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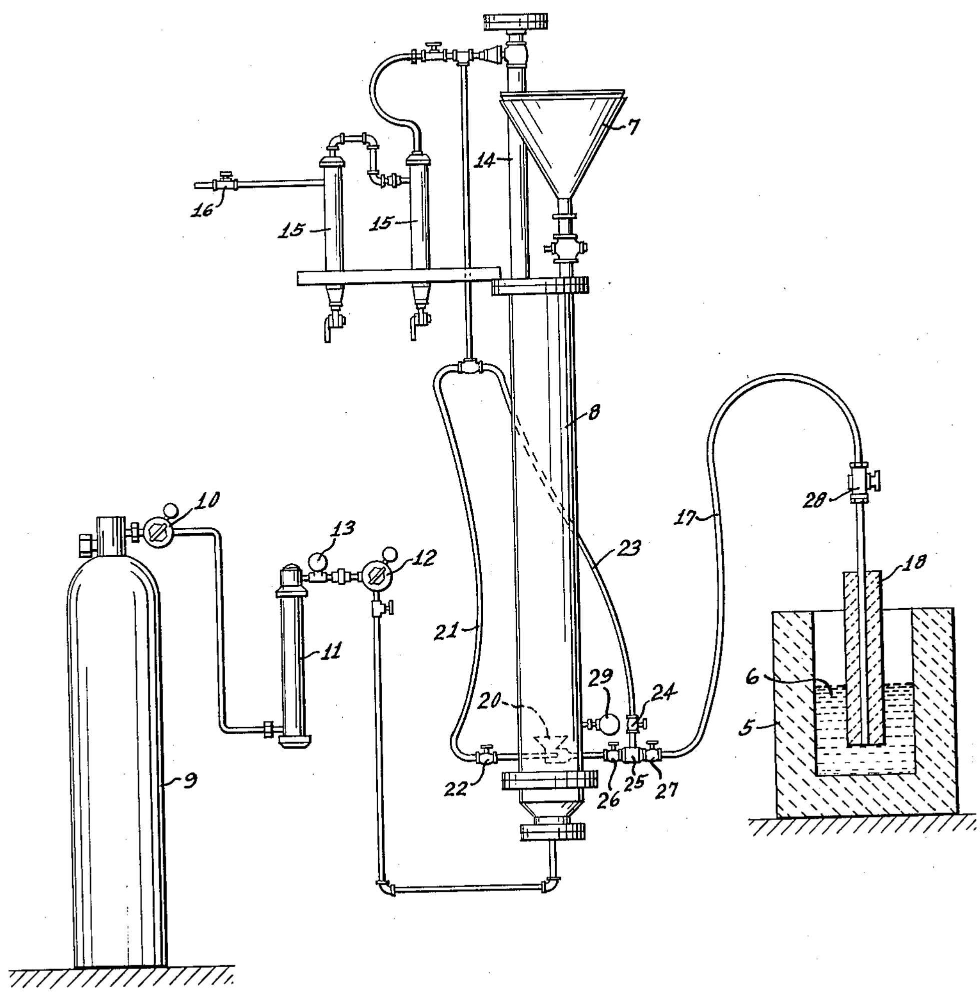

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METHOD FOR INTRODUCING SOLID MATERIALS INTO MOLTEN METAL

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This invention provides an improved method for introducing finely divided solid materials into molten metal. The invention is directed particularly to bringing finely divided solid materials into direct intimate contact with molten metal for effecting a reaction between the solid particles and liquid metal; but it can be employed also for introducing such materials into molten metal for other purposes, such as alloying.

Because of their inherent properties or characteristics, certain effective reagents such as calcium carbide are highly resistant to all ordinary methods for bringing them into intimate reactive contact with molten metal. These reagents have high melting points, and thus melt only at temperatures far above the temperatures to which molten metal is heated in conventional practices. Consequently they do not lend themselves to reactions of the liquid-liquid or slag-metal type across a liquid interface. Further such reagents generally have densities which are very much less than those of the metal, and they are not readily wetted by molten metal, so that when they are shoveled on to the surface of the molten metal, they float high with but a very small proportion of their surface in contact with the metal, and hence with but an exceedingly small solid-liquid interface across which they may react with the molten metal or with impurities therein.

