United States Patent

[11] 3,539,165

[72] Inventor **Glenn R. Ingels**
9940 Memorial Drive, Houston, Texas 77024

[21] Appl. No. **833,308**
[22] Filed **June 16, 1969**
Continuation-in-part of application Ser. No. 597,290, Nov. 28, 1966, abandoned, which is a continuation-in-part of application Ser. No. 292,280, July 2, 1963, abandoned
[45] Patented **Nov. 10, 1970**

[54] **APPARATUS FOR TREATING METALLIC AND NONMETALLIC MATERIALS**
24 Claims, 9 Drawing Figs.

[52] U.S. Cl. 263/40, 263/15
[51] Int. Cl. F27b 17/00
[50] Field of Search 263/40, 43, 15, 16

[56] **References Cited**

UNITED STATES PATENTS

2,504,320	4/1950	Gamble	263/43
2,589,811	3/1952	Holcroft	263/40
3,331,594	7/1967	Davies	263/15

Primary Examiner—John J. Camby
Attorneys—James F. Weiler, Jefferson D. Giller, William A. Stout, Paul L. DeVerter II, Dudley R. Dobie, Jr., and Henry W. Hope

ABSTRACT: A system for treating metallic and nonmetallic materials in the presence of an environment of inert gases, such as argon and helium, or of a nitriding gas, such as nitrogen, or of liquid water saturated with or without a major amount of carbon dioxide, a minor amount of methane and lesser amounts of hydrogen and carbon monoxide at temperatures of about 32°F. to about 160°F. under pressures up to the equilibrium pressure of water 218.5 atmospheres. Means are also provided for generating the saturated liquid water. Means are provided for controlling the pressure, volume, temperature and relative humidity of the exhaust gases from the furnace which provides an effective control within the furnace. Means are also provided for preheating the environment to at least the treatment temperature and controlling its pressure just prior to entrance into the furnace. This provides very exact control conditions of treatment. Means are also provided to add carbon and inert material to the saturated fluid mixture to control the temperature of the exhausting gases.

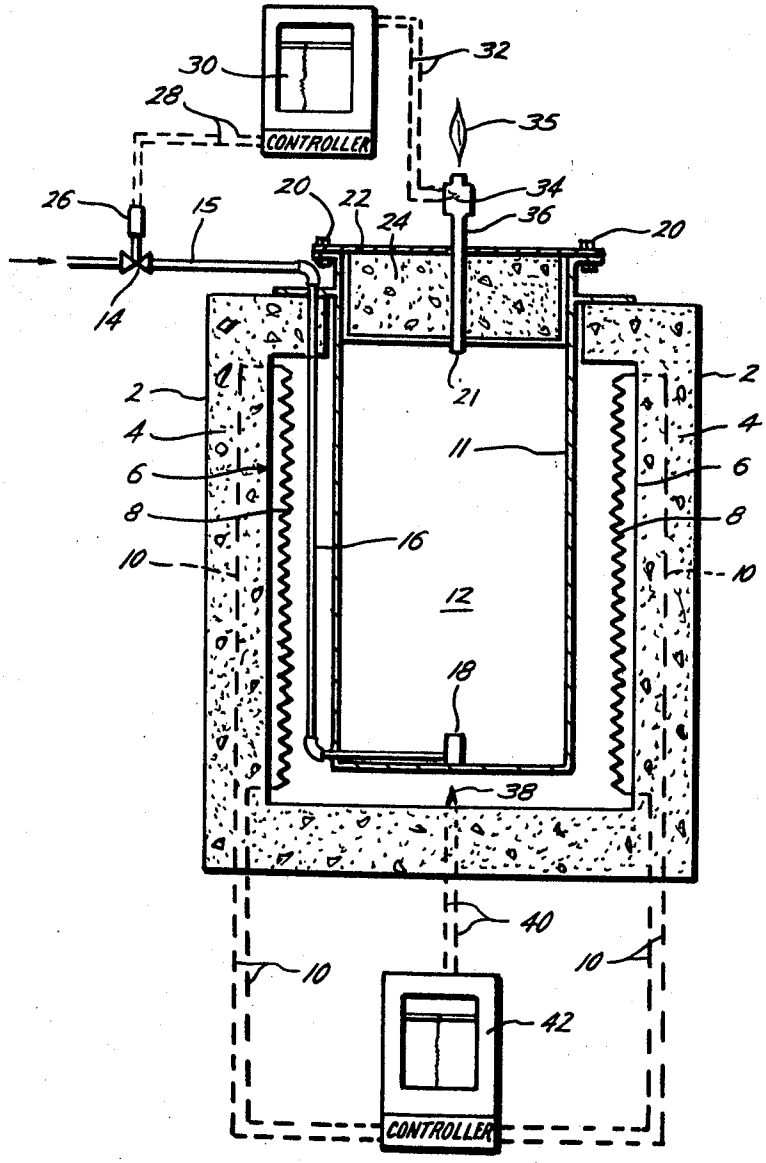


Fig. 1

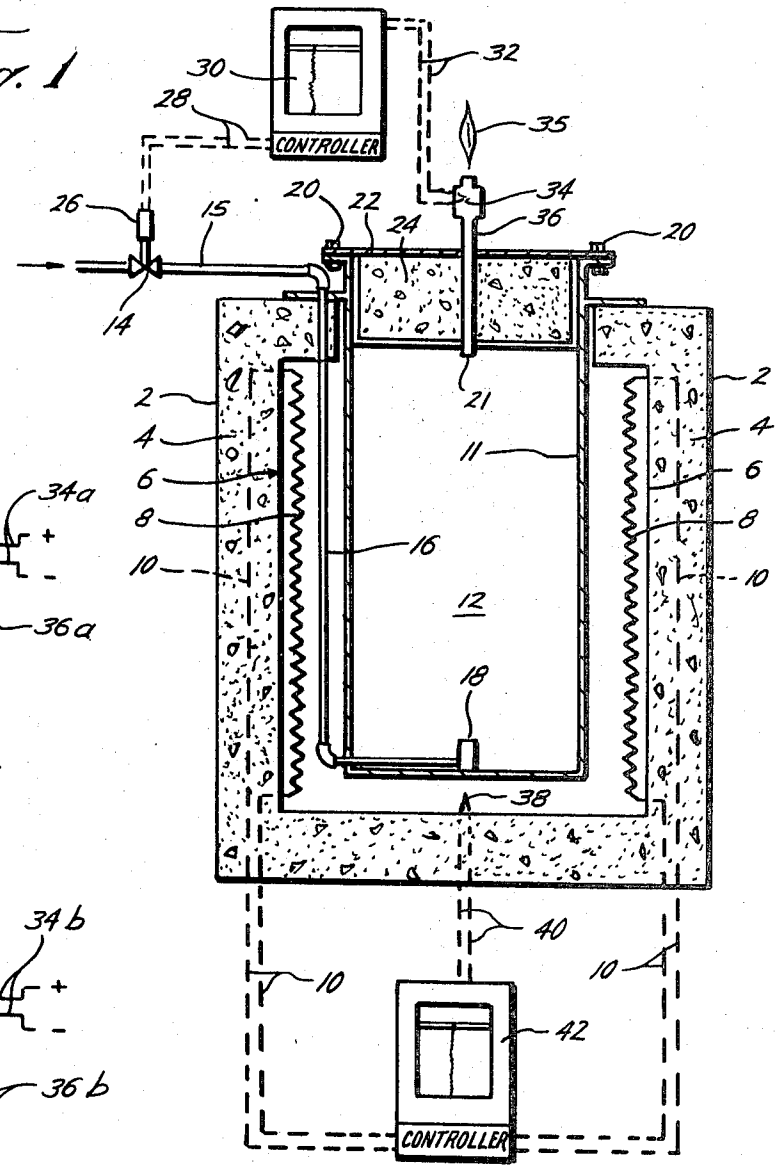


Fig. 2

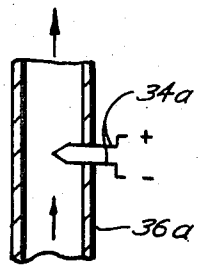


Fig. 3

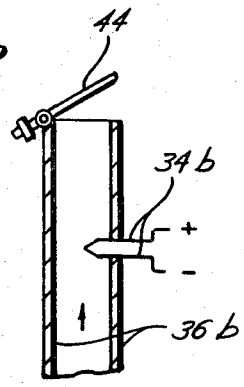
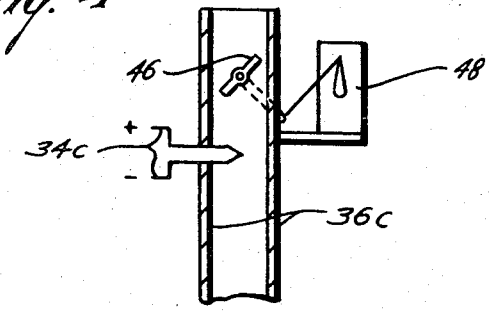


Fig. 4



Glenn R. Ingels
INVENTOR.

