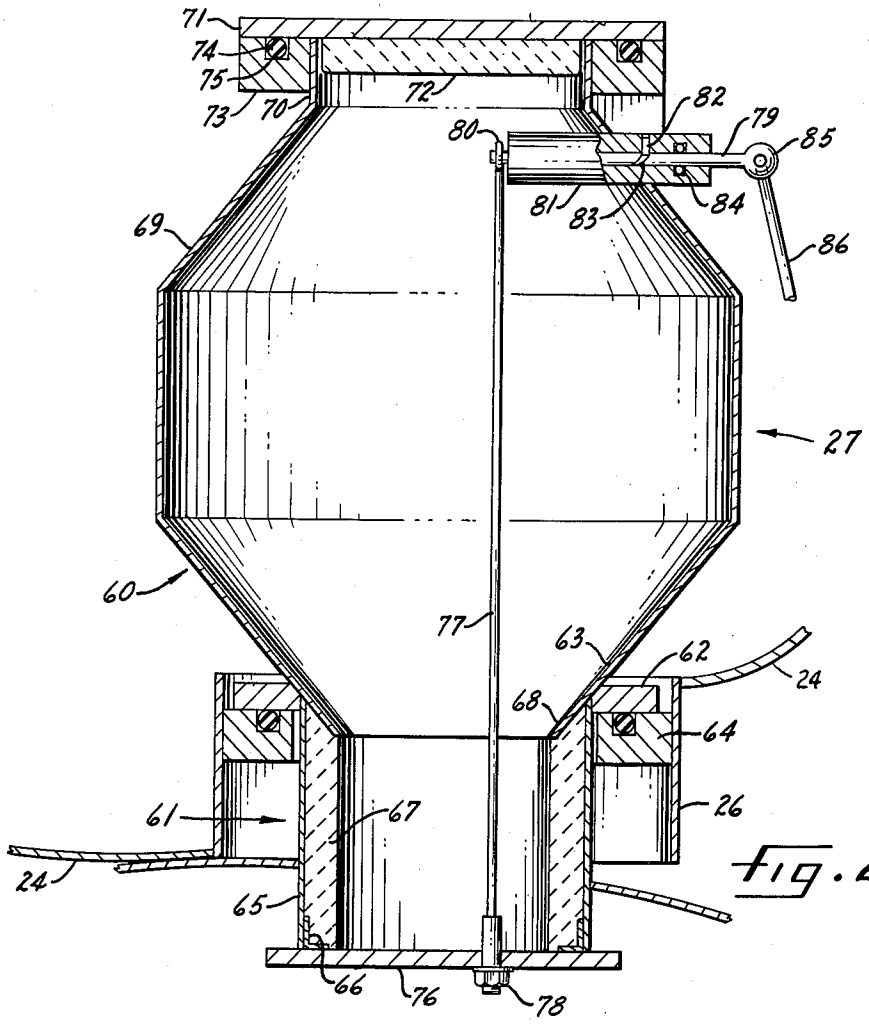

Fig. 2.

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3,071,458

METHOD OF ADDING CHARGE MATERIAL TO MOLTEN METAL UNDER VACUUM

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This invention relates generally to methods and apparatus for adding alloys to molten metal under vacuum, and specifically to a method and apparatus whereby the time of admission of the alloys to the molten metal can be closely controlled.

More and more steel is being vacuum degassed as steel consumers realize the many advantages such steel possesses. Among these advantages are reduction of hydrogen embrittlement caused by the dissolved hydrogen and fewer oxide inclusions resulting in a cleaner steel with better machinability.

Recently a new method of vacuum degassing has been developed in which a purging gas is bubbled upwardly through a melt while the melt is exposed to a vacuum. Exceptionally good results have been attained from this procedure. For a more complete description of the advantages and means whereby heats of molten metal may be purged under vacuum, reference is made to co-pending application Serial No. 777,664 assigned to the assignee of this application.

