

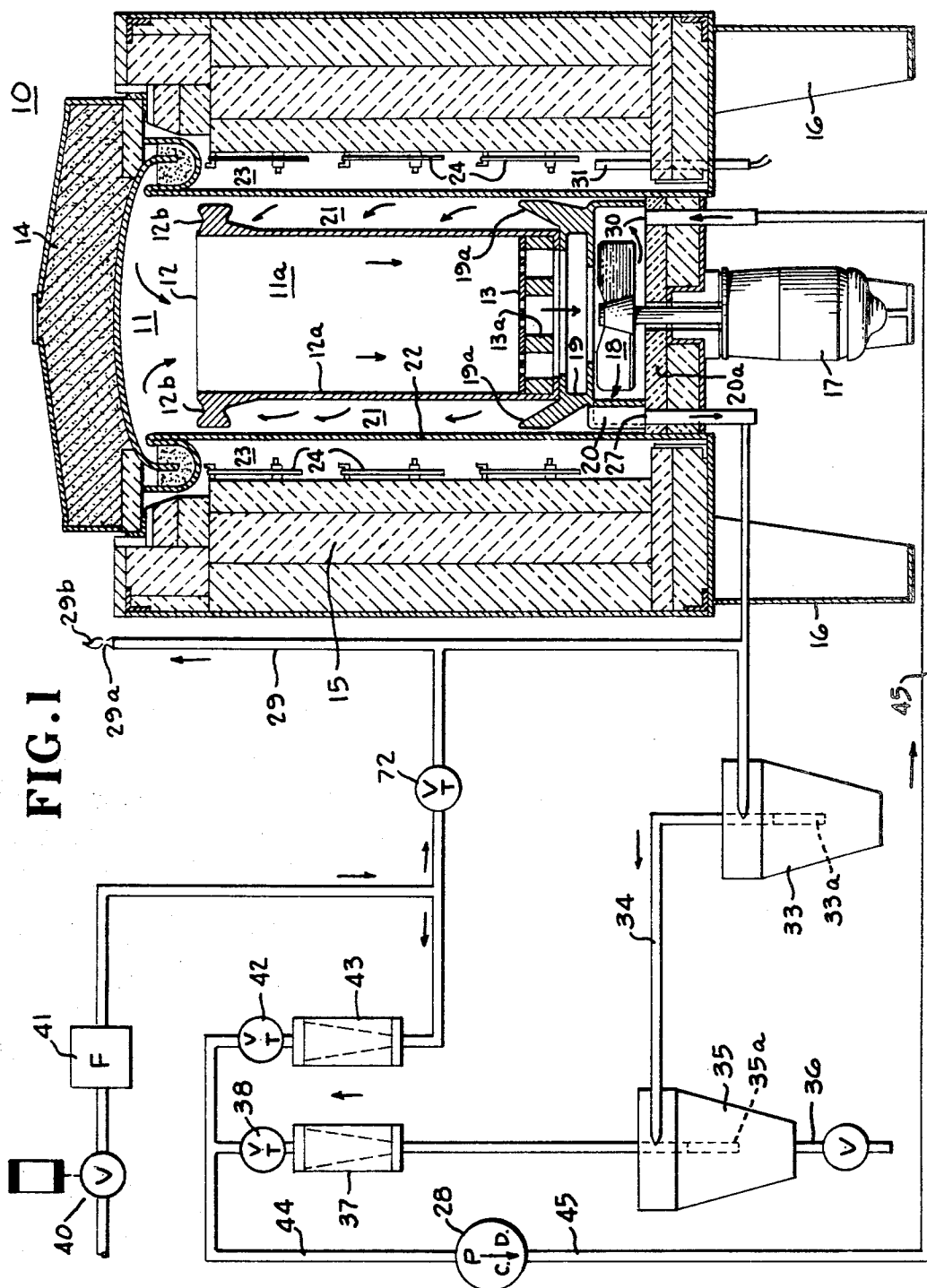
Aug. 20, 1968

R. L. DAVIS, II
 APPARATUS FOR MAINTAINING A CARBURIZING
 ATMOSPHERE DURING HEAT TREATMENT

3,397,875

Filed May 20, 1966

3 Sheets-Sheet 1



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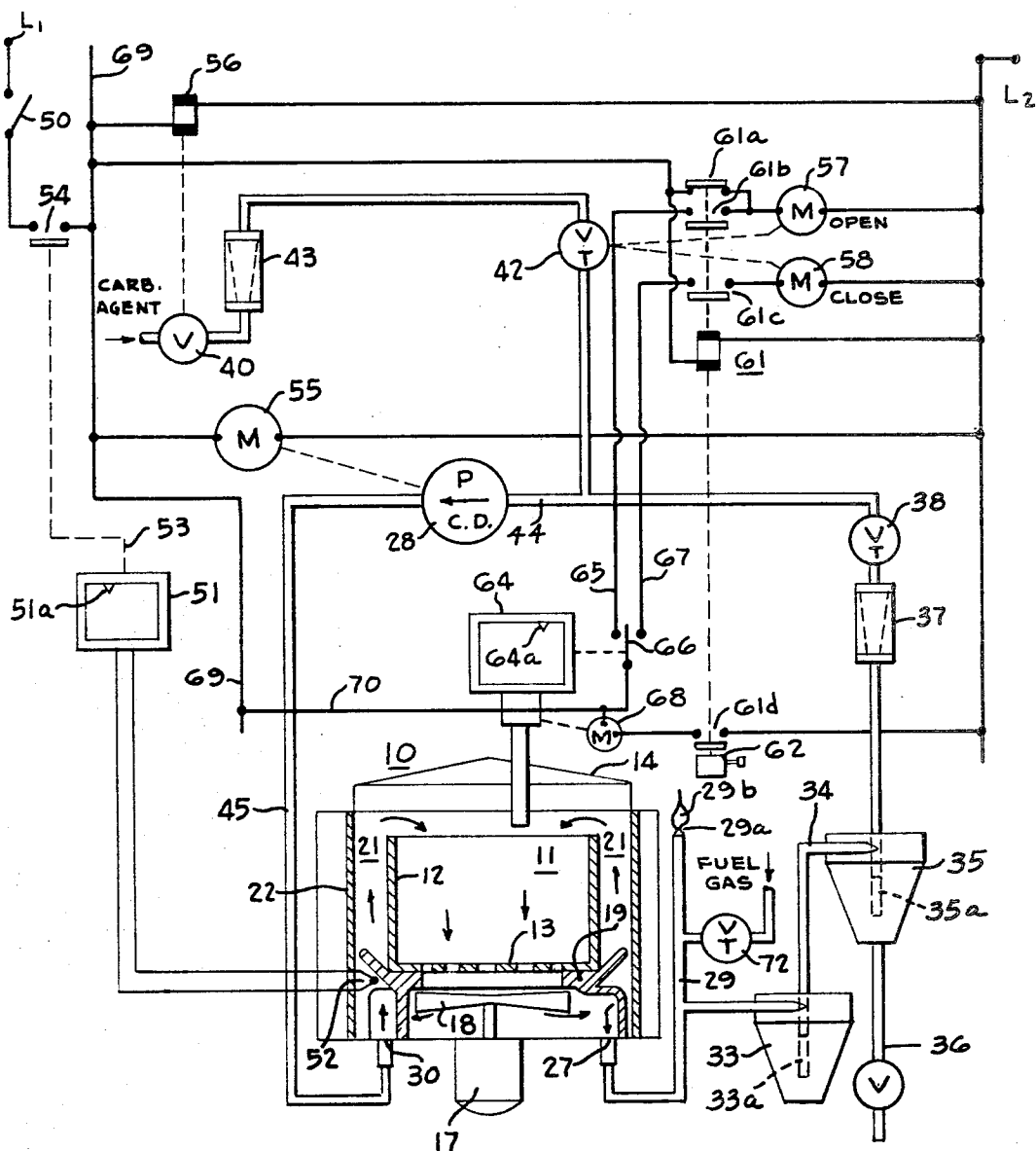