BY James F. Ukeiley
Jefferson D. Giller
Paul L. Dellekey II
Dudley R. Dobie, Jr.
ATTORNEYS

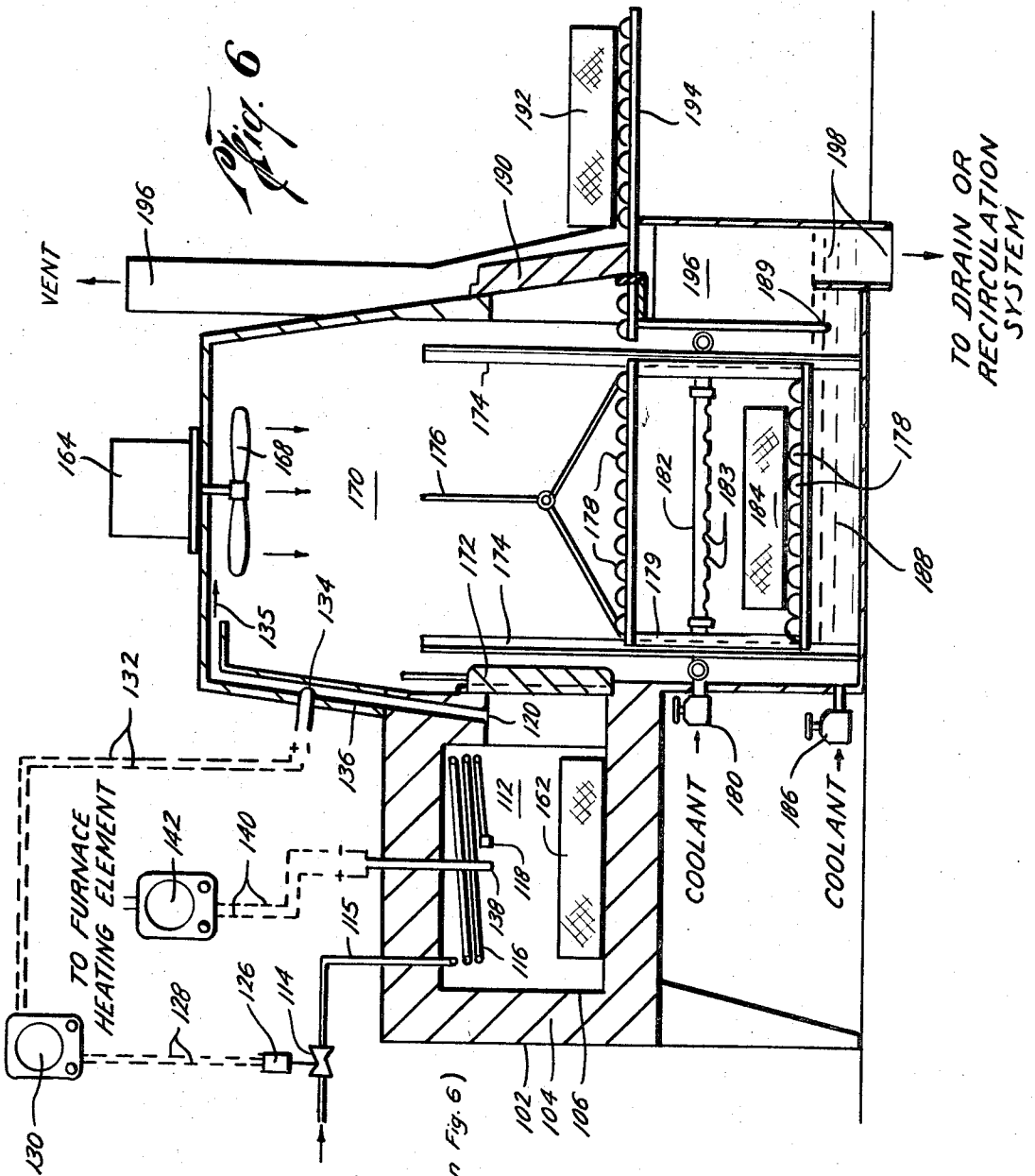


Fig. 6

Fig. 5

Glenn R Ingels
INVENTOR.
James F. Wiley
BY Jefferson D. Giller
Paul L. De Venter II
Dudley R. Dobie, Jr.
ATTORNEYS

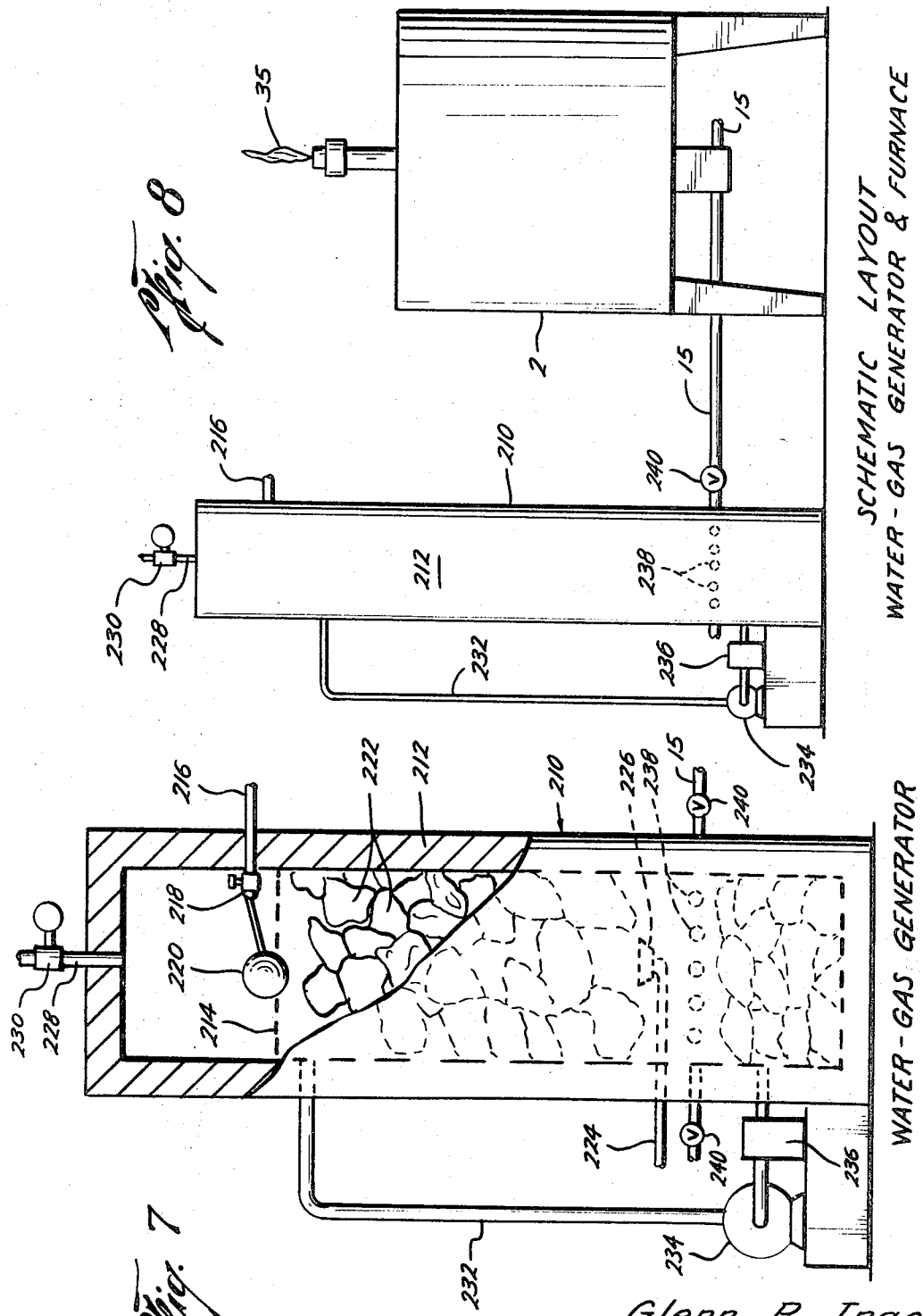


Fig. 8

Fig. 7

Glenn R. Ingels
INVENTOR.
James F. Weiler
BY Jefferson D. Giller
Paul L. De Vesley II
Dudley R. Dobie, Jr.
ATTORNEYS

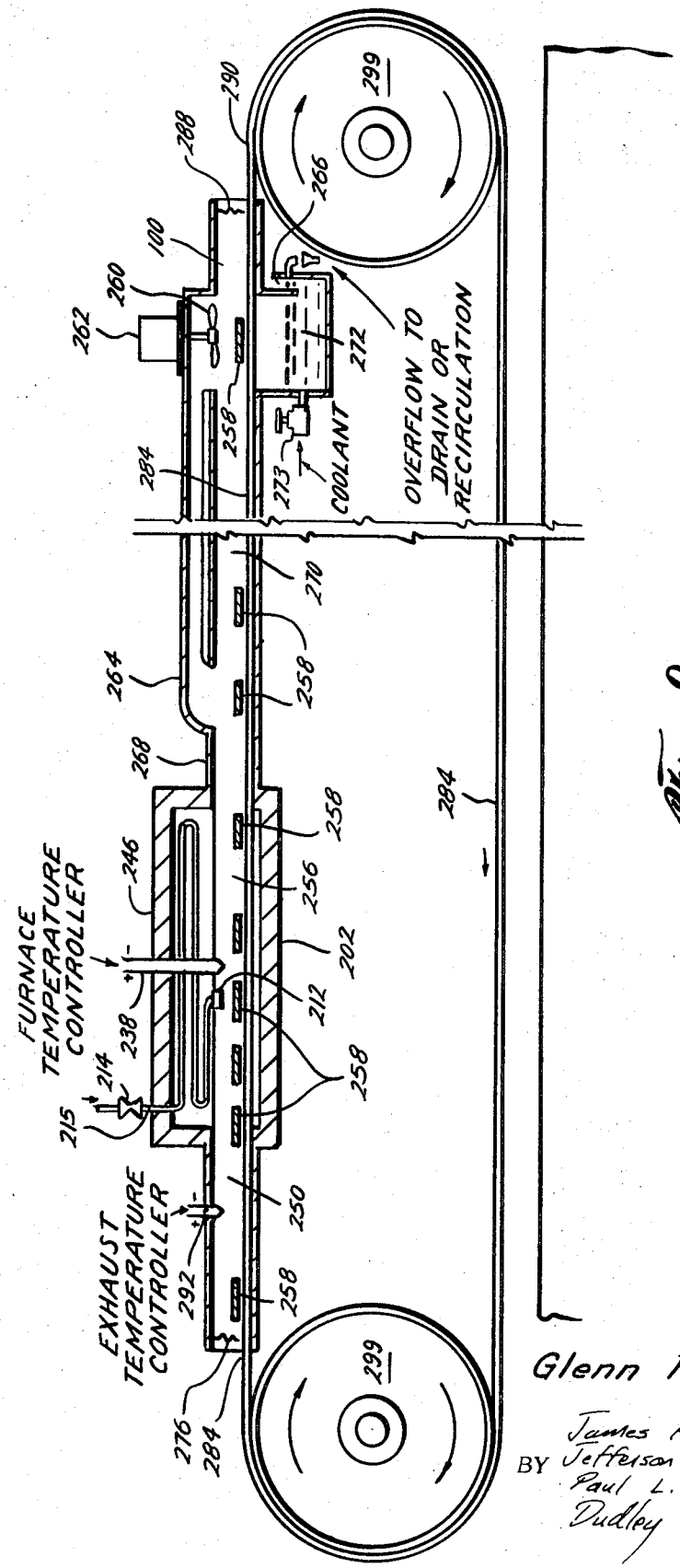


Fig. 9

Glenn R. Ingels
INVENTOR.
James F. Weiler
BY Jefferson D. Giller
Paul L. DeVeyler II
Dudley R. Dobie, Jr.
ATTORNEYS

APPARATUS FOR TREATING METALLIC AND NONMETALLIC MATERIALS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 597,290 filed Nov. 28, 1966, now abandoned which in turn is a continuation-in-part of application Ser. No. 292,280, filed July 2, 1963 now abandoned in which restriction was required. Continuation-in-part applications, Ser. No. 719,613 filed Apr. 8, 1966 and Ser. No. 828,600, filed May 28, 1969, include claims to other inventions disclosed and claimed herein.

BACKGROUND OF THE INVENTION

The present invention relates to the treatment of metallic and nonmetallic materials. More specifically, the present invention relates to the melting, heat treating, welding, cold treating, casting, surface treating, and the like of metallic and nonmetallic bodies by which advantageous properties in the material are obtained.

It has long been desired in the art to provide a system for treating metals and nonmetals in a suitable gaseous environment by which very exact control conditions in the furnace are obtained so that desired properties can be imparted to these metals and nonmetals. In the metallurgical art until the present development, there was no system for treating metals and nonmetals in which the temperature and the pressure of the gaseous environment are controlled in a preheater prior to entrance to the treating zone of a furnace and the temperature or energy level of the gases exhausting from the treating zone of the furnace are controlled, by which very exact control conditions in the furnace are obtained so that desired properties can be imparted to these metals and nonmetals.

It also has been desired in the art to treat metals and nonmetals in a gaseous environment which may be in equilibrium or neutral to them, may be oxidizing and decarburizing, oxidizing and carburizing, reducing and decarburizing, or reducing and carburizing under operating conditions.

The present invention is directed to such methods and treatment.

SUMMARY

The present invention relates to systems of treating metallic and nonmetallic materials by which highly desired properties are obtained in these materials. The present invention relates to systems of melting, heat treating, welding, cold treating, casting, surface treating and the like of metallic and nonmetallic bodies by which advantageous properties in the bodies are obtained.

More particularly, the present invention relates to a furnace for treating metals and nonmetals in the presence of a gaseous environment, as hereinafter set forth, having means for very exact control conditions in the furnace including means for controlling the temperature and pressure of the gaseous environment before its entrance into the treating zone of the furnace and means for controlling the temperature, or energy level, of the environment as it exhausts from the treating zone of the furnace thereby controlling the reaction energy released by the environment in the treating zone which is thus available to control the reactions with the metallic and nonmetallic bodies being treated at the treatment temperature thereby imparting desired properties to the metals and nonmetals being treated. The furnace atmosphere or environment may be a generated fluid mixture composed of liquid water saturated with a major amount of carbon dioxide, with or without a minor amount of methane and lesser amounts of hydrogen and carbon monoxide while in the temperature range of from about 32°F. to about 160°F. and while maintaining the solute gases under atmospheric pressures up to the critical pressure of water, which is 218.5 atmospheres. This generated saturated fluid mixture may be in equilibrium or neutral, may be oxidizing and decarburizing, may be oxidizing and carburizing, may be reducing and carburizing, or may be reducing and decarburizing by controlling the temperatures and pressures within the range mentioned during its generation. Also, the furnace atmosphere may be inert gases, such as argon and helium, or may be a reducing gas, such as hydrogen, or may be a nitriding gas, such as nitrogen.

The metals which may advantageously be treated with the method include all of the elements of the periodic table. The nonmetals include the oxides, sulfides, sulphates, silicates, phosphates, and carbonates of the elements of the Periodic Table.

It is therefore an object of the present invention to provide a treating system for metals and nonmetals having means for controlling the temperature and pressure of the gaseous environment just prior to entering the treatment zone and means for controlling its temperature as it exhausts from the treatment zone by which very exact control conditions in the furnace are obtained.

A further object of the present invention is to provide a treating system for metals and nonmetals which includes a generator for generating a gaseous environment composed of liquid water saturated with a high or major concentration of carbon dioxide, with or without a minor amount of methane and lesser amounts of hydrogen and carbon monoxide to impart desired properties to the metals and nonmetals.

A further object of the present invention is the provision of an improved system of heat treating and cold treating of metallic and nonmetallic bodies in which the constituents of the furnace atmosphere at any given temperature are balanced out thereby establishing an equilibrium between the gases in the atmosphere and the composition of the bodies in the furnace and which balance is maintained as the furnace temperature changes.

A still further object of the present invention is the provision of an improved system for heat treating and cold treating metallic and nonmetallic bodies which includes means for balancing the furnace atmosphere to the body in the furnace and automatically maintaining this balance at all times as the furnace temperature changes.

Yet a further object of the present invention is the provision of an improved system of treating metallic and nonmetallic bodies by which new and unusual structures having highly advantageous properties are obtained in comparison to those obtained by present commercial systems.

A still further object of the present invention is the provision of a system for treating metallic and nonmetallic bodies in a balanced atmosphere by which new and improved properties are imparted to the bodies.

Yet a further object of the present invention is the provision of an improved system for processing metallic and nonmetallic bodies, such as annealing, normalizing, hardening, tempering, carburizing, nitriding, surface coating, freezing and the like by which improved results are obtained.

A further object of the present invention is the provision of a system in which metallic and nonmetallic materials are treated in an atmosphere which has the characteristics or properties of being in equilibrium or neutral, oxidizing and decarburizing, oxidizing and carburizing, reducing and carburizing, or reducing and decarburizing.

A further object of the present invention is to provide a system having means closely controlling the release of heat energy or reaction energy or both within the treating zone to obtain a desired heat balance for the bodies being treated.

It is further an object to provide a system which controls the heat balance in a treating zone while treating metallic and nonmetallic materials by having means controlling the enthalpy of the environment during generation, prior to its entrance into the treating zone, and finally as it exists from the treating zone thereby controlling the heat energy or reaction energy released in the treating zone at the treatment temperature (difference between the energy entering the treating zone and the energy leaving the treating zone) thereby imparting desirable properties to metallic or nonmetallic bodies. In this connection, for most metallic and nonmetallic bodies extremely

close enthalpy control is desired, of the order of a few B.t.u.'s per cubic foot.

A still further object of the present invention is the provision of a system for treating metallic and nonmetallic bodies including means for preheating the environment to a controlled heat content or enthalpy just prior to its use as a treating environment to provide a super heated environment with an energy level equal to or higher than the energy level existing during treatment and including means controlling the heat content or enthalpy of the environment on its exit from treatment thereby controlling the energy released by the environment surrounding the metallic and nonmetallic bodies during treatment by which advantageous properties are imparted to them.

A still further object of the present invention is the provision of an improved system of processing metallic and nonmetallic bodies including means closely controlling the heat or reaction energy or both released by the environment to the bodies at treatment temperatures by which new and unusual structures having highly advantageous properties are obtained in comparison to those obtained by methods of the prior art.

Other and further objects, advantages and features of the invention will be apparent from the following description of presently preferred embodiments of the invention, given for the purpose of disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view, partly in section, illustrating a retort furnace according to the invention for treating metallic and nonmetallic bodies;

FIG. 2 is a sectional view of an exhaust pipe to an environment of less than one atmosphere, such as found when a partial pressure is pulled on the exhaust, and containing an energy level sensing element, here shown as a thermocouple;

FIG. 3 is a sectional view similar to that of FIG. 2 illustrating an exhaust pipe from a treating zone to an environment of one atmosphere of pressure with a counter weight flapper valve and an energy level sensing element;

FIG. 4 is a sectional view, similar to FIGS. 2 and 3, of an exhaust pipe from a treating zone where control is maintained at a pressure higher than one atmosphere by a butterfly valve connected to a pressure control motor and an energy level sensing element controlling at an elevated pressure;

FIG. 5 is an elevational view, partly in section, of a back pressure relief valve which operates at the temperature of a treating zone and releases the treating environment into the treating zone only when a preset pressure level is reached;

FIG. 6 is an elevational view, partly in section, of a treating furnace, containing a treating chamber or zone connected to a cooling or quenching chamber or zone with an exhaust pipe between the treating and cooling chambers containing the energy level sensing element, such as illustrated in FIGS. 2—4, inclusive;

FIG. 7 is an elevational view, partly in section, of a water-gas generator according to the invention;

FIG. 8 is a schematic view of the water-gas generator of FIG. 7 and the furnace of FIG. 1;

FIG. 9 is still another sectional elevation of a tube type furnace with a preheater coil within the furnace, but outside of the treating zone, with the exit end of the coil open into the treating zone, entrance and cooling chamber of the furnace being so constructed to control equilibrium pressures on heating and cooling at all temperatures.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the art, previous efforts have been directed to the elimination of the oxidizing gaseous constituents, such as carbon dioxide and water, in atmospheres for processing material at elevated temperatures. Surprisingly, however, a treatment environment having a high water content is extremely beneficial in treatment of metallic and nonmetallic bodies if the environment contains water balancing gases, carbon dioxide, carbon monoxide, hydrogen and methane while kept under very close control.

It has further been found that liquid water will act as a carburetor to absorb finite amounts of the water balancing gases to reach an equilibrium depending on the temperature and pressure of the solute water balancing gases over the water as explained in my copending U.S. Pat. Ser. No. 719,613. The reactions are according to the following water-gas reactions:

$$(1)\ CO_2+H_2=CO+H_2O+\text{heat}$$
$$(2)\ CO_2+CH_4=CO+H_2+H_2O+C+\text{heat}$$

The generated fluid mixture therefore constitutes liquid water balanced with the water balancing gases carbon dioxide, carbon monoxide, hydrogen and methane. The generated fluid mixture may have the characteristics or properties, depending on the temperature and pressure, of being in equilibrium or neutral, oxidizing and decarburizing, oxidizing and carburizing, reducing and carburizing or reducing and decarburizing.

The generated fluid mixture, on leaving the generator, has a preset enthalpy characteristic with known properties, but which must be controlled throughout the process as the enthalpy requirement (heat) of equations (1) and (2) changes drastically with any change in temperature of the fluid mixture.

In one aspect of the present invention, the saturated fluid mixture is preheated under closely controlled temperature and pressure conditions, the metallic and nonmetallic materials are treated with the saturated fluid mixture in a pressure tight treating chamber zone, and the enthalpy of the saturated fluid mixture exhausting from the chamber or zone is closely controlled, both with or without cooling.

All materials, both metallic and nonmetallic, have a definite and finite energy requirement for each particular temperature level. Static heat energy from a heating furnace is not sufficient by itself to control these definite and finite energy requirements of metallic and nonmetallic bodies being treated. The heat content or enthalpy of the environment surrounding these materials during their treatment at any treatment temperature has a pronounced effect on their final properties. In the present method these energy requirements are provided and controlled.

To provide and control such environmental energy during treatment in the treating chamber an environment, which may be a fluid or fluid mixture, of known and predictable response to heating and cooling must be generated or provided. The inert fluid argon has the lowest absolute heat content at all temperatures. The nitriding gas nitrogen has the next highest absolute heat content. The water-gas fluid mixture has the highest absolute heat content. To increase the heat content of each of these gases it is necessary to increase the pressure. For instance, to increase the heat content of argon at 400°F. from 10 B.t.u./c.f. to 20 B.t.u./c.f. it is necessary to increase the pressure to two atmospheres or 29.394 p.s.i.a. To increase the heat of the superheated water-gas at 1700°F. from 22 B.t.u./c.f. to 61.5 B.t.u./c.f. it is necessary to increase the pressure to 2.8 atmospheres or 41.15 p.s.i.a.

Control of the energy entering the treating chamber through the preheater and by the exhaust control to control the energy leaving the treating chamber, control of the energy released in the treated chamber is obtained at any furnace temperature level.

This released energy is reactive energy capable of shifting equations (1) and (2) from an equilibrium or neutral state to one which is oxidizing and decarburizing, oxidizing and carburizing, reducing and carburizing or reducing and decarburizing. Any of these combinations can be obtained and controlled by the apparatus of this invention.

The generated saturated fluid mixture comprises liquid water saturated with a major amount of carbon dioxide, with or without a minor amount of methane and lesser amounts of hydrogen and carbon monoxide. Other components may be

present. This is accomplished by saturating liquid water, while it is maintained at a temperature of from about 32°F. to about 160°F. while the gases are maintained from atmospheric pressure up to the critical or equilibrium pressure of water, 218.5 atmospheres. The carbon dioxide or the liquid water may comprise the largest percentage by volume of the generated fluid mixture. The generated fluid mixture composition has relatively low or minor amounts of hydrogen and carbon monoxide. Methane, when present, is present in minor amounts; although, there is more methane present than either hydrogen or carbon monoxide.

A preferred temperature of the liquid water is within the range from 105°F. to 140°F. with a constant pressure of the gases in the range of 25 to 80 p.s.i.a. Particularly good results have been obtained by maintaining the liquid water at a temperature of the order of about 120°F. with a constant gas pressure of the order of about 28 to 60 p.s.i.a.

The gases which may be used to saturate the liquid water may be any combination of oxidizing and reducing or oxidizing and carburizing gases which will react to form in liquid water, within the temperature and pressure ranges specified, a high saturation of the water with carbon dioxide with or without a minor amount of methane, and with lesser amounts of hydrogen and carbon monoxide. Suitable gases for this purpose are mixtures of carbon dioxide and hydrogen or carbon dioxide and methane, or methane and oxygen, with or without combustion, which are presently preferred. If desired, additional carbon may be provided to the water in the form of charcoal, coke, graphite and the like for the purposes of stabilizing the oxidizing properties of carbon dioxide and water and the reducing and carburizing properties of methane. This additional carbon may be omitted. By controlling temperatures and pressures within the ranges set forth liquid water saturated with these gases is produced, which may be in equilibrium or neutral, may be oxidizing and decarburizing, may be oxidizing and carburizing or may be reducing and decarburizing. It is essential, however, that the saturated fluid mixture generated by the process be maintained in essentially its generated condition and transported to a treatment zone for treatment of metallic and nonmetallic materials in order to obtain the beneficial result of the present invention.

The metallic bodies subject to treatment by the generated saturated fluid mixture include all of the elements of the Periodic Table and their alloys, for example, steel, stainless steel, tungsten, molybdenum, vanadium and the like. The nonmetallic materials include the oxides, sulfides, sulphates, silicates, phosphates and carbonates of the elements of the Periodic Table.

By controlling the temperature and pressure the properties or characteristics of the generated saturated fluid mixture are controlled. For example, if the temperature of the liquid water is maintained at 50°F. and the pressure of the gases is maintained at 10 p.s.i.a., the generated saturated fluid mixture would have oxidizing and decarburizing properties. If the temperature of the liquid water were raised to 90°F., then the characteristics and properties of the generated saturated fluid mixture would be oxidizing and carburizing.

If the temperature of the water were maintained at 150°F. and the gases at a pressure of 45 p.s.i.a., then the generated saturated fluid mixture would have the properties of reducing and carburizing. If the temperature of the water is reduced to 90°F. and the gases held at a pressure of 45 p.s.i.a., the generated saturated fluid mixture would have the properties of reducing and decarburizing.

