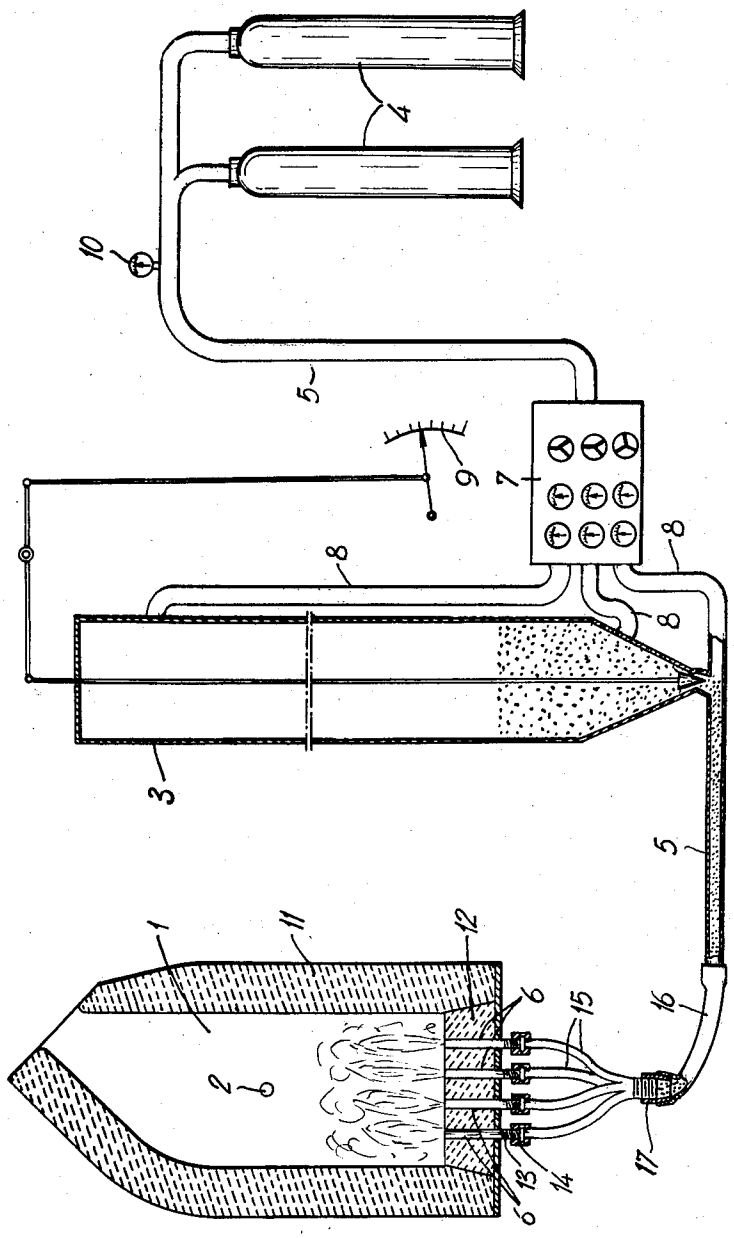
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METHOD FOR DESULFURIZING MOLTEN METAL AND IN PARTICULAR LIQUID PIG IRON

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METHOD FOR DESULFURIZING MOLTEN METAL AND IN PARTICULAR LIQUID PIG IRON

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Our invention has for its object a new method for desulfurizing molten metal and in particular liquid pig iron.

Even small amounts of sulfur have an extremely high objectionable effect on the grade of cast iron and steel and consequently it is generally desired to remove the sulfur through various means during the production of liquid pig iron or steel.

For instance, it is possible to charge the blast furnace with large amounts of limestone or manganese ore so as to obtain operation under highly basic conditions or else to produce high manganese hot metal, but such procedures are expensive by reason of the increased consumption of fuel thus required or of the cost of manganese ore. It is also possible to remove the sulfur from the steel in the electric or open-hearth furnace through the agency of highly basic slags but such methods are generally expensive and reduce the yield of the furnaces.