Other solid treating agents, such as magnesium metal, have a high degree of reactivity and comparatively low boiling points. When these agents are introduced into molten metal in the usual way, substantial volatilization losses occur; and thus their introduction into molten metal is impractical, a fact well known in the art. In general, such agents have densities which are less than that of the metal; but the present invention is also applicable to those solids having densities greater than that of the metal, particularly if they are very reactive.

A specific embodiment of this invention involves the use of calcium carbide as a highly effective reagent for desulphurizing iron and steel. It is also a useful reagent for treating molten ferrous metals for other purposes, such as raising the quality of the resulting products, or promoting the formation of nodular cast iron. Because of its very high melting point, however, calcium carbide is highly resistant to conventional methods for bringing it into intimate reactive contact with the metal, for reasons given above.

It has been attempted to introduce calcium carbide into molten iron by forcing it (with a screw conveyor or equivalent mechanical device) through a suitable conduit which extends through the wall of a furnace or forehearth and which opens into the interior thereof at a point below the surface of the molten iron. This procedure has proved ineffective, because the calcium carbide invariably packs tightly in the conduit beyond the end of the screw, and cannot be forced out the end of the conduit into the molten metal.

Efforts have also been made to deliver calcium carbide to beneath the surface of the molten metal by blowing it in gaseous suspension through a pipe which extends to beneath the surface of the molten metal. Such procedure has in practice been found to be quite ineffective,

for the reason that the carbide is carried up through the molten metal in the bubbles of gas in which it is suspended or contained, and thus for the most part never comes into intimate or reactive contact with the molten iron. As a result, this procedure has been found to be no more effective, and sometimes even less effective, than simply shoveling the carbide on to the surface of the molten metal.

The only commercially practical procedure heretofore devised for introducing finely divided calcium carbide into reactive contact with molten iron, beneath its surface, is that described in the Philip M. Hulme Patent No. 2,577,764, granted December 11, 1951. In the procedure of said patent, a gas stream of very low velocity is passed into the molten metal beneath its surface. Finely divided calcium carbide is fed into this gas stream, in large amounts relative to the volume of the gas stream (at least about ½ pound of carbide per cubic foot of gas that enters molten metal). The gas stream flowing slowly through a feed pipe into the molten iron holds open a pathway in the feed pipe through which the calcium carbide may descend to beneath the surface of the molten metal; and the bubbles of gas slowly passing into the molten metal enable the carbide to flow out through the lower end of the feed pipe into the molten metal beneath its surface. Because of the large weight of carbide relative to the volume of the escaping gas, the latter is incapable of carrying very much of the carbide unreacted, in suspension or contained therein, up through the molten iron and in consequence, the carbide for the most part is brought into effective reactive contact with the molten iron. Once such reactive contact is established, the reaction between the carbide and the molten metal or the impurities which it contains proceeds rapidly.

It has now been discovered that if the calcium carbide is projected forcibly into the molten metal beneath the surface thereof, while at the same time maintaining a ratio of carbide weight to gas volume that is at least as high as described in the aforesaid Hulme patent, a substantially increased efficiency of carbide utilization in reacting it with the molten metal is achieved. Accordingly, the present invention provides for introducing calcium carbide (or other finely divided solid material) into reactive contact with molten iron or other metal by forming a gas-fluidized stream of such solid, in which the ratio of gas volume to weight of solid is much too low for any significant proportion of the finely divided solid particles to be carried out of the molten metal with the fluidizing gas, and projecting such stream at high velocity into contact with the molten metal at a substantial distance beneath its surface. The momentum of the individual solid particles in the fluidized stream must on the average be high enough for such particles (1) to resist retention in the fluidizing gas bubbles, (2) to cause such particles to penetrate the surface of the molten metal at the interface with the fluidizing gas, and (3) to carry such particles some distance into the molten metal beyond such interface. Thereby the solid particles are driven forcibly into direct contact with the molten metal, and substantially none of the finely divided solid is carried out of the molten metal by the fluidizing gas bubbles which rise up through the molten metal.

