PROPELLING OF ADDITION AGENTS INTO MELTS

Filed Jan. 20, 1964 3 Sheets-Sheet 1

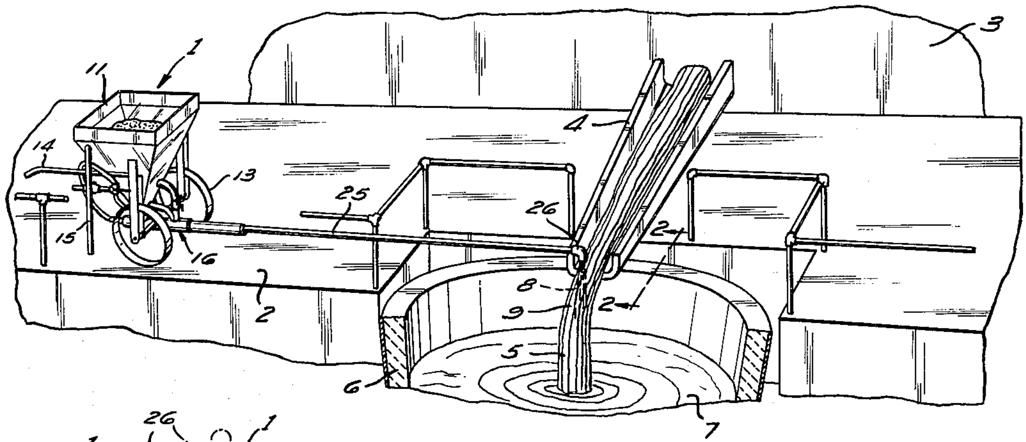

Fig. 1

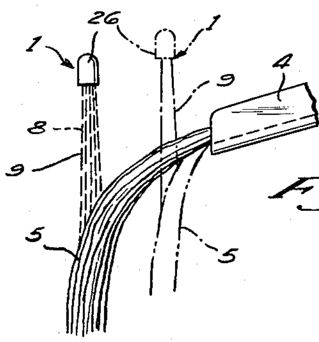

Fig. 2

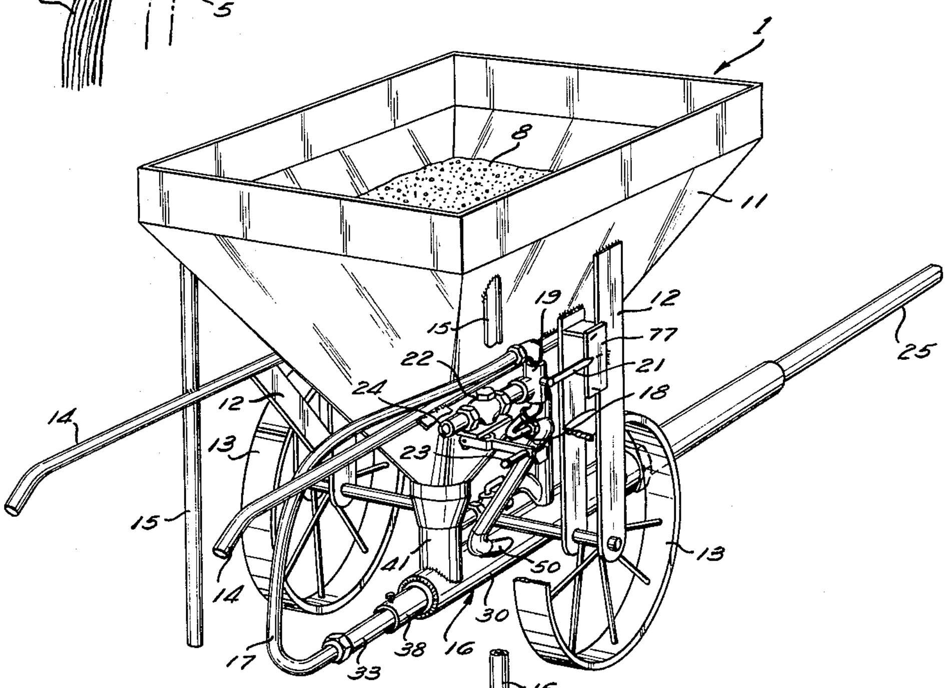

Fig. 3

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PROPELLING OF ADDITION AGENTS INTO MELTS

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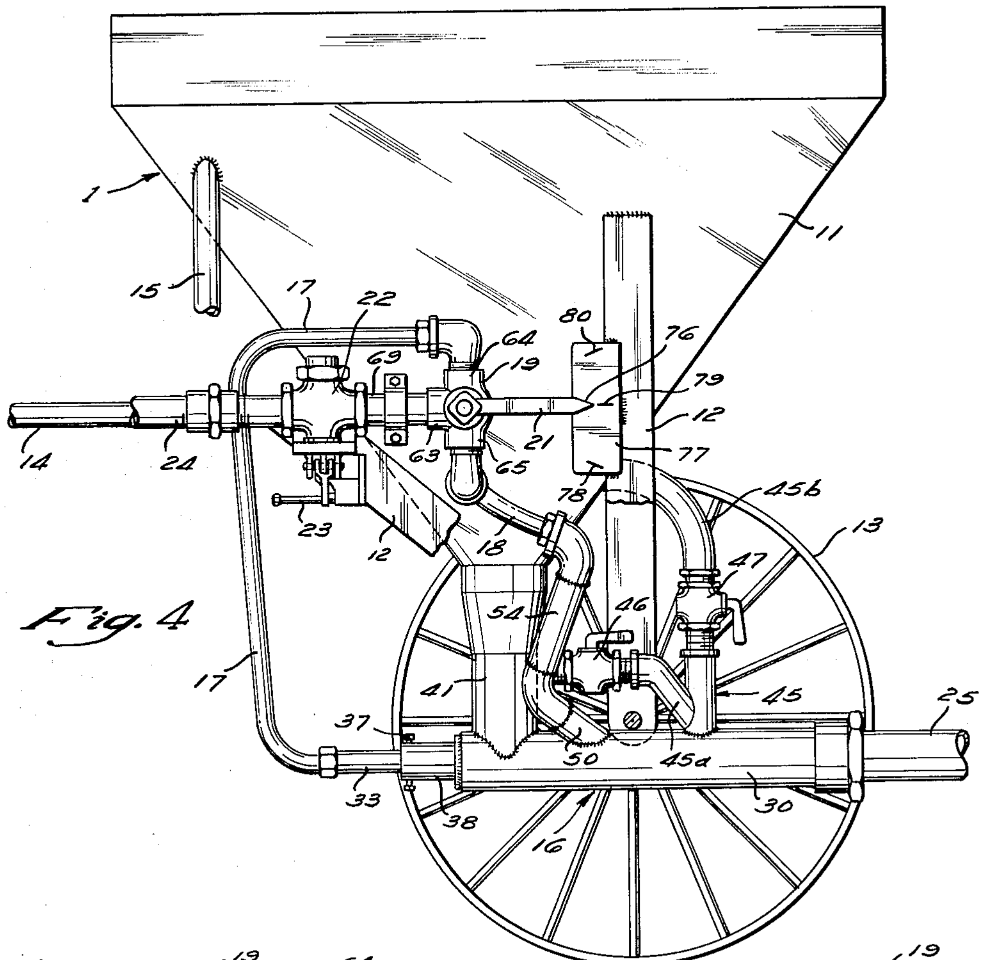

Fig. 4

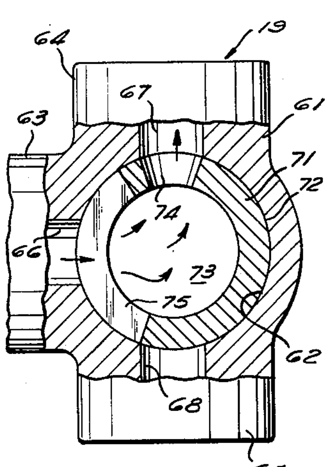

Fig. 7

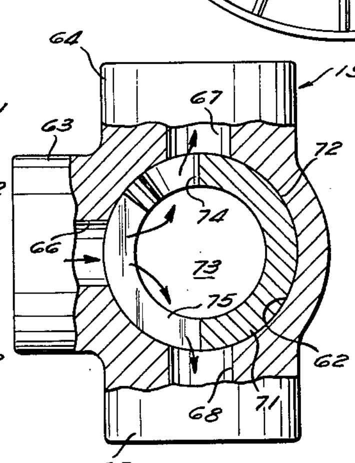

Fig. 8

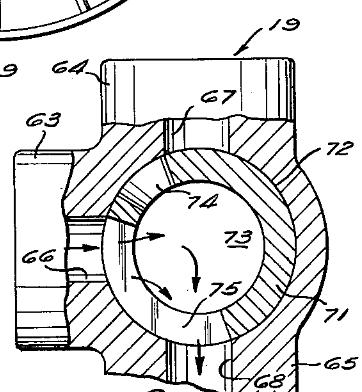

Fig. 9

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PROPELLING OF ADDITION AGENTS INTO MELTS

Filed Jan. 20, 1964 3 Sheets-Sheet 3

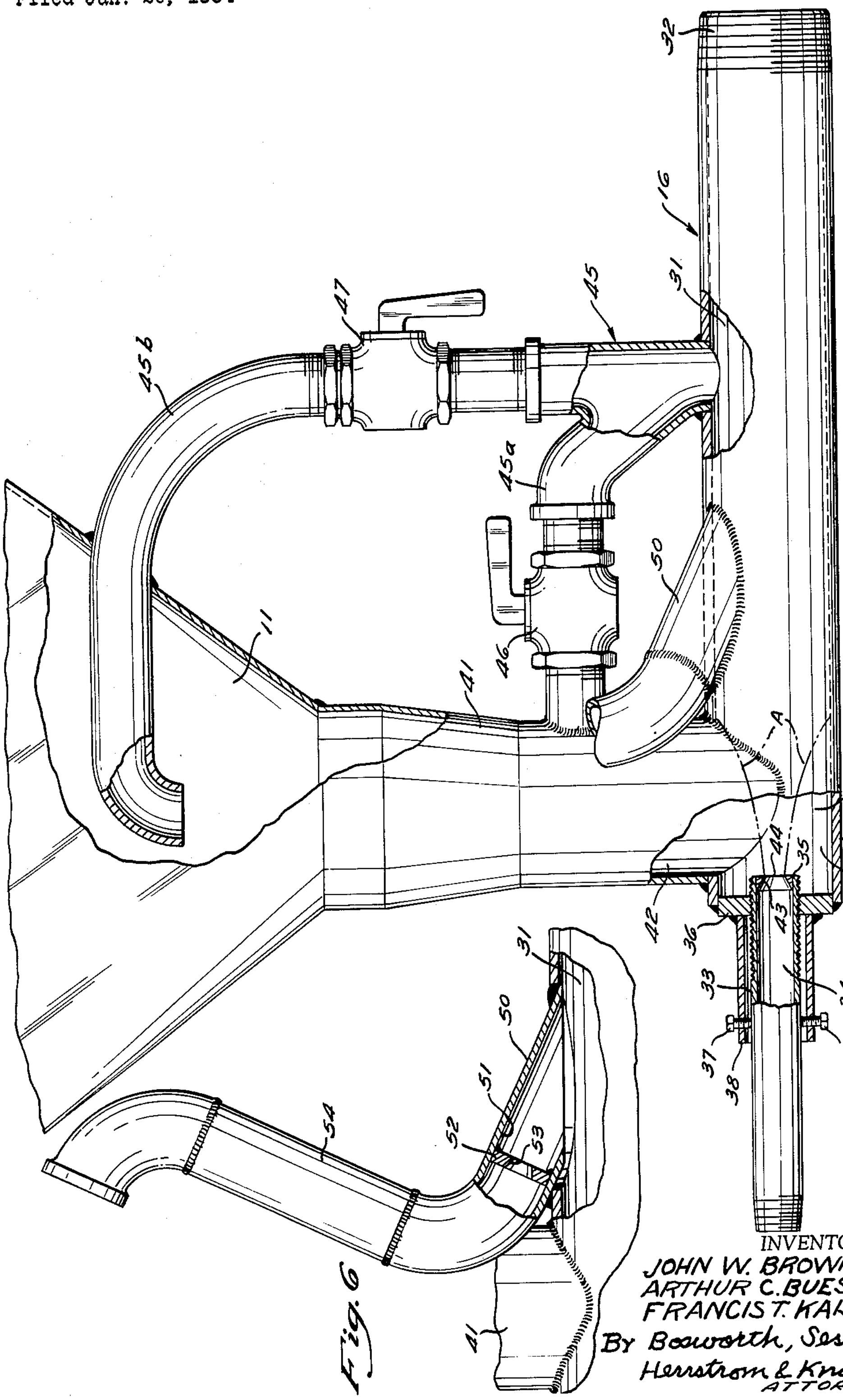

Fig. 5

Fig. 6

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PROPELLING OF ADDITION AGENTS INTO MELTS

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8 Claims. (Cl. 75—53)

This invention relates to methods of propelling particulate material into melts, and more particularly to methods for injecting solid particulate addition material, such as aluminum particles, into molten metal such as steel.

In the preparation of certain metals and metal alloys it is often desired to effect certain chemical or metallurgical reactions between the molten metals and various addition agents. For example, metallic aluminum is often introduced into the molten steel for deoxidizing the steel or providing residual aluminum for control of grain structure or alloying. However, these addition agents often have such characteristics that it is difficult thoroughly to intermix them with the molten metal, as because they are considerably lighter (as is aluminum added to steel), or because they required considerable time for reaction even at high temperatures. In order to overcome these difficulties it has been proposed to introduce finely divided solid addition agents into molten metal by a method of injection like that disclosed in co-pending application Serial No. 170,204, filed January 31, 1962, by J. W. Brown, Jr., A. C. Buesing and F. T. Kaiser, according to which particles of addition agent are laterally propelled by a stream of gas such as air into a freely falling stream of molten metal, the particles being propelled with sufficient force to penetrate the molten metal so that the addition agent becomes intermixed with, and commences reacting and dissolving in, the stream of molten metal after its falls into the receptacle. The agent is further intermixed with and disseminated in the molten metal by the turbulence, of the metal in the receptacle. The present invention provides unique advantages over and above those disclosed in said prior application, some of which advantages are explained below.

It is necessary to inject the desired amount of addition agent during a relatively short pouring time. In modern steel making practice, several hundred tons of steel may be poured from a furnace into a ladle in a few minutes, and several hundred pounds, often more than a thousand pounds, of aluminum must be added to the steel before the slag pours into the ladle to achieve the desired results indicated above. Consequently, a large quantity, often several hundred pounds, of aluminum particles must be injected per minute into the stream of molten steel freely falling into the ladle. In order to achieve the desired results, the particles should be propelled with sufficient velocity so that they can penetrate the molten metal which is especially important when particles of lightweight aluminum are being injected into heavy steel, and the particles should be accurately directed in a compact stream so that they can intersect the stream of molten metal without appreciable particles scattering. Otherwise, many of the particles that are not trapped in the flowing stream of metal are lost in the slag or ricochet out of the ladle. This not only results in loss of addition agent, but also makes it difficult if not impossible to insure that the proper amount of addition agent is added to the metal to achieve the desired results.

These problems are intensified when a heat of metal is being poured from a smaller furnace into a ladle, since in such case the smaller, freely falling stream of metal has a tendency to deviate from a generally circular cross section and also to vary in its rate of flow, so that the stream widens or sheets out either momentarily or for a

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considerable period. When the stream of particles is directed laterally to intercept such a freely falling stream of molten metal that changes from a generally circular cross section, many of the particles will miss the stream entirely and be lost if the stream of molten metal presents its narrower side to the particle stream, while on the other hand many of the high velocity particles will pass entirely through the stream and be lost iif the stream of molten metal presents its wide side to the particle stream.

It is an object of this invention to provide improved methods for introducing addition agents into melts to overcome the above problems. Another object of this invention is to provide methods by which there may be added to melts, such as molten steel, particles of one or more addition agents such as aluminum having a lower density than the material of the metals. A further object is the provision of a method whereby a predetermined quantity of particles of one or more addition agents such as aluminum can be introduced into a freely falling stream of molten metal under conditions which cause thorough distribution of the particles in the metal without undue contact of the addition agent with ambient air. A further object is the provision of an improved method for discharging into molten metal particles of addition agents under conditions and in accurately controlled quantities that will promote the uniformity of distribution and reaction, by propelling the stream of addition agent into the freely falling stream of molten metal even though the stream varies widely as to shape of cross section and rate of flow.

Other objects and advantages of the invention will be apparent from the following description of several embodiments of the invention, in connection with the accompanying drawings in which:

FIGURE 1 is a perspective showing of an apparatus for carrying out a method embodying the invention when used in the injection of aluminum particles into a freely falling stream of molten steel pouring from an open hearth furnace into a ladle;

FIGURE 2 is a detail side elevation, generally from line 2—2 of FIGURE 1, the conditions at the beginning of the pour being illustrated in full lines and those near the end of the pour by broken lines;

FIGURE 3 is a perspective view, to an enlarged scale, showing the major portion of the illustrated apparatus for discharging particles;

FIGURE 4 is an elevation of the portion of the apparatus show in FIGURE 2, but to a somewhat larger scale, the near wheel and other parts being omitted to show more clearly the propelling portion of the gun, and associated parts;

FIGURE 5 is a vertical elevation, to a scale considerably larger than that of the preceding figures, of the propelling portion of the gun;

FIGURE 6 is a detail elevation, partially broken away, showing the relationship of the auxiliary conduit to the main passage;

FIGURE 7 is a somewhat diagrammatic section of elevation through the control valve showing one extreme position of the movable closure member of the valve relative to the port openings into the supply conduit and into the conduits connected to the gun;

FIGURE 8 is a similar cross section showing an intermediate position of the closure member relative to such ports;

FIGURE 9 is a similar cross section showing another extreme position of the closure member.

In FIGURE 1, the injection apparatus generally indicated by **1**, is shown as standing on a pouring platform **2** along the pouring side of an open hearth furnace **3**. The furnace has a pouring spout **4** shown as discharging a stream of molten metal 5 in conventional manner from its end into a ladle 6 to form a body 7 of molten steel in the ladle. The apparatus 1, referred to herein as a gun, is shown in FIGURES 1 and 2 as discharging particles 8 of metallic aluminum for deoxidizing purposes into the stream 5, the particles being discharged downwardly and substantially vertically into the stream at the location thereof at which it begins to fall substantially vertically, as described in more detail later.

As shown in FIGURES 3 and 4, gun 1 comprises a supply hopper 11 having its upper end open to the atmosphere and hence readily available for filling and inspection. The hopper contains a weighed amount of finely divided aluminum particles 8, which may be the usual button-shaped particles about 1/4 to 1/2 inch in diameter and 1/8 to 3/8 inch thick. The hopper 11 is fixed to a frame 12 supported by a pair of wheels 13. Frame 12 has handles 14 for guiding the apparatus, and legs 15 to aid in supporting it when it is stationary.

A propelling portion 16 is fixed to the frame below hopper 11, which is preferably tapered downwardly and inwardly to facilitate gravitational movement of the particles into portion 16. As shown in FIGURES 3 and 4, propelling portion 16 is connected by metal tubes 17 and 18 to a control valve 19 actuated by a valve handle 21. Valve 19, to be described later, controls the rate of flow of propellant fluid through the tubes 17 and 18 to the propelling portion 16 and thereby controls the rate of discharge of particles from the gun. Valve 19 is connected through a conventional shutoff valve 22, operated by handle 23, to a hose 24 supplying a suitable source of propellant fluid under pressure, such as air at about 100 pounds per square inch, commonly available in steel plants.

The other end of propelling portion 16 is connected to the feed end of an elongated barrel 25 (FIGURES 1, 3 and 4). This barrel preferably is a tube of heat resistant metal such as stainless steel of a length such that when its discharge end 26 is in operative location, the hopper 11 and persons working around it are not exposed to excessive heat. The discharge end portion 26 is curved downwardly as shown so that the stream of propellant air and particles can be directed substantially vertically downwardly by manual positioning of the apparatus. Preferably, the end portion 26 is so shaped to discharge the particles 8 perpendicularly to barrel 25, with a minimum loss of velocity due to the change in direction.

Propelling portion 16 as shown in detail in FIGURES 5 and 6, comprises a body 30 having a laterally extending main internal passage 31 terminating in a discharge end 32 connected to the barrel 25. At its other end the body 30 carries an internal axial nozzle 33 having a bore 34 communicating with air supply tube 17 and discharging into main passage 31. The discharge end 35 of nozzle 33 is axially located by being threaded in plate 36 closing the end of body 30, and locked by set screws 37 that are threaded in body sleeve 38 and bear against the outward projection of the nozzle.

Propelling portion 16 also includes a downwardly extending tubular feed conduit 41 having an internal passage 42 communicating at its upper end with the bottom of hopper 11 and at its lower end with the main passage 31 at a location downstream from nozzle 33.

To increase the velocity of air discharging from nozzle 33, the walls of the bore 34 at the discharge end of the nozzle are tapered inwardly at 43 to define an orifice 44 of a cross section substantially smaller than bore 34 and much smaller than the cross section of the main passage 31. The air discharging from the orifice 44 travels in an expanding stream, indicated diagrammatically by broken line A in FIGURE 4. Close to the orifice 44 the stream has a relatively small cross section and travels at its highest velocity; the velocity of the stream decreases and its cross section increases with increasing distance from the orifice until the cross section approaches that of the passage 31 and the stream velocity is substantially reduced. The pressure in the zone B surrounding the stream A therefore is substantially lower than elsewhere in main passage 31; preferably the parts are so related that the pressure in zone B is less than atmospheric pressure and the opening 42 of feed conduit 41 discharges into this zone. This promotes flow of particles from feed passage 42 into main passage 31, and the entrainment of these particles into the air stream discharged from the nozzle 33 and traveling through the main passage 31 into and through the gun barrel 25.

Another feature that increases the quantity of particles drawn into and discharged from the gun is a return conduit generally indicated by 45 through which some of the air from main passage 31 flows into the passage 42 of the particle feed conduit 41 and also preferably into the lower portion of the hopper 11 discharging into conduit 41. Conduit 45 communicates with main passage 31 at a location that is downstream from the orifice 44, from the opening of feed passage 42 into passage 31, and from the low pressure zone described above, at which location a substantial proportion of the kinetic energy of the air has been transferred to the particles. Conduit 45 has a branch 45*a* communicating with feed passage 42 substantially above its opening into the main passage 31 and another branch 45*b* having a downwardly directed discharge end in hopper 11 directly above and close to where hopper 11 enters feed conduit 42.

The locations at which the conduit branches 45*a* and 45*b* discharge into the particle feed passage 42 and hopper 11 should be far enough from the outlet of passage 42 into main passage 31 to prevent air emanating from the branch conduits from short circuiting downward into passage 31 without acting on the particles in passage 42, and sufficiently below the lowest level of particles of the hopper 11 during normal operation to prevent short circuiting of air upwardly. Branch conduits 45*a* and 45*b* respectively include valves 46 and 47 to permit adjustment of the flow of air through each of such conduits.

The restricted orifice 44 and the return conduit 45 in combination increase the output of particles discharged from the gun by much more than the additive effect.

The illustrated propelling portion 16 also includes an auxiliary conduit 50 having a passage 51 (FIGURES 5 and 6) disposed with its axis at a flat angle to the axis of the main passage 31 so that air is discharged downstream from conduit 50 into passage 31 at a location downstream of the relatively close to the opening of passage 42 into main passage 31 but upstream of the opening of return conduit 45 into the main passage 31. This auxiliary conduit 50 includes a plate 52 providing an orifice 53 that is substantially smaller in cross section than the main passage 31 of body portion 30. Orifice 53 is located close to the opening of passage 51 into the passage 31. Conduit 50 includes an extension 54 connected by tube 18 to valve 19.

The rate of flow of particles from the gun can be readily controlled by valve 19, which varies the rate of flow of air through the main passage 31 in relation to the rate of flow of air through the auxiliary passage 51. As is apparent from FIGURES 4, 7, 8 and 9, valve 19 comprises a body 61 having a conventional bore 62 of cylindrical or frusto-conical shape. The body includes bosses 63, 64 and 65 respectively having ports 66, 67 and 68. Boss 63 is connected by pipe 69 through shutoff valve 22 to main air supply line 24, so that port 66 is connected to the air supply. Boss 64 is connected by pipe 17 to nozzle 33, so that port 67 thus communicates with the main passage 31 through orifice 44. Boss 65 is connected to air tube 18 that is connected to the auxiliary conduit 50, so that port 68 communicates with orifice 53 and auxiliary passage 51.

The valve 19 also includes a turnable member 71 having a curved outer surface 7 that fits closely in bore 62 of body **61**, and a hollow interior **73** communicating with ports **74** and **75** of member **71**. Ports **74** and **75** are so located relatively to each other and to the fixed body ports **66**, **67** and **68** to permit the desired control of the flow of air through ports **67** and **68**. Thus, as shown in FIGURE 7, turnable member **71** is so positioned that all air supplied from port **66** can pass through port **67** and into the main passage **31** to cause maximum flow of air past the lower end of particle supply passage **42** to entrain and propel the maximum amount of particles per time unit. In FIGURE 8, the member **71** is so turned that the air supply body port **66** is completely open but the body port **67** that communicates with the main passage **31** and the port **68** that communicates with the auxiliary conduit **51** are only approximately half open and the rate of flow of particles from the apparatus is reduced substantially below that when the valve is set as in FIGURE 7. When member **71** is turned to the position shown in FIGURE 9, body port **67** communicating with main passage **31** is completely closed, while port **68** communicating with the auxiliary passage **51** is completely open and all of the air supplied through port **66** thus travels through auxiliary passage **51**. The flow of particles from the gun is at a minimum for the particular design. The particle flow can, of course, be entirely halted by stopping the flow of air by valve **22**.

As shown in FIGURE 4, the valve **19** has a control handle **21** that also indicates the position of the turnable member **71** by pointed end **76** that moves parallel to an indicator dial **77** fixed to the frame of the apparatus and carrying indicia marks **78**, **79** and **80**.

The apparatus thus makes it possible readily and accurately to vary and adjust the flow of additional agent particles from the gun, by means of a single control which can be readily manipulated.

According to a method of invention as practiced by using the above described gun **1**, the particles **8** are propelled by the gun so they travel in a stream **9** directed downwardly and so that substantially all of the particles **8**, when they are traveling substantially vertically, strike the stream of molten metal **5** from above stream **5** at a loctaion thereon where it is traveling substantially vertically, as shown in FIGURE 2. Particles 8 are propelled, with sufficient force to penetrate this stream **5** of molten metal, from the gun end portion **26** that is positioned far enough away from stream **5** so it is not damaged by heat, but otherwise preferably as close as possible to the stream **5** for accurate direction of stream **9**.

The freely falling stream **5** describes a generally parabolic path after it leaves the spout **4** and before it terminates in the ladle **6**. This path comprises a generally laterally extending portion indicated by A and a substantially vertical portion indicated by B. The length of this substantially vertical portion is greatest when the ladle is empty and decreases as the ladle fills with molten metal. Preferably, stream **9** of particles **8** is substantially narrower than the normal width of the stream **5** of molten metal at the location where the stream **9** intercepts stream **5**, so that substantially all particles strike stream **5**. Stream **9** preferably is so propelled and located that it travels substantially vertically and intercepts the stream **5** from above the portion of stream **5** where it first assumes the substantially vertical direction, the particles bieng propelled with sufficient force to penetrate the stream, the relative proportions of streams **9** and **5** being such that substantially all particles of stream **9** penetrate into stream **5**. Consequently, even though the cross sectional shape of stream **5** varies substantially from a circle or even if stream **5** sheets out, there is little if any tendency for particles of stream **9** to miss the stream **5** since the variation of the shaped stream **5** usually occurs below the location at which it first assumes the generally vertical path and since in any event the particles **8** approach and penetrate the stream **5** from an aspect thereof which does not vary greatly in dimension even though the stream might vary greatly when viewed laterally. In any event, any particles that might miss the stream merely travel downwardly until they strike the molten metal in the ladle, where they melt and their material disseminates in the molten metal due to its turbulence.

Furthermore, the particles that strike and penetrate the freely falling stream **5** are projected into and well below the unconfined surface of the molten metal, and are carried downwardly by the stream. The particles initially strike the stream **5** at a location where the molten metal is considerably hotter than it is in the ladle. Complete penetration of the particles for a substantial distance into this exceptionally hot metal causes them to melt more rapidly than would otherwise be the case, and they are protected by this surrounding molten metal from the ambient air. Depending on the size and the material of the particles, and the length of the path of travel in the stream of molten metal, the particles may be largely or even completely melted before the metal in the stream enters the mass of molten metal in the ladle.

The material of the particles is thoroughly and uniformly distributed in the molten metal, both while in particle form and after melting. In the preferred method, the particles are added throughout substantially the entire duration of the flowing stream of molten metal, before the beginning of the slag flow, at a rate that supplies to each increment of metal in the stream substantially the amount of addition agent that is required for that increment. Thus, the particles are distributed throughout the metal flowing into the stream, and also these relatively small increments of molten metal containing submerged particles or droplets of addition agent are dropped into and thoroughly mixed with the large body of molten material in the ladle. While it is preferred to add the addition agent to the stream at a rate commensurate with the flow of molten metal in the stream, in many instances satisfactory results can be obtained if the agent is added at a higher rate for a shorter time, in which case the apparatus may be operated for less than substantially the entire duration of flow of the stream of metal.

Under any circumstances, thorough dispersion and distribution of the addition agent material are promoted by the turbulence of the liquid molten metal, which arises from several causes, such as turbulence of the liquid metal is stream **5** caused by discharge of the metal from the furnace pouring spout, turbulence imparted by impingement of the particles on the metal of stream **5**, and great turbulence arising when the metal in stream **5** plunges into and agitates the metal in the ladle.

Injection of particles into the stream **5** is preferably halted before the slag begins to drain from the furnace onto the metal in the ladle, although it is possible to add appropriate types of addition agents while the slag is draining.

For the above and other reasons, aluminum or other addition agents thus added to the molten steel according to the present invention can be thoroughly distributed throughout the body of molten steel in the ladle in an extremely finely divided condition and with a high degree of uniformity, so that molecular dispersion is approached. The finely dispersed aluminum reacts with the iron oxides and with dissolved or combined oxygen in the steel to deoxidize the steel effectively and uniformly; if added in sufficient quantity it also performs alloying or grain control functions effectively and with high uniformity. Furthermore, the extremely highly dispersed aluminum performs its deoxidizing, alloying or other functions before it can collect in a film on the surface of the steel, where it could be wasted by reaction with air or slag; and in its finely dispersed state it can not chill the steel or form harmful concentrations or inclusions of metallic aluminum or aluminum oxide. Degradation or scrap loss due to improper deoxidation arising from improper amounts and poor dispersion of addition agents are greatly reduced if not entirely eliminated for these reasons.

Furthermore, since the invention makes possible the reproducible, accurate introduction of a precisely controllable predetermined amount of addition agent into a small volume stream of molten steel at an accurately controllable period in the pouring cyce, it is possible to obtain reproducible results from heat to heat. Consequently, a great deal of guess work that has heretofore been necessary in steel making can be completely eliminated, and the quality of steel from heat to heat can be improved and rendered more uniform.

For these reasons, required amounts of addition agents can be greatly reduced, which is particularly important in cases where large amounts of relatively expensive addition agents are required.

While the invention has been discussed in connection with the addition of aluminum to steel, it is apparent that it may be employed in the introduction of other addition agents, either alone or in admixture, into steel or other molten materials. Examples of other addition agents are lime, calcium carbide, various types of finely divided alloying metals, etc. The term "finely divided" as used in the claims is intended to include particles ranging in size from a small fraction of an inch to approximately an inch or more, to include the sizes of addition agent particles commonly used in metallurgical industries. Although the invention has been described in connection with the introduction of addition agents into steel poured from an open hearth furnace, it may be employed to introduce addition agents into steel emanating from other types if heating equipment for producing molten steel, such as oxygen convertor equipment or electric furnaces; and the term "furnace" in the claims is intended to cover such equipment.

The gun described in this application has been found preferable for carrying out the method of the invention since the discharge end of the gun can be accurately and readily located in the desired position to cause the stream of particles to intercept the stream of molten metal at the proper location, and because the quantity and velocity of discharged particles can be readily and accurately controlled; this gun is disclosed and claimed in copending application Serial Number 338,755, also filed January 20, 1964. However, other types of equipment may be used to carry out the methods of the invention.

It is to be noted that modifications other than those indicated above may be made in the embodiment described above as illustrative of the invention. The essential characteristics of the invention are set forth in the appended claims.

We claim:

1. The process of introducing finely divided particles of addition agent into molten metal, comprising discharging a stream of molten metal to form a freely falling stream having a portion thereof which is substantially vertical, and discharging a stream of solid particles of addition agent into said stream of molten metal, said stream of particles being discharged from above said stream of molten metal so that when traveling in a substantially vertical direction it intersects the stream of molten metal above the portion thereof that is traveling substantially vertically, the particles being discharged at a velocity sufficient to cause them to penetrate the stream of molten metal.

2. The process of introducing finely divided particles of addition agent into molten metal, comprising discharging molten metal to form a freely falling solid stream having a substantially vertical portion, and discharging a stream of solid particles of addition agent into said stream of molten metal, said stream of particles being discharged from above said stream of molten metal so that when traveling in a substantially vertical direction it intersects said stream of molten metal above the portion thereof that is traveling substantially vertically, the cross secion of said stream of particles at its intersection with said stream of molten metal being narrow enough so that substantially all particles in said stream of particles strike said stream of melten metal, the particles being discharged at a velocity sufficient to cause them to penetrate said stream of molten metal.

3. The process of claim 1 comprising discharging said stream of particles by propellent gas.

4. The process of claim 1 in which particles of said addition agent are formed of a material of a substantially lower density than the molten metal.

5. The process of claim 2 in which particles of said addition agent are aluminum and the molten metal is steel.

6. The process of introducing finely divided particles of addition agent into molten steel, comprising discharging into a receptacle a stream of molten steel generally laterally to form a freely falling stream of generally paraboic shape that has a substantially vertical lower portion that drops into the receptacle, and discharging a stream of solid particles of addition agent into said stream of molten steel, said stream of particles being discharged from above said stream of molten steel so that when traveling in a substantially vertical direction it intersects the stream of molten steel above the portion thereof that is traveling substantially vertically, the particles being discharged at a velocity sufficient to cause them to penetrate the stream of molten steel so that the material of the particles is carried by the stream of molten steel into the receptacle.

7. The process of claim 6 in which said addition agent particles are aluminum.

8. The process of introducing finely divided particles of addition agent into molten metal passing from a furnace into a ladle, comprising discharging a stream of molten metal generally laterally from the furnace to form a freely falling stream of generally parabolic shape having a substantialy vertical portion, and discharging a stream of solid particles of addition agent into said stream of molten metal, said stream of particles being discharged from above said stream of molten metal in a substantially vertical direction to intersect the stream of molten metal above the portion thereof that is traveling substantially vertically, the particles being discharged at a velocity sufficient to cause them to penetrate said stream of molten metal.

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DAVID L. RECK, *Primary Examiner.*