

[54] STEEL CONVERSION METHOD AND APPARATUS

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[58] Field of Search 266/13, 27, 35, 36 P, 34 PP, 75/52

[56] References Cited

UNITED STATES PATENTS

84,335	11/1868	Absterdam	266/35
94,997	9/1869	Bessemer	266/35
1,505,281	8/1924	Nagelvoort	266/36 P
2,696,663	12/1954	Wright et al.	266/36 P
3,220,826	11/1965	Okaniwa et al.	266/35
3,294,386	12/1966	Willenbrock	266/36 P
3,330,645	7/1967	Moustier et al.	266/34 PP
3,342,472	9/1967	Namy et al.	266/35
3,706,549	12/1972	Kruppel et al.	266/35 X

FOREIGN PATENTS OR APPLICATIONS

2,076	5/1879	Great Britain	266/36 P
4,370	10/1878	Great Britain	266/35
13,483	10/1886	Great Britain	266/36 P

584,036	10/1958	Italy	266/34 PP
14,013	10/1904	Norway	266/36 P
1,027,901	4/1966	Great Britain	75/60

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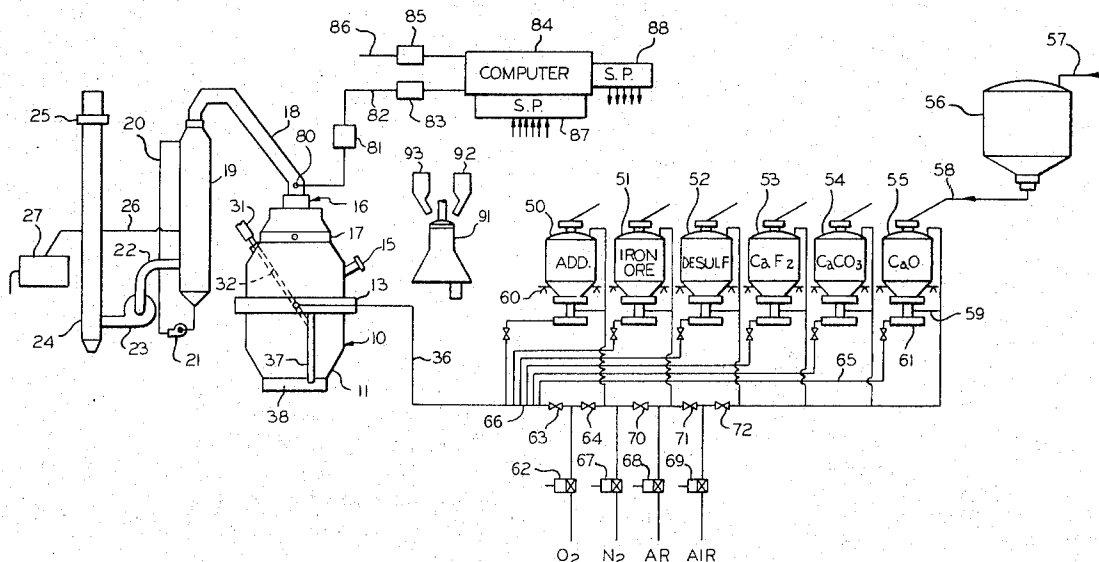
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ABSTRACT

A vessel for converting impure molten metal to steel has bottom tuyeres for blowing oxygen upwardly through the molten metal. Various additives which have heretofore been introduced into the top of the converter vessel are introduced as fine powders which are entrained in the oxygen or other gas being blown into the vessel. Finely powdered iron ore, desulphurizing agents, fluorspar, limestone and burnt lime are typical of materials which are bottom blown. A closed duct delivers the carbon monoxide and other gases produced in the vessel to apparatus which removes solids from the gas so that it can be burned in a flare chamber. The temperature of the melt is monitored continuously as is the composition of the gas at the entrance end of the duct. This data is fed into a computer which, in turn, regulates the flow of the bottom fed gases and the powdered additives in accordance with the desired metallurgy of the melt. The invention is particularly well adapted for converting existing steel making facilities to reduce production cost, to reduce capital investment and to meet pollution control standards.