It has been proposed since a long time to resort to methods for desulfurizing liquid pig iron outside the actual producing apparatus and generally sodium carbonate is resorted to for this purpose and this sodium carbonate admixed with the liquid pig iron inside a ladle allows removing a part of the sulfur, but it shows however the drawback of leading to the production of a highly fluid corrosive slag together with the release of noxious vapors. Furthermore, said prior method does not allow obtaining very low sulfur contents or removing the large amounts of sulfur contained in the liquid pig iron produced through certain methods such as the acid operation of the blast furnaces or again when using certain ores or certain cokes.

On the other hand, solid lime the desulfurizing properties of which are well known does not show the above mentioned drawbacks and has often been resorted to for desulfurizing the liquid pig iron.

Thus, it has already been attempted to desulfurize liquid pig iron, through the agency of crushed burnt lime to which is incorporated pulverulent coke, inside a rotating furnace heated with gases produced in a coke oven or else with atomized coal. In spite of operative cycles lasting several hours it has not been possible to reach in this manner very small residual contents of sulfur.

Similarly, a method is known which allows treating with the best results liquid pig iron, inside a cylindrical container revolving at a high speed, through the agency of pulverulent lime to which is possibly incorporated pulverulent coke and which is introduced before the beginning of operation over the metal bath, while the introduction of oxidizing substances before and after operation is limited to an amount as small as possible.

A further method is known according to which the lime admixed with fluorspar is fed into the metal bath and is stirred through the agency of a low frequency alternating current.

All the above mentioned prior methods show various advantages and drawbacks and lead to more or less satisfactory results, but none is completely satisfactory as

concerns industrial operation, more particularly when it is necessary to take into account a high rhythm of production.

Such methods do not resort furthermore to any suspension of lime in a stream of gas.

However, in the case of oxidizing and deoxidizing reactions, methods exist which provide for the suspension of pulverulent material in a gas and its blowing into a metal bath.

As concerns desulfurizing reactions, methods are also known according to which the desulfurizing reagent is suspended inside a stream of gas and then injected by means of a lance into the metal bath contained in a crucible or in a ladle or in an electric furnace. Those methods which resort to lime as a desulfurizing reagent in association with a non oxidizing gas such as nitrogen for instance, although they may lead to a substantial removal of sulfur have however not allowed obtaining systematically a high rate of desulfurization leading to low final contents of sulfur in the treated liquid pig iron and this comparative failure explains why the injection of pulverulent lime through a lance has not been developed on an industrial scale for the execution of high desulfurizing procedures.

The reasons of said failure reside firstly in the difficulties encountered when immersing a lance inside a metal bath and due to the reaction of the bath, to the vibrations and wear of the lance and to the projections of metal. These difficulties may be easily removed on a small laboratory scale or even when a few ten kilograms of metal are to be produced, but these difficulties increase rapidly with the weight of metal to be treated as in the case of applications on an industrial scale and the deep immersion of the lance forms a serious problem.

Even if this problem is solved for conventional industrial operations, there remains an important reason for the failure of prior attempts towards reaching systematically low contents of sulfur, said reason residing in the actual nature of the method for blowing the lime through the immersed lance which leads to a local action of the blown desulfurizing reagent so that if locally and round the lance large rates of sulfur removal are obtained, the remainder of the bath is not reached at once by the reagent and is only reached partly and subsequently. This drawback is all the more serious for a given duration of treatment when the mass of metal to be desulfurized during a single operation is higher and this will be readily understood since the mass of desulfurized metal round the lance corresponds to only a small fraction of the mass to be desulfurized so that the result is a lower average rate of sulfur removal.

Our invention which is the result of numerous experiences made by ourselves both on a pilot scale and on an industrial scale has for its object an industrial sulfur-removing method which shows none of the above referred-to drawbacks by reason of its resorting to a combination of steps leading to a very energetic, rapid and economical elimination of sulfur out of molten metal and in particular out of liquid pig iron.

A further object consists in removing large amounts of sulfur contained in the cast iron produced through acid methods in blast furnaces or the like apparatuses.

A still further object of our invention consists in obtaining within a very short duration very low contents of residual sulfur in such liquid pig irons, which contents may be in fact not measurable through conventional chemical analyzing methods, a result which is very difficult or in fact impossible to reach through any other known methods.