In general, in generating the saturated fluid mixture the gases may be flowed under controlled pressure into a chamber into intimate contact with liquid water in the chamber maintained from 32°F. to 160°F. with a gas head above the upper level of the water maintained at a pressure up to the equilibrium or critical pressure of liquid water, which is 218.5 atmospheres. When the gases cease to flow into the chamber, the liquid water is saturated and this may be used as an indication of such saturation. A saturated fluid mixture according to the invention has thus been formed and may then be discharged from the chamber, care being taken to maintain the properties and characteristics of the formed saturated fluid mixture on discharge from the chamber and transfer to a treating zone or chamber.

The following tables illustrate generated saturated fluid mixtures in which liquid water is saturated at the temperatures and pressures set forth with carbon dioxide, carbon monoxide, hydrogen and methane which were provided by mixtures of carbon dioxide and hydrogen, mixtures of carbon dioxide and methane, and mixtures of methane and oxygen, with and without combustion. These tables indicate the percentage of the pure components by volume saturating the water at the temperatures and pressures indicated.

TABLE I

The temperature of the water was maintained at 41° F. and a constant pressure of the gases was maintained at 19.2 p.s.i.a. The saturated fluid mixture had the following composition.

Pure component:	Percentage by volume
CO_2	62. 58
CO	1. 38
H_2	. 90
CH_4	2. 11
H_2O	33. 03
	100. 00

This saturated fluid mixture was reducing and decarburizing.

TABLE II

The temperature of the water was maintained at 41° F. but the pressure was increased to 44 p.s.i.a. The saturated fluid mixture had the following composition.

Pure component:	Percentage by volume
CO_2	76. 92
CO	1. 70
H_2	1. 10
CH_4	2. 60
H_2O	17. 68
	100. 00

This saturated fluid mixture was reducing and decarburizing.

TABLE III

The temperature of the liquid water was maintained at 122° F. but the gas pressure was decreased to 19.2 p.s.i.a. The saturated fluid mixture had the following composition.

Pure component:	Percentage by volume
CO_2	38. 36
CO	1. 42
H_2	1. 41
CH_4	1. 88
H_2O	56. 93
	100. 00

This saturated fluid mixture was oxidizing and carburizing.

TABLE IV

The temperature of the water was maintained at 122° F. and the pressure of the gases was raised to 44 p.s.i.a. The generated saturated fluid mixture had the following composition.

Pure component:	Percentage by volume
CO_2	56. 53
CO	2. 09
H_2	2. 08
CH_4	2. 77
H_2O	36. 53
	100. 00

This saturated fluid mixture was reducing and slightly carburizing.

TABLE V

The temperature of the water was maintained at 41° F. and the pressure was raised to the pressure of 218.5 atmospheres. The generated saturated fluid mixture had the following composition.

Pure component:	Percentage by volume
CO_2	93. 16
CO	2. 06
H_2	1. 34
CH_4	3. 14
H_2O	. 30
	100. 00

This saturated fluid mixture was reducing and decarburizing.

TABLE VI

The pressure of the gas was maintained at 218.5 atmospheres and the temperature of the water was raised to and maintained at 122° F. This resulted in a saturated fluid mixture having the following composition.

Pure component:	Percentage by volume
CO_2	88. 36
CO	3. 27
H_2	3. 26
CH_4	4. 32
H_2O	. 79
	100. 00

This saturated fluid mixture was reducing and decarburizing.

TABLE VII

The following is a typical composition generated by a conventional endothermic generator in the art today.

Pure component:	Percentage by volume
CO_2	0. 40
CO	19. 60
H_2	40. 00
CH_4	. 02
H_2O	[1]. 87
N_2	38. 93
	100. 00

[1] Dew point 43° F.

It can be seen from the composition of this fluid mixture that it is very low in the water and water-forming constituents, carbon dioxide and methane. The composition is mainly carbon monoxide, hydrogen and nitrogen, which is strongly carburizing and decarburizing and not neutral, and which provides a very stable atmosphere which changes very little in pressure during changes in temperature and thus is not in equilibrium.

Referring now to FIG. 1 a heating furnace containing a retort for a treating chamber is illustrated. The heating furnace may be any conventional furnace, any type of shape and design. As illustrated the furnace includes an outer shell 2 with insulation 4 and an inner shell 6 with any type of heating means, here shown to be electric with heating elements 8 connected by leads 10 to relays, not shown, common in the art to controller 42, actuated from thermocouple 38 through leads 40, which controls the temperature of retort 11 containing the metallic or nonmetallic bodies being treated (not shown) in treating zone 12. The saturated fluid mixture from a generator (not shown) or other fluid environment from a suitable source, not shown, enters through pipe 1 through a proportional flow control valve 14 actuated by a proportional flow mechanism 26 common in the art, through a pipe 15 to preheater 16 which may be a single pipe, a series of pipes, straight or coiled, and connected to a back pressure control mechanism 18, which is open to the treating chamber 12 containing the bodies to be treated. The fluid or fluid mixture in the preheater may be heated to the temperature of the treating chamber 12 and at a controlled pressure from the pressure ambient within the treating chamber to a pressure equal to the critical pressure of water (218.5 atmospheres), as determined by the controlled setting on the back pressure regulator 18. When the saturated fluid mixture is at the controlled temperature and pressure (controlled enthalpy) it is expelled into the treating chamber 12 containing the metallic or nonmetallic bodies or parts to be treated, and out through exhaust pipe opening 21 through an exhaust pipe 36 containing a sensing device 34 to sense the enthalpy of the exhausting fluid or fluid mixture at point 34 in exhausting from the treating chamber. The enthalpy at 34 depends primarily on the internal energy, the volume and the pressure of the fluid or saturated fluid mixture at that point. Therefore, by controlling the flow of fluid or saturated fluid mixture at 14 a control of the enthalpy at 34 is obtained.

Now referring to FIG. 2, there is shown a section of the exhaust pipe to which the letter A has been added to like parts for convenience of reference. The exhaust pipe 36A contains the enthalpy sensing device 34A, here shown as a thermocouple, and is exhausting the fluid or fluid mixture to an environment of less than one atmosphere pressure. Thus, the enthalpy at 34A is being controlled at a partial pressure.

In FIG. 3 is shown a section of the exhaust pipe here give the letter B for like parts. The exhaust pipe 36B contains the enthalpy sensing device 34B and the counter weight flapper valve 44 to control the enthalpy at one atmosphere pressure at 34B.

FIG. 4 shows another modification of the exhaust pipe where the letter C has been added for like parts. Here the exhaust pipe 36C contains an enthalpy sensing device 34C operating at a pressure higher than one atmosphere controlled by the butterfly valve 46 through a pressure control mechanism 48 common in the art. Thus, the enthalpy level is being controlled at a higher pressure than one atmosphere.

FIG. 5 illustrates the back pressure regulator designated as 18 in FIG. 1 and 118 in FIG. 6. This regulator operates at the temperature of the treating chamber to permit the fluid or fluid mixture to leave the preheater 16 (116 in FIG. 6) when the fluid or fluid mixture has reached the pressure set by a controlled weight pressing down on a controlled dimensioned area. The preheated fluid or fluid mixture from 16 (or 116 in FIG. 6) enters an opening 60 closed with a plug 56 having an

orifice 58 of controlled dimension with a weight 52 pressing down on the orifice area 58, here shown as ball 52. This weight 52 may be of any shape or configuration. The known and controlled weight 52 pressing on a known and controlled orifice area 58 builds up a known and controlled pressure at 60. As the fluid or fluid mixture reaches the temperature of the treating chamber and at a pressure set by the weight 52 and orifice 58 combination it expels out into the treating chamber through openings 54 at a controlled enthalpy level.

In FIG. 6, to which reference is now made, is shown an elevational view, partly in section, of a treating furnace connected to a cooling or quenching chamber 170 by an exhaust pipe 136 and a closable door 172. The saturated fluid mixture from a generator similar to the one described and claimed in my copending application, Ser. No. 719,613, enters the pipe 101 through a flow control valve 114 through a connecting pipe 115 into the preheater 116 located in the heated zone 112 of the furnace 102 and is expelled out through back pressure regulator 118 into the treating zone 112 of the furnace. A furnace thermocouple 138 controls the furnace temperature through leads 140 to a temperature controller 142 which actuates a heating means common in the art and not shown in the drawing. The fluid or fluid mixture in being expelled form the back pressure regulator 118 circulates in the treating zone 112 and flows out exhaust opening 120 through an exhaust pipe 136 in which is located an enthalpy sensing element 134, such as a thermocouple connected through leads 132 to a temperature controller 130 which actuates the proportional flow control valve 114. The fluid or fluid mixture on leaving the exhaust pipe 136 at 135 enters the cooling or quenching chamber 170. A blower fan 168 driven by the motor 164 pulls a partial pressure at the exhaust 135 and pushes the hot fluid or fluid mixture down toward the cooling water 188 which cools and thereby contracts its volume and moves out under a baffle 189 to an overflow 198 to a drain or recirculating system, not shown. The gases not absorbed pass out through a vent 196. The proportional flow of the fluid or fluid mixture is controlled by the enthalpy at 134 controlled through the flow control valve 114 in the inlet pipe 101. The temperature of the cooling water 188 is regulated by a control valve 186 to hold approximately 90°F. A temperature control mechanism, common in the art, and not shown, may be utilized to operate a control valve 186 to hold a constant temperature of the cooling water 188. A spray pipe 182 is equipped with the nozzles 183 to spray quench the hot parts 184 if so desired by opening the coolant valve 180.

With the furnace being controlled at a desired temperature and the flow of fluid or fluid mixture through the flow control valve 114 being controlled by the exhaust controlled thermocouple 134 to hold a constant temperature in the range of 250°F. to 1500°F. a desired energy balance flow is established and the metallic materials are ready to be treated in a new and unique manner. The parts are loaded on suitable trays or baskets 192 resting on a roller conveyor 194, or any other suitable means of conveyances. The cooling chamber door 190 is raised, or a water spray curtain may replace door 190, and the work load 192 is pushed into chamber 170 onto hearth 178 attached to an elevator 179, here shown to have a double hearth, but a single hearth may be used. The furnace door 172 is raised, and work is pushed to 162 through the opened door 172 which is then closed. If elevator 179 has a double hearth, as shown, a second work load 192 can be rolled on hearth 178 and elevator 179 raised by any convenient means 176. The upper hearth with its load is in the hot part of the cooling chamber and is being preheated, while the lower hearth 178 is empty. The furnace control 142 is maintaining a constant temperature in the treating chamber 112, and the exhaust control 134 controls the release of the reactive energy from the environment. After a given processing time, the door 172 is raised and the hot work 162 is pulled to the lower hearth 176 of the elevator 179 and the elevator 179 is lowered to its cooling position, while the preheated work on the upper hearth 178 of elevator 179 is pushed to 162 in the treating chamber and the door 172 is closed. The cooling chamber door 190 is then raised and another work load 192 is pushed onto the upper hearth 178 of the elevator 179, and the cooling chamber door 190 is again closed. After the work on the lower hearth 178 is cooled the elevator 179 is raised and the cooled processed work is pulled form the furnace back to 192 and down the processed line, not shown. The cycles may be repeated in production runs.

No details have been given of the various controllers, thermocouples, valves and the like as these are all conventional and are readily available.

Referring now to FIG. 5, a generator which produces the saturated fluid mixture is illustrated which is highly advantageous. The generator is generally indicated by the reference numeral 210 and includes an insulated chamber 212 kept partially filled with water 214 through the water inlet 216 controlled by the float valve 218 by the liquid level float 220.

The water is in intimate contact with a carbon material 222, through which carbon dioxide and hydrogen, and/or carbon dioxide and methane are bubbled through the inlet 224 and the nozzle 226. Any gaseous mixture which will form carbon dioxide and hydrogen, and/or carbon dioxide and methane may be used, such as air and methane, air and any hydrocarbon, oxygen and methane, oxygen and any hydrocarbon. In any case the gas or gases are bubbled up through the water 214 in intimate contact with carbon material 222 and is exhausted through the exhaust 228 controlled by the back pressure regulator 230 to result in a saturation of the reactive constituents of the water-gas reaction in the water 214. Any carbon containing material reactive to the oxidizing components of the selected gas or gases may be used, for example, coke, charcoal, graphite and any of the saturated or unsaturated hydrocarbons, such as methane, ethane, propane and the like may be used. The flow of CO_2 gas, air and oxygen, including hydrogen and/or methane, if desired, can be regulated so that very little waste is incurred. The water may be circulated in the circulation line by the means of the pump 234 through the refrigerated or heating coil 236 back into the insulated chamber 212. The water-fluid mixture may be maintained at any temperature between 32°F. and 160°F. In the heat treatment of steel, best results have been obtained by maintaining the temperature of the water-fluid mixture at approximately 120°—140°F. and at pressures of the order of two atmospheres.

The water after a sufficient exposure to the action of the carbon containing matter, including one or more of CO_2 gas, air, oxygen, hydrogen or methane, at this controlled temperature and pressure is saturated and/or superheated and ready for transportation to the furnace. A single generator may be used for a plurality of furnaces. Any carbon containing material in which the carbon is reactive to the oxidizing components of the gas may be used, for example, coke, charcoal, graphite, saturated and unsaturated hydrocarbons, such as methane, ethane, propane and the like.

It is readily apparent that the generator illustrated in FIG. 7 produces a fluid mixture low in nitrogen (less than 0.5 percent) or one free of nitrogen. If air is bubbled through the water 214 in the chamber 212, the solubility of nitrogen in water is quite low. The undissolved gases are exhausted through the exhaust line 228 controlled by the back pressure valve 230 and the water 214 with its dissolved gases, including less than 0.5 percent nitrogen, passes by the outlet 238 controlled by the valve 240 in the line 15 into the furnace 2 as a balanced atmosphere, as shown in elevation in FIG. 8 and in detail in FIG. 1. If no nitrogen containing gases are used no nitrogen will be in this fluid mixture. For example, by replacing air with oxygen in the generator 210, no nitrogen will be found in the balanced atmosphere. The control of nitrogen is of paramount importance in making it possible to heat treat some materials with extreme hardness and high ductility.

Thus, the saturated fluid mixture generated in the generator 212 of FIG. 7 flows by line 15 into the furnace 2 illustrated in FIGS. 1 and 8 under very carefully controlled conditions.

In FIG. 9 a tube type sintering furnace is shown according to the invention, to which reference is now made. In this embodiment a suitable environment, such as a saturated fluid mixture, inert gas, reducing gas or nitriding gas enters the inlet pipe **215** at the upper part of the furnace **202** controlled by a suitable control valve **214** into the preheater coil of pipe or tubing **246** placed in the furnace **202**. The saturated fluid mixture or other gaseous environment in moving through the preheater **246** is converted to a high enthalpy gas and is expanded into the tube treating zone **256** through the back pressure relief valve **212**. The work baskets **258** are moved on a conveyor belt or chain **284** which runs all the way through the tube treating zone **256** driven by the drums **299**. The tube treating zone **256** and the preheater **246** are heated by any conventional means in the furnace **242** controlled through the furnace temperature controller **238**. It is advisable to place a curtain or door **288** at the inlet and outlet of the tube treating furnace or zone **256**. The baskets **258** enter through the entrances **276** on the conveyor belt **284** into the entrance exhaust **250** which serves as a vapor lock zone. A balanced fluid mixture in going from a gas to liquid water tends to lock if the container temperature change is abrupt. In this zone the exhaust temperature controller thermocouple **292** is placed a short distance from the furnace **202**. The temperature in the exhaust chamber **250** is indicated by the thermocouple **292** through proper instrumentation common in the art which controls the flow of the fluid mixture or gaseous environment through the flow valve **214** in the inlet pipe **213** into the preheater **246** and into the treating zone **256**. It can be seen that the atmosphere flow from the treating zone **256** is in two ways—through the entrance-exhaust **250** and through the exit-exhaust **268** into the cooling chamber **270**. In FIG. 9 the exhaust control thermocouple **292** is shown in the entrance-exhaust **250**, but it may also be placed in the exit-exhaust **268** or in both. The cooling chamber **270** may be water-jacketed to speed up the rate of chamber cooling. Also, it may have a bypass vent **264** to pull the heat from the cooling chamber **270** at the position shown thereby creating a partial vacuum at that point and transferring this heat by the fan blades **260** driven by motor **262** to a water bath **272** and out through the overflow system **266** to drain or for recirculation. The cooling chamber **270** is open to ambient environment through the exit curtain **288** only. Thus, the temperatures and pressures in the cooling chamber **270** may be regulated and controlled.

The work baskets **258** entering through the curtain **276** on conveyor belt **284** are subjected to a preheat by the entrance-exhaust **250** controlled by the exhaust temperature control thermocouple **292**, then pass into the treating zone **256**, the temperature of which is controlled by the furnace temperature control thermocouple **257**, then out through the exit-exhaust **268** on the conveyor belt **284** through the cooling chamber **270**. By the time the work baskets **258** reach the water bath **272** they will be down to a temperature of about 212°F. to approximately 280°F. and can be safely carried on the belt conveyor through the exit **288** to the ambient temperature and environment without any damage. It can be seen that the work baskets can also be spray quenched as they move across the cooling bath **272**. In most cases this is not necessary and the work baskets are permitted to leave the cooling chamber at a temperature slightly above the boiling point of water.

Numerous controls for maintaining the pressures and temperatures of the exhaust gas may be utilized, which controls are readily available, and accordingly, no further detailed description is deemed necessary or given. It is important, however, that the sensing head of each of the above instrumentalities can be located in or near the exhaust so that the information obtained is at the controlled enthalpy at the exhaust **250**.

The control of the exhaust fluid is the final link in maintaining the proper control conditions in the treating zone of the furnace by which very exact controlled treating conditions are maintained.

The following examples are illustrative of the beneficial effect of treating metals and nonmetals with the saturated fluid mixture and other fluids according to the invention.

EXAMPLE I

In this example parts made of N.E. 8620, a carburizing grade of steel, was treated in a furnace similar to that of FIG. 6. The liquid water in the generator **210** (FIG. 7) was saturated with a mixture of carbon dioxide and methane gas at a pressure of 41.5 p.s.i.a. and controlled at a temperature of 120°F. The back pressure regulator **118** in the furnace **102** (FIG. 6) was set to hold a pressure of 33.5 p.s.i.a. on the preheater. The flow control valve **126** was manually operated and was set to provide an exhaust temperature of 840°F. at **134**. The cooling water was manually controlled to hold a temperature of 90°F. The furnace temperature was 1,700°F.

The parts carburized under these conditions showed a carbon content of 0.96 percent and with a case of depth of .080 inches. Examination of the carburized cases indicated the structures were fine grain, completely free of free carbides, and retained austenite. The overall structures was more dense and finer grained as compared to parts carburized in a conventional manner. Testing the parts in a laboratory bearing testing machine showed the wearing surfaces to hold up 16—18 hours with 0.010 to 0.020 inches wear before final failure of the carburized surface. Other of the same parts were given the same treatment in the presence of a conventional endothermic type of atmosphere held up only 12—14 hours with 0.010 to 0.020 inches wear before final failure of the carburized surfaces.

EXAMPLE II

In this example a study was made of the affect of the saturated fluid mixture on the nonmetallic inclusions contained within a commercial grade of S.A.E. 1040 steel. Examination of steel prior to the tests indicated the nonmetallic inclusions were of the oxide and silicate type with ratings of approximately No. 3 to No. 4 on the A.S.T.M. rating chart. After treatment in the saturated fluid mixture with the exhaust being controlled at a temperature of 730°F. and with other conditions as described in example I there was a reduction of these nonmetallic inclusions bringing the A.S.T.M. ratings up to No. 1 to No. 2.

The same steel when given the same treatment in the presence of the conventional endothermic type of atmosphere showed no change in the size, shape or number of nonmetallic inclusions.

EXAMPLE III

In this example a study was made of the effect of the exhaust temperature control on the treatment of metallic and nonmetallic bodies. The fluid, argon, was used for an environment because it is inert and will not react with the parts being treated. Any reactions found in the metallic or nonmetallic bodies would be due to the enthalpy of the environment as controlled by the preheater and the exhaust control. The samples were made from a medium carbon steel, known in the trade as D6 ac.

A retort furnace similar to that shown in FIG. 1 with the preheater **16** but without the back pressure regulator **18**, was connected at **1** to an argon cylinder carrying 150 p.s.i.g. pressure through regulators common in the art to deliver a constant pressure of 20 p.s.i.g. at **14**. The flow of the argon through the valve **14** was manual and the exhaust temperature sensed by thermocouple **34** was recorded on a chart on the recorder **30**.

With the retort **12** being controlled at 1,600°F. by thermocouple **38** through controller **42**, the inert gas argon was fed through valve **14** into the treating chamber **12** and out through the exhaust opening **21**, the exhaust pipe **36** containing the thermocouple **34** and recording on recorder **30**, the exhaust pipe **36** being connected through a flexible pipe to a hose maintained under water to give a constant back pressure of 2 ounces/sq. inch gage (2.0 p.s.i.g.), not shown. With the argon flow being manually controlled to record an exhaust temperature of 200°F. on the recorder **30** by the flow of 18 cubic feet of argon per hour (18 c.f.h.) the D6 ac steel was

held at temperature for one hour time. Thereafter, the retort **11** was allowed to cool with the argon still flowing. As the treating chamber **12** cooled the flow of argon had to be increased to hold the exhaust temperature **34** at 200°F. For instance the retort **12** at 1,400°F. required a flow of 20 c.f.h., at 1,200°F. required 25 c.f.h., and at 1,000°F. required a flow of 30 c.f.h. When the retort was cooled to room temperature the lid **22** was removed by loosening the nuts **20** and the D6 ac parts examined by a hardness check and microscopic studies. Under the microscope the surface showed a nonmetallic oxide layer of scale, with an underneath layer of decarburized metal to a depth of .008". The evidence was clear that too low an enthalpy had been maintained by the exhaust being controlled at 200°F. and the preheater operating at the retort **12** pressure, to prevent the metallic material changing to the lower heat balance nonmetallic oxide of the pure elements.

EXAMPLE IV

In this example the exhaust temperature control was raised to 600°F. with all other conditions as described in example III. In this test with the treating chamber **12** at 1,600°F. the flow of argon was 55 c.f.h. to maintain an exhaust temperature of 600°F. As the treating chamber cooled the flow of argon was changed to hold the 600°F. exhaust temperature as follows: at 1,400°F. the required flow of argon was 62 c.f.h. to hold the 600°F. exhaust temperature, at 1,200°F. the flow had to be increased to 74 c.f.h., while at 1,000°F. the flow was further increased to 91 c.f.h. to hold the 600°F. exhaust temperature.

On examination the D6 ac was completely free of any nonmetallic oxide and any decarburization. No carburization was present because unlike the saturated fluid mixture of this invention argon cannot carburize. The enthalpy of the environment surrounding the work in the treating chamber had been maintained at a good level for the medium carbon D6 ac steel.

EXAMPLE V

In this example the exhaust temperature control was raised further to 1,000°F. with all other conditions as described in example III. With the treating zone **12** controlled at a temperature of 1,600°F. the flow of argon had to be 92 c.f.h. to obtain an exhaust temperature of 1,000°F. As the treating chamber **12** was cooled the argon flow had to be increased as follows: treating zone **12** at 1,400°F. the argon flow had to be increased to 105 c.f.h., at 1,200°F. the required argon flow was 124 c.f.h., at 1,000°F. the argon flow had to be 152 c.f.h.

On examination the D6 ac steel was free of any nonmetallic oxides but had a very serious decarburized surface with evidence that the internal structure had an imbalance of energy. Very fine grinding of the sample would start an exothermic release of this imbalance in energy and the specimen would get very hot. This is evidence that the enthalpy control of the environment surrounding work being treated by the control of the exhaust temperature is of paramount importance in the processing of metallic and nonmetallic bodies.

EXAMPLE VI

In this example a saturated fluid mixture was used. The gases used in saturating the liquid water were air from a central air compressor storage at about 120 p.s.i.a. combined with a synthetic mixture of hydrocarbon gases composed mainly of methane and propane.

Both the air and the hydrocarbon gases had their pressures adjusted and balanced to apply a head pressure of 44 p.s.i.a. The saturated fluid mixture flowed through the flow controlled valve **14** (FIG. **1**) into the preheater **11** and into the treating zone **12** and out through the exhaust **21** in which was placed the thermocouple **34** to measure the heat content, or the energy level of the generated environment. With the furnace controlled at a temperature of 1,550°F. and showing an exhaust temperature of 425°F. the following samples were tested:

1. Shim stock .010 inch thick — for carbon potential determinations.
2. Pure iron with less than .02 percent contained carbon
3. S.A.E. 1018 — a low carbon steel
4. S.A.E. 4340 — a medium carbon, high alloy steel
5. S.A.E. 52100 a high carbon tool steel.

The samples were run for two hours in the furnace and pulled with tongs and water quenched. The results of the tests on these samples showed the fluid mixture under the above conditions to be reducing and with controlled carburizing/decarburizing potential of 0.60 percent carbon.

EXAMPLE VII

In this example, vanadium oxide ore containing 41.98 percent oxygen was run in the manner explained in example VI with the exception that the time in the furnace was for 12 hours. In this treatment the nonmetallic ore was reduced by approximately 98.0 percent of the contained oxygen. The sample was found to be clean and free of all soot.

The same nonmetallic ore run in the same manner in presence of the conventional endothermic type of atmosphere was found to have been reduced only 24.6 percent and with a pickup of carbon soot.

EXAMPLE VIII

In this example pure tungsten power of 99.98 percent purity was converted to tungsten carbide when treated in a furnace in the presence of a saturated fluid mixture. The powder was exposed for a period of 18 hours to the furnace temperature controlled at 1,880°F. The saturated fluid mixture was generated in a generator, not shown. In this example, the gas used in saturating the liquid water was carbon dioxide and methane. The saturated fluid mixture, under control of the rate of flow, moved to the preheat coil **11** located in the treating zone **12** of the furnace, into the treating zone **12** of the furnace, and out the exhaust **21** in which was located the thermocouple **34** to measure the heat content or energy level of the exhausting gases. With the exhaust running at 840°F. the gaseous mixture had a heat content of 50 B.t.u./c.f.

Examination of the treated tungsten powder showed the material to be free of soot, and on analysis showed the tungsten to have been converted to a tungsten carbide containing 1.78 percent carbon.

The same tungsten run in the same manner in the presence of the conventional endothermic type of atmosphere was found to be sooted up without the formation of any tungsten carbide.

EXAMPLE IX

In this example, iron oxide ore containing 29.6 percent oxygen and ground to a particle size of 30 to 80 mesh was treated in a furnace controlled at a temperature of 1,700°F. with the exhaust gases controlled at 600°F. in the presence of the saturated fluid mixture of table IV. After the ground ore was exposed for a period of **12** hours to the furnace temperature of 1,700°F. in the presence of the saturated fluid mixture, the furnace was cooled to below 800°F. with the exhaust gases still maintained at a temperature of 600°F. All controls were then shut off and the furnace system was allowed to cool to room temperature.