9 Claims, 4 Drawing Figures



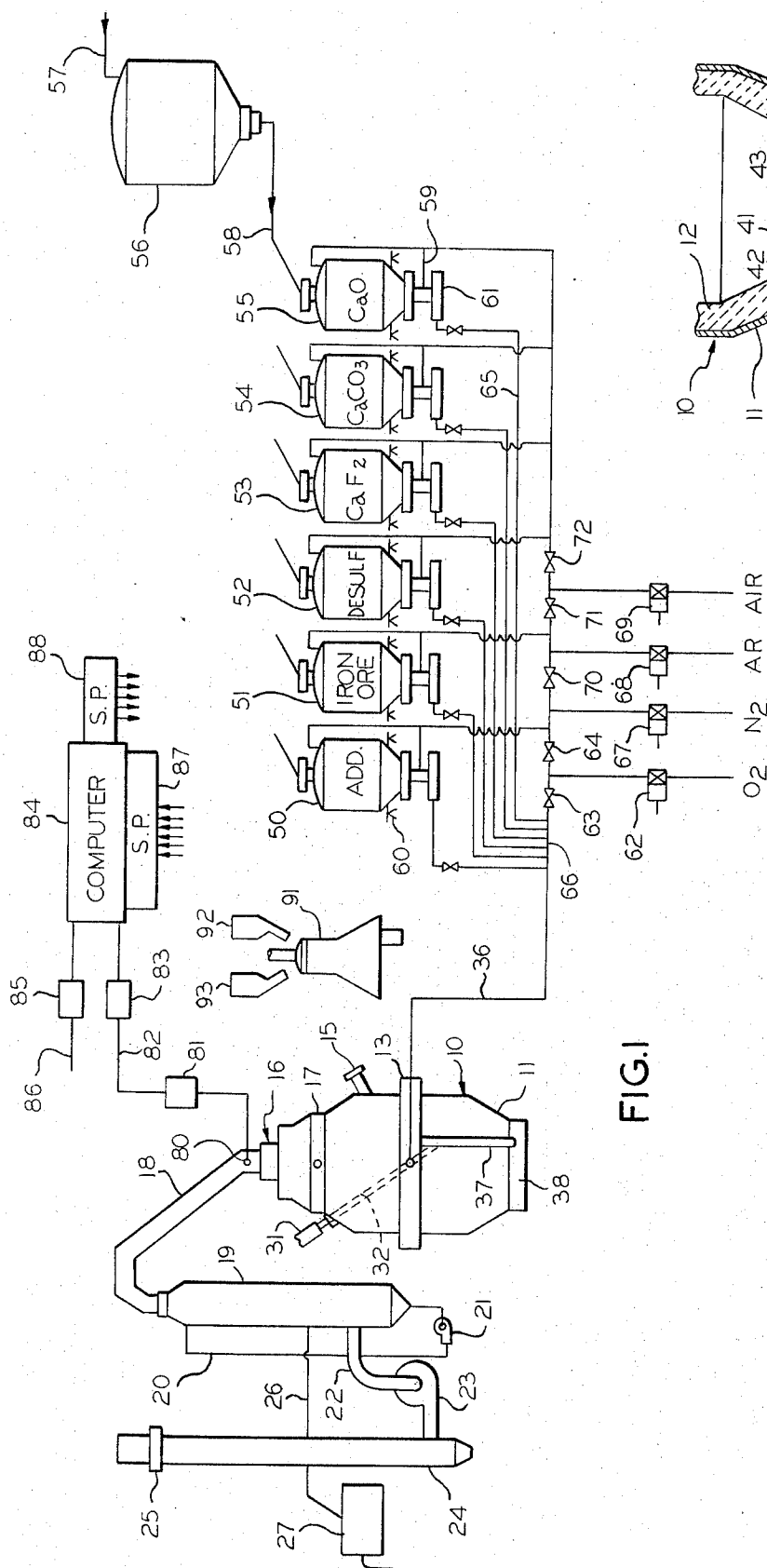


FIG. 1

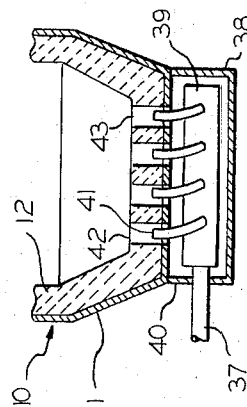


FIG. 2

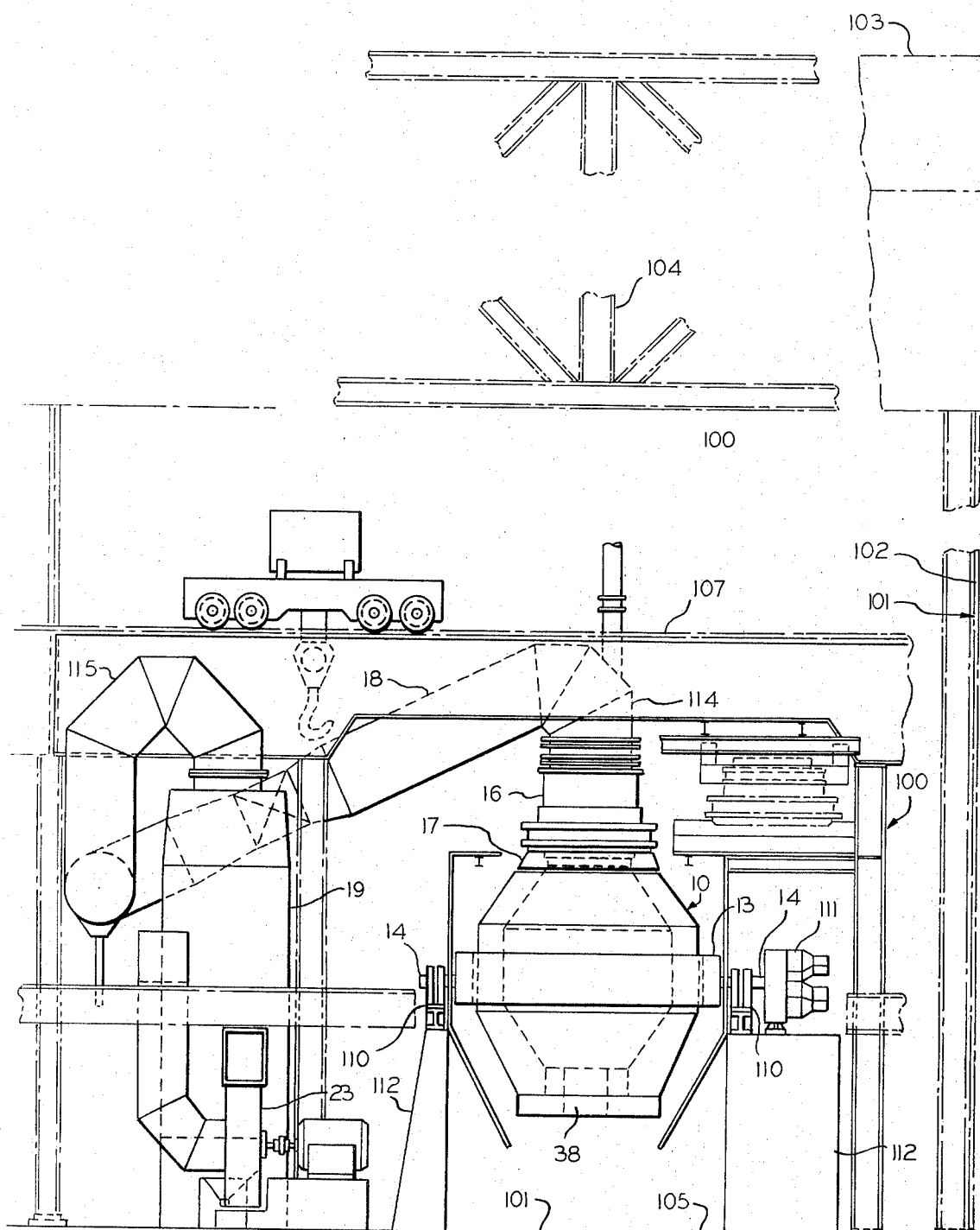


FIG.3

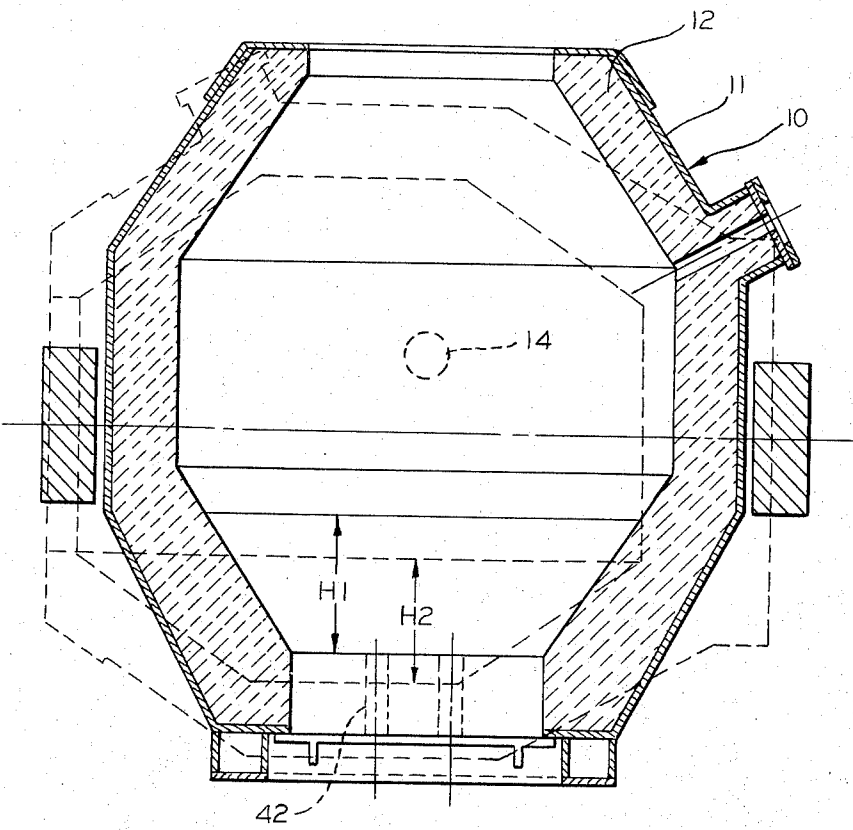


FIG. 4

STEEL CONVERSION METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

Objectives of modern steel plant designs are to reduce both operating and capital investment, to reduce pollution that is incidental to the process and to more fully automate the process. As is well known, considerable progress has been made in recent years in reducing cost and pollution by use of the basic oxygen methods of converting steel. As currently practiced, this method involves charging a converter vessel with a mixture of molten pig iron and solid scrap steel and then blowing pure oxygen into the top surface of the melt by means of an oxygen lance that is inserted through the top of the vessel. The exothermic reaction between oxygen and silicon, manganese, phosphorus and carbon in the hot metal produces sufficient heat to melt the scrap metal and produce liquid steel. The temperature of the melt is taken periodically to determine when the reaction is complete and when the melt is ready for discharge from the vessel for use or further treatment. Openings must be left in the gas collecting hood over the vessel to insert the thermocouple and oxygen lances and to introduce fluxing materials and other additives.

The established procedures have disadvantages. For instance, projecting the oxygen lance vertically downwardly into the center of the converter vessel requires that the vessel be in a very high building since the oxygen lance is usually fifty or more feet long and is of even greater size when its suspension mechanism is considered. Measuring the temperature of the melt is also problematical because it is difficult to locate the thermocouple where it will measure a temperature that is truly representative of the melt. The top blown oxygen method is characterized by hot spots developing in the top of the melt where the oxygen impinges because that is the primary reactive region. Moreover, the hot spots on the melt surface radiate to the refractory lining, causing hot spots to develop on it. Thus, the refractory is not a good place for locating a thermocouple if a temperature that is representative of the melt or proportional to it is to be attained. The inability to sense melt temperature precisely, instantaneously and continuously is one of the factors that has retarded automating the steel making process.

Another disadvantage of present day top blown oxygen converters is that they slop over and eject slag and metal from the melt. It has also been recognized that feeding fluxes and other additives into the top of the vessel does not produce the best metallurgical conditions because these materials must be in lump form so they take longer to go into solution. Also, materials put on top of the slag bring about poor flux reactions and produce a lot of dust. Introduction of these materials through the top of the vessel results in poorer thermal efficiency of the process as a whole.