A systematic series of investigations relating to the transformation of the sulfur in a basic Bessemer converter has confirmed the existence, already mentioned by

prior experimenters, of a certain grade of sulfur removal, often of the magnitude of 15 to 20% appearing at the beginning of the refining of liquid pig iron in a basic Bessemer converter. This desulfurization produced by the stirring of the liquid pig iron with lumps of lime incorporated into the charge at the beginning of operation is speedily brought to an end, chiefly as a consequence of the oxidation of the silicon through the oxygen of the air blown into the converter during the refining.

Comparison with the particular problem of the removal of sulfur out of liquid pig iron has allowed us to foresee that, provided the air is replaced by a non-oxidizing gas while the lumps of lime introduced at the beginning of the operation are replaced by pulverulent lime blown with said gas through the blow holes, the advantages of the intimate contact and intense stirring obtained in a converter through said blowing would allow obtaining a substantial and speedy desulfurizing of the liquid pig iron. In order to obtain a very high desulfurization ratio, desulfurizing executed by means of lime requires non oxidizing conditions, which is a well-known fact ascribable to the general laws of thermodynamics (in particular Le Châtelier's law).

Tests executed on a pilot scale have brought a complete confirmation for these assumptions, to a point such that the results were rapidly applied on an industrial scale.

The efficiency and speed of desulfurizing are due to the blowing into the converter of lime powder together with a non-oxidizing or very slightly oxidizing gas, as provided through the agency of tuyeres opening into the wall or the bottom of the apparatus and which lie underneath the metal level during operation, which leads to stirring under intimate contacting conditions the desulfurizing substance with the metal to be desulfurized, and this is all the more true because the actual movement of the bath may be associated with a relative movement of the tuyeres. In the case for instance of the application of a converter to such a desulfurizing operation, the tilting of the converter round its axis through a predetermined angle will constrain each tuyere to sweep through the same angle.

The high speed of the operation is of particular advantage for the limitation of losses of heat, which is of a considerable interest for operations on industrial scale, said advantage being increased when the container serving for the transportation of the metal serves also for desulfurizing purposes, since it is possible to prevent thus any drop in temperature arising as a consequence of the transfer of the metal from one container into another.

Our improved method distinguishes clearly from the known methods for blowing pulverulent lime suspended in a stream of gas through the agency of an immersed lance because the stirring and contacting conditions obtained when blowing through tuyeres covered by the molten metal during operation with the sole object of desulfurizing the metal are far better and allow desulfurizing the latter to a very marked extent in a very speedy manner whereas the use of an independent immersed lance does not allow obtaining, chiefly in the case of industrial operation, an equivalent desulfurization within so short a time with the same consumption of the same desulfurizing substance.

Our method distinguishes also fundamentally from the numerous methods using the blowing of various powdery products in order to obtain in a same vessel several metallurgical operations such as desulfurization, desiliconization, dephosphorization. As previously stated, in order to obtain a rapid and important desulfurization, it is fundamental that the vessel be used for desulfurization only.

Our invention will be now described in a more specific but non-limiting manner, reference being made to the accompanying drawing the single figure of which is a diagrammatic showing of a plant intended for the execution of our invention inside a converter as a container for the reaction media.

As illustrated, the plant includes chiefly an apparatus 1 in the shape of a steelwork converter the capacity of which is of the order of 300 kilograms of metal to be treated, said converter being adapted to be tilted round its axis 2 through the agency of an electric motor which is not illustrated, the plant including further a powder-distributor 3 designed in a known manner and feeding uniform outputs of highly concentrated suspensions of a very fine powder, a group of bottles 4 containing compressed nitrogen, a pipe 5 feeding the nitrogen with the subsequent admixture of the desulfurizing reagent to the tuyeres 6 extending through the bottom of the small converter and lastly a control board 7 for checking and adjusting operation.

This control board shown very diagrammatically at 7, carries the manometers, the flowmeters and the different valves through which it is possible to control and adjust the flow of the fluid carrying the operative powder. We have illustrated in the drawing the fluid conveying channels 8 connecting the valves and measuring instruments on the control board with the corresponding elements of the blowing system. We have shown at 9 the scale which allows adjusting as required the opening of the powder distributor device. Lastly we have illustrated at 10 the pressure reducing and measuring valve for the battery of gas-containing bottles of which only two have been illustrated at 4 on the drawing.