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3 Sheets-Sheet 2

FIG. 2



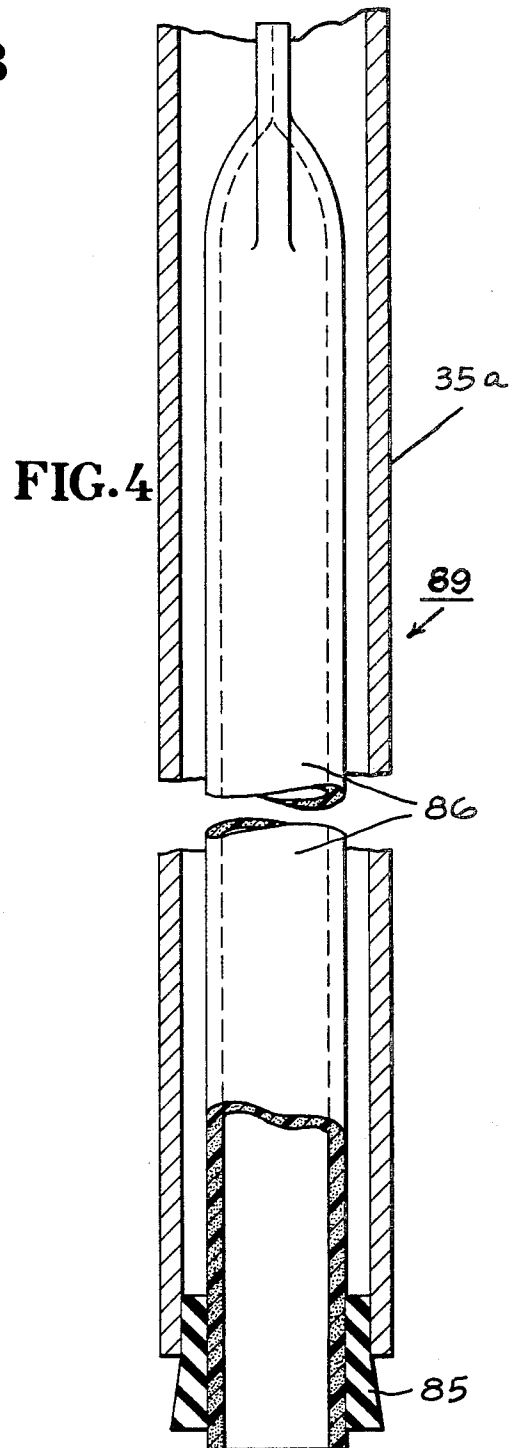
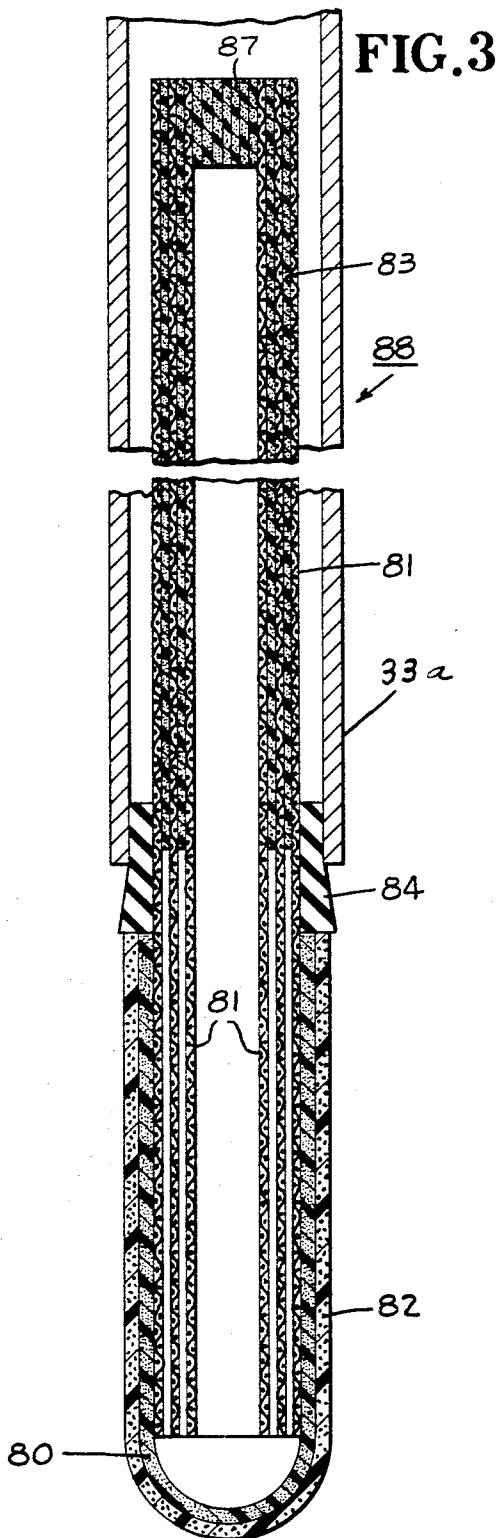
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APPARATUS FOR MAINTAINING A CARBURIZING ATMOSPHERE DURING HEAT TREATMENT