In carrying out the new method, it is of paramount importance that the volume of gas used in forming the fluidized stream of calcium carbide (or other finely divided solid particles) be sufficient to impart the flow characteristics of a fluid to the stream, but that the volume of gas be insufficient to serve for effecting gaseous suspension of the finely divided solid particles. The fluidizing gas must flow through the finely divided solids with sufficient velocity to separate the individual solid particles by the small distance necessary to enable them to move freely in the manner of a fluid. However, the volume of such flowing gas must be insufficient to incorporate the solid particles into a gaseous suspension, in which the solid particles are actually carried by the gas rather than merely being physically separated enough to flow freely as a fluid independently of the gas. This requires a sufficient velocity of gas flow through and in contact with the solid particles to enable them to flow freely substantially as a liquid, but it requires also that the volume of gas be low enough so that the fluidized particles do not tend to become widely separated by expansion into increased volume upon diminution of the gas pressure, which is the characteristic behavior of gaseous suspension.

The distinction between a gaseous suspension and a gas-fluidized mass of finely divided solid particles is characterized by a large difference in the apparent density of the gas-solid mixture. The term "apparent density" is sometimes defined as weight of solid particles per unit volume of the mixture, or alternatively as the volume of gas per unit weight of solids. For purposes of the present invention, the apparent density of the gas-fluidized stream at the point of its introduction into the molten metal will in no circumstances be less than that corresponding to two cubic feet of gas per pound of solid, which is the least dense mixture specified in the aforesaid Hulme Patent No. 2,577,764; and it may be even greater than that corresponding to the ratio of one-quarter cubic foot of gas per pound of solid mentioned in said patent. The maximum dense stream will obviously be that mixtured which can be secured without losing the fluidized characteristics of the stream.

It is of course characteristic of the invention that the fluidized stream of finely divided solids is projected with much force into the molten metal well beneath its surface. In this respect, the method of the present invention differs from that of the aforesaid Hulme Patent No. 2,577,764. In the method of that patent, no provision is made for directing the calcium carbide particles forcibly into the molten iron, and as a matter of fact they enter therein at no more than the rather low velocity with which the gas stream passes through the feed pipe and bubbles gently into the molten metal. In the method of the present invention, on the other hand, a high velocity is imparted to the fluidized stream of solid particles, and such stream is delivered into the molten metal at high velocity so that the individual solid particles of calcium carbide or other solid possess sufficient energy upon entering the molten metal to be driven forcibly into and through the metal and for a significant distance away from the injection apparatus. The total force of the fluidized stream is thus sufficient to prevent any clogging of the feed line and injection apparatus, resulting in a continuous and uniform flow of stream. This feature is especially important in a continuous operation where it is essential to maintain a steady flow of treating agent for the purpose of obtaining a product of uniform and predetermined content.

It is of course necessary, in order to secure the benefits of the invention, that the high velocity stream of solid particles delivered into the molten metal be of the high density which characterizes a gas-fluidized solid, rather than of the low density which characterizes a gaseous suspension of the solid. In the case of a gaseous suspension of the solid particles, the large volume of gas delivered into the molten metal along with the solid particles has the effect of cushioning the suspended particles and preventing them from being driven into effective reactive contact with the molten metal, even though the gaseous suspension may be blown into the molten metal at high velocity.

The method or procedure whereby the finely divided solid material is brought into the fluidized condition is not in itself an element of this invention. Techniques are already available and well known for creating fluidized beds of finely divided solids. Any such techniques may be adopted for carrying out the method of this invention.

An advantageous embodiment of the invention for treating molten iron with calcium carbide is described below with reference to the accompanying drawing, the single figure of which shows a form of fluidizing apparatus and an arrangement for delivering a stream of gas-fluidized calcium carbide into a body of molten iron. The gas-fluidizing apparatus shown in the drawing is a particularly convenient form of apparatus with which to form the high density, high velocity fluidized stream of solid particles, which in accordance with the method of the invention is directed into contact with the molten metal at a point well beneath its surface.

Referring to the drawing, a receptacle **5** contains a charge **6** of molten iron for treatment with calcium carbide in a batch operation. Finely divided calcium carbide, having a screen analysis of say 100% minus 48-mesh (Tyler screen series) is charged through a funnel **7** into a fluidizing column **8**. The fluidizing column may be supported on any suitable base (not shown).

A gas for fluidizing the finely divided calcium carbide is provided in a container such as a cylinder **9**. Any gas which is not objectionable for reasons of health or explosion hazard or because of its undue corrosive characteristics may be used, including oxidizing gases such as air or carbon dioxide, neutral or inert gases such as argon and nitrogen, and reducing gases such as propane. Gas is discharged from the cylinder through a pressure regulator valve **10** and passes through a flowmeter **11** and a second pressure regulator valve **12** to the base of the fluidizing column **8**. The pressure of the gas leaving the flowmeter is indicated by a gauge **13**.

The fluidizing column is filled to approximately two-thirds of its depth with finely divided calcium carbide, so that there is substantial open disengaging space in the upper end of the column. Extending above the column **8** is a standpipe **14** in which residual entrained carbide particles may separate from gas passing out of the column. Such gas may if desired be passed through conventional glass-wool or steel-wool filters **15** to remove the last traces of carbide dust, and is then vented to the atmosphere through a throttling valve **16**. By controlling the degree to which the valve **16** is opened, the desired pressure may be established and maintained in the fluidizing column.

It has been found experimentally that calcium carbide having the screen analysis given above is satisfactorily fluidized in the column **8** when the superficial velocity of the fluidizing gas in the column is in the range from 0.10 to 0.30 foot per second, as measured under the pressure existing in the column (say 25 to 50 pounds per square inch) and at room temperature (approximately 70° F.)

Fluidized calcium carbide is delivered from the column **8** through a feed line **17** to an injector tube **18**, from which it passes into the molten metal **6**. The fluidized carbide enters the feed line through a funnel-shaped inlet **20** located in the lower interior of the column. A by-pass tube **21** controlled by a valve **22** connected to the upper end of the standpipe **14** is provided to direct a stream of gas into a venturi-like injector at the base of the funnel-shaped inlet **20**, thereby to insure ready flow of the carbide into and through the feed pipe. Tube **21** has still another purpose. The fluidized stream in column **8** may have a ratio of carbide solid to gas so high that it does not feed through line **17**. The auxiliary stream of gas supplied by tube **21** decreases such ratio and enables the fluidized stream to be conveyed through line **17** and into the molten metal. As a result, the settling of carbide particles and their accumulation in the feed line are eliminated or greatly minimized. The auxiliary stream of gas thus provides a means for controlling the dilution of the stream in the feed line, independent of the dilution of the fluidized mixture in column **8**. It is believed further that this auxiliary stream of gas also aids in introducing a fluidized stream from a column of relatively large diameter (about 6" to 18") to a transport line of much smaller diameter (about 3/16").

A purge tube **23** controlled by a valve **24** connects the upper end of the standpipe **14** with the feed line **17** through a **T** connector **25** flanked on each side by valves **26** and **27**. The purge tube provides for directing a purging flow of gas free of carbide particles through the feed line.

It is generally convenient to connect the tubes **21** and **23** to the standpipe **14**, as shown, in order to utilize gas escaping from the upper end of the column **8** for assisting introduction of carbide particles into the feed line and for purging the feed line. However, the tubes **21** and **23** may equally well be connected to a branch (not shown) of the pipe leading from the pressure regulator **12**, or to some other source of gas under pressure.

By opening valves **22**, **26** and **27**, a stream of fluidized carbide from the column **8** is caused to enter the feed line **17** (which is made of flexible metal hose or other suitable tubing) and to flow at high velocity to and through the injector tube **18**. A valve **28** is provided to control the flow of fluidized carbide through an injector tube. The injector tube itself comprises an extra heavy steel tube which is surrounded by a refractory material, for example a refractory cement composed predominantly of 95% alumina and 5% silica. This assembly will withstand the temperature of the molten metal quite satisfactorily, and is easily replaced. It extends a substantial distance (preferably at least six inches) below the surface of molten iron.