To the refractory wall 11 of the converter is secured the converter bottom at 12 provided with tuyeres 6 forming tubular connections with threaded outer ends 13, which ends carry through the agency of fastening collars 14 the lime distributing tubes 15. The substances to be projected into the converter are fed through a yielding pipe 16 connected with the tube 5 at one end and through the threaded connection 17 at the other end with the lime distributing tubes 15. It should be remarked that the blowing means do not include any wind box.

Many other types of apparatuses may be used for executing our invention. Thus, instead of a converter, we may resort to a tilting ladle which serves both for the transportation of liquid pig iron and for the execution of the desulfurizing operation. During the transportation of the liquid pig iron, the tuyeres in the ladle project above the level of the molten metal so that they may be brought through a tilting movement of the ladle round its axis underneath the level of the bath during the desulfurizing operation.

It is also possible to resort to a special intermediate container similar to a so-called tea-pot ladle and to subject the liquid pig iron to a continuous treatment during the casting of the blast furnace.

The method according to our invention which may be executed in the arrangement referred to hereinabove, consists in producing a suspension, inside a neutral or slightly oxidizing or reducing gas of the desulfurizing agent in the form of a highly subdivided powder, said suspension being very concentrated so as to damp the cooling action of the carrier-gas and to reduce the duration of the operation; the suspension formed is then blown into the metal bath through the openings provided in the bottom or along the wall of the metallurgical container carrying the molten metal to be treated, said openings registering with the inside of the bath underneath the level of the latter in the container.

The desulfurizing agent used should be of a very fine granulometry such for instance that it may pass entirely through a 20 mesh Tyler sieve. It is possible to use advantageously pulverulent lime or more generally an oxide or a compound of alkaline or earth alkaline metal or magnesia or a mixture of such oxides or compounds,

It is also possible to resort to one or more of the precedingly mentioned desulfurizing agents with the addition of pulverulent reducing substances.

The desulfurizing agent may also act as a reducer in which case it is constituted e.g. by calcium carbide or calcium cyanamide.

As to the carrier gas it is also possible to use various gases for this purpose. Although we prefer using nitrogen, it is possible to incorporate into the carrier gas a reducing gas such for instance as hydrogen or carbon monoxide or hydrocarbons.

The following examples are given by no means in a limiting sense but only to show various means for executing our invention together with the results which may be expected.

Example 1.—A small converter provided with a basic lining and tuyeres associated therewith is heated up to 1000° C. and laid horizontally. A ladle containing about 300 kgs. of liquid pig iron previously melted in a small induction furnace is then brought near the converter so that the metal may be poured into the latter.

Immediately after the liquid pig iron has been poured into the converter, a sample is removed and shows sulfur contents of 0.080%, the temperature of the liquid pig iron being equal to 1300° C. The nitrogen is then introduced and a few seconds afterwards, the powder distributor is adjusted so as to produce the desired flow. The desulfurizing agent used in said example is constituted by crushed commercial burnt lime adapted to pass through a 20 mesh Tyler sieve. It is a well known fact that lime when crushed assumes for its major part the form of a flour dust. The appearance of a white cloud at the mouth of the converter is a signal meaning that the converter is then to be raised into its vertical position. The blowing is then performed normally without any substantial projection out of the converter. A flame appears at the mouth of the converter and this flame shrinks gradually during the operation together with the small cloud of lime; in the case considered the output of lime is equal to about 3 kgs. per minute. After the blowing has lasted about 3 minutes, the converter is returned into its horizontal position while its lime and nitrogen circuits are cut off in succession. A sample removed 20 seconds after the converter has been returned into its horizontal position shows sulfur contents of 0.006%, which corresponds to a rate of desulfurization equal to 93%. The metal bath is then poured without any difficulty into a ladle while the desulfurizing mixture remains inside the converter and may be removed for its major part through a complete tilting down of the converter.

The following Table I gives further details relating to the above test in particular as concerns the composition of the liquid pig iron.

We may also mention in said Table I the data relating to two other tests made on about 300 kgs. of metal with commercial lime of the same batch as in the preceding test of which other tests that numbered 3 relates in particular to the treatment of liquid pig iron with high contents of sulfur equal to 0.191%.

The use of only 300 kgs. of metal for successive tests which are separated from one another by substantial intervals of several hours is somewhat objectionable and leads to a consumption of lime which is higher than that required in the case of continuous operation or when treating larger amounts of metal during a single test.

Example 2.—It has been found in fact through tests on larger amounts of liquid pig iron inside a converter of 2.5 to 3 tons that the difficulties encountered have been smaller.

The above Table I also shows the result of four tests made on a larger scale while resorting to commercial lime of the same type as in the preceding example: two of these tests included a blowing period of 3 minutes and the two others a blowing period of only 1 minute and 30 seconds. The consumptions of lime were of a magnitude of 2% of the weight of treated metal while the rate of desulfurization ranged between 83 and 94%. The concentrations of lime in the nitrogen are very high and reach 40 kgs. per cubic meter. In all the cases the samples have been removed immediately after the apparatus has been titlted down without waiting for any settling as is generally required with other known blowing methods. The rhythm of production is very high since the pouring into a ladle of the treated iron may be executed as soon as the blowing of the pulverulent lime through the bath is at an end.

Example 3.—The speed and the efficiency of the desulfurizing method resorting to pulverulent lime according to our invention are evidenced in a particularly clear manner by the following test executed with an apparatus containing 2,500 kgs. of metal as shown in the following Table II. In said test less than 3 minutes after the beginning of the operation, the liquid pig iron is practically devoid of any sulfur.

Table II

Sample No.	Weights of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	Percentage of sulfur	Desulfurization efficiency, percent
1	2,500	0	0	0.092	(1)
2	2,500	1′ 30″	25	0.025	73
3	2,500	3′	51	<0.003	>96
4	2,500	4′ 30″	77	<0.003	>96

[1] Starting value.

Example 4.—We should also mention the use of lime with the addition of pulverulent charcoal; the Table III refers to tests executed with a mixture of 80% of lime with 20% of charcoal.

Table I

Test No.	Weight of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	C, percent	Mn, percent	Si, percent	P, percent	S at the beginning of the operation, percent	S at the end of the operation, percent	Desulfurization efficiency [1] percent
1	300	3′	9.5	3.6	0.43	0.64	1.75	0.080	0.006	93
2	300	3′	5	3.6	0.40	0.80	1.70	0.079	0.019	76
3	320	3′ 30″	13.5	3.6	0.40	0.61	1.70	0.191	0.013	93
4	2,500	3′	49	3.3	0.1	1.5	0.15	0.096	0.010	90
5	3,000	3′	57	3.8	0.4	1.8	0.6	0.080	0.005	94
6	2,500	1′ 30″	55	3.9	0.5	1.5	0.65	0.073	0.012	83
7	2,500	1′ 30″	53	3.8	0.5	1.85	0.58	0.087	0.005	94

[1] Desulfurization efficiency is defined by:

$$\frac{\text{S, at beginning} - \text{S, at end}}{\text{S, at beginning}}$$

Table III

Test No.	Weight of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	S at the start, percent	S at the end percent	Desulfurization efficiency, percent
1	300	4′ 30″	8.5	0.026	0.004	85
2	300	3′	5	0.069	0.009	87
3	300	4′ 30″	6	0.059	0.009	83
4	300	3′	7.5	0.072	0.008	89

Example 5.—We should further mention the use of lime of the same type as precedingly with the addition of a small percentage of pulverulent aluminium; in Table IV are recorded the data corresponding to tests executed in apparatuses containing 300 and 2500 kgs. of metal with a percentage of aluminium equal to 2% of the weight of lime.

Table IV

Test No.	Weight of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	S at the start, percent	S at the end percent	Desulfurization efficiency, percent
1	300	3′	7	0.059	0.006	92
2	300	3′	7.5	0.058	<0.003	95
3	300	4′ 30″	11	0.300	0.004	99
4	2,500	3′	64	0.095	0.007	93
5	2,500	3′	72	0.060	0.004	93
6	2,000	3′	69	0.136	0.010	93

Example 6.—We will give further details relating to the test Number 3 shown in the Table IV so as to emphasize the extraordinary speed and efficiency of the method even in the case of liquid pig iron with high contents of sulfur, say 0.3% in the test Number 3 referred to.

Table V

Number of sample	Weight of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	Sulfur in percent	Desulfurization efficiency, percent
3_1	300	0	0	0.300	0
3_2	300	1′ 30″	4	0.056	81
3_3	300	3′	7.5	0.015	95
3_4	300	4′ 30″	11	0.004	99

Example 7.—We may also mention the use of lime into which is incorporated a small percentage of pulverulent magnesium; the Table VI shows two tests executed respectively on 300 kgs. of liquid pig iron with lime incorporating 2% of magnesium and on 2,500 kgs. of liquid pig iron with lime containing only 1% of magnesium.

Table VI

Test No.	Weight of metal in kg.	Duration of blowing in minutes	Weight of lime in kg.	S at the start, percent	S at the end, percent	Desulfurization efficiency, percent
1	300	1′ 30″	7	0.101	<0.003	>97
2	2,500	3′	57	0.084	<0.003	>96

The efficiency of the method is such that very small amounts of magnesium are sufficient for the substantially complete elimination of the sulfur out of the liquid pig iron to be treated and it will be readily understood that the method is of a considerable economical interest in particular when applied to certain problems such as that of nodular cast iron.

Example 8.—It is possible to substitute for the lime, according to the local conditions or present problems, oxides or compounds of alkaline or earth alkaline metals or mixtures thereof or else magnesia or burned dolomite, any of said oxides or compounds or mixtures thereof being blown into the cast iron in accordance with our improved method. The use of magnesia or burned dolomite in particular can be of advantage for the treatment of liquid pig iron at high temperature since the melting point of the slag forming in the presence of silica and iron oxide is raised through the presence of magnesia and thus the desulfurization may be continued until minimum contents are actually obtained.

Example 9.—We may also resort to other desulfurizing agents such as calcium carbide or calcium cyanamide with yields which are far better than with the methods applied hitherto, this being ascribable to the large contacting surfaces provided by the use of tuyères opening into the bath. Table VII shows the results obtained with three tests executed respectively with calcium cyanamide admixed with aluminium with lime incorporating calcium carbide and with lime incorporating calcium cyanamide.

Table VII

Test No.	Blown mixture	Blown weight in percent of metal bath	Duration of blowing in minutes	Sulfur contents at—		Contents of carbon and silicon, at—		Temperature of the liquid pig iron at start, ° C.
				Start, percent	End, percent	Start	End	
1	Lime plus 20% calcium carbide	3	3	0.063	0.007	3.84C and 0.67Si	3.78C and 0.52Si	1,375
2	Lime plus 45% CN_2Ca	3	3	0.071	Not measurable <0.003	3.75C and 0.58Si	3.75C and 0.49Si	1,355
3	CN_2Ca plus 2% Al	3	3	0.053	do	3.66C and 0.69Si	3.63C and 0.49Si	1,380

Subsequent tests have allowed a substantial reduction of the consumption of carbide or cyanamide, which is somewhat large in the case of these first tests.

Example 10.—A further embodiment of our invention consists in resorting to a carrier fluid constituted by a gas which is itself an energetic reducing agent. It might be preferable not to use pure hydrogen for this purpose by reason of the dangers arising in the handling of this gas and we have executed a test with a suspension of lime in nitrogen with the admixture in the latter of a small amount of ammonia. The desulfurization obtained is particularly large in this case as shown in Table VIII. Obviously it is also possible to use hydrogen, provided the plant is designed specially for the use of such a gas.

Table VIII

Blown mixture	Weight of blown lime, percent	Duration of blowing in minutes	Sulfur at the start, percent	Sulfur at the end, percent	Temperature of iron, ° C.
Lime in nitrogen plus 2% ammonia.	3	3	0.085	Not measurable <0.003.	1,340

But it is also possible in accordance with local conditions to resort to other gases, such for instance as coke oven gases or natural gases.

Obviously the above disclosed examples and the diagrammatic showing of the arrangement used have been given solely by way of examples and by no means in a limiting sense and the methods may be executed in any

other desired manner within the scope of the accompanying claims.

What we claim is:

1. In a method of desulfurizing molten metal with a selected desulfurizing agent, the step of introducing into a bath of molten metal in liquid state a highly concentrated suspension containing at least 5 kgs. of finely subdivided particles of said selected desulfurizing agent per cubic meter of gas so as to speed—due to said high concentration of said finely subdivided solid particles of desulfurizing agent in said relatively small quantity of gas—the rate of reaction to such a value that the temperature drop of the molten metal—due to admission of said gas—is so small that the desulfurizing reaction takes place at a high temperature and before a considerable temperature drop occurs, thereby ensuring reaction between said molten metal and said selected desulfurizing agent at a temperature at which the efficiency of the desulfurizing action of said selected agent is substantially greater than after said considerable drop of the temperature of the molten metal.

2. In a method of desulfurizing molten metal with a selected desulfurizing agent, the step of introducing into a bath of molten metal in liquid state a highly concentrated suspension containing at least 5 kgs. of finely subdivided particles of said selected desulfurizing agent per cubic meter of gas and at a high specific admission rate equal to at least 19 kgs. of said desulfurizing agent for each 3,000 kgs. of molten metal per minute, so as to speed—due to said high concentration of said finely subdivided solid particles of desulfurizing agent in said relatively small quantity of gas and due to said high specific admission rate—the rate of reaction to such a value that the temperature drop of the molten metal—due to admission of said gas and due to the time needed for such admission—is so small that the desulfurizing reaction takes place at a high temperature and before a considerable temperature drop occurs, thereby ensuring reaction between said molten metal and said selected desulfurizing agent at a temperature at which the efficiency of the desulfurizing action of said selected agent is substantially greater than after said considerable drop of the temperature of the molten metal.

3. A method of desulfurizing molten metal as defined in claim 1, wherein said selected desulfurizing agent is introduced simultaneously at a plurality of points spaced from each other and located below the upper surface of said bath of liquid metal.

4. A method of desulfurizing molten metal as defined in claim 1, wherein said selected desulfurizing agent is introduced simultaneously at a plurality of points located spaced from each other at the bottom of said bath of liquid metal.

5. A method of desulfurizing molten metal as defined in claim 1, in which said molten metal is a molten ferrous metal in liquid state.

6. A method of desulfurizing molten metal as defined in claim 1, in which said molten metal is molten pig iron in liquid state.

7. A method of desulfurizing molten metal in liquid state as defined in claim 1, wherein said finely subdivided particles of said selected desulfurizing agent are capable of passing through a 20-mesh Tyler sieve.

8. A method of desulfurizing molten metal in liquid state as defined in claim 1, wherein the concentration of said finely subdivided particles of said selected desulfurizing agent in said gas is between about 5 kgs. and about 40 kgs. of said particles per cubic meter of said gas.

9. A method of desulfurizing molten metal in liquid state as defined in claim 1, wherein said selected desulfurizing agent is pulverulent lime.

10. A method of desulfurizing molten metal in liquid state as defined in claim 1, wherein said selected desulfurizing agent is selected from the group consisting of lime, oxides of alkaline earth metals, calcined dolomite, calcium carbide and calcium cyanamide.

11. A method of desulfurizing molten metal in liquid state as defined in claim 1, wherein, together with said selected desulfurizing agent, a relatively small quantity of a pulverulent reducing substance is introduced into said bath of molten metal.

12. A method of desulfurizing molten metal as defined in claim 1, wherein, together with said selected desulfurizing agent, a relatively small quantity of a pulverulent reducing substance selected from the group consisting of carbon, aluminum, magnesium, calcium carbide and calcium cyanamide is introduced into said bath of liquid metal.

13. A method of desulfurizing molten metal in liquid state as defined in claim 12, wherein said selected desulfurizing agent is lime and said reducing substance is aluminum.

References Cited in the file of this patent

UNITED STATES PATENTS

239,621	Pirath	Apr. 5, 1881
387,952	Fronheiser	Aug. 14, 1888
1,043,371	Sundberg	Nov. 5, 1912
1,471,401	Koppers	Oct. 23, 1923
1,590,730	Evans	June 29, 1926
2,290,961	Heuer	July 28, 1942
2,502,259	Hulme	Mar. 28, 1950
2,577,764	Hulme	Dec. 11, 1951
2,587,573	Wynne	Feb. 26, 1952
2,665,982	Crego et al.	Jan. 12, 1954
2,692,196	Hulme	Oct. 19, 1954

FOREIGN PATENTS

622,419	Great Britain	May 2, 1949

OTHER REFERENCES

Camp and Francis: The Making, Shaping and Treating of Steel, 6th edition, pp. 385–386, section III, "Operation of the Plant," U. S. Steel Co., Pittsburgh, Pa.