Another characteristic of some present oxygen converters is that they burn the gases which evolve from the melt at the upper end or mouth of the vessel. This requires that the hood which collects the gases from the vessel be spaced from the latter by a considerable distance in order to provide an inlet for the air that is required to burn the gases. The process results in production of additional heat near the mouth of the vessel. An incidental effect of this gas handling method is that the

burned gases are not fully representative of the bath oxidation conditions. When an oxygen lance is introduced through the vessel top, stray oxygen leaks in, which upsets the true analysis of the evolved gases. Disability to make an accurate gas analysis has precluded efforts to automate the steel making process because gas analysis as well as temperature data must be available in an automated or computer-controlled steel making system.

Another impediment to automating the steel making process has been the effect which introducing materials to the top of the vessel has on the temperature and chemical analysis of the melt. When materials are introduced through the vessel top and, particularly, through the slag layer on the top of the melt, there is a delay before the ultimate temperature and effects on analysis can be determined. Thus, there is a time lapse between introduction of the material and determining whether too much or too little has been added. If an additive is in short quantity, more must be added and the ultimate effect must be awaited. The same is true if too much of a material is added in which case one or more additional materials might have to be added to compensate for the excess and achieve the desired temperature and chemical analysis. It is evident, therefore, that steel making by the most modern methods is still as much an art as it is a science and that automation will be achieved only when the melt composition is subject to precise control and the effects of varying any or all of the parameters of the process can be anticipated and accurately measured.

The trend in this country is to supplant existing open hearth steel making plants with the top blown oxygen converters and to install the latter in the new plants. In addition to the oxygen steel making process being more economical, it also produces less atmospheric pollutants than the open hearth process. Equipping open hearth plants with modern pollution abatement apparatus is difficult and extremely costly but it is being done because in many cases substituting a conventional oxygen converter is even more costly since this requires drastic equipment rearrangements and modification of existing buildings. One of the reasons for conventional oxygen converter vessels not fitting into existing buildings is that these vessels operate in conjunction with apparatus for blowing oxygen and for adding flux and other additives through the top mouth of the vessel. Much overhead space is required to accommodate this equipment and this space is only obtainable in most cases at the expense of modifying the building.

