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Baum et al.

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[54] **APPARATUS FOR PROCESSING MOLTEN METAL**

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[73] Assignee: **Pennsylvania Engineering Corporation,** Pittsburgh, Pa.

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[52] **U.S. Cl.** **266/16**

[51] **Int. Cl.** **C21c 5/38**

[58] **Field of Search** .... 266/35, 36 P, 15, 16; 75/60

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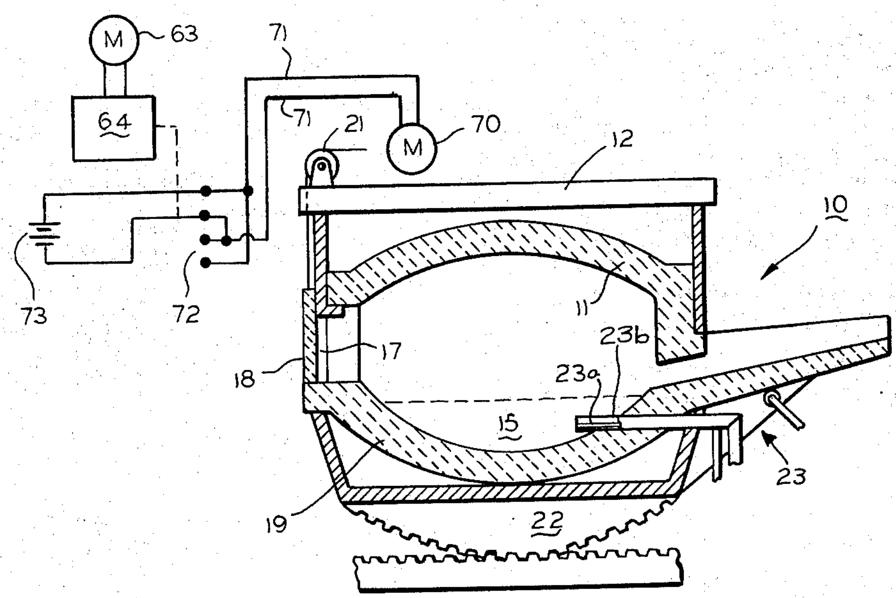
[57] **ABSTRACT**

A gas cleaning system for hearth furnaces having means for injecting process fluids below the level of molten metal and means for adjusting air intake by means of dampers in the furnace or the gas flow system or adjustable gaps between the furnace and the gas cleaning system. The furnace may be operated in the full or partial combustion mode wherein suitably located dampers control air flow to obtain the desired degree of combustion. Control means adjusts the damper or gap in the event normal air flow is disturbed. Provision is made in the system for measuring the calorific value of the off-gases and recovery of those off-gases having usable fuel capacity.

43 Claims, 8 Drawing Figures



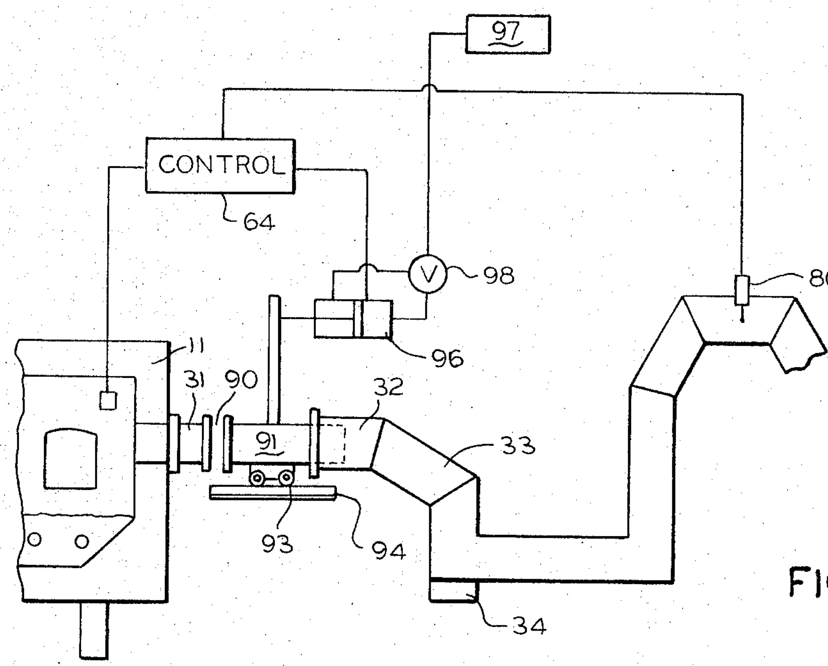

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FIG.3

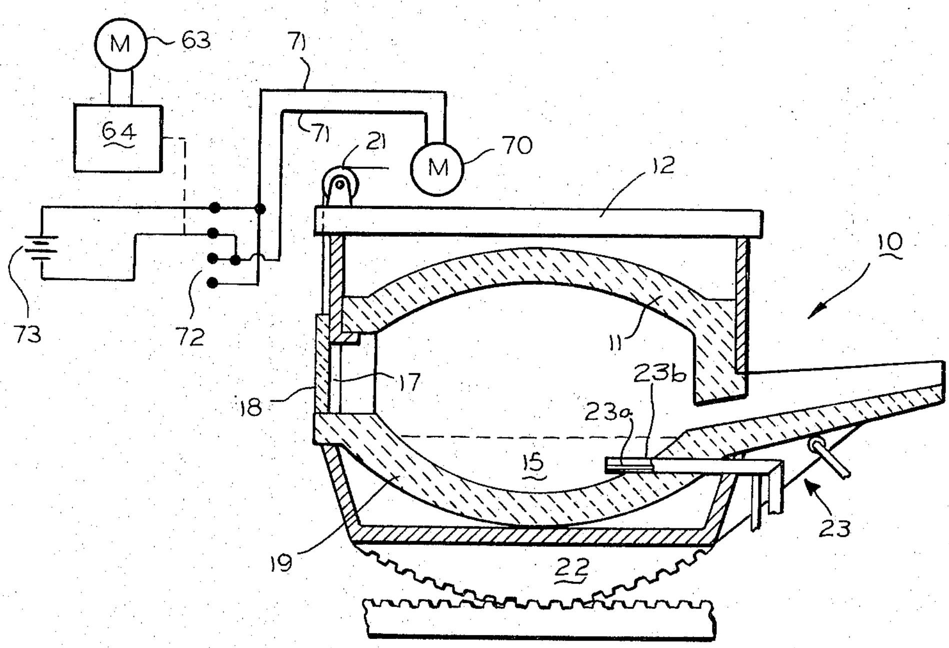
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FIG.1

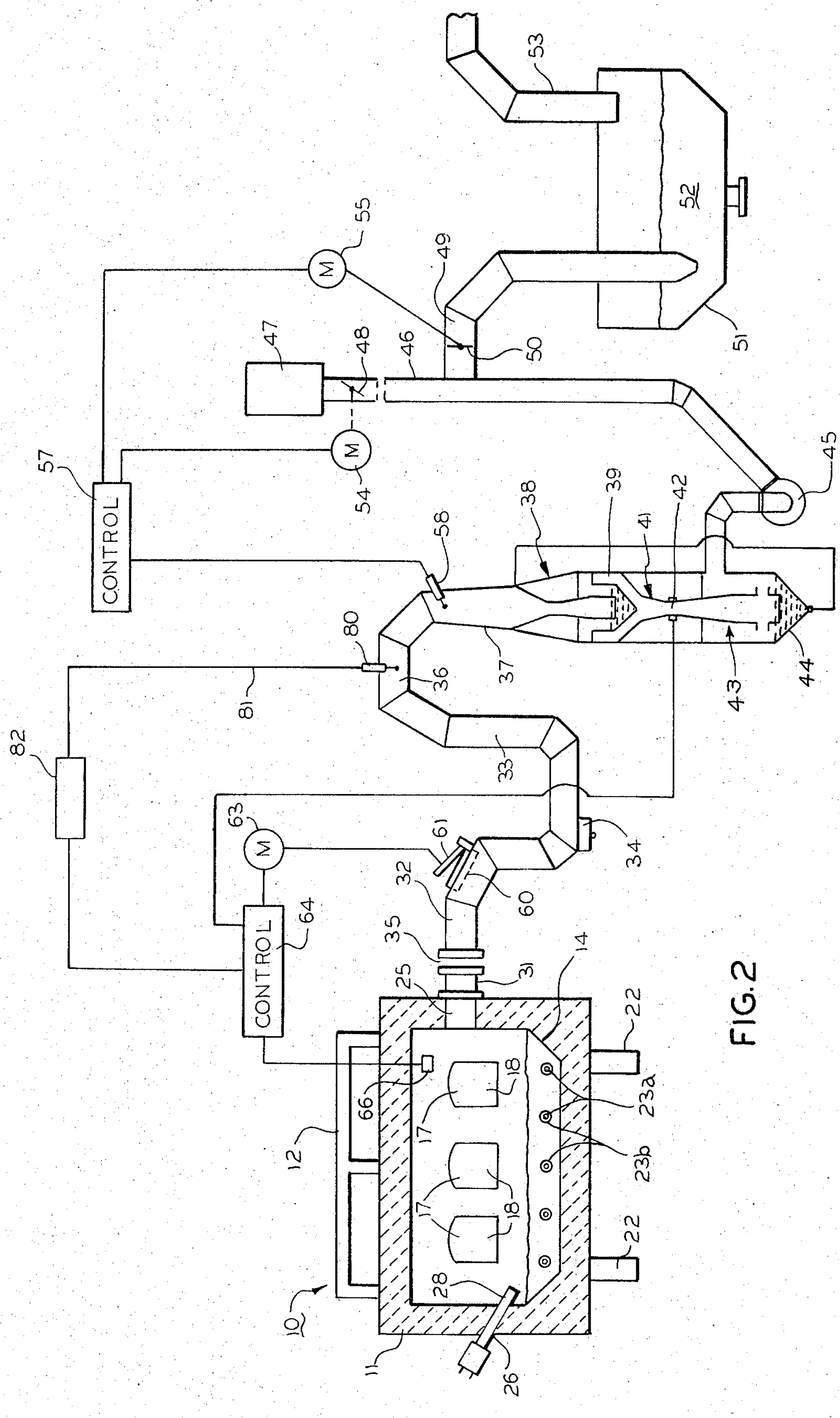
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FIG. 2

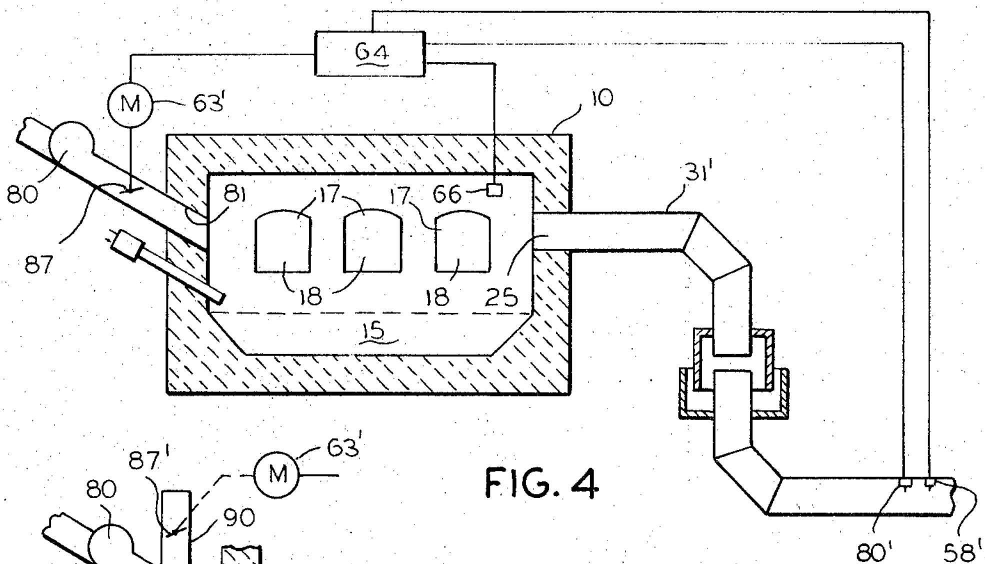

FIG. 4

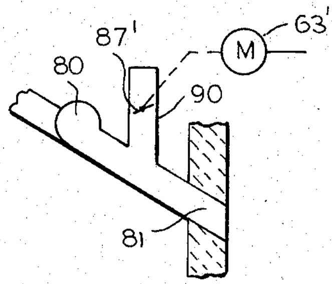

FIG.6

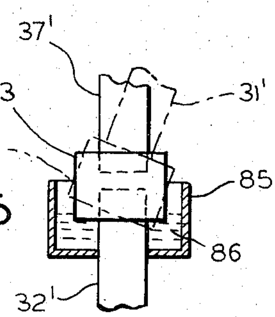

FIG.5

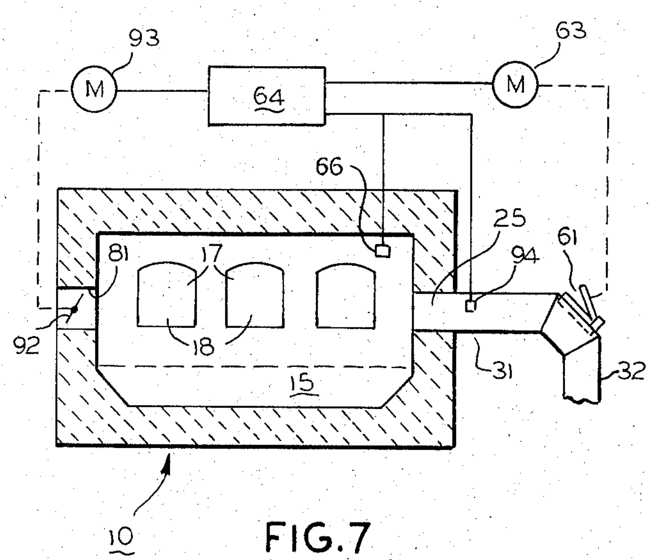

FIG.7

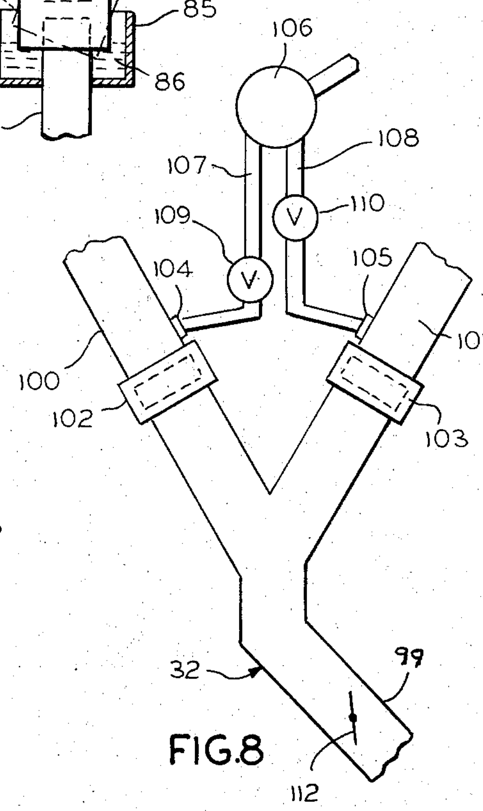

FIG.8

APPARATUS FOR PROCESSING MOLTEN METAL

BACKGROUND OF THE INVENTION

Conventional open hearth furnaces are generally reverberatory wherein a burner is disposed on either side of the hearth for being alternately activated, and a regenerative chamber or checker is connected to the gas inlet at each end of the furnace for preheating incoming air and for recovering heat from the discharging gases. When the burners are alternated, the flow of gases through the furnace system is similarly alternated wherein incoming air is drawn over the checkers previously heated by discharged gases and the discharging gases are passed over the exit checkers. Open hearth furnaces are also normally provided with doors which are opened for charging and deslagging. Recently it has been proposed to modify open hearth furnaces by the inclusion of one or more tuyeres for injecting oxygen and other fluids below the level of molten metal. The use of submerged tuyeres, as well as the regenerative system and the charging doors make the application of gas cleaning systems to such open hearth furnaces difficult. For example, when the charging doors are opened, the gas cleaning system, which is preferably of the constant volume type, may be overloaded with a large amount of excess air. Moreover, if large amounts of air are allowed to enter the gas cleaning system when the system is operating under partial combustion conditions, there is a possibility that enough oxygen will be present to react with the hot carbon monoxide in the off-gases to cause an explosion.

Another problem involved in the application of gas cleaning systems to open hearth type furnaces is the wide range of possible operating conditions. For example, the furnace may be operated in a full combustion mode wherein combustible off-gases are burned above the bath wherein the heat energy available in these gases is employed in the furnace. On the other hand, the furnace off-gases may be only partially oxidized and recovered for their calorific value. In addition, the percentage scrap-to-hot metal of the metallic charge may vary from 0–100%. Such wide variations in scrap charging ratios provide substantial variations in the furnace heat input requirements and in the off-gas composition.

SUMMARY OF THE INVENTION

A general object of this invention is to provide a gas cleaning system for a metallurgical furnace which is subject to large fluctuations in the amount of gas evolved from the melt or otherwise present in the furnace during a process cycle.

Another object of the invention is to provide a gas cleaning system wherein the amount of oxygen in the system is maintained below the amount at which combustion of refining gases can occur.

Still another object of the invention is to provide a metallurgical system including a gas cleaning system wherein the oxygen is maintained at a level wherein combustion can be controlled.

A further object of the invention is to provide a gas cleaning system for metallurgical vessels wherein the volume of off-gases and intermixed air is held within the capability of the gas cleaning system.

An additional object of the invention is to provide a metallurgical furnace gas cleaning system operable

under various combustion conditions and scrap-to-hot metal charging ratios.

A still further object of the invention is to provide a gas cleaning system which measures the calorific value of the gases passing therethrough and is adapted for collection of useful fuel gases.

Yet another object of the invention is to provide a gas cleaning system which can be utilized with both fixed and tiltable furnaces.

How the foregoing and other more specific objects of the invention are achieved will be set forth in a more detailed description of the preferred embodiments of the invention taken in conjunction with the accompanying drawings.

Generally, the invention comprises providing a metallurgical vessel gas cleaning system having sensing devices for determining when excess air enters the system and for adjusting the same. In addition, gas analyzers are provided for measuring the calorific value of the gases entering the gas cleaning system, for altering the gas cleaning system flow path and for collection of those gases which are suitably high in calorific value so that the economic benefits of the fuel may be realized.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view illustrating a furnace with which the invention may be employed;

FIG. **2** schematically illustrates an open hearth furnace and the gas cleaning system according to the invention; and

FIG. **3** schematically illustrates an alternate embodiment of the invention; and

FIGS. **4–8** illustrate alternate embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. **1** and **2** schematically illustrate a furnace **10** which may be employed with a gas system according to the invention. Furnace **10** generally includes a refractory shell **11** surrounded by a supporting framework generally designated by the reference numeral **12**. The refractory shell or lining **11** defines a vessel having a shallow hearth **14** for containing a bath of molten metal **15**. One or more charging openings **17** are formed along one side of the furnace **10** and each is provided with a charging door **18** which may normally be raised and lowered when desired in any suitable manner such as by means of a motor operated hoist **21** mounted on frame **12**. The furnace **10** itself may be mounted on stationary concrete or steel supports (not shown) or it may be mounted on rockers **22** whereby it may be tilted about an axis perpendicular to the plan of FIG. **1** for purposes of charging, pouring and deslagging.

A plurality of tuyeres **23** may extend through at least one side of the furnace **10** with their inner ends below the level of the bath **15**. Tuyeres **23** may include two or more concentric pipes **23*a*** and **23*b*** wherein a first process gas, such as oxygen, may be blown through the inner pipe **23*a*** and a hydrocarbon shielding fluid such as propane may be blown through the gap between the inner pipe **23*a*** and the outer pipe **23*b***. As those skilled in the art will appreciate, the shielding gas prolongs refractory and tuyere life. In addition to oxygen and propane, other process gases such as argon and nitrogen may be blown through one or both of the tuyere pipes and finely divided material such as lime, limestone, iron oxide, fluorspar, burnt lime and other materials may be entrained in the gas stream to provide the desired metallurgical reaction.

For purposes of illustrations, only one end of furnace **10** is shown to be provided with an opening **25** and only a single burner **28** is provided through the other end **26.** In normal operation of the furnace **10,** it will typically be charged with scrap and hot metal which is then melted and/or preheated by means of the burner **28.** The tuyeres **23** may also be employed during the preheat period by blowing fuel and oxygen into the furnace. After charging and the preheat period, the burner **28** will be turned off and the main furnace operation initiated. During waiting periods, deslagging and tapping inert gases such as nitrogen and argon are blown into the melt through both tuyere pipes **23***a* and **23***b* to maintain sufficient pressure within the tuyeres to maintain them free of metal. Also, when desulfurization is required, an inert gas such as argon or nitrogen is blown into the melt in this manner while lime is charged through the doors **17** or entrained as a powder in the gas stream. Refining is accomplished by the delivery of oxygen and other process gases and materials to the bath **15** by means of the tuyeres **23.** The oxygen reacts with impurities in the melt, such as carbon, phosphorous, silicon and manganese. At the end of the refining period, the carbon level of the melt may be determined in any suitable manner and then adjusted by the blowing of additional oxygen or by the introduction of carbon. The carbon may be in the form of a gas which is injected into the bath through the outer tuyere with an inert gas inserted through the inner tuyere. On the other hand, powdered carbon may be entrained in an inert gas. The bath temperature may also be adjusted by injecting oxygen which raises the bath temperature by exothermic reactions or the temperature may be lowered by the use of coolants.

As a result of the gases generated by the use of the burner **28,** which typically employs a mixture of fuel oil or gas and air and the gas emanating from the bath during the oxygen blow, a substantial quantity of off-gas is discharged through opening **25.** In accordance with the invention, the off-gases from the furnace are not discharged through checkers as is the case with conventional open hearth furnace installations, but instead the gases are conveyed to a gas cleaning system **30** which will be described below. For this purpose a short conduit **31** is mounted on furnace **10** in concentric surrounding relationship to opening **25.** Disposed adjacent the remote end of conduit **31** is the horizontal end of an otherwise generally U-shaped conduit **33.** Conduit **33** is preferably formed of adjacently disposed water pipes through which cooling water is circulated when the apparatus is in operation. Conduit **33** is configured in the manner of a trap and may have a collection door **34** at its lower end for collecting the particulates which are driven downwardly at high velocity by the gas in which they are entrained. The change in gas direction brought about by the U-shaped configuration assists in accomplishing this purpose. As seen in FIG. **2,** a gap **35** exists between conduit **31** and the end **32** of conduit **33** which allows the furnace **10** to be tilted and also permits entry of some fixed amount of atmospheric air into conduit **33** and the ensuing gas cleaning system **30.** If furnace **10** is fixed, no gap is required between conduits **31** and **33.**

The gas cleaning system **30** may be of any type conventionally employed with pneumatic metallurgical vessels. For example, the exit end **36** of conduit **33** may be coupled to pipe **37** which in turn is connected to a first venturi scrubber or gas cleaning device **38** which leads to a liquid separator **39** for removing particulates from the gas. An outlet not shown may be provided in separator **39** for periodically removing sludge formed therein. A second venturi scrubber or gas cleaner **41** having an adjustable throat **42** is coupled to receive the gases discharging from venturi **38** and a second separator **43** is coupled to the exit end of venturi **41.** The water formed in the second separator **43** may be recirculates from sump **44** to venturi **38.** The first venturi **39** is essentially a constant volume or low pressure drop device while the second venturi **41** may be a high pressure drop device which may function as an auxiliary pressure control for the gas cleaning system according to the invention. The two venturis **39** and **41** need not, of course, be placed on top of each other but could be connected in series in any manner known to the art.

A blower **45** connects the separator **43** to a discharge stack **46** having burner **47** at its upper end and a damper **48** intermediate its ends. A takeoff pipe **49** is connected at one end to stack **46** between damper **48** and blower **45** and the other end of pipe **49** is connected to water trap **51.** A second damper **50** is disposed intermediate the ends of pipe **49.** A quantity of water **52** is disposed in water trap **51** to a level above the lower end of pipe **49** and a second pipe **53** is coupled at one end to trap **51** above the level of water **52** and at its other end to a suitable gas storage means not shown. It will be appreciated that when damper **48** is open and damper **50** is closed the off-gases entering stack **46** pass upwardly to burner **47** whereupon any combustible components therein are oxidized or burned before discharge to the atmosphere. On the other hand, when damper **48** is closed and damper **50** is open, the off-gases are diverted through pipe **49** to water trap **51** from which they may be then conducted through pipe **53** to suitable storage containers not shown.

The dampers **48** and **50** are selectively controlled by servo motors **54** and **55,** respectively, and which in turn are regulated by a controller **57** which dictates alternate closing and opening of the dampers. Controller **57** is coupled to receive signals from a sensor **58** which extends into pipe **36.** The sensor may be of any well known type which measures the chemical content and hence the calorific value of the gases entering the venturi **38.** For example, the sensor **58** may include an oxygen partial pressure analyzer of any well known type such as the "Oxysensor" sold by the General Electric Company. In this device, an electrical potential is developed between two electrodes immersed into media having different oxygen partial pressures and which are separated by an oxygen-ion conducting calcium stabilized zirconium oxide electrode. With a preset temperatre and a known reference gas oxygen partial pressure, the open cell voltage between the two gases can be used to calculate the oxygen partial pressure of the gas to be measured in accordance with the Nernst equation. In addition, sensor **58** may include an infrared sensor which may be connected in series with the oxygen partial pressure analyzer indicating the percentage of carbon monoxide, carbon dioxide and water vapor in the gas being analyzed. Any well known type of infrared gas analyzer may be employed such as the Mine Safety Appliance Company model **300** infrared analyzer. Signals functionally related to the oxygen partial pressure analysis and the percentages of CO, CO_2 and H_2O in the gas being analyzed are processed in the control **57** to actuate servo motors **54** and **55** when gas conditions dictate. If sensor **58** indicates that the gas is of sufficiently high calorific value as would normally be the case during the oxygen blowing period, controller **57** actuates servo motors **54** and **55** to close damper **48** and open damper **50** whereby the off-gases are collected. On the other hand, if the sensor **58** indicates that gases are of insufficient calorific value as would normally occur at the beginning and end of the process cycle, servo motors **54** and **55** are operated to open damper **48** and close damper **50** whereby the gases are burned and discharged as indicated above.

When the furnace **10** is operated in its partial or incomplete combustion mode, the off-gases may contain about 25% carbon monoxide which is combustible or even explosive provided that adequate oxygen is available to support combustion. Accordingly, the oxygen level in the gas cleaning system should be maintained at a safe level which is 50% or below the amount required for sustaining combustion. This is accomplished according to another aspect of the invention. Specifically, pipe **33** has an opening **60** formed therein and adjacent which a damper **61** is pivotably mounted. The position of damper **61** relative to opening **60** determines the volume of air entering pipe **33** through opening **60.** Damper **61** may be adjusted relative to opening **60** by means of a servo motor **63** which in turn is adjustably positioned by a controller **64** to receive signals indicative of pressure within furnace **10** and from pressure responding device **66.** Alternately, the pressure sensing device may be placed within pipe section **32.** In the event furnace **10** is fixed so that there is no gap **35,** the size of opening **60** and the adjustment of damper **61** will be such as to permit the inflow of the desired volume of oxygen.

The sensing device **66** itself emits electric signals which are proportional to the pressure within the furnace (or in pipe **32** depending on placement of sensor **66**). The electrical signals are then compared by controller **64** to reference signals in a manner well known in the art and controller **64** actuates servo motor **63** which in turn adjusts damper **61** when the magnitude of an error signal reaches some predetermined value. It will also be noted that controller **64** may control the adjustable throat **42** of the second venturi **41** which as stated before functions to assure uniform pressure to the constant volume blower **45.** Control of variable throat **42** is usually only required during the initial charging and preheating steps of the refining cycle since those steps are full combustion. During the period of the oxygen blow wherein there is less than full combustion, suitable regulation may be accomplished by damper **61** in pipe **33** as more fully explained hereafter.

During normal furnace operation, that is, when the doors **18** are closed, substantially all of the air entering the off-gas stream is that which is drawn through gap **35** and opening **60.** Damper **61** and gap **35** are set such that a predetermined amount of air is emitted to pipe **33** along with the off-gases blowing therethrough. The amount of air is preferably limited to 50% or less of that which is required to support combustion.

When one or more of the furnace doors **18** are open, as may be required, for example, in a deslagging operation, pressure sensor **66** senses a drop in pressure within furnace **12.** Sensor **66** thereupon delivers an electrical signal functionally related to the pressure drop to controller **64** which operates servo motor **63** for moving damper **61** toward a closed position relative to opening **60** in conduit **33.** This reduces the amount of air which may enter through opening **61** to compensate for the increased volume of air now entering furnace **10** and exiting with the off-gases through the charging openings **17.** The volume of air entering opening **60** is thus reduced so that the total amount of air flowing into gas cleaning system **30** is maintained preferably at a level below 50% of that which is required to support combustion. When the furnace charging doors **18** are again closed, increased pressure is again detected by sensor **66** which affects the operation of servo motor **63** by means of controller **64** whereby damper **61** is returned to its normally open position.

According to an alternate embodiment of the invention shown in FIG. **1,** a motor **70** of the reversing type is operative to open and close door **18** and is electrically interlocked with servo motor **63.** This can be accomplished in any suitable manner such as by coupling controller **64** to the motor **70** energizing conductors **71.** When reversing switch **72** is placed in a first closed position to couple motor **70** to source **73** in a first sense for opening door **18,** servo motor **63** is operated to close damper **61.** Similarly when switch **72** is placed in an alternate closed position to couple motor **72** to source **73** in an opposite sense for closing door **18,** servo **63** is operated to open damper **61.**

FIG. **2** further illustrates an alternate embodiment of the invention wherein an oxygen partial pressure analyzer **80** is disposed in the conduit **36** and is connected by conductor **81** through oxygen analyzer **82** which in turn is connected to motor controller **64.** The analyzer **80** may be of the electrolytic type discussed above with respect to probe **58.**

It will be appreciated that the gas evolved from the bath **15** varies over the metal treatment period and accordingly the air aspirated through the gap **35** and the damper **61** and by controlling the venturi throat opening **42.** Prior to the blowing of oxygen, an inert gas, such as nitrogen, is blown through the bath **15.** When the oxygen blow is commenced, the evolution of combustible gases will likewise commence. Analyzer **80** is operative to control the position of damper **61** in accordance with the percentage of oxygen in the off-gases. For example, during the initial portion of the oxygen blow, when the quantity of evolved gases is low, CO and H_2 evolution from the bath **15** is relatively low. Air aspirated through the gap **35** and damper **61** permits full combustion to CO_2 and H_2O with the remainder of the gas passing to gas cleaning system being nitrogen. The mixture of CO_2, H_2O and N_2 is inert and noncombustible. At this stage the gas acts like an inert plug which flows through the gas cleaning system **30** purging it of oxygen for combustion and then discharging from stack **46.** The oxygen partial pressure sensor **80** detects when the stoichiometric combustion point of the gases is reached. At this point, damper **61** is partially closed and the safe capture of waste gases may be initiated without a danger of explosion.

More specifically, as the initial period of a heat progresses, the combined CO and H_2 concentration of the evolved gases increases markedly and combined CO_2 and H_2O concentration decreases. Since the volume of gas flow in this initial period is set by the preset position of the variable venturi throat **42**, air intake must necessarily be reduced at this time. The oxygen partial pressure sensor **80** detects the stoichiometric combustion point and thereby the absence of oxygen in the system and causes damper **61** to be partially closed to maintain the percentage of air within the system to a predetermined percentage of the total gas flow or about 50% of that required for stoichiometric combustion.

After the damper **61** has been positioned to provide the desired gas flow through the variable venturi throat **42** is used for finer operational corrections. The signals controlling the movement of the venturi throat **41** are based on furnace pressure which provides system sensitivity and minimizes pulsations of evolved gases through the air gap **35** to the atmosphere. Major fluctuations in flow rate are then corrected by the damper **61**.

When the oxygen blow approaches its end point, the combined concentrations of CO and H_2 in the off-gases decrease and those of CO_2+H_2O increase. The rate of gas flow at this time is controlled by the variable venturi throat **42** and damper **61**. As air is aspirated through the air gap **35** and damper **61**, conditions for stoichiometric combustion once again occurs. This condition is sensed by the oxygen partial pressure sensor **80** whic initiates the signal for further opening damper **61**. In the event furnace **10** is fixed, the gap **35** can be eliminated in which event, the air inlet will be limited to damper **61**.

FIG. 3 shows yet another embodiment of the apparatus for controlling the quantity of air provided to pipe **33**. Here the gap **90** between conduit **35** and the inlet to pipe **33** is adjusted and may be used along or together with the damper of the type shown in FIG. **2** to regulate air addition. More specifically, a conduit member **91** is disposed between end **32** of conduit **33** and conduit **31** attached to furnace **11**. The conduit **91** has a first end spaced from the end of furnace conduit **31** to provide the gap **90** therebetween. The other end of conduit **91** is telescopingly received within the inlet end **32** of gas cleaning system conduit **33**. Conduit **91** may be mounted in any suitable manner for movement toward and away from conduit **31** for increasing and decreasing the size of gap **90**. For example, conduit **91** may be mounted on rollers **93** which are in turn mounted on generally horizontal rails **94** mounted therebelow. Any suitable means may be provided for moving pipe section **91** horizontally on rails **94** such as a hydraulic cylinder **96**. A suitable source of hydraulic pressure **97** may be selectively coupled to the opposite sides of cylinder **96** through a reversing valve **98**. Servo motor **99** is operative to selectively actuate valve **98** in accordance with signals from the controller and thereby to pressurize either of the opposite ends of cylinder **96** to adjust the size of gap **94** in accordance with a pressure within vessel **10**. Specifically, when door **18** is open to decrease the pressure within vessel **10** and indicating excess air entering the gas cleaning system, cylinder **96** will be pressurized so as to decrease the size of gap **90** while on the other hand when the door **19** is closed the opposite end of cylinder **96** will be pressurized to return conduit **91** to its initial position and thereby re-establish the initial size of gap **90**.

As mentioned previously, a damper **61** may be used in conjunction with this embodiment of the invention, in which case the initial large adjustments may be made by moving pipe conduit **91** while fine corrections may be made by use of the damper **61**. Motor **63** cooperates with controller **64** as described in connection with FIG. **2**. Placement of sensor **66** may be either in the furnace **10** or in conduit **91** as explained in conjunction with FIG. **2**.

FIGS. **4** and **5** illustrate an alternate embodiment of the invention wherein the furnace **10** is operated in a full combustion system. Here a fan **80** is coupled to the furnace through a port **81** for blowing combustion air into the furnace during the various furnace operations. As a result, the combustible gases emanating from the bath **15** are oxidized prior to the delivery to the gas system **30**. In this embodiment, of course, gas storage is not employed. In addition, because of the delivery of air to the furnace **10** through port **81**, an air intake gap is not necessary or desirable at the discharge port **25**. Accordingly, the juncture between furnace exhaust conduit **31′** and the gas cleaning system inlet conduit **32′** is preferably closed. In the event the furnace **10** is of the tilting type, the connection between conduits **31′** and **32′** should be flexible. For example, the flexible connection may comprise a water seal **82** having hood member **83** connected to the end of conduit **31′** and extending downwardly past the end of conduit **32′**. In addition, a water container **85** extends upwardly from the end of conduit **32′** and past the lower end of hood **83**. A quantity of water **86** is disposed within the container **85** and above the level of the lower end of hood **83** to provide a liquid seal between conduits **31′** and **32′**. As seen in FIG. **4**, when vessel **10** is tilted to tilt conduit **31′**, the lower end of hood **83** remains below the level of the water **86** to maintain the seal between conduits **31′** and **32′**.

Referring again to FIG. **4**, it can be seen that a damper **87** is provided between fan **80** and the inlet port **81**. Damper **87** may be positioned to control the flow of air into furnace **10** by means of a servo motor **63′** coupled to control **64**. The opening of furnace doors **18** will be sensed in the manner discussed with respect to the embodiment of FIG. **2**, such as for example, by means of a pressure measuring device **66** within vessel **10**. Thus, when one of the doors **18** are opened motor **63′** is actuated to partially close damper **87** to reduce the amount of air entering port **81** and compensate for the air entering the furnace through the open door. When the door is reclosed, the motor **63′** will reposition damper **87** in its normal operating position. When doors **18** are closed, the position of damper **87** is normally controlled by an oxygen partial pressure sensor **80′** and a series connected gas analyzer **58′**, which may be of the infrared type. When appreciable quantities of CO or H_2 are detected by analyzer **58** and sensor **80**, motor **63′** will be actuated to further increase the opening of damper **87**. On the other hand, oxygen partial pressure sensor **80′** will effect the movement of damper **87** toward a closed position when the percentage of excess oxygen exceeds a preselected level.

According to an alternate embodiment of the invention shown in FIG. **6**, damper **87′** is disposed in a vent conduit **90** coupled to fan **80** and in parallelism with furnace inlet port **81**. The damper **87′** is operable to vent a portion of the air provided at the outlet of fan **80** when the furnace doors are opened in the manner similar to that discussed with respect to the embodiment of FIG. 4.

A further embodiment of the invention is shown in FIG. 7 wherein a damper **92** is shown to be disposed in a wall of furnace **10** opposite the vent opening **25.** The vent **92** is controlled by a motor **93** and control **64** in response to the opening doors **18** in a manner similar to that discussed with respect to the vent **87** in FIG. 3. A gas cleaning system such as that shown in FIG. 2 is coupled to pipe **32** of FIG. 7 wherein an exhaust fan (not shown in FIG. 7) will create a sufficient indraft through opening **81** to draw air into the furnace to combust at least a portion of the gases discharging from the bath **15.** If it is desired to control the combustion of gases within the furnace **10** so as to maintain a predetermined temperature for various portions of the process cycle, a temperature measuring device **94** may be suitably located, such as for example, within the outlet **31.** When used in a partial combustion system, the temperature measuring device **94** is connected to the controller **64** for positioning the damper **92** so as to provide sufficient combustion of the off-gases to maintain the desired temperature conditions. A second damper **61** is also provided in the gas cleaning system inlet pipe **32** to regulate the amount of additional air required to maintain substantially constant gas flow to the gas cleaning system (not shown). The damper **61** is positioned by motor **63** and controller **64** in a reverse relation to damper **92** so as to maintain the gas flow to the cleaning system substantially constant. If the damper **92** was employed in a complete combustion system, a closed discharge conduit arrangement is employed. In the latter event, dampe **92** is controlled in relation to the opening and closing of doors **18** in addition to the heat requirements of the furnace.

The invention may also be used with conventional open hearth furnaces having a burner and a port at each end, the latter of which leads to a slag pocket which in turn are connected to a regenerator.

FIG. **8** schematically illustrates another embodiment of the invention wherein a pipe **99** is coupled to the gas cleaning system inlet (not shown) and to the flues **100** and **101** of an open hearth furnace. Although the furnace and checkers are not shown in FIG. **8,** those skilled in the art will appreciate that each of the flues **100** and **101** are connected to one of a pair of furnace checkers which in turn are connected to vertical gas passages extending upwardly from slag pockets into the ends of the open hearth furnace. Suitable control valves or dampers **102** and **103** are disposed in flues **100** and **101** respectively to control the direction of the gas flow. In addition, air inlets **104** and **105** are respectively coupled to a blower fan **106** through ducts **107** and **108** and valves **109** and **110.** It will be appreciated that the dampers **102** and **103** and the valves **109** and **110** control the direction of gas flow through the system. For example, if damper **102** and valve **110** are open and damper **103** and valve **109** closed, air will flow through flue **101,** its associated checkers and air uptake and into one end of the furnace (not shown) while hot gas will discharge through the waste gas downtake at the other end of the furnace, through the connected checkers and through flue **100,** the open damper **102** and to the gas cleaning system inlet pipe **32.** When a number of furnaces are coupled to a common gas cleaning system, a damper **112** may be provided in pipe **99** for controlling furnace pressure. In addition, a damper (not shown) may be provided in the furnace wall (not shown) for controlling combustion air flow. In any event, such dampers are controlled in the manner discussed above with respect to FIGS. **2** and **7.** When a change in the direction of gas flow is desired, dampers **102** and **103** and valves **109** and **110** will be reversed. In any event, the damper **112** is controlled in the manner shown in FIGS. **1–3.**

Although only a few embodiments of the invention have been described, the invention is not to be limited thereby but is only to be limited by the scope of the claims appended hereto.

What is claimed is:

1. A metallurgical process system comprising:

a metallurgical vessel for containing a quantity of molten metal to be processed,

said vessel including first means for introducing reactants to said molten metal whereby substantial quantities of gases are evolved therefrom, an exit opening formed in said vessel for discharging said gases,

gas disposal means for receiving said gases,

second means for coupling said exit opening to said gas disposal means,

said second means including third means for controlling the amount of air admitted to said gas disposal means through said second means,

and fourth means respective to a change in air flow conditions into said vessel and being operable to actuate said third means to adjust the amount of air admitted to said gas disposal means,

an access opening formed in said vessel, closable means operatively associated with said access opening and movable between open and closed positions for opening and closing said access opening whereby air is admitted into said vessel when said closable means is open,

said fourth means being operative to sense the position of said closable means and operable to actuate said third means to decrease the amount of air admitted to the gas disposal means through said second means when said closable means is open and for increasing the amount of air admitted through said second means when said closable means is closed.

2. The system set forth in claim **1,** wherein said first means includes tuyere means extending through said vessel and having an inner end disposed below the level of molten metal normally disposed within said vessel for injecting oxygen beneath the level of said metal.

3. The system set forth in claim **1** wherein said second means includes conduit means having a terminal end disposed a predetermined distance from said exit opening to provide a gap therebetween to permit the entrance of air into said second means.

4. The system set forth in claim **3** wherein said third means comprises means for adjusting the gap between said terminal end of said second means and said exit opening to adjust the quantity of air entering said gap.

5. The system set forth in claim **4** wherein said second means has an opening therein, and said third means additionally comprises means for controlling the size of said opening to control the amount of air entering said second means therethrough.

6. The system set forth in claim **1** wherein said second means has an opening formed therein, said third means comprising means for controlling the size of said opening to control the amount of air entering said second means therethrough.

7. The apparatus set forth in claim **1** wherein said fourth means comprises pressure sensing means disposed within said vessel for sensing pressure changes therein.

8. The apparatus as claimed in claim **1** wherein said fourth means comprises pressure sensing means disposed within said second means for sensing pressure changes therein.

9. The apparatus set forth in claim **1** and including selectively operable means for moving said closable means between its open and closed positions and said fourth means being coupled to said selectively operable means for actuating said third means in response to movement of said closable means by said selectively operable means.

10. The apparatus set forth in claim **1** wherein said gas disposal means comprises a gas cleaning system.

11. The apparatus as claimed in claim **10** wherein said gas cleaning system includes a first low pressure drop venturi scrubber coupled to said second means and a second venturi scrubber having an adjustable throat coupled to said first venturi scrubber for regulating the pressure of gas exiting the separator.

12. The apparatus set forth in claim **1** wherein said fourth means includes oxygen sensing means disposed in said second means for sensing the percentage of oxygen in the gases flowing therein, said oxygen sensing means being coupled to said third means to effect a reduction in the air entering said second means when the percentage of oxygen in the gases flowing in said second means reaches a predetermined value.

13. The system set forth in claim **1** wherein said vessel comprises an open hearth furnace having heating means provided in one end thereof, said exit opening being disposed in the other end thereof.

14. The system set forth in claim **13** wherein said first means includes tuyere means extending through said vessel and having an inner end disposed below the level of molten metal normally disposed within said vessel for injecting oxygen beneath the level of said metal.

15. The system set forth in claim **14** wherein said tuyere means includes an inner pipe means coupled to receive oxygen and to inject the same into said metal and a second pipe means surrounding said first pipe means for receiving a shielding fluid and for injecting the same into said metal in a substantially surrounding relation to said oxygen.

16. The system set forth in claim **15** wherein said second means includes conduit means having a terminal end disposed a predetermined distance from said exit opening to provide a gap therebetween to permit the entrance of air into said second means.

17. The system set forth in claim **16** wherein said third means comprises means for adjusting the gap between said terminal end of said second means and said exit opening to adjust the quantity of air entering said gap.

18. The system set forth in claim **16** wherein said second means has an opening therein, and said third means additionally comprises means for controlling the size of said opening to control the amount of air entering said second means therethrough.

19. The apparatus set forth in claim **18** wherein said fourth means includes oxygen sensing means disposed in said second means for sensing the percentage of oxygen in the gases flowing therein, said oxygen sensing means being coupled to said third means to effect a reduction in the air entering said second means when the percentage of oxygen and the gases flowing in said second means reaches a predetermined value.

20. The apparatus as claimed in claim **19** wherein said gas disposal means is a gas cleaning system and said fourth means comprises pressure sensing means disposed within said second means for sensing changes in pressure within said second means.

21. The apparatus set forth in claim **19** wherein said gas disposal means is a gas cleaning system and said fourth means comprises pressure sensing means disposed within said vessel for sensing changes in pressure within said vessel.

22. The apparatus as claimed in claim **21** wherein said gas cleaning system includes a first low pressure drop venturi separator coupled to said second means and a second venturi separator having an adjustable throat coupled to said first venturi separator for regulating the pressure of gas exiting the separator.

23. The system set forth in claim **21** wherein said third means comprises means coupled to said vessel for admitting air thereto above the level of said molten metal to effect the combustion of gases in said vessel.

24. The system set forth in claim **23** and including means associated with said third means to controlling the flow of air to said vessel.

25. The system set forth in claim **24** wherein said vessel has a vent opening for discharging gases therefrom and a gas cleaning system coupled to said vent opening.

26. The system set forth in claim **25** wherein said vessel comprises an open hearth furnace having heating means provided in at least one side thereof, said vent opening being displaced from said heating means, said first means includes tuyere means extending through said vessel and having an inner end disposed below the level of molten metal normally disposed within said vessel for injecting oxygen beneath the level of said metal, said tuyere means includes an inner pipe means coupled to receive oxygen and to inject the same into said metal and a second pipe means surrounding said first pipe means for receiving a shielding gas and for injecting the same into said metal in a substantially surrounding relation to said oxygen.

27. The system set forth in claim **26** and including an opening formed in said vessel and spaced from said vent opening, said third means including means for controlling the volume of air entering said opening.

28. The apparatus set forth in claim **27** wherein said fourth means comprises pressure sensing means disposed within said vessel for sensing changes in pressure within said vessel.

29. The apparatus as claimed in claim **28** wherein said fourth means comprises pressure sensing means disposed within said second means for sensing changes in pressure within said second means.

30. The system set forth in claim **29** and including means coupling said vent opening to said gas cleaning system and having a second air admitting opening therein, and means for controlling the size of said second opening to control the amount of air entering said gas cleaning system therethrough.

31. An open hearth furnace having heating means provided in at least one side thereof, a vent opening formed in said vessel for discharging gases therefrom, said vent opening being displaced from said heating means.

tuyere means extending through said vessel and having an inner end disposed below the level of molten metal normally disposed within said vessel for injecting oxygen beneath the level of said metal, said tuyere means including an inner pipe means coupled to receive oxygen and to inject the same into said metal and a second pipe means surrounding said first pipe means for receiving a shielding gas and for injecting the same into said metal in a substantially surrounding relation to said oxygen,

a second opening formed in said vessel and spaced from said vent opening.

air control means coupled to said second opening for admitting air thereto above the level of said molten metal to effect the combustion of gases in said vessel, and including means for controlling the volume of air flow to said vessel and through said second opening.

pressure sensing means disposed within one of said vessel or gas cleaning system for sensing changes in pressure within said vessel,

a gas cleaning system, coupling means for coupling said vent opening to said gas cleaning system and having a third air admitting opening therein, and means for controlling the size of said third opening to control the amount of air entering said gas cleaning system therethrough, and

oxygen sensing means disposed in said coupling means for sensing the percentage of oxygen in the gases flowing therein, said oxygen sensing means being coupled to said air control means to effect a reduction in the air entering said vessel when the percentage of oxygen in the gases flowing in said second means reaches a predetermined value.

32. The apparatus as claimed in claim **31** wherein said gas cleaning system includes a first low pressure drop venturi separator coupled to said second means and a second venturi separator having an adjustable throat coupled to said first venturi separator for regulating the pressure of gas exiting the separator.

33. The apparatus set forth in claim **2** wherein said vessel includes charging door means, said door means including at least one charging door and operating means coupled to said door for effecting movement of the same between open and closed positions, said fourth means being coupled to said charging door means and being responsive to the position thereof.

34. A metallurgical process system comprising:

a metallurgical vessel for containing a quantity of molten metal to be processed,

said vessel including first means for introducing reactants to said molten metal whereby substantial quantities of gases are evolved therefrom, an exit opening formed in said vessel for discharging said gases,

gas disposal means for receiving said gases,

second means for coupling said exit opening to said gas disposal means,

gas delivery means coupled to said vessel for delivering oxygen containing gas thereto and above the level of said molten metal for oxydizing combustable gases emanating from said molten metal,

third means coupled to said gas delivery means for controlling the amount of oxygen containing gas admitted to said vessel,

an access opening formed in said vessel, closable means operatively associated with said access opening and movable between open and closed positions for opening and closing said access opening whereby air is admitted into said vessel when said closable means is open,

fourth means operative to sense changes in the position of said closable means and operable to actuate said third means to decrease the amount of oxygen containing gas admitted to the vessel through said gas delivery means when said closable means is open and for increasing the amount of said gas admitted through said gas delivery means when said closable means is closed.

35. The system set forth in claim **34** wherein said vessel has a vent opening for discharging gases therefrom and a gas cleaning system coupled to said vent opening.

36. The system set forth in claim **35** wherein said vessel comprises an open hearth furnace having heating means provided in at least one side thereof, said vent opening being displaced from said heating means, said first means includes tuyere means extending through said vessel and having an inner end disposed below the level of molten metal normally disposed within said vessel for injecting oxygen beneath the level of said metal, said tuyere means includes an inner pipe means coupled to receive oxygen and to inject the same into said metal and a second pipe means surrounding said first pipe means for receiving a shielding gas and for injecting the same into said metal in a substantially surrounding relation to said oxygen.

37. The system set forth in claim **36** wherein said gas delivery means includes an opening formed in said vessel and spaced from said vent opening, said third means including means for controlling the volume of air entering said opening.

38. The apparatus set forth in claim **37** wherein said fourth means comprises pressure sensing means disposed within said vessel for sensing changes in pressure within said vessel.

39. The apparatus as claimed in claim **37** wherein said fourth means comprises pressure sensing means disposed within said second means for sensing changes in pressure within said second means.

40. The system set forth in claim **37** wherein said fourth means includes pressure sensing means disposed in one of said vessel and second means for sensing changes in pressure therein and including means coupling said vent opening to said gas cleaning system and having a second air admitting opening therein, and means for controlling the size of said second opening to control the amount of air entering said gas cleaning system therethrough.

41. The apparatus set forth in claim **37** wherein said fourth means includes oxygen sensing means disposed in said second means for sensing the percentage of oxygen in the gases flowing therein, said oxygen sensing means being coupled to said third means to effect a reduction in the air entering said vessel when the percentage of oxygen in the gases flowing in said second means reaches a predetermined value.

42. The apparatus as claimed in claim **41** wherein said gas cleaning system includes a first low pressure drop venturi separator coupled to said second means and a second venturi separator having an adjustable throat coupled to said first venturi separator for regulating the pressure of gas exiting the second separator.

43. A metallurgical process system comprising:

a metallurgical vessel for containing a quantity of molten metal to be processed,

said vessel including first means for introducing reactants to said molten metal whereby substantial quantities of gases are evolved therefrom, an exit opening formed in said vessel for discharging said gases,

gas disposal means for receiving said gases,

second means for coupling said exit opening to said gas disposal means,

third means for controlling the amount of air admitted to one of said vessel and gas disposal means,

and fourth means responsive to a change in air flow conditions into said vessel and being operable to actuage said third means to adjust the amount of air admitted to the one of said vessel and gas disposal means,

an access opening formed in said vessel, closable means operatively associated with said access opening and movable between open and closed positions for opening and closing said access opening whereby air is admitted to said vessel when said closable means is open,

said fourth means operative to sense changes in the position of said closable means and operable to actuate said third means to decrease the amount of air admitted to the vessel through said gas delivery,

said vessel comprising an open hearth furnace having a pair of spaced apart vent openings and tuyere means below the expected level of metal in said vessel,

conduit means connected to each of said vent openings, and valve means for selectively coupling one of said conduit means to a source of air and the other of said conduit means to a gas cleaning system.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,873,073 Dated March 25, 1975

Inventor(s) Joerg P. Baum 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 10, line 28, change "respective" to --responsive--.

Signed and Sealed this

second Day of *September 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks