

Aug. 21, 1956

H. J. NESS

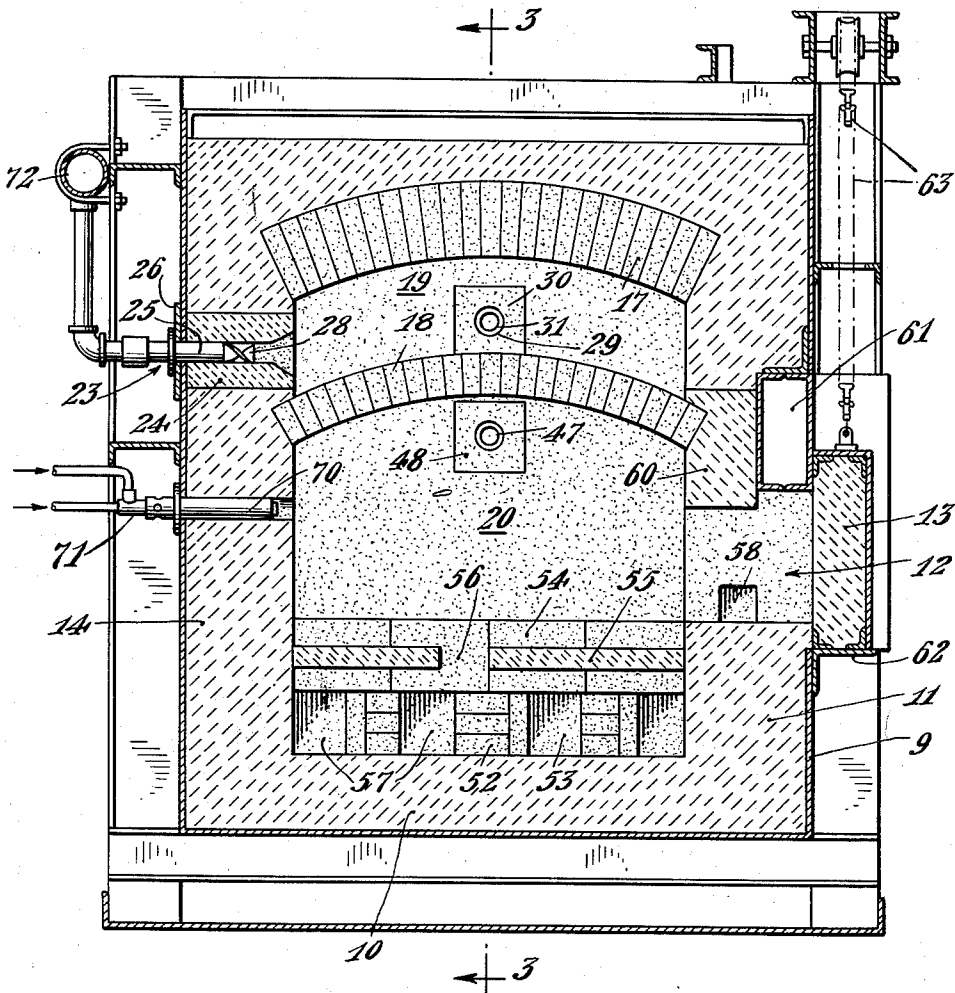
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PROCESS AND APPARATUS FOR CARBURIZING

Filed Nov. 29, 1951

8 Sheets-Sheet 1

Fig. 1



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