SUMMARY OF THE INVENTION

A general object of this invention is to provide a blown oxygen steel conversion plant apparatus which has economical and technical advantages over present basic oxygen furnace and open hearth furnace plants and, particularly, which enables transforming existing plants such as open hearth plants to an oxygen converter plant without drastic modification of existing buildings and to provide new plants which are based on blown oxygen and produce steel more economically.

Another object is to supplant presently used top blown oxygen converter vessels with a bottom blown type of vessel in which the oxygen or other gases are introduced through tuyeres in the bottom of the vessel and in which the fluxing materials and other additives

are introduced through the vessel by injecting them in powdered form with the blown gas.

Another object of this invention is to provide a steel making facility in which the fluxing and additive materials are introduced through the converter vessel bottom in powdered form so that the materials are in intimate contact with the constituents of the molten metal to thereby effect more rapid chemical reactions and more economical use of the materials.

Still another object of this invention is to provide a low profile steel making facility with an oxygen converter vessel which allows introducing fluxing and additive materials through its bottom to thereby eliminate the dust and slopping that occurs in prior top blown oxygen converter systems.

Another object is to use the analysis of non-combusted gas from the converter vessel and the temperature of the melt as input data to an operator or to a computer which may regulate the introduction of materials for the purpose of establishing the proper finishing temperatures and metallurgical analysis of the melt.

Another object is to inject not only fluxing materials through gas inlets at the bottom of the vessel but to inject materials and additives which become components of the final product as well. This object being exemplified by a plant which permits making carbon steels and alloy steels such as stainless steel as well in the same converter vessel.

Yet another object of this invention is to capitalize on the high speed and short cycle of a new type of oxygen converter vessel by using the same with a vacuum degassing vessel in which the melt may be alloyed or otherwise finished while the converter vessel is recycled.

How the foregoing and other more specific objects are achieved will appear from time to time throughout the course of a description of a preferred embodiment of the invention which will be set forth hereinafter.

Briefly stated, the new steel making process involves use of a bottom blown oxygen converter vessel. The vessel is first charged with high carbon content hot-metal and steel scrap metal is added thereto as is the case with present top blown basic oxygen converter vessels. After charging the vessel, oxygen is blown in through the bottom of the vessel to initiate the customary oxidation reactions. The additives and fluxing materials which have heretofore been introduced through the top of the vessel are stored in finely powdered form in separate containers. These powdered materials are mixed separately or jointly with the blown gas stream so that they may be forced through the bottom of the converter vessel and the melt therein by the oxygen or other gas. Signals indicative of melt temperature and of the analysis of the gas which is evolved from the vessel are provided to an operator or a computer. These may be employed to control the flow rates of the various additives and to control other parameters as well. Thus, time, temperature and chemical composition are coordinated with flow rates in such manner that the proper analysis and temperature of the melt may be controlled.

A more complete description of the invention will now be set forth in reference to the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows diagrammatically a steel making plant in accordance with the invention;

FIG. 2 is a fragmentary vertical sectional view of the converter vessel shown in the preceding figure;

FIG. 3 is a front elevational view of the apparatus according to the invention when applied to an existing open hearth shop; and

FIG. 4 is a sectional view illustrating the preferred embodiment of the converter vessel.

DESCRIPTION OF A PREFERRED EMBODIMENT

In FIG. 1 the converter vessel is generally designated by the reference numeral 10. It comprises the usual melt shell 11 and a refractory lining 12 as can be seen in FIG. 2. Converter 10 is supported on a trunnion ring 13 from which two diametrically opposite trunnion shafts 14 extend. The columns in which these trunnion shafts are journaled are not shown since they are conventional. Converter vessel 10 is supported inside of trunnion ring 13. Vessel 10 is adapted for being tilted through an angle of 360° about the axis of trunnion shafts 14. A pouring spout 15 extends radially upwardly from the side of vessel 10 so that the usable molten contents of the vessel may be poured out as desired when the vessel is tilted. Slag is removed from the vessel by inverting it.

A water cooled gas hood 16 encloses the top mouth of the vessel 10 during operation as shown. Hood 16 has a movable section 17 which is displaceable on a suitable support, not shown, to provide clearance for tilting and relining of vessel 10. The vessel is tilted through a limited angle to expose its mouth for the purpose of charging the vessel with hot metal and the vessel is tilted through a greater angle for pouring a finished heat of metal from spout 15. Gases which evolve from the interior of the vessel 10 during refining are conducted through a water cooled duct 18 from hood 16 to a gas cleaner 19 in which particulate matter is removed from the gases. The gas cleaner is a conventional type venturi type scrubber which uses water to capture solids. Most of the water used for separation is reused by recirculating through a pipe 20 under the influence of a recirculation pump 21. The cooled gases from which the solids are extracted are withdrawn from scrubber 19 through a duct 22 by means of an exhaust fan 23 and these gases are delivered to a stack 24. The top of the stack is equipped with a flare chamber 25 which effectuates burning of the gases as they evolve from the upper end of the stack. Sludge is withdrawn from scrubber tower 19 through a pipe 26 which conducts the sludge to a thickener 27 which is merely symbolized and is not shown in conjunction with the piping and other equipment with which it is usually associated. For the purposes of the present invention, it is only necessary to recognize that gases evolve from converter vessel 10 are not burned at the top thereof as they are in conventional full combustion oxygen converter systems, but, instead, are scrubbed of solids and burned in a purified dust free form at the outlet stack 24. There is also a distinction between the present gas cleaning method and that used in open hearth systems which usually employ electrostatic precipitators for separating solids from the gases. When electrostatic precipitators are used the gases must be cooled at great expense down to 500° F. or cooler before they can be fed into

the precipitator. In the present invention, the gas cleaning equipment has a low profile and may be mounted at ground level inside or outside of the building, thereby avoiding the engineering problems of existing high profile top blown converters.