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Continuation-in-part of application Ser. No. 279,053, May 9, 1963. This application May 20, 1966, Ser. No. 551,731

5 Claims. (Cl. 266—5)

This application, a continuation-in-part of my application Ser. No. 279,053, filed May 9, 1963, now Patent No. 3,252,694, relates to methods of and apparatus for treating metal of the type in which metal work is disposed within a treating chamber of a furnace and is subjected to an elevated temperature with an atmosphere of desired character within the treating chamber.

The present invention is applicable to metal treating furnaces of many kinds, and in particular to those in which it is desired to control the carbon content of the work and to those where heat-treating and annealing is desired in the presence of a carburizing atmosphere which assures the maintenance of the carbon content of the work at a predetermined value. In heat-treating processes a number of problems arise, particularly in the need for purging the treating chamber of undesirable gases and contaminants which may be present. These contaminants frequently take the form of foreign materials which may have adhered to the work and since they volatilize as the temperature of the treating chamber rises to the range needed for heat treatment or carburizing, they need to be eliminated during and subsequent to the purge.

In order to purge the furnace of undesirable gases and contaminants, it is desirable to utilize a purge gas, i.e., a gas which will not react adversely with the work, which will not be detrimental to the finish or carbon content of the work and one which will not deposit soot.

For a great many years, those skilled in the art have been seeking better solutions to the problem of economically carburizing work in a manner which will produce a clean and uniformly carburized product.

In my Patent No. 3,252,694, I deemed it necessary to provide a unique atmosphere generator within the treating chamber of a metal treating furnace and in heat-exchange relation therewith. This generator had a catalyst bed to promote desired reactions.

The foregoing proposal left something to be desired in the provision of a system of enhanced simplicity, of greater reliability, and one without the problem of sooting, while at the same time providing for the maintenance around the work of an atmosphere having a desired carburizing potential. I have discovered a system of greater simplicity than that heretofore deemed feasible for reliable heat-treating and carburizing of work of wide variety and kind and one in which, if certain conditions be provided within the treating chamber, new and unexpected results will be obtained, i.e., the constancy and uniformity of the carburizing potential maintained, the protection of the work at all times and the greater flexibility in providing desired purge and work-treating conditions.

In accordance with my invention, there must be a concurrence of the following operations and conditions.

First, the furnace atmosphere of the treating chamber must be violently circulated therein to maintain it at substantially the same temperature upon leaving the work as it had at the point of entry into the work. This condition is met by providing a fan which can move a large volume of gas and which produces within the treating chamber a mass rate of circulation of the gases therein which is

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quite high relative to the mass rate of recirculation of gases withdrawn from and after conditioning thereof returned to the treating chamber. In addition to uniformity of temperature, the foregoing high rate of flow of furnace atmosphere through the work maintains the atmosphere leaving the work at substantially the same composition it had as it entered the work.

Second, an external recirculation path for the furnace atmosphere is provided in which the furnace atmosphere is enriched. The recirculation of the furnace atmosphere is accomplished by means of a gas compressor located in the recirculation path and external to the furnace. A carburizing material preferably in the form of fuel gas, is also supplied to the inlet of the gas compressor externally of the furnace together with the furnace atmosphere. In this manner there is provided thorough dispersal, dilution and mixture of the fuel gas with the stream of furnace atmosphere withdrawn from the treating chamber thus providing an enriched carrier gas for carburizing.

Third, the inlet side of the gas compressor is connected to the treating chamber through a conduit having its inlet or mouth preferably disposed near the bottom of the treating chamber. The diameter of the conduit limits the withdrawal of gases from the treating chamber in amount so that the mass rate of flow of these gases is small compared with the mass rate of circulation of the gases through the work.

Fourth, the carrier gas derived from the treating chamber of the furnace, after mixture with the enriching gas, is introduced into the treating chamber of the furnace first via the region of the fan, and then by means of an annular chamber leading to the treating chamber. In this manner, any flame formed at the inlet is isolated from the work surfaces so as not to mar or otherwise spoil the work. Further, the gas mixture is immediately subjected to vigorous agitation as it enters the output region of the fan, whereupon the mixture is moved rapidly along the walls of the annular chamber to provide rapid rise of its temperature in order that the temperature of the gases entering the treating zone remains uniform within that zone to avoid any cooling effect therefrom.