Following is an example of a batch operation involving the treatment of molten iron, using apparatus of the character just described. Assuming that column **8** is empty, the maximum pressure existing within the gas system is atmospheric, and all valves vented to the atmosphere are closed. Prior to starting, the air in the system is dried to prevent reaction of any moisture contained with carbide. Carbide is fed through funnel **7** into column **8** until the column has the desired quantity of carbide. Nitrogen is introduced into column **8** until the approximate desired pressure is indicated by gage **29**. Final control of such pressure is made with valve **16**. The fluidizing velocity in column **8** is indicated on a volumetric basis by flowmeter **11**. Prior to any injection of carbide into the molten metal, the conveying line **17** (with injection tube **18** attached thereto but not inserted into the molten metal) is purged in both directions by manipulating valves **24**, **26** and **27**. With injector tube **18** still withdrawn from the metal, valves **26** and **27** are opened and desired flow conditions established. Upon inserting tube **18** into the bath, the fluidizer pressure is increased an amount corresponding to the static head of molten metal. Thus a fixed differential pressure is maintained across the conveying line and consequently a fixed carbide feed rate. Differential pressures are calibrated for varying feed rates, assuming a given size of calcium carbide particle, length and diameter of feed line.

The charge in the vessel **5** consisted of molten iron having a sulphur content of 0.07%. The gas supplied from cylinder **9** was nitrogen under a pressure of 150 p.s.i.; and the pressure of the gas in the fluidizing column was approximately 30 p.s.i. gage. The superficial velocity of the fluidizing gas, measured under the existing pressure in the column and at room temperature, amounted to 0.2 foot per second. All of the carbide was finer than 48-mesh. The feed line consisted of copper tubing, 3/16 inch inside diameter and forty feet long. The injection tube consisted of a steel tube 3/16 inch inside diameter and about four feet long connected at its discharge end to a cylindrical nozzle of carbon, also 3/16 inch inside diameter and two inches long. The steel injection tube and the carbon nozzle were both enclosed in a refractory sleeve of alumina. The differential pressure across the feed line (that is, the pressure in the fluidizing column **8** minus the pressure at the discharge end of injection tube) was approximately 28 p.s.i. gage. The injection tube extended approximately six inches below the surface of molten metal. The density of the fluidized stream of carbide delivered through the feed line was approximately 30.9 pounds of carbide per pound of gas, which corresponded to 0.45 cubic foot of gas per pound of calcium carbide at the point of introduction into the molten iron. The velocity at which the fluidized calcium carbide was discharged from the injection tube into the molten metal was 72.6 feet per second. The sulphur content of the molten iron reduced from 0.07% to 0.005%, or about 93%, indicating that the calcium carbide came into sufficiently intimate contact with the molten metal to react effectively with the sulphur therein.

Following is a general description of the characteristics which the stream flowing through the feed line should possess: The static pressure of the gas in the fluidizer is sufficient (1) to insure continuous feeding of the gas and solid stream through the feed line; (2) to overcome the static pressure of the molten bath at the end of the injection tube; (3) to maintain a gas-filled cavity in the metal immediately below the exit opening of the injection tube; and (4) to impart sufficient velocity energy to the carbide particles to overcome the surface tension of the molten metal at its interface wth the gas and to overcome the viscous and buoyant forces tending to resist penetration of the particle a significant distance into the molten metal.

In general, the fluidized stream is introduced to beneath the surface of the molten metal at a velocity exceeding twenty-five feet per second; and in a typical case it is advantageously delivered into the molten metal at a velocity exceeding 50 feet per second. In actual operation, the velocities ranged from 50 to 115 feet per second. In the fluidizer operations, the density of the stream is at least one pound of calcium carbide per cubic foot of gas.

Since the impulse of the stream leaving the injector tube is a function of the mass and velocity, it may be varied by changing either the density or velocity of the stream. A change in velocity may be obtained by varying the pressure of the nitrogen supplied from cylinder **9**; and a change in density may be obtained by varying the ratio of gas volume to weight of solids.

It will be understood that in carrying out the present invention, the fluidized stream of finely divided solids entering the feed line has sufficient momentum initially to flow uninterruptedly through such line and penetrate into the molten metal sufficiently to prevent any settling and accumulation of carbide particles in the feed line and to prevent any clogging of the injector tube by accumulation of carbide particles at the exit end thereof. These characteristics of the stream eliminate an uneven slug-type discharge of carbide from the feed line, and insure a uniform and continuous flow of treating agent.

We have found that the characteristics of the fluidized stream may be improved by the use of agents which promote or aid a steady and free flow of such stream, such as finely divided magnesium silicate or diatomaceous earth. These agents prevent agglomeration of carbide particles in the feed line, which if it occurs is likely to obstruct the desired steady and uniform flow of the gas and solid stream. In treating molten metal with calcium carbide, the use of about 3% by weight of such agents is satisfactory.

It has been found experimentally that when using the method of the invention, the fluidizing column may have a height of about 6" and an inside diameter of 4", in sharp contrast to known fluidizing columns for coal particles which have corresponding dimensions of about 6' and 18". An auxiliary hopper of any desired capacity feeds carbide particles more or less continuously into the small fluidizing column, at a rate sufficient to keep the column substantially full at all times.

The specific embodiment of the invention has been described in connection with calcium carbide for treatment of molten metal. It is understood that equally good results may also be obtained by the application of the invention for bringing other finely divided materials into the molten metal, for the purpose of effecting a reaction between the solid particles and liquid metal, or for any other purpose, such as alloying. Broadly, the general principles involved in the introduction of calcium carbide beneath the surface of molten metal will apply to any other solid agent. For each solid agent, obviously there is a preferred solid-gas ratio which will vary according to the physical characteristics peculiar to each agent. But the characteristics of the various fluidized streams will be the same generally. As in the case of calcium carbide, the characteristics of the various streams may be modified by the use of agents promoting free flow, auxiliary gas streams, and the like.

The invention is particularly applicable to methods for producing upgraded and nodular cast irons, such as disclosed in the copending application, Serial Nos. 246,314, filed September 12, 1951, now abandoned, and 305,315, filed August 20, 1952, now Patent 2,963,364, issued December 6, 1960, assigned to the assignee of the present application. The treating agent comprises calcium carbide alone, or calcium carbide together with relatively small amounts of nodulization-impelling agents, such as magnesium and rare earth elements.

The apparatus involved in the practice of the present invention is simple, consisting essentially of a gas cylinder, a pressurized column and hopper, a feed line, and metering and control devices. The apparatus is inexpensive, installed readily, operated easily, and adapted for various metallurgical operations in the same or different localities. Further, the apparatus contains no moving parts, thus providing means for feeding reagents more dependably, and means which require the minimum amount of inspection and servicing.

It will be understood that the invention is not limited to the specific examples described herein, but may be practiced in other ways without departing from the spirit and scope of the invention as defined by the following claims.

We claim:

1. The method of bringing a finely divided solid having substantially the density of calcium carbide into direct contact with a molten metal which comprises forming a fluidized bed of said solid and a gaseous medium, drawing a fluidized stream of said solid out of said bed, transporting said stream through a feed line, said stream having an apparent density of at least one-half pound per cubic foot and containing insufficient gas in relation to the weight of solid material for the solid material to become suspended in the gas, and projecting said stream from said feed line into the molten metal beneath the surface thereof at a velocity exceeding 25 feet per second, whereby the particles of solid material are caused to penetrate completely through the interface between the gaseous medium and the molten metal and to pass a substantial distance into the molten metal beyond such interface and thus are separated from the gas bubbles rising to the surface of the molten metal.

2. The method in accordance with claim 1 in which the apparent density of said stream is at least one pound per cubic foot.

3. The method in accordance with claim 1 in which an auxiliary stream of gas in introduced into the feed line whereby dilution of the fluidized stream is automatically controlled.

4. The method in accordance with claim 1 in which an agent is introduced into the fluidized stream to promote a steady and free flow thereof.

5. The method of bringing a finely divided solid having substantially the density of calcium carbide into direct intimate contact with a molten metal which comprises forming said solid into a gas-fluidized stream which flows at a velocity exceeding twenty-five feet per second, said stream having an apparent density of at least about one pound of solid per cubic foot of gas, and delivering said stream at said velocity and density into the molten metal at a substantial distance beneath the surface thereof.

6. The method of bringing a treating agent comprising finely divided solid calcium carbide into reactive contact with a molten ferrous metal which includes forming a fluidized bed of said carbide and a gaseous medium, drawing a fluidized stream out of said bed, transporting said stream through a feed line at a velocity exceeding twenty-five feet per second, the volume of said gas being sufficiently small in relation to the weight of said carbide so that the apparent density of the flowing stream is at least one pound of carbide per cubic foot of gas, and delivering said stream at said velocity and said density into the molten metal beneath the surface thereof.