The initial step of charging vessel 10 with hot molten and scrap metal is the principal feature of similarity between the present invention and the established top blown basic oxygen method of converting impure iron to steel. Thus, in the prior and present case vessel 10 is tilted slightly and a charge of molten iron and steel scrap, are introduced into the vessel which is then returned to its upright position. In accordance with the prior method an oxygen lance is then projected through the mouth of the vessel and oxygen is injected into the melt for oxidizing the carbon and other metalloids. As is known, this reaction is exothermic and is relied upon exclusively for elevating the melt to the desired pouring temperature and for providing the heat necessary to effectuate the desired metallurgical reactions. Under the prior practice, the top of vessel 10 remains substantially open during oxygen blowing so that fluxing agents such as burnt lime, iron ore, concentrates, fluorspar and other additives may be introduced to the melt through the top of the vessel. The introduction of these materials is accompanied by production of considerable dust, smoke and eruption or slopping out of slag and some molten metal. A further disadvantage of introducing lime and other materials through the top of a top blown converter vessel is that these materials are deposited on a slag layer rather than directly in the melt where they would react most rapidly and completely as is desired. This lengthens the refining process and results in a waste of materials because all of the materials do not penetrate the slag layer and, hence, do not become involved in the chemical and metallurgical reactions which are being promoted in the refining vessel. There is a high iron oxide loss as well. Moreover, materials which are introduced through the top of converter vessel 10 must necessarily be in lump form which means that a longer time is required before the lumps break down physically and react completely. This also extends refining time.

Another disadvantage to blowing oxygen into the center of the top of the melt as in the conventional basic oxygen conversion methods is that an intense hot spot develops in the center of the melt where most of the oxygen is reacting. This hot spot radiates to the interior refractory walls and develops hot spots on the refractory in unpredictable locations. As a consequence, it has been difficult heretofore to measure a temperature in the vessel which is representative of the melt and which can be used as a positive indication that refining is complete and the melt is ready for pouring. The best that could be achieved was to discontinue oxygen blowing momentarily and insert a thermocouple lance through the open mouth of the vessel in the hope that the temperature of the molten mass had equalized. This introduced another delay in the refining process.

Since the present invention blows oxygen from the bottom of the vessel rather than the top and since the vessel is substantially closed during operation, it is possible to obtain a representative temperature by inserting a thermocouple at almost any desired place in the melt. As shown in FIG. 1, a carriage 31 has a thermocouple lance 32 extending from it into vessel 10. The

lance is disposed at an angle with respect to vertical so that its temperature sensitive tip may be positioned directly in the center of the melt without being subjected to the anomalous effects of the concentrated oxygen stream which prevails in the center of the vessel in known conversion methods. The ability to obtain a precise and representative temperature measurement is an important aspect in automating the entire steel making process as will be more fully discussed hereinafter.

A distinctive feature of the present invention is that oxygen and other gases, and such materials as desulphurizing agents, iron ore, limestone, burnt lime and additives are blown into the converter vessel 10 from its bottom. This is achieved by using a hollow trunnion shaft 14 for conducting these materials. The end of the trunnion shaft is equipped with a swivel joint, not shown in detail, which is connected to a stationary conduit 36 through which gas and powdered materials are conducted. The inboard end of trunnion shaft 14 is also provided with a swivel joint, not shown, that connects to a conduit 37 which is stationary with respect to vessel 10. As can be seen particularly well in FIG. 2, conduit 37 passes through the walls of a chamber 38 and into a turbulator distributor chamber 39. A plurality of curved pipes 40 extend from chamber 39 and connect with an array of tuyeres such as 42 and 43. It will be evident that any high pressure gas and entrained powdered solids will rise through the melt within vessel 10. Because the solid materials are finely powdered they present the largest surface area to the melt per unit weight and the resulting intimate contact between the molten constituents and the solid material as well as blown gas result in substantially complete chemical and metallurgical reactions before the materials reach the top of the melt and produce by-products which join the slag layer.

Note that blowing the gas and powdered solid materials from the bottom initiates reactions in the most desired place, that is, in the molten metal itself and that undesirable flux reactions that would result from putting the materials on top of the slag and the failure of the materials to go into solution due to their being in lump form as in the prior practice, are avoided. It is also significant that no slopping occurs when fluxing lime is introduced in powdered form through the bottom of the melt.

The various materials to be added to the molten metal in vessel 10 are typically stored in vessels 50-55. The vessels are located at ground level, thereby avoiding the difficulties of locating them overhead as required with conventional top blow vessels. This gives the whole installation a low profile. Of course, the number of storage vessels will correspond with the number of different materials that are to be injected to the bottom of vessel 10. For the sake of illustration six vessels 50-55 are shown. Powdered additives may be stored in vessel 53, limestone in vessel 54, and burnt lime in vessel 55. As a general rule, 90 percent of the powdered grains should be less than 0.1 millimeters in size although in the case of certain fluxes grain size may be as high as 2.0 millimeters which might be termed granular. However, powder and powdered will be used herein as generic terms for any finely divided particles which fulfill the purposes of the invention. Large grain size fluxed accentuate abrasive problems in the conduits, nozzles and other fixtures.

The pressure vessels 50-55 are interconnected so that powdered materials entrained in gas may be delivered to converter vessel 10 separately or in combination. Typically, each of the vessels contains enough material for one heat of the converter vessel and at each subsequent heat additional materials are transferred from storage vessels 56. The day storage bins may be replenished from larger storage hoppers which may be located outside of the building if desired. There may be a storage hopper for some or all of the vessels 50-55. In fact, all powdered material storage vessels may be located outside of the building. In any event, powdered materials may be withdrawn from suitable railroad cars, not shown, under the influence of pressurized air and through conduits such as 57. A conduit 58 is used to convey powdered materials from storage hopper 56 to a utilization vessel 55, for example. For burnt lime which is used in great quantities, additional storage containers are sometimes required.

The feed vessels 50-55 are similarly constructed and piped. Taking vessel 55 as an example, it is provided with a gas input conduit 59 through which oxygen or other powder entraining gas is injected. Each vessel has a weighing device 60 affiliated with it. Each vessel also has on its discharge side at least one metering device 61. Oxygen for transporting the powdered materials is introduced to the system through a manual or solenoid operated valve 62. There are also isolating valves 63 and 64 in the system. When valve 63 is closed, oxygen is delivered through valves 62 and 64 and to the various pressure vessels 50-55 where powdered materials may be selectively entrained in accordance with whether the discharge valves are open or closed. In any event, the gas entrained powders separately or in combination are delivered by means of transverse conduits such as 65 to a junction region 66 where they join with vessel feeding conduit 36. As explained earlier, these gas entrained powdered materials are then forced singly or in combinations through the tuyeres in the bottom of vessel 10 for reaction with the molten metal therein.