An examination of the furnace system showed no sooting with clean, reduced particles. Analysis of the particles indicated the oxygen content to be 1.3 percent. The treatment of the iron ore oxide in the saturated fluid mixture had removed 95.8 percent of the oxygen in the iron oxide ore.

The same iron oxide ore was treated in the furnace under the same conditions as previously indicated in the presence of the endothermic type atmosphere of table VII. After the test runs, the furnace system had a heavy soot deposit and the iron oxide ore contained 21.4 percent oxygen, or a removal of only 27.7 percent of the oxygen from it.

The following tables illustrate the flow of argon and nitrogen to hold exhaust temperature as indicated.

TABLE VIII

Argon flow, in cubic feet per hour at 77° F., required at 1 to hold exhaust temperature at 34 (or 134) when the treating zone 12 (or 112) is controlled as shown.

Treating zone temperature at 12 (or 112) ° F.	Exhaust temperature control 34 (or 134) ° F.	Argon flow at 9 generator to hold exhaust temperature at 34° (or 134) c.f.h. at 77° F.
1,000	200	30
	400	60
	600	91
	800	120
	1,000	152
1,200	200	25
	400	48
	600	74
	800	98
	1,000	124
1,400	200	20
	400	42
	600	62
	800	84
	1,000	105
1,600	200	18
	400	36
	600	55
	800	73
	1,000	92

TABLE IX

Nitrogen flow, in cubic feet per hour (77° F.) required at 1 to hold exhaust temperature at 34 (or 134) when the treating zone 12 (or 112) is controlled as shown.

Treating zone temperature at 12 (or 112) ° F.	Exhaust temperature control 34 (or 134) ° F.	Nitrogen flow at generator to hold exhaust temperature at 34° (or 134) c.f.h. (77° F.)
1,000	200	21
	400	42
	600	63
	800	84
	1,000	108
1,200	200	17
	400	34
	600	51
	800	68
	1,000	85
1,400	200	15
	400	28
	600	42
	800	57
	1,000	72
1,600	200	12
	400	24
	600	37
	800	49
	1,000	61

The foregoing examples are representative and similar results may be obtained when treating any of the elements of the Periodic Table and their alloys or their oxides, carbides, silicates, sulfides, sulphates, phosphates and carbonates.

It is apparent from the foregoing that the present invention is well suited and adapted to attain the objects and ends and has the features and advantages mentioned as well as other inherent therein.

While presently-preferred embodiments and examples have been given for the purpose of disclosure, many changes may be made therein and the invention may be applied to many additional uses and materials to obtain desired properties in various materials which are within the spirit of the invention as defined by the scope of the appended claims.

I claim:

1. In a treating system for treating metallic and nonmetallic material to alter its properties:
- means for generating a saturated fluid mixture selected from the group consisting of liquid water saturated with a major amount of carbon dioxide, a minor amount of methane, and lesser amounts of carbon monoxide and hydrogen and liquid water saturated with a major amount of carbon dioxide and lesser amounts of carbon monoxide and hydrogen including means for maintaining the temperature of the water from 32°F. to about 160°F. and under pressure from atmospheric to 218.5 atmospheres;
- a furnace provided with a treating zone for treating the material;
- means for flowing the generated saturated fluid mixture from the generator to the furnace retaining the properties of the generated saturated fluid;
- means for introducing the generated saturated fluid mixture into the treating zone of the furnace for providing a gaseous environment about the material in the treating zone of the furnace during treatment;
- exhaust means communicating with the treating zone for exhausting the environment from the furnace; and
- means responsive to the pressure of the environment within the exhaust means controlling the pressure of the environment in the exhaust means exhausting from the treating zone.

2. The treating system of claim 1 including, means responsive to the temperature of the environment exhausting from the treating zone in the exhaust means in the temperature range of from about 212°F. to about 1,500°F.

3. The treating system of claim 1 including, means responsive to the temperature of the environment exhausting from the treating zone in the exhaust means in the temperature range of from about 250°F. to about 400°F.

4. The treating system of claim 1 including, means responsive to the temperature of the environment exhausting from the treating zone in the exhaust means in the temperature range of from about 250°F. to about 980°F.

5. In a treating system for treating metallic and nonmetallic material to alter its properties:
- a furnace provided with a treating zone for treating the material;
- means for preheating an environment to a temperature at least equal to the operating temperature of the treating zone of the furnace thereby providing a high enthalpy environment;
- means for flowing the high enthalpy environment into the treating zone of the furnace with a minimum loss of enthalpy thereby providing a gaseous environment about the material in the furnace during treatment;
- exhaust means for exhausting the environment from the furnace; and
- means responsive to the temperature of the environment within the exhaust means controlling the temperature of the environment in the exhaust means between about 212°F. and about 1,500°F.

6. The treating system of claim 5 including, means controlling the flow of the environment to the treating zone thereby assisting in maintaining the temperature of the environment exhausting in the exhaust means within the temperature range of from about 212°F. to about 1,500°F.

7. The treating system of claim 5 including, means responsive to the pressure of the environment within the exhaust means controlling the pressure of the environment within the exhaust means thereby assisting in maintaining the temperature of the environment exhausting in the exhaust means within the temperature range of from about 212°F. to about 1,500°F.

8. The treating system of claim 5 including, means for controlling the volume of the environment exhausting from the exhaust means thereby assisting in maintaining the temperature of the environment in the exhaust means within the range of from about 212°F. to about 1,500°F.

9. The treating system of claim 5 including, means responsive to the temperature of the environment in the exhaust means maintaining the temperature of the environment in the exhaust means within the range of from about 250°F. to about 980°F.

10. The treating system of claim 5 including, means responsive to the temperature of the environment in the exhaust means maintaining the temperature of the environment in the exhaust means within the range of from about 250°F. to about 400°F.

11. In a treating system for treating metallic and nonmetallic material to alter its properties:

a furnace provided with a treating zone for treating the material, inlet means for flowing an environment into the treating zone thereby providing a gaseous environment about the material during treatment;

exhaust means communicating with the treating zone for exhausting the environment from the furnace; and

means responsive to the temperature of the environment within the exhaust means maintaining the temperature of the environment exhausting from the treating zone in the exhaust means between 212°F. and about 1,500°F.

12. The treating system of claim 11 including, pressure responsive means in the inlet means permitting flow into the treating zone above a predetermined pressure.

13. The treating system of claim 11 including, means controlling the volume of gaseous environment exhausting from the treating zone in the exhaust means.

14. The treating system of claim 11 including, means for controlling the volume and pressure of gaseous environment exhausting in the exhaust means from the treating zone.

15. The treating system of claim 14 including, pressure responsive means in the inlet means permitting flow into the treating zone above a predetermined pressure.

16. The treating system of claim 15 where, the means responsive to the temperature is such that the temperature of the environment exhausting in the exhaust means from the treating zone is within the range of about 250°F. to about 980°F.

17. The treating system of claim 15 where, the means responsive to the temperature is such that the temperature of the environment exhausting in the exhaust means from the treating zone is within the range of about 250°F. to about 400°F.

18. In a treating system for treating metallic and nonmetallic material to alter its properties:

a furnace provided with a treating zone for treating the material;

inlet means for flowing an environment into the treating zone thereby providing a gaseous environment about the material during treatment;

exhaust means communicating with the treating zone for exhausting the environment from the furnace; and

means responsive to the pressure of the environment within the exhaust means controlling the pressure of the environment exhausting from the treating zone in the exhaust means.

19. The treating system of claim 18 including, pressure responsive means in the inlet means permitting flow into the treating zone above a predetermined pressure.

20. The treating system of claim 18 including, means controlling the volume of gaseous environment exhausting from the treating zone in the exhaust means.

21. The treating system of claim 20 including, pressure responsive means in the inlet means permitting flow into the treating zone above a predetermined pressure.

22. The treating system of claim 18 including, means responsive to the temperature of the environment within the exhaust means maintaining the temperature of the environment exhausting from the treating zone in the exhaust means between 212°F. and about 1,500°F.

23. The treating system of claim 18 including, means responsive to the temperature of the environment within the exhaust means maintaining the temperature of the environment exhausting from the treating zone in the exhaust means within the range of about 215°F. to about 980°F.

24. The treating system of claim 18 including, means responsive to the temperature of the environment within the exhaust means maintaining the temperature of the environment exhausting from the treating zone in the exhaust means within the range of about 215°F. to about 400°F.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,539,165 Dated November 10, 1970

Inventor(s) Glenn R. Ingels

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

IN THE SPECIFICATION

Abstract

Line 4, after "with" delete -- or without --

Line 5, after "dioxide," insert -- with or without --

Description of the Preferred Embodiments

Column 8, line 55, change "give" to -- given --

Column 10, line 12, change "5" to -- 7 --

Column 12, line 18, change "was" to -- were --

Column 12, line 73, change "(2.0 p.s.i.g.)" to -- (2.0 o.s.i.g.) --

Column 15, Table IX, Nitrogen flow column, change "42", second occurrence, to -- 43 --

Signed and sealed this 23rd day of March 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, J
Commissioner of Patent