7. The method of bringing a finely divided solid having substantially the density of calcium carbide into direct intimate contact with a molten metal of relatively high density which comprises forming of said solid a gas-fluidized stream in which the density is at least one pound of solid per cubic foot of gas, and projecting such stream into contact with the molten metal beneath the surface thereof at a velocity exceeding 25 feet per second, whereby the solid particles are caused to penetrate completely through the interface between the fluidizing gas and the molten metal and to pass a substantial distance into the molten metal beyond such interface and thus are separated from the gas bubbles which rise to the surface of the molten metal and substantially none of the finely divided solid is carried out of the molten metal in said gas bubbles.

8. The method in accordance with claim 7 in which the finely divided solid particles comprise calcium carbide.

9. The method of injecting a treating agent comprising finely divided solid calcium carbide into reactive contact with a molten ferrous metal which includes feeding said carbide particles and gaseous medium into a feed line at a regulated rate of flow, transporting the resulting mixture of gas and carbide particles through said feed line in the form of a high velocity stream, said stream having an apparent density of at least one pound of solid per cubic foot of gas, and projecting such stream into contact with the molten metal beneath the surface thereof at a velocity exceeding 25 feet per second and in any event sufficient to cause the solid particles to penetrate completely through the interface between fluidizing gas and molten metal and to pass a substantial distance into the molten metal beyond such interface, whereby the carbide particles are substantially completely separated from the gas and substantially none of the carbide particles are carried out of the molten metal in the gas bubbles which rise through the molten metal.

10. The method of bringing a finely divided solid having substantially the density of calcium carbide into direct intimate contact with a molten metal which comprises forming of said solid a gas-fluidized stream in which the ratio of gas to solid is too low for the finely divided solid particles to be carried thereby in gaseous suspension, and projecting such stream into contact with the molten metal at a substantial distance beneath the surface thereof at a velocity exceeding 25 feet per second and in any event sufficient to cause the solid particles to penetrate completely through the interface between fluidizing gas and molten metal and to pass a substantial distance into the molten metal beyond such interface, whereby the solid particles are substantially completely separated from the fluidizing gas and substantially none of the finely divided solid is carried out of the molten metal by the fluidizing gas bubbles which rise through the molten metal.

11. In the method of forming a fluidized powder stream and injecting the same into molten metals through an injection tube partially immersed in said molten metal for the metallurgical treatment thereof, the improvement which comprises forming said fluidized powder stream by feeding powder under a controllable regulated pressure into an inert gas stream at a point remote from the point of injection to form said fluidized powder stream, conveying said fluidized powder stream through conduit means to said injection tube, and correlating the value of said controllable regulated pressure with the powder feed rate desired to said fluidized powder stream while maintaining the pressure in said injection tube at a value at least greater than that required to prevent molten metal from rising within said partially immersed injection tube.

12. In the method of forming a fluidized powder stream and injecting said stream into molten metal through an injection tube partially immersed in said molten metal for the metallugical treatment thereof, the improvement which comprises forming a bed of powder in a closed container, passing a gas upwardly through said bed at a velocity sufficient to fluidize at least a portion of said bed in said container, withdrawing a fluidized stream of said powder out of the fluidized portion of said bed, conveying said fluidized stream through conduit means to said injection tube, injecting said stream from said tube into said molten metal below the surface thereof, and maintaining a pressure in said container sufficient to maintain the pressure in said injection tube at a value at least greater than that required to prevent molten metal from rising within said injection tube and sufficient to provide the desired feed rate of said powder through said injection tube and into said molten metal.

13. The method in accordance with claim 12 in which the apparent density of said stream is at least about one pound of solid per cubic foot of gas.

References Cited in the file of this patent

UNITED STATES PATENTS

1,038,781	Myles et al.	Sept. 17, 1912
2,291,221	Gibson	July 28, 1942
2,502,259	Hulme	Mar. 28, 1950
2,577,764	Hulme	Dec. 11, 1951
2,636,642	Gorin	Apr. 28, 1953
2,803,533	Bieniosek et al.	Aug. 20, 1957

OTHER REFERENCES

Desulphurization of Pig Iron with Calcium Carbide, by Wood et al., Transactions AIME, vol. 140 (1940), pp. 87–105.