Adding alloys to melts before conventional vacuum degassing treatments has presented serious problems because of the inhibitory effect of some alloys on the degassing. This problem has even persisted to some extent in the simultaneous vacuum-purging process. Aluminum for example is desired in many alloy steels because of its ability to control grain structure. It is, however, a highly deoxidizing alloy so that degassing is markedly inhibited if it is added to the melt too soon in the vacuum degassing operation. This follows because the aluminum combines avidly with the oxygen in the melt to form alumina and this combined oxygen cannot, of course, be removed as readily as when it is simply dissolved in steel. Other alloys such as vanadium may be added as a substitute for aluminum to refine the grain, but the results are not substantially better than those obtained with the use of aluminum and most of the other substitute alloys, including vanadium, are substantially more costly than aluminum.

Another problem that has bothered alloy steel makers who utilize the vacuum degassing process is the inhibiting effect that the presence of slag has on the degassing operation. It is highly desirable that the surface of the melt be covered with a layer of slag between the time the melt is transferred from the vacuum treating chamber to the teeming station, and during teeming. The slag acts as a blanket which substantially reduces temperature loss during this period, and of course the more fluid the steel, the better the casting.

Adding the slag to the melt at the start of the operation raises several difficulties. First and foremost the presence of the slag reduces the degassing effect because the slag itself has mass and must itself be degassed. In addition, it covers the surface of the melt so that the action of the vacuum on the surface is considerably reduced. Secondly, the slag attacks the ladle refractory and the stopper rod, and the longer the slag is in contact with these refractories the greater will be the erosion of these parts. Thirdly, the slag itself liberates a considerable amount of gas which is evolved under vacuum. This excess gas may overload the ejectors at the commencement of operations with attendant disastrous effects. Fourthly, the presence of slag during the entire operation creates a substantial amount of dust which must be cleaned up eventually to insure proper functioning of the apparatus and to maintain a clean working area. Finally, the slag may create an explosion hazard.

Additions of lime or insulating covers to the melt at the end of the degassing operation reduces the rate of heat loss while teeming and transferring from the degassing station to the teeming station but its presence at this point may considerably reduce the overall effectiveness of the degassing operation. The slag or insulation may contain a substantial quantity of moisture which disassociates into hydrogen and oxygen upon contact with the melt and diffuses into the melt. The effect of the just completed degassing operation is thereby partially nullified to the extent these gases are dissolved in the melt.

Another drawback with many present vacuum alloy addition systems is the fact that they are not automatic. To add alloys to a melt, the vacuum treatment must be interrupted while the alloy material is maneuvered into dumping position and the addition made. This results in an increase in the treatment time which results in an increased heat loss. An increased heat loss, of course, requires higher tapping temperatures which carries with it attendant disadvantages such as greater attack on furnace refractories. Perhaps even more important is the fact that since the furnace time is lengthened, production is reduced.

Accordingly, the primary object of this invention is to provide a method of adding charge materials including alloys and slag forming materials to molten metal at a preselected time in a vacuum degassing cycle to thereby realize the full advantages of vacuum degassing and obtain a cleaner steel having a high recovery.

Yet another object is to provide a method of adding highly deoxidizing alloys such as silicon and aluminum to steel at a point in the vacuum degassing cycle of operations which will not inhibit degassing.

Yet another object is to provide a method of automatically adding slag forming material, such as burnt lime, toward the end of the vacuum degassing cycle to thereby reduce the overloading of the gas ejection system and to provide an insulating blanket which considerably reduces the heat loss subsequent to the degassing operation and during teeming.

Yet another object is to provide a method of adding alloys to heats of molten metal which is completely automatic in operation so that treatment time is not increased and heat loss over the whole cycle is kept at a minimum.

Another advantage is to provide a method of adding alloys to heats of molten metal in which the time of addition of the alloys to the heat can be controlled to the second.

Other objects and advantages will become apparent upon reading the following description.