Nitrogen, argon, air and other gases are also available for entraining powdered materials or for being directly injected into the bottom of converter vessel 10. The input pipes for the nitrogen, argon and air may also contain manual or solenoid operated control valves 67, 68 and 69, respectively, which cooperate with path selecting valves 70, 71 and 72 to permit directly injecting any of these gases into vessel 10, or in the alternative, entraining any of the powdered materials from vessels 50-55.

The underlying objects of the invention are to achieve dynamic control of the steel making process by introducing gas and powdered materials through the bottom of the converter vessel in a time sequence that is suitable to the metallurgy of the heat. Reducing the time for making a heat is also an important objective. In general, a metal heat produced in accordance with the invention may be in condition for pouring in about 12 or 15 minutes after refinement begins.

The steps of producing a heat of steel in accordance with the invention will now be discussed. As explained earlier, the initial step is to charge vessel 10 with hot metal and scrap, start the blow and then close hood 16. The next step is to reduce the sulphur content of the melt. Usually the sulphur content will be reduced to 0.025 percent or less. This is done with the invention by blowing into converter vessel 10 a powdered desul-

phurizing agent such as calcium cyanamide or other suitable substance which is derived from a pressure reservoir 52 and is entrained in and delivered by high pressure nitrogen to the bottom of the converter vessel 10. Lime may be introduced simultaneously or independently with the desulphurizing agent, depending on the starting sulphur level. Due to the small particle size and uniform distribution of the desulphurizing agent as it passes through the melt, under the influence of nitrogen, the melt usually desulphurizes within one to three minutes although it may be stated generally that the time depends on the rate and quantity of nitrogen and desulphurizing agent injected. In the conventional top blown basic oxygen converter desulphurization cannot be conducted in this way because slag is on top of the melt and it is difficult, if not impossible, to blow through both the slag and a depth of the metal to get the necessary turbulence and mixing for adequate desulphurization in a reasonably short period of time. In the present case, however, a good solid state reaction between the finely divided desulphurizing agent and the metal is obtained throughout the depth of the melt. This is true of the reactions between the melt and other additives as well.

After desulphurization is complete, the melt is next blown with oxygen that entrains burnt lime. The lime is obtained from pressure vessel 55, for instance. The quantity of lime required depends on the amount of silicon and phosphorous in the hot metal as is well known. The invention makes it possible, as will appear more fully hereinafter, to control the quantities of these materials with considerable precision. Silicon, manganese, carbon and phosphorous are the most usual constituents which must be removed or reduced in the melt and they are reduced in the order in which they were named. The silicon is usually removed first, manganese next, and carbon and phosphorous go together lastly. Concurrently or sequentially with the blowing of lime, other fluxing agents or additives such as fluorspar may be injected with the oxygen as the refining process proceeds. If the melt is otherwise ready for pouring but is slightly hotter than desired, its temperature may be reduced incrementally as desired by injecting powdered calcium carbonate and/or iron ore from vessel 54 by entraining the same in oxygen or nitrogen. The heat required for dissociating limestone into calcium oxide and carbon dioxide, of course, reduces the temperature of the melt.

Alternatively, ly, temperature corrections can be made by injecting powdered iron ore from vessel 51 into the converter vessel 10 with oxygen or nitrogen as required. This has the advantage of increasing the iron content of the heat. Even flue dust fines may be disposed of by injecting this material through the bottom of the converter vessel.

The system makes it convenient to produce alloys in the converter vessel. The alloying additives may be stored in one or more vessels such as that marked 50 in FIG. 1 and these may be introduced sequentially or concurrently as required by the metallurgy of the process.

In most cases the amount of materials injected are less than the amounts which are required in the conventional top blown oxygen converter vessel where materials are added through the top mouth of the vessel. For example, with one iron analysis about 176 pounds of lime is required per ton of steel in prior top blown

processes whereas the new system herein described uses about 110 pounds of lime per ton of steel.

The invention also facilitates making stainless steel in a single converter vessel by the process which involves blowing the melt with oxygen and argon simultaneously. As is known, the argon dilutes or reduces the partial pressure of carbon monoxide which is produced by the carbon-oxygen reaction and, therefore, indirectly inhibits absorption of chromium by the slag. Of course, the components of stainless steel such as nickel and chromium may be added into the melt after it is adequately decarburized so that little if any of these valuable constituents will be lost to the slag as would be the case if they were present during the entire oxygen blowing process.

As mentioned earlier, continuous accurate monitoring of the temperature and the chemical composition of the evolved gases from the converter vessel 10 are imperative to automating the steel making process. Blowing oxygen through the bottom of the melt to produce rather uniform temperature conditions which may be representatively measured with a centrally located thermocouple lance has been discussed earlier. Mention was made too of the fact that the gases evolved from the vessel are substantially unburned or non-combusted at the mouth of the converter vessel in accordance with the invention and such gases are normally not diluted with stray oxygen as is the case in existing top blown oxygen processes. This makes it possible to get a true analysis of the evolved gases as required for automation or dynamic control of the steel making process. For this purpose the gas sampling device inlet 80 is inserted in the fume duct 18 immediately above vessel hood 16. The gases are delivered to a multiple-gas analyzer 81 which produces electric signals that are functionally related to the concentrations of the individual gases. The electric signals are delivered by means of a cable 82 to a signal processing module 83 and then to a computer 84. The object of analyzing the flue gas is, of course, to enable relating the gas analysis to the amount of carbon which remains in the melt which in turn serves as an indicia of the extent to which the refining process has proceeded. As indicated earlier, both temperature and metallurgical composition of the melt must be within specifications before it can be poured.