Fifth, I have found that filtering, in conjunction with the foregoing features, is of great importance. As new loads of work are periodically introduced into the treating chamber, quite frequently a load is encountered in which there are present solids and liquids adhering to the work. These materials, when volatilized into gases and particulate solids, have what seems to be a catalytic action promoting formation within the treating chamber of decarburizing materials such as carbon dioxide and water vapor. Accordingly, I provide a purge cycle, during which the volatilized material is either exhausted to atmosphere, or withdrawn from the furnace with the stream of gases and subjected to centrifugal force to eliminate the solid and liquid particles, especially those of greater mass and/or adhering character. The stream of gases and remaining material are then passed through multiple zones of filtering in which there are filters of decreasing pore size. Accordingly, there is progressively eliminated from the treating chamber all solids while at the same time part of the moisture content is removed. In this manner, there is eventually attained in the treating chamber an atmosphere having greatly reduced concentrations of decarburizing materials. The elimination of the decarburizing material with its consequent catalytic action, taken in conjunction with the above operations, permits the use of a lesser amount of carburizing material for treating the work than heretofore deemed feasible and proper.

Sixth, I have found it is unnecessary to add oxygen to

the treating chamber or to employ carburizing materials comprised of oxygen releasing materials. On the contrary, I utilize oxygen-free carburizing materials. During a purge cycle of the furnace following the introduction of each new load, these carburizing materials are introduced to the furnace at a relatively high rate in order to use up the oxygen within the work chamber which is inducted along with the new load of work. Thereafter, during the normal treatment period, the rate of supply of the carburizing material is substantially reduced and maintained under the control of a carbon-potential sensing system.

With the foregoing operations and conditions met, the carburizing system of the present invention may be operated through long periods without the occurrence of sooting. Further, the carbon potential of the atmosphere within the treating chamber may accordingly be maintained at any desired level uniformly throughout the treating zone.

For further objects and advantages of the invention, and for an understanding of how to practice the same, reference is made to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 diagrammatically illustrates the system as a whole together with a sectional view of a preferred form of furnace;

FIG. 2 diagrammatically illustrates in more detail a system embodying the invention;

FIG. 3 is a sectional view of the filtering section forming a part of the first centrifugal separator of FIGS. 1 and 2; and

FIG. 4 is a sectional view of the filtering section forming a part of the second centrifugal separator of FIGS. 1 and 2.

Referring now to FIG. 1, the invention has been shown in its preferred form as applied to a carburizing furnace 10 having a treating chamber 11 into which may be loaded a container 12 which supports the work or load of materials to be subjected to a carburizing atmosphere. The container has a metallic side wall 12a and a bottom comprising a grid 13a and a screen 13 upon which the work may be stacked for carburizing. The grid 13a is carried by an intumed flange of the wall 12a. The enclosing wall 12a is also provided with ears 12b which are used for introducing and withdrawing the loaded container into and from the furnace, as by a crane, through the open, upper end of the furnace after removal of the heat-insulated closure 14 thereof. The entire container 12 rests on a casting 19 which includes guiding elements 19a which extend upwardly from the casting to aid in guiding the container 12 into a central position above a fan 18 as the container is lowered into the furnace. The casting also includes a lower portion 20 which acts as a shroud for the fan 18. The furnace further includes insulated walls 15 and furnace walls 22 between which there is formed a heating chamber 23 which houses a series of heating resistors 24 which generate the required furnace heat uniformly along the length of the furnace. The furnace as a whole is supported upon legs 16.

A motor 17, supported from the bottom of the furnace, drives the fan 18 located below the perforated bottom 13-13a of the treating chamber 11. It will be noted that the bottom 13-13a of the container 12 provides an open communication between the central portion of the fan 18 and the work-treating zone 11a formed by the container 12.

The motor 17 drives the fan at a relatively high speed, i.e., in the order of 1700 r.p.m. The fan shroud 20 disposed around the fan 18 causes the fan to create a reduced pressure in the region of the grid 13a which consequently causes a gas flow from the work treating zone 11 toward the fan. The atmosphere of the treating chamber 11 so circulated is agitated violently upon its entrance into the fan whereupon it is thrown outwardly of the shroud 20 with considerable centrifugal force into the lower portion of an annular chamber 21 formed between the wall 12a of

the container 12 and the furnace wall 22 which isolates the treating chamber 11 from the outer heating chamber 23. To assist in producing a helical flow of the gases through the annular chamber 21, the shroud 20 includes four equally spaced discharge ports facing in the same tangential direction. The shroud itself rests upon heat insulating and supporting members 20a which, in turn, are supported by a bottom plate of the furnace.

An outlet pipe 27 is provided in the bottom of the treating chamber 11 through which atmosphere from the treating chamber may be withdrawn. The furnace atmosphere will discharge from outlet pipe 27 by reason of the combined action of the elevated pressure within the treating chamber 11, for reasons to be developed later, and lowered pressures in outlet pipe 27 resulting from its connection to the suction side of a gas compressor 28. The outlet pipe 27 is also connected to a second pipe 29, which extends to near the top of the furnace and has a restricted opening 29a therein. This second pipe 29 provides for removal of a portion of the gases from the system including the treating chamber 11.

The mass rate of flow of gases removed by way of the outlet pipe 27 is small in proportion to the mass rate of flow of gases recirculating within the furnace through a path which may be traced from the peripheral delivery portion of the fan 18 upwardly through the annular chamber 21 and thence downwardly over the work within the treating zone 11a and thence to the central inlet region of the fan 18. By reason of the rapid and violent circulation of the furnace atmosphere through the described path, there is assured a uniformity of temperature and mixture of the gas. Further, as will be discussed in more detail later, the recirculation path assures that all needed reactions of the furnace atmosphere with enriching fuel introduced to the furnace by way of conduit 30 will be complete prior to the arrival of the mixture to the work.

Returning now to the exit pipe 27, the furnace atmosphere flows through a hot centrifugal separator and filter 33 which removes solid particles from the gas. The gases are then cooled as they move through pipe 34 to a cold centrifugal separator and filter 35. In this unit, part of the water vapor, formed during the purging reactions within the treating chamber 11, is condensed and the condensate removed by way of line or pipe 36 to drain. The removal of solid particles is also carried to a further degree of refinement in this unit. The filtered and dried atmosphere from the treating chamber 11 then passes by way of a meter 37 and regulating valve 38 to the inlet of the compressor 28.

During normal treatment of the work, a safety solenoid valve 40 is maintained in an open position and fuel gas or other carburizing material, such as methane, ethane, propane, butane or mixtures thereof, is supplied by way of a filter 41 through a flow meter 43 to a motorized throttle valve 42 and thence to the inlet pipe 44 of the compressor 28. Within the gas compressor itself, the cleansed (also dried, if and when furnace-dew point is appreciably above ambient temperature) atmosphere is thoroughly mixed with the supply of carburizing material. The thorough mixing of the two is, as previously indicated, an important requirement of the present invention.

The mixture now passes by way of an outlet pipe 45 from the compressor to the inlet pipe 30 whereupon the mixture is discharged within the discharge region of fan 18. In the region of the outlet of the fan, the mixture receives violent mechanical agitation, which again insures thorough mixing of the stream including the carburizing material with the recirculating stream of gases. The relatively high volume of gas being recirculated through the annular chamber 21 further acts to continuously dilute the inlet stream. The inlet stream is also heated to a limited degree as it passes through the inlet pipe 30 and, in its diluted state, is rapidly heated as the stream passes upwardly through the annular chamber 21.

The flow of the atmosphere within the furnace is in a

helical path along the walls of the annular chamber, thus providing excellent heat transfer between the heat source 24 and to the circulating gases and work. At the upper end of annular chamber 21, the rapidly circulating stream flows into the upper end of the treating chamber 11 and thence downwardly through the treating zone 11a, and over the work within the treating zone. By the time the recirculating furnace gas reaches the upper end of the treating chamber 11, it will be seen that the circulating stream will have a high degree of uniformity, both in respect to temperature and in respect to the concentration of the constituents (later to be described) which give rise to the carbon potential of the atmosphere within the treating chamber 11.

Heretofore, it has been deemed by me, and indeed, by all of those with whom I have consulted or whose writings I have read, that more would be needed than I utilize in my present carburizing system to provide a system which assures uniformity of treatment of the work within an adequate supply of carbon for carburizing dense loads, as well as one which operates in the absence of soot formation while at the same time providing sufficient flexibility and capability for purging the system and preventing undesirable infiltration of air subsequent to the purge period.

My present system is the result of thinking which was contrary to my original thinking which resulted in the system as set forth in my Patent No. 3,252,694. My prior experience and the prior art led me to believe there would arise problems during the time the treating chamber was being purged, both in respect to sooting and in respect to uniformity of carbon potential within the treating chamber, unless additional oxygen in some form was provided for producing a high input of purge gas and a high exhaust rate for at least the initial portion of the cycle of furnace operation. Hence, in my parent application, I provided a catalyst for promoting the reaction between air containing oxygen and the carburizing material to provide the foregoing increase in volume together with a decrease in carburizing potential to establish within the treating chamber an atmosphere suited for purging the chamber and for beginning carburizing. That system, though useful, leaves something to be desired by way of further simplification. Despite my former contrary beliefs, I have now discovered that with the system here disclosed, I not only achieve satisfactory purging of the treating zone without addition of oxygen or use of a catalyst, but also I achieve the desired uniformity of carbon potential within the treating chamber 11, with a complete absence of sooting, particularly on any of the parts within which the atmosphere is violently recirculated by the fan 18.

The foregoing features of the present invention produce greater efficiency in the reactions within the furnace which give rise to the carburizing constituents. Hence, a lesser amount of carburizing material need be introduced into and utilized within the system than has heretofore been the case. A part of the success of the present system can be attributed to this greater efficiency and consequent requirement for a reduced amount of carburizing material which occurs by reason of the absence of intentionally added oxygen, the elimination of soil from the system, the complete mixing, the high velocities and violent agitation which provide quick equilibration of the atmosphere with minimization of decarburizing gases (carbon dioxide and water vapor) and the uniformity of temperature control.

There will now be set forth, in connection with the diagrammatic drawing of my invention comprising FIG. 2, further theories as to why my new system operates as it does together with a specific illustration of one embodiment of the invention including a discussion of the requirements of a control system needed to take into account the multiplicity of variables involved.

It is to be understood that in FIG. 2 the carburizing furnace 10 of FIG. 1 has been shown diagrammatically and, for simplicity, there has been omitted illustrations of the heating resistors, insulating walls, and the like. Consider-

ing that the carburizing furnace 10 has dimensions adequate to accommodate a work-supporting container 12 approximately 15" in diameter and 18" high, the outer wall 22 will form an annular flow channel 21 which is 3" wide. From these dimensions, it will be seen that the internal volume of the treating chamber 11, enclosed by the outer wall 22, can be readily computed. Thus, at the time that the furnace is charged with a fresh load of work and the closure 14 placed in position to complete the sealing of the treating chamber, the total amount of oxygen in the aforesaid volume will be known. This is the first quantity of importance in the practice of my invention and for the reason that the furnace must not only first be purged but, in the purging thereof, there must be utilized a rich purging atmosphere having a total quantity of carburizing agents which will use up the oxygen within the furnace without producing soot. After the oxygen has been consumed and when the furnace has been purged of products of combustion, the supply of carburizing material is then greatly reduced. In the alternative, the carburizing material may be gradually reduced during the course of the purge period, i.e., such as a gradual closing of the fuel gas throttle valve 42. In this manner, there is avoided sooting of any and all parts of the system during the entire course of the metal treating operation.

As soon as the preheated furnace has been charged with the work load, the switch 50 is closed. The heating elements 24, shown only in FIG. 1, may be continuously energized by means not shown. The opening of the furnace and the introduction of a cold charge of work reduce the temperature of the furnace to a point indicated by the pointer 51a of a temperature measuring instrument and controller 51. This instrument responds to the temperature within the annular chamber 21, as indicated by the presence therein of the thermocouple 52. In FIG. 1, a thermocouple well 31 has been illustrated in the heating chamber and contains a thermocouple utilized for safety purposes. A similar well, not shown, is used to enclose the thermocouple 52.

After the closure 14 is in place, the fan motor 17 is energized, by means not shown, and the atmosphere of the treating chamber is recirculated by the fan 18 as described above. As soon as the furnace temperature rises to a predetermined safe value, for example, about 1200° F., the pointer 51a of controller 51 will be moved to approximately the position of the dotted line 53, representative of the operation of the instrument 51, to close the contacts 54. Several energizing circuits are thereby completed. The motor 55 driving the compressor 28 is energized. The operating coil 56 of valve 40 opens the valve to increase the supply of the carburizing material passing through the flow meter 43 to the throttling valve 42. Though a single motor may be utilized to operate the throttling valve 42, two motors 57 and 58 have been illustrated which symbolically represent the forward and reverse windings of a single motor. The motor 57 is energized by reason of the normally closed contacts 61a of a time delay relay 61, the operation of which is indicated by a dashpot 62 associated therewith. Thus the motor 57 operates the valve 42 to its fully open position.

The carburizing material is thus supplied at a relatively high rate of flow to the inlet region of the compressor 28. The throttling valve 42 has provisions for predetermining the rate of flow when the motor 57 has moved to its fully open position. Thus, the throttling valve may be manually set to predetermine the rate of flow for the fully-open position effected by operation of motor 57. In this connection, when the motor 58 is energized, as will later be described, the throttling valve 42 decreases the rate of flow, with zero flow as a limit, although the valve can be set for any predetermined flow (less than the maximum) as a lower limit.

As the carburizing material enters the inlet pipe 44 to the compressor 28, it is there mixed with the furnace gases which have been withdrawn from the furnace by

way of outlet 27, the filter and hot separator 33, the filter and cold separator 35, the flow meter 37 and the throttling valve 38. In the compressor itself, there is further mixing and mechanical agitation of the carburizing material so that it is thoroughly dispersed through the stream of furnace gases. The resultant mixture then flows by way of pipe 45 to the inlet 30 and thence to the annular chamber 21.

This relatively rich mixture is subjected to violent agitation in the peripheral output region of the fan 18 after which it is driven upwardly through its helical flow path in good heat exchange relationship with the hot furnace wall 22 and the colder container wall 12.

The carburizing materials may be any one of, or a mixture of, methane, ethane, propane, butane, or commercial fuel gases containing one or more of the foregoing components. Because of the elevated temperature, now rapidly rising above 1200° F., there is combustion of the flammable components resulting in the formation of combustion products comprising carbon dioxide, water vapor and nitrogen.

Since the size of the carburizing furnace is known and since the average load will be more or less constant for a given carburizing operation, it is known approximately how long will be required for the temperature of the treating chamber to rise to the set point and within the carburizing range of from about 1600° F. to 1750° F. The timing relay 61 is designed to time out by the time the temperature of the furnace reaches approximately 150° F. below the set point. This will be about 30 to 60 minutes depending upon the weight of metal being treated. The timing relay now operates to open its contacts 61a and to close its contacts 61b, thus transferring control of the valve-opening motor 57 by way of conductor 65 to a control switch 66 operated by the instrument 64 which is responsive to the carburizing potential within the treating chamber 11. The carbon potential sensing system, including the instrument 64, is preferably of the type further disclosed by me and by my co-inventor, Wayne L. Besselman, in our United States Patent No. 2,541,857.

Contacts 61c are also closed at this time and establish control of the valve closing motor 58 by way of conductor 67 which likewise is under the control of switch 66. The corresponding closure of contacts 61d energizes a motor 68 to lower the sensing element of the carburizing potential measuring means of instrument 64 into the region of the treating chamber 11. The details of this motorized operation of the carburizing potential sensing element are fully described in my United States Patent No. 3,011,873.

There has now been described the manner in which the control of the throttling valve 42 is shifted from a time-control operation to one under the control of the constituent measuring system including instrument 64.

For some applications, it may be desirable to provide a second timer to earlier initiate a predetermined reduction in the rate of flow of the carburizing material as the oxygen within the furnace is used up in the combustion reactions. But in this case, using only one timer, the purge flow of carburizing material is lower in value, but is in operation for a longer period of time, supplying the same total quantity of pure gas to the furnace. However, I have found that by the typical example here being described, the reduction in the supply of the carburizing material may be satisfactorily achieved by the carbon potential controlling instrument 64 having a set point indicator 64a. This set point indicator 64a is manually adjustable to select the carbon potential to be produced and maintained within the treating chamber 11. The carbon potential for heat-treatment alone, without carburizing, will be set to correspond with the carbon content of the work in the heating chamber. Where carburizing or decarburizing is to take place, it will be set to correspond with the carbon content desired in the work undergoing treatment.

Though, in general, the carburizing potential within

the treating chamber 11 will be less than the set point at the time the instrument 64 is placed in control of the switch 66, in some instances, that carburizing potential could be higher than the set point. In any event, the instrument 64 responds to operate the switch 66 to close an energizing circuit for the valve-closing motor when the carburizing potential is above the set point. If the carburizing potential is below the set point, the switch 66 will be operated to restore the closed circuit to the valve-opening motor 57 until such time as the carburizing potential arrives at the set point, at which time the switch 66 will be restored to its illustrated neutral position intermediate its two associated stationary contacts. Control instrument 64 can be of the type to provide proportional control action as well as the two-position control action described herein, if a more sophisticated control action is desired.

The action of the compressor 28, in generating a suction at the outlet 27 of the treating chamber and returning the mixture of carburizing material and furnace atmosphere to the treating chamber 11 by way of inlet line 30, develops a differential pressure which produces an outward flow of furnace gases through the outlet 27. These gases will be a flammable mixture and a part of the gas will pass by way of line 29 to the restriction 29a where the gas is ignited and burned as a flame, as illustrated at 29b. This restriction is generally in the form of a fixed orifice.

With the throttling valve 72 closed, the flow of gas through the orifice 29a represents the difference of volume between the gases supplied to the carburizing furnace by way of inlet 30 and the gases returned to the compressor 28 by way of meter 37. Thus, the exhaust orifice 29a in conjunction with additions to the system of fresh fuel gas by way of valve 42, serves the purpose of assuring a super-atmospheric pressure within the carburizing furnace. By maintaining a super-atmospheric pressure, ingress into the furnace of the ambient atmosphere, including it oxygen, is minimized. Since the pressure drop across the orifice 29a is the pressure differential which gives rise to an elevation of pressure within the carburizing furnace, it will be seen that the control of that pressure differential will control the magnitude of the pressure within the carburizing furnace. This pressure differential is readily regulated by the throttling valve 72 which supplies fuel gas to the line 29. By thus increasing the volume of gases flowing through the orifice 29a, the pressure drop across that orifice is increased and so is the pressure within the furnace 10. It may be desirable to increase the pressure in the treating zone during the more critical portion of the carburizing cycle. To accomplish this, the operation of the throttling valve 72 may be manual or automatic as desired.

The continual withdrawal of gases from the treating chamber 11 assures expeditious withdrawal of the combustion products at the beginning of the cycle and during the purging of the carburizing furnace. Likewise, the continual withdrawal of the gases from the treating chamber 11 during heat treating and carburizing operations provides the stream of gases needed for dilution of the carburizing material and for the performance of the several functions described above.

With a system functioning as described in connection with FIGS. 1 and 2, the fan powered by a one-horsepower motor 17 for the size of the furnace described, drives the gases through the annular flow path 21 at a rate in excess of 100 cu. ft. per minute. Where the carburizing material is natural gas, its supply during the purging operation before the timing relay 61 is timed out will be at the rate of about 15 cu. ft. per hour. After the purging operation and while the treating chamber is maintained at a selected carburizing potential corresponding to a carbon content in the work of 1%, the natural gas will then be flowing to the inlet of compressor 28 at the rate of about 4 cu. ft. per hour.

The foregoing is in contrast with prior systems where the flow rates of carburizing material under both the purging and the carburizing operations are greatly in excess of those which I have found necessary to utilize. It would not be unusual with a prior system to supply, for generation of atmosphere in this size furnace, a total of about 100 cu. ft. per hour of fuel gas and air in suitable ratio.

More particularly, in the system of the present invention, the flow meter 37 for both purging operations and carburizing operations will indicate a flow of approximately 50 cu. ft. per hour. For other systems such as that shown in my parent case, the flow through the corresponding meter during purge would be of the order of 100 cu. ft. per hour for the reason that in that system and other systems of the prior art, there has always been present added oxygen.

This flow is less than prior systems would usually employ, but more significantly, it represents gas which is already largely part of the system, not fresh expendable gas as with prior systems.

Though the equations of carburizing are well known, in accordance with the conditions I have described above, I have been successful in maintaining high ratios of $\text{CO}:\text{CO}_2$, of $\text{H}_2:\text{CH}_4$, and of $\text{H}_2:\text{H}_2\text{O}$, meaning that the carbon monoxide present in the treating chamber is maintained at approximately 20%, and that the carbon dioxide may range from 0.03% to 0.1%. The hydrogen is maintained in the order of 35% to 45%, while the water vapor, or H_2O , remains at a low value corresponding with the dew point of 20° F. or less.

Methane (CH_4) may attain a value of about 2.5% or even higher early in the carburizing period. However, at all times the ratio of hydrogen to methane remains quite high. During carburizing, this particular ratio is increased by virtue of the actions I have described above. Even though the methane concentration rapidly rises at first thereby providing a gas rich in carburizing agents, this high concentration level is permitted to prevail only for a short time thus preventing deposition of soot during any phase of the operation.

It may be further noted that the thorough withdrawal and elimination from the system of all material volatilized during and subsequent to the purge period, are necessary for the achievement of the aforesaid high ratios which provide the desired carburizing potentials with the minimized ratio of addition of the carburizing material to the treating zone. This, I have found to be so for the reason that if there be returned to or circulated within the treating zone volatilized material (or even some materials not volatilized but in fine particulate form), an apparent catalytic action takes place which tends to maintain or increase the formation of the decarburizing materials including carbon dioxide and water vapor.

To assure the removal of all such catalytic materials which promote the formation of carbon dioxide and water vapor, I have provided not only the centrifugal type of separators 33 and 35, but I have also added to them internal filtering structures as shown in FIGS. 3 and 4. Thus, for the "hot" centrifugal separator 33, there is provided within the outlet pipe 33a a filter 88 of multiple pore size.

Slipped over the lower end of a screen 81 of about $\frac{1}{2}$ " O.D. and having an open inner channel of about $\frac{3}{8}$ " I.D., is an intermediate section 80 of expanded polyurethane having an intermediate pore size of about 45 pores per inch. The intermediate section 80 extends along the screen to a cork 84 which fully encloses the end of screen 81. Similarly positioned around intermediate section 80 is a second layer 82 of expanded polyurethane having a coarse pore size of approximately 30 pores per inch or less. Interleaved between the turns of the screening 81 is a third grade of polyurethane material 83 which has a still finer pore size of approximately 100 pores per inch or above. The cork 84 carried by the screening 81 is pressed into the lower end of the pipe 33a, thus suspending the coarse and intermediate sections 80 and 82

below the lower end of the pipe while supporting the fine section material 83 within the pipe. A plug 87 disposed in the upper end of the screening 81 blocks the escape of gas in that direction, thus forcing the gas to pass through the fine section material to the interior of outlet pipe 33a. The internal diameter of the outlet pipe 33a may be of the order of $\frac{3}{4}$ " and the coarse, intermediate and fine filter sections may have lengths of approximately 4", 4" and 7", respectively for the specific embodiment being described. In addition to presenting fine pores or flow passages to the flow of gas for trapping and entrainment of matter, filters of this design also have the advantage of presenting large surface areas for deposition by the gas of materials having adhering characteristics.

A cold filter 89, as shown in FIG. 4, is further utilized in the system and operates in conjunction with the centrifugal separator 35. This filter, like filter 88, is carried within separator 35 by means of a cork 85 disposed within the end of the outlet pipe 35a. The filter itself consists of a polyethylene tube 86 of filter grade; i.e., with less than 100 pores per inch, the upper end of which is closed by heat sealing. This filter is effective in removing all water droplets in the mixture, partly owing to the hydrophobic properties of the polyethylene.

While particular embodiments of the invention have been shown and described, it will of course, be understood that modifications may be made. The appended claims are, therefore, intended to cover such modifications without departing from the true spirit and scope of the present invention.

What is claimed is:

1. A system for maintaining a carburizing atmosphere for work undergoing heat treatment and for carburizing work up to at least 1.2% carbon without soot deposition comprising:

a furnace provided with heat-generating means and a treating chamber heated by said heat-generating means and adapted to receive work to be heat treated under a protective atmosphere of the carburizing type,

a fan disposed within said treating chamber adjacent a wall thereof,

driving means for said fan for producing violent agitation and circulation of the gases forming the furnace atmosphere within said treating chamber at high rates of flow to establish thermal equilibrium throughout said work chamber and to maintain chemical equilibria between the constituents of said atmosphere and the surface of the work,

conduit means having both an inlet and an outlet in communication with said treating chamber and forming a closed external recirculation path for withdrawal and return of atmosphere to and from the treating chamber,

means including a gas compressor in said conduit means having its inlet connected to said outlet from said treating chamber and its outlet connected to said inlet to said treating chamber for movement of furnace atmosphere through said closed external recirculation path,

valve means associated with said conduit means for regulating the rate of flow of the stream of furnace atmosphere to be recirculated,

means for cooling said stream prior to its arrival at said gas compressor,

filtering means included in said conduit means for removing from said stream, after cooling thereof, solid and liquid materials,

supply means for introducing carburizing material into said stream on the inlet side of said gas compressor, said compressor serving as a mixing means to disperse the carburizing material thoroughly through said stream, and said supply means serving in conjunction with said gas compressor to develop within said treating chamber a positive pressure for mini-

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mizing ingress into said treating chamber of oxygen and its compounds thereby quantitatively to reduce the amount of carburizing material required to carburize the work to a desired level under soot-free conditions,

means for controlling the rate of flow of said carburizing material with reference to the selected carburizing potential for said treating chamber,

a mixing zone in heat exchange relationship with said heat-generating means and including said fan and said inlet of said conduit means located adjacent said fan for flow therethrough of the resultant mixture, prior to arrival at the treating zone of said treating chamber, for preventing a sudden reduction in the temperature of the atmosphere in the region of said work and for attainment of equilibrium conditions of said mixture without the formation of soot in the atmosphere in the region of said work, and

a temperature control regulating system for said heat-generating means for regulating the rate of heat generation to maintain the temperature of said treating chamber at a selected temperature within a range of from 1400° F. to 2000° F. to maintain substantially constant the equilibrium constants of the gas ratios of the atmosphere within said treating chamber with the ratios respectively of $\text{CO}:\text{CO}_2$, $\text{H}_2:\text{CH}_4$ and $\text{H}_2:\text{H}_2\text{O}$ at high values.

2. The system of claim 1 in which said supply means has a purge position for greatly increasing the rate of flow of the carburizing material for the purging of the treating chamber.

3. The system of claim 1 in which said fan is located near the bottom of the treating chamber and in which said mixing zone includes an annular mixing zone extending from the region of said fan to the top of a treating

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zone within said treating chamber, said inlet and outlet to said treating chamber being located for flow of said stream into said mixing zone where, after violent agitation and mixture thereof, it moves downwardly through said treating zone over the work and outwardly through the bottom portion thereof, a small fraction leaving by way of said outlet and the major fraction thereof being recirculated by way of said mixing zone.

4. The system of claim 1 in which said filtering means comprises a centrifugal type separator for removal of said solid materials in particulate form and which also includes a screen having at least two filter sections, a first of which is characterized by a relatively coarse meshwork of the order of 30 pores per inch, and the remaining sections thereof being of progressively finer porous structures for removal of progressively finer particulate material withdrawn with said gases from said treating chamber.

5. The system of claim 4 including a second centrifugal separator in which condensate formed as a result of cooling of said gases is removed, said second centrifugal separator including a tubular filter characterized by a pore size of filter grade having less than 100 pores per inch for further removal of water and other liquid droplets.

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