The invention is illustrated more or less diagrammatically in the accompanying drawings, wherein:

FIGURE 1 is a sectional view, partly diagrammatic, with parts omitted for clarity of a combination vacuum and purging degassing apparatus illustrating the novel alloy addition system of the invention;

FIGURE 2 is a detailed view to an enlarged scale of the alloy addition container illustrated in FIGURE 1;

FIGURE 3 is a sectional view similar to FIGURE 2 of the modification of the invention; and

FIGURE 4 is a reproduction of a variable scale pressure-time chart showing the time of addition of slag and alloy to the melt.

Like reference numerals will be used to refer to like parts throughout the following description of the invention.

A combination vacuum and gas purging degassing setup is illustrated in FIGURE 1. The apparatus consists essentially of a vacuum chamber or tank indicated generally at **10** resting on any suitable support, such as the I-beams **11**, which in turn rest on bearing pads **12** secured to a suitable foundation **13**. The chamber is shown in this instance as composed of an upper vertically and horizontally movable section **14** and a lower stationary portion **15**. The lower, permanent portion **15** consists of a circular wall section **16** secured about its lower periphery to a base plate **17** which in turn rests upon the supporting beams **11**. The upper periphery of the tank wall terminates in a bearing ring **18** whose upper surface is recessed to receive a suitable O-ring seal **19**. An annular layer of refractory **20** overlies base plate **17** to protect it from excessive heat and spillage.

The upper or movable half of the vacuum chamber is a composite structure including a wall portion **21** formed roughly as a lop-sided frustum of a cone. The lower edge of cone **21** terminates in a bearing ring **22** which mates with and overlies the bearing ring **18** so that when the two rings are in engagement, the O-ring **19** forms an air-tight seal between the upper and lower sections of the chamber. The upper edge of cone **21** terminates in another bearing ring **23**. A downwardly dished cover plate **24** is welded at its upper edge to the lower inner edge of the upper bearing ring **23** to complete the vacuum chamber.

The downwardly dished cover includes a projection **25** which provides clearance for a stopper rod **52** and an aperture ring **26** which will be described in detail hereinafter.

A charge container is indicated generally at **27**. The container forms an air-tight seal with the aperture ring **26** and will be described in detail hereinafter.

The upper portion of the chamber is lifted by a lift and swing device indicated generally at **30**. This device consists essentially of a hydraulically actuated piston and cylinder assembly **31** secured to the crossbeams **11** by an anchoring structure indicated generally at **32**. A vertically reciprocable piston **33** travels between its lower retracted position, shown in FIGURE 1, to an upper operative position in which it abuts seat **34** of a collar member **35**. Collar member **35** in turn is connected to the cone wall section **21** and bearing ring **23** by a suitable arm **36**. The piston and cylinder assembly **31** is maintained vertically aligned by a yoke structure **37** secured to the exterior of the lower wall **16** by suitable bolts, not numbered. Any suitable mechanism may be utilized to swing the upper portion **14** horizontally once it has been elevated by piston and cylinder assembly **30**.

A ladle for treating molten metal is indicated generally at **40**. The ladle consists essentially of an outer metallic shell **41** and an inner layer of refractory material **42**. An extra reinforcing plate **39** is positioned across the bottom of the ladle. A plurality of feet **43**, **44**, are secured to the ladle bottom so that it may be rested upon any suitable supporting surface when not positioned within the vacuum chamber.

The ladle rests on a support ring **45** extending upwardly from the base plate **17**. The ring terminates in a ladle bearing ring **46**. An annular bearing ring **47** is welded or otherwise suitably secured to the shell **41** of the ladle. A layer of refractory **48** protects the base plate **17** within the ladle support ring **45** from excessive heat and spillage. The interior of the vacuum chamber is connected to a source of vacuum through an outlet **50** surrounded by a suitable hood structure **51**.

Apparatus for bubbling a purging gas upwardly through the melt is indicated generally at **52**. The purging apparatus consists essentially of a source of purging gas **53** under a pressure greater than the static head of the metal in the ladle and is connected by a gas line **54** to the upper end of a combination purging and stopper rod **55**. The rod is so constructed that gas passes downwardly through a longitudinal passage, and is then directed radially outwardly into the melt. For further details of the structure of the purging-stopper rod, reference is made to co-pending application Serial Number 805,927 assigned to the assignee of this application. The combination purging-stopper rod seats in a suitable nozzle assembly **56**, described in detail in co-pending application 855,442, also assigned to the assignee of this application. Any suitable actuating mechanism **57** may be utilized to raise and lower the rod from the illustrated seated position.

The charge container **27** is illustrated in detail in FIGURE 2.

In this embodiment, the time of addition of the charge materials to the melt can be controlled to the second.

Charge container **27** consists essentially of an upper expanded section **60** and a lower composite section **61**. A positioning flange **62** welded to the upwardly outwardly inverted conic section **63** rests upon bearing flange **64**. The lower section **61** consists of a shell **65** to which a continuous circular L channel **66** is welded about its inner periphery at its bottom. The channel supports a layer of refractory **67** which protects the shell **65** and the overlapping portion **68** of the lower conic section **63** from the heat of the melt. The upwardly inwardly inclined conic section **69** terminates in a neck **70** which receives the closure member of composite cover **71**, **72**. The cover or plug forms an air-tight seal with the upper flange **73** which is welded to neck **70**. The overhang of plate **71** rests upon and makes the air-tight seal with O-ring **74** in aperture **75** in the top surface of cover flange **73**.

A circular steel plate **76** is held in snug engagement against the bottom of circular channel **66** by a rod **77**. The rod is secured to plate **76** at its lower end by a nut and washer **78** threadably received on the lower end of the rod. The outer end of a short shaft **79** is received in an eyelet **80** formed at the upper end of rod **77**.

Shaft **79** is rotatably received in bearing journal block **81** which is welded to the upwardly inwardly conic section **69** of the container. A pin **82** projects downwardly a slight distance into a helix **83** milled in the shaft. O-ring **84** between the shaft and its bore completes the air-tight seal. The outer end of the shaft **79** terminates in an eyelet **85** to which a suitable handle **86** is connected. Helix **83** is so located that clockwise rotation of shaft **79** will cause this shaft to move to the right as viewed in FIGURE 2.

The steel bottom plate **76** supports a quantity of charge material indicated generally at **87**.

A variant form of charge container having a heat destructible bottom is indicated generally at **90** in FIGURE 3. In this figure, the container consists of an outer tubular shell **91** to which is welded a positioning flange **92**. The flange rests upon a bearing flange **93** welded to the internal surface of collar **26** which in turn is welded to the dished cover **24**. An air-tight seal is formed between the positioning flange **92** and bearing flange **93** by an O-ring **94** received in a recess in the upper surface of the bearing flange.

A cover flange **95** whose upper bearing surface is recessed as at **96** to receive another O-ring seal **97** is welded to the outside of the tubular shell **91** at its upper end.

The interior of shell **91** is protected from the heat in the vacuum chamber by a layer of refractory **98** held in place by a plurality of studs **99** welded at appropriate intervals about the internal surface of the shell. An annular ring **100** is welded to the bottom of shell **91**, and an annular layer of refractory **101** supported by downwardly projecting studs **102** protects the ring from the heat of the melt. The radial depth of ring **100** is somewhat greater than the thickness of composite wall **91**, **98** so that an annular shoulder **103** is formed about the bottom of the container. A closure member, which in this instance is illustrated as a plug, **71**, **72**, similar to the plug of FIGURE 2, forms an air-tight seal with the upper flange **95**.

A heat destructible or disintegratable bottom for the

container is indicated at **104**. It rests upon the shoulder **103** to form a support for a quantity of charge material. Its thickness will depend upon the length of time it is desired to hold off addition of the alloys and/or slag forming material to the melt.

The use and operation of the invention is as follows: Molten metal **110** in ladle **40** is subjected to vacuum through vacuum connection **50**. Upwardly traveling bubbules of purging gas **111** from the pressurized source **53** set up an internal circulation within the melt which brings virgin metal from the lower portions of the melt to the surface where the occluded deleterious gases such as hydrogen, nitrogen, and oxygen may be removed by the vacuum. The bubbles themselves provide a vehicle for removing the included deleterious gases in that these gases migrate into the bubbles during their upward passage.

To add materials to the melt at a preselected time during the degassing cycle, the container of FIGURES 2 or 3 is loaded with alloying materials, or slag forming material, or both, and placed in the aperture ring **26**, as illustrated in FIGURE 1.

When using the structure of FIGURE 2, container **60** is loaded with the desired charge before the ladle is positioned within the tank in the usual manner. When the operator wishes to add the alloys to the melt, he rotates handle **86** clockwise which moves shaft **79** to the right due to the action of pin **82** riding in helix **83**. As soon as the inner, or left end, of shaft **79** is retracted to a position within the journal block **81**, steel plate **76**, rod **77** and the charge materials in the container drop into the melt.

This structure has the great advantage of permitting the operator to add the charge materials at any desired instant. In addition, good mixing of alloyed materials, even those lighter in weight than steel, is insured because the steel plate and rod will poke a hole in the slag so that the light-weight additions will contact the molten material and not float on top of the slag. There is no possibility that any portion of the alloyed materials will remain in the container because the entire bottom falls away.

The steel plate **76** and rod **77** should, of course, be composed of a material compatible with the composition of the melt. In general, a low-carbon steel is quite satisfactory.

When using the structure of FIGURE 3, the thickness of heat destructible bottom plate **104** is so correlated to the heat of the melt and the time it is exposed to the heat that it will give way at a predetermined time in the cycle to permit the alloying constituents to pass gravitally downwardly into the melt.

Several materials may be used for this plate. One of the best is plywood, although pine might also be utilized. If the metal is tapped at a given temperature, and that temperature is determined beforehand, it is possible to select plywood of a thickness which will burn through within 15 seconds of the desired time. Aluminum could also be utilized. Usually aluminum is one of those alloys which should be added late in the degassing operation because it is rather highly deoxidizing, but it can be utilized for the bottom plate because it retains its structural shape for several minutes and then gives way suddenly.

A typical treating cycle is indicated in FIGURE 4 which illustrates a variable scale pressure-time chart. In this instance, the pressure has been calibrated in units of mercury in a radial outwardly direction from a base line **112**, and time in minutes is shown as roughly pie shaped truncated sectors extending circumferentially about the base line.

Referring to the graph, it can be seen that the pressure in the vacuum chamber at the start of the operation was approximately 760 millimeters of mercury, or standard atmospheric pressure. The starting point is indicated at point A. After the vacuum system was turned on, the pressure within the chamber decreased gradually at first and then rather sharply down to point B which was in the neighborhood of 100 millimeters of mercury. From A to B, the chart was calibrated to read pressure over a range of zero to 1,000 millimeters of mercury.

At point B the scale of the chart was expanded ten times so that the chart covers the range of from zero to 100 millimeters of mercury. The stylus or chart indicator jumped immediately to point C. Actually point B and point C represent equal absolute pressure values. The vacuum was then pumped down to point D which was on the order of 10 millimeters of mercury, and then it was again expended ten times so that the range of the chart now covered a range of zero to 10 millimeters of mercury. The stylus pumped to point E which represents a value of approximately 8.5 millimeters of mercury and pump-down continued until the pressure within the chamber reached a value of approximately one-half millimeter of mercury at point F. By this time, the treatment had been in operation for approximately 6¼ minutes. At this time, the chart was again expanded ten times so that it covered a range of from zero to 1,000 microns of mercury. The indicating pen then jumped to point G which represents a value of approximately 530 microns of mercury. The pressure in the chamber then gradually decreased to approximately 360 microns, indicated at point H, at which time bottom plate **76** and a charge of burnt lime and aluminum dropped into the melt. In this particular heat of 33 tons of low alloy steel, a charge of approximately 200 pounds of burnt lime and 20 pounds of aluminum was admitted to the melt. As soon as the burnt lime came into direct contact with the melt, the heat caused a considerable quantity of gas to be evolved, and the pressure in the chamber immediately jumped to point J which represented a value of about 700 microns. The gas contained within the burnt lime was then gradually removed from the chamber until the treatment was discontinued at point K, 12 minutes after it started. By the time the charge was added to the melt, the melt had been substantially completely degassed so that substantially all of the gas evolved from the charge was subsequently removed from the system. When the upper removable portion **14** of the vacuum chamber was swung away, the heat was ready for pouring and contained an insulating blanket of slag which substantially reduced the heat loss between the time the cover was removed and the ingots teemed.

Although the alloy addition method and apparatus has been described in conjunction with a degassing process utilizing both vacuum and purging gas, it should be understood that the invention is equally utilizable in a vacuum degassing process which does not utilize a purging gas. It should also be noted that it is highly desirable that the charge container be so positioned that its upper end forms a portion of the vacuum chamber. The advantages of the invention are just as readily obtained, however, if the container is located entirely within the chamber. The illustrated embodiment takes advantage of existing equipment. Likewise, although the charge container has been shown as positioned substantially directly above the ladle, it should be understood that in some instances it may be advantageous to position the container to one side of the ladle, as when necessitated by equipment design. It is really only essential in the FIGURE 3 embodiment that the bottom of the container be exposed to the heat of the ladle so that its disintegration will be related to the time it is exposed to the heat.

It is therefore apparent that the invention provides means for adding highly deoxidizing alloys such as aluminum or silicon to a melt at a time subsequent to which degassing operations would be inhibited by the deoxidizing effect of the alloys. The advantages of making additions under vacuum, particularly the production of cleaner steel having a higher recovery are obtained and of course the advantages of any particular alloy such as aluminum are realized. As discussed heretofore, vanadium could be

substituted for aluminum, for example, but the cost of each heat would increase considerably. With this system aluminum, with its grain refining properties, may be added at any given point in the cycle.

This system also provides means for ensuring good mixing of the alloys throughout the melt. Since the time of admission of the charge can be controlled to the second if desired, ample time may be allowed for purging or carbon monoxide boil subsequent to addition, which ensures desegregation.

The system described above makes possible the addition of slag forming materials during the degassing operation which reduces the possibility of inhibiting degassing by presence of these materials at the start of the operation. Likewise, the corrosive effect of the slag on the refractory parts and the possibility of overloading the ejectors early in the cycle are overcome. Finally, the explosion hazard resulting from early introduction of the slag is eliminated and the dust is completely controlled.

Other alloys, such as silicon, vanadium, and exothermic chrome may be added at a later point in the cycle which is an advantage in that a cleaner steel is produced, and a better alloy recovery is obtained.

This invention enables steel to be tapped from the furnace at temperatures lower than those required when charge materials are to be added after degassing. As a result, furnace life is prolonged. Since the alloy addition which is automatic is generally made after a substantial quantity, and, if possible, the bulk of the included deleterious gases have been removed, the treatment time is not lengthened beyond the time necessary to pump out the gas evolved from the added constituents so that production time is substantially the same as for vacuum degassed heats to which no alloy additions are made.

Although two embodiments of the invention have been illustrated and described, it will be understood that it is shown in this manner for illustrative purposes only. Consequently, the scope of the invention should be limited only by the scope of the appended claims.

I claim:

1. A method of reducing heat loss from, and substantially eliminating the reabsorption of deleterious gases by, a ferrous melt subjected to vacuum treatment in a receptacle, said method including the steps of

subjecting the surface of the melt to a vacuum and maintaining the aforesaid vacuum until a substantial quantity of the included deleterious gases have been removed from the melt, thereafter,

adding charge material containing at least a substantial quantity of slag-forming material to the melt, all the while maintaining the aforesaid vacuum above the surface of the melt, and thereafter,

subjecting the charge material which has been added to the melt, including the slag formed therefrom, to the vacuum for a period of time sufficient to remove included deleterious gases from the charge material.

2. The method of claim 1 further including the step of subjecting the charge material, prior to its addition to the melt, to the same vacuum to which the melt is subjected substantially simultaneously therewith whereby removal of deleterious gases from within the charge material commences substantially immediately upon contact with the melt.

3. The method of claim 1 further characterized in that alloy materials are added to the melt, said alloy material addition being made after a substantial quantity of the included deleterious gases have been removed from the melt.

4. The method of claim 1 further characterized by and including the subsequent step of maintaining the insulating blanket formed by the slag over the melt throughout subsequent operations such as pouring from the receptacle.

5. A method of reducing heat loss from, and substantially eliminating the reabsorption of deleterious gases by, a ferrous melt subjected to vacuum treatment in a receptacle, such as a ladle, said method including the steps of

subjecting the surface of the melt to a vacuum sufficiently low to effectively degas the melt,

bubbling a purging agent upwardly through the melt for at least a portion of the time the melt is subjected to the vacuum to thereby bring remote, undegassed portions of the melt to the surface,

maintaining the aforesaid vacuum until a substantial quantity of the included deleterious gases have been removed from the melt,

adding charge material containing at least a substantial quantity of slag-forming material to the melt, all the while maintaining the aforesaid vacuum above the surface of the melt, and thereafter,

subjecting the charge material which has been added to the melt, including the slag formed therefrom, to the vacuum for a period of time sufficient to remove included deleterious gases from the charge material.

6. The method of claim 5 further including the step of subjecting the charge material, prior to its addition to the melt, to the same vacuum to which the melt is subjected substantially simultaneously therewith whereby removal of deleterious gases from within the charge material commences substantially immediately upon contact with the melt.

7. The method of claim 5 further characterized in that alloy materials are added to the melt, said alloy material addition being made after a substantial quantity of the included deleterious gases have been removed from the melt.

8. The method of claim 5 further characterized by and including the subsequent step of mantaining the insulating blanket formed by the slag over the melt throughout subsequent operations such as pouring from the receptacle.

9. The method of claim 7 further characterized in that the alloy materials include highly deoxidizing alloys.

10. A method of reducing heat loss from, substantially eliminating the reabsorption of deleterious gases by, and adding charge material to a ferrous melt in a vacuum degassing receptacle at a predetermined time in a vacuum degassing cycle, said method including the steps of

positioning a charge material container containing at least a substantial quantity of slag forming material and having a heat disintegrable bottom above the melt,

subjecting the surface of the melt to a vacuum,

drawing a vacuum in the container simultaneously with subjection of the surface of the melt to the vacuum,

opening the interior of the container to communication with the melt after a substantial quantity of the included deleterious gases have been removed from the melt by disintegrating the bottom of the container to thereby enable the charge material in the container to mix with the melt, and

maintaining the vacuum above the melt after the admission of the charge material for a period of time sufficient to remove included deleterious gases from the charge material.

11. The method of claim 10 further characterized in that the interior of the container is opened to communication with the melt by dropping the bottom in toto into the melt along with the charge material.

12. A method of reducing heat loss from, substantially eliminating the reabsorption of deleterious gases by, and adding deoxidizing alloying material to a ferrous melt during a degassing cycle without inhibiting degassing of the melt, said method including the steps of

positioning a container containing at least a substantial quantity of slag forming material and deoxidizing alloying material and having a heat destructible bottom above a receptacle containing a melt whereby the bottom of the container is exposed to the heat of the melt,

degassing the melt by exposing the melt to a vacuum

sufficiently low to effectively degas the molten metal and bubbling a purging gas through the melt,

passing the deoxidizing alloying material into the melt after the melt has been substantially degassed by disintegrating the botom of the container from the heat of the melt, the time of the destruction of the bottom of the container substantially coinciding with the removal of a substantial portion of the deleterious gases removable by the degassing procedure, all the while maintaining a vacuum above the surface of the melt, and thereafter

subjecting the deoxidizing alloying material and the melt to the vacuum for a period of time sufficient to remove included deleterious gases therefrom.

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