The ratio of carbon monoxide to carbon dioxide, the ratio of carbon monoxide to hydrogen or the ratio of hydrogen to water in the flue gases are each suitable indicia for determining the extent to which the metal is refined in the vessel 10. A signal corresponding with the instantaneous value of the selected ratio may be processed in module 83 and used as input information to a process control computer 84. The melt temperature information is also fed into the computer from a temperature signal processing module 85 which has input leads 86 which connect to the thermocouple in lance 32 that projects into the converter vessel during operation. The computer 84 also has signal processing modules which are designated collectively by the reference numeral 87 for receiving, processing and introducing into the computer signals representative of the various parameters of the powdered material feed system such as the rate of entraining gas flow and the weight of the materials being delivered from the powder vessels 50-55. Computer 84 uses this input data along with temperature and gas analysis data to pro-

duce signals which regulate the flow of gases and powdered materials in accordance with the predetermined quantities that are necessary to produce a melt of certain specifications. Control signals from computer 84 are processed in suitable modules which are collectively designated with the reference numeral 88. Some of the conductors for delivering control signals to the various valves in the powder distribution system are shown symbolically as extending from the bottom of signal processing module 88. The computer regulates the system in such manner that the total time for producing a melt and the frequency of corrective reblows are minimized. Finally, the computer indicates when the melt is within specifications and ready to pour.

The refined steel output of the system may be further increased by using the converter vessel in conjunction with a degasser unit 91. By transferring the preceding heat from vessel 10 into degasser 91 for finishing operations it is possible to initiate recycling and production of a new heat in the converter vessel 10 thus reducing the total time for consecutive heats and thus increasing the time for vessel 10 for production. This is a desirable mode of operation when the system is being used to supply molten steel to a continuous casting machine. There is also a saving of time if the molten heat is not only degassed but is also alloyed in the degasser unit 91. In such case, the alloying elements may be stored in overhead hoppers such as 92 and 93, for introduction into the degasser 91 in a well known manner.

FIG. 3 illustrates the application of the converter 10 according to the invention to the conversion of an open hearth shop 100. Conventionally shops of this type are enclosed in a building 101 which may include sidewalls 102 and a roof 103 both of which may be suitably supported by a structural framework 104 on a support floor 105. Normally the building 101 would be sized to accommodate the requirements of an open hearth furnace not shown. In addition, auxiliary equipment, such as the crane rail 107 for the furnace charging crane 108 are constructed and arranged in accordance with the physical dimensions and requirements of furnaces of this type. It was not possible with top charging BOF vessels to convert this type of shop without expensive reconstruction of the building 101 and the supporting apparatus. With the apparatus according to the invention, however, existing facilities and particularly open hearth shops may be readily converted without substantial structural modifications or equipment relocation.

More specifically the vessel 10 support trunnion 13, bearings 110 and drive motor 111 are suitable mounted on columns 112 which extend upwardly from the existing floor 105. Because the gas and material feed is through the bottom tuyeres 38, the vessel 10 may be accommodated below the existing roof 103 and crane rail 107.

The smoke hood duct 18 is shown more specifically in FIG. 3 to include an elbow section 114 coupled to the upper end of the smoke hood 18 and extending downwardly at a sharp angle away from the vessel 10. A second generally U-shaped conduit section 115 couples the elbow section to the upper end of the gas scrubber 19. This configuration of the smoke hood and conduit similarly facilitates the employment of the vessel 10 in the low head shop 100.

The clean gas from the exhaust fan 23 of the scrubber system is led through existing open hearth furnace flues to an existing stack equipped with flare chamber 25.

Preferably the vessel 10 is made substantially spherical for strength and metal accommodation consistent with the employment of as many standard refractory shapes in lining 12 as possible. Toward this end the vessel 10 is shown in FIG. 4 to be generally octagonal in vertical section with an internal height substantially equal to its inside diameter. In actual practice height to diameter ratios of from 1.1:1 to 1.2:1 have been found to be the most satisfactory. The vessel 10 will normally be charged with hot metal to a height H1 represented by full lines in FIG. 4. When the vessel is tilted 90° counterclockwise about trunnion 14 for sampling as shown by broken lines in FIG. 4, the vessel shape and height to diameter ratio indicated above will maintain the metal height H2 below the tuyeres 42. The metal height will similarly be below tuyeres 42 when the vessel is tilted 90° clockwise for tapping.

In summary, a new system that permits dynamic control of the steel making process has been described. It is characterized by blowing gas and substantially all solid materials, except the hot metal and scrap charge, through the bottom of an otherwise substantially enclosed oxygen converter vessel. The temperature of the melt and the analysis of non-combusted gases evolved from the melt are accurately determinable and provide data which is used in conjunction with other data supplied to a computer to control the entire process and the quality of the steel. The new method shortens the refining process by virtue of the powdered solid materials being in intimate contact with the molten metal to thereby accelerate the chemical reactions which are the objectives of the refining process. The system produces less atmospheric pollutants than either the conventional top blown oxygen method or the open hearth method of making steel. An open hearth plant can be converted to employ the new method without significant building modifications and at a lower cost than would be incurred if an open hearth plant were to be equipped with pollution abatement apparatus which meets present day standards.

Although an embodiment of the apparatus and the new process have been described in considerable detail, it is to be understood that such description is intended to be illustrative rather than limiting, for the invention may be variously embodied and practiced and is to be limited only by interpretation of the claims which follow.

We claim:

1. A vessel for treating ferrous melts comprising: refractory lining having an opening in its top end and

a refractory material closing the lower end of said refractory lining and tuyere means extending there-through for injecting gases into molten metal contained within said lining when said top opening is in a generally upward attitude, means for rotating said vessel about a substantially horizontal axis, said refractory lining defining an interior surface for said vessel, said lining surface including a generally cylindrical portion disposed intermediate the ends of said vessel and frusto conical surface portions adjacent the upper and lower ends thereof,

the large diameter ends of said frusto conical surfaces terminating at the opposite ends of said cylindrical surface, the small diameter ends of said upper and lower conical surfaces terminating adjacent the open upper and lower ends of said lining surface respectively, the distance between the small diameter portions of said frusto conical surfaces being about 1.1 to 1.2 times the diameter of said cylindrical surface portion and the height of each of said frusto conical surface portions being substantially equal to each other and to the height of said cylindrical surface portion so that when said vessel is pivoted from a normal vertical position to a substantially horizontal position a substantial quantity of molten metal can be retained in said vessel with the upper surface of said metal lying below said open upper end and the tuyeres contained in the refractory bottom.

2. The apparatus in accordance with claim 1 and including hood means positioned above said opening and being adapted to substantially close said opening so as to collect gas which evolves from said vessel, elbow means coupled to said hood means, gas cleaning apparatus displaced horizontally from said vessel and lying substantially within the height confines of the vessel and the hood means, duct means having one end coupled with said elbow means, said duct means being below the upper height limit of said elbow means and extending generally downwardly therefrom so as to not require appreciable inside height clearance within the building, the other end of said downwardly extending duct means communicating with said gas cleaning apparatus for conducting evolved gases to said gas cleaning apparatus.

3. The apparatus in accordance with claim 1 including at least one storage vessel or finely divided materials, said storage vessel being displaced horizontally from said converter vessel with said storage vessel being substantially within the height confines of the converter vessel and hood means, conduit means arranged to conduct pressurized gas and gas entraining finely divided materials to said tuyere means, and means selectively connecting said storage vessel to said conduit means whereby to entrain said finely divided material in a gas stream for injecting the same through said tuyere means to permeate upwardly through the molten metal in the converter vessel.

4. The apparatus set forth in claim 1 and including conduit means coupled to said tuyere means, a plurality of sources of gas under pressure, each of said sources being coupled to said conduit means,

a plurality of selectively operable valve means, one of said valve means being disposed between each of said gas sources and said conduit means for selectively controlling the flow of each of said gas means to said tuyere means.

5. The apparatus set forth in claim 1 including, conduit means coupled to said tuyere means, a plurality of sources of gas under pressure, each of said sources being coupled to said conduit means,

a plurality of selectively operable valve means, one of said valve means being disposed between each of said gas sources and said conduit means for selectively controlling the flow of each said gas means to said tuyere means,

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material storage vessel means for containing powdered material and having an outlet coupled to said conduit means,

additional valve means disposed between said outlet means and said conduit means, and

control means coupled to each of said plurality of valve means and said additional valve means for selectively coupling said gas sources to said tuyere means and said material storage vessel means to said conduit means for entraining powdered material disposed in said material storage means in the gas flowing in said conduit means.

6. The apparatus set forth in claim 5 wherein said gas sources comprise oxygen, air and an inert gas selected from the group consisting of argon and nitrogen.

7. Apparatus set forth in claim 6 and including hood means positioned above said opening in the top end of said vessel and being adapted to substantially close said opening so as to collect gas which evolves from said vessel, gas cleaning apparatus displaced horizontally from said vessel and lying substantially within the height confines of the vessel and the hood means, duct means having one end coupled with said hood means and extending generally downwardly therefrom, the other end of said downwardly extending duct means communicating with said gas cleaning apparatus for conducting evolved gases to said cleaning apparatus.

8. Apparatus for converting molten ferrous metal to steel and including a refractory lined metallurgical vessel, a charge receiving opening at its upper end and a refractory material closing the lower end thereof, said tuyere means extending through said refractory material for injecting gases into molten metal contained within said lining,

means for rotating said vessel about a substantially horizontal axis;

said refractory lining having an open top and bottom,

said refractory lining defining an interior surface for said vessel,

said lining surface including a generally cylindrical portion disposed intermediate the ends of said vessel and frusto conical surface portions adjacent the upper and lower ends thereof,

the large diameter ends of said frusto conical surfaces terminating at the opposite ends of said cylindrical surface, the small diameter ends of said upper and lower conical surfaces terminating adjacent the open upper and lower ends of said lining surface respectively, the distance between the small diameter portions of said frusto conical surfaces being 1.1 to 1.2 times the diameter of said cylindrical surface portion and the height of each of said frusto conical surface portions being substantially equal

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to each other and to the height of said cylindrical surface portion so that when said vessel is pivoted from a normal vertical position to a substantially horizontal position a substantial quantity of molten metal can be retained in said vessel with the upper surface of said metal lying below said open upper end and the tuyeres contained in the refractory bottom,

conduit means coupled to said tuyere means,

a plurality of sources of gas under pressure, each of said sources being coupled to said conduit means, said gas sources comprising oxygen, air and an inert gas taken from a group consisting of argon and nitrogen,

a plurality of selectively operable valve means, one of said valve means being disposed between each of said gas sources and said conduit means for selectively controlling the flow of each of said gas means to said tuyere means,

material storage vessel means for containing powdered material and having an outlet coupled to said conduit means,

additional valve means disposed between said outlet means and said conduit means,

control means coupled to each of said plurality of valve means and said additional valve means for selectively coupling said gas sources to said tuyere means and said material storage vessel means to said conduit means for entraining powdered material disposed in said material storage means in the gas flowing in said conduit means,

hood means positioned above said charge receiving opening and being adapted to substantially close said opening so as to collect gas which evolves from said vessel, gas cleaning apparatus displaced horizontally from said vessel and lying substantially within the height confines of the vessel and the hood means, duct means having one end coupled with said hood means and extending generally downwardly therefrom, the other end of said downwardly extending duct means communicating with said gas cleaning apparatus for conducting evolved gases to said gas cleaning apparatus.

9. The apparatus set forth in claim 8 and including a plurality of storage vessels, each of said vessels including a discharge opening coupled to said conduit means and selectively operable valve means disposed between each of said outlets and said conduit means, said control means being coupled to each of said additional valve means and operative to selectively couple each of said material storage vessels to said conduit means whereby the contents of said vessels may be entrained in the gas flowing through said conduit means.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,820,768 Dated June 28, 1974

Inventor(s) Walter Sieckman et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 1, column 11, line 52, before "vessel" insert

---metallurgical---

same column, line 53, before "refractory" insert

---a---

column 12, line 3, after "surface" insert ---portion---

same column, line 5, cancel "open"; and

same column, line 17, cancel "tuyeres" and substitute

---tuyere means---

Claim 3, column 12, line 36, cancel "vessel" and substitute

---container---

same line, cancel "or" and substitute ---for---

same column, line 38, cancel "converter" and substitute

---metallurgical---

same column, lines 40 and 47, cancel "converter" and substitute

---metallurgical---; and

Signed and sealed this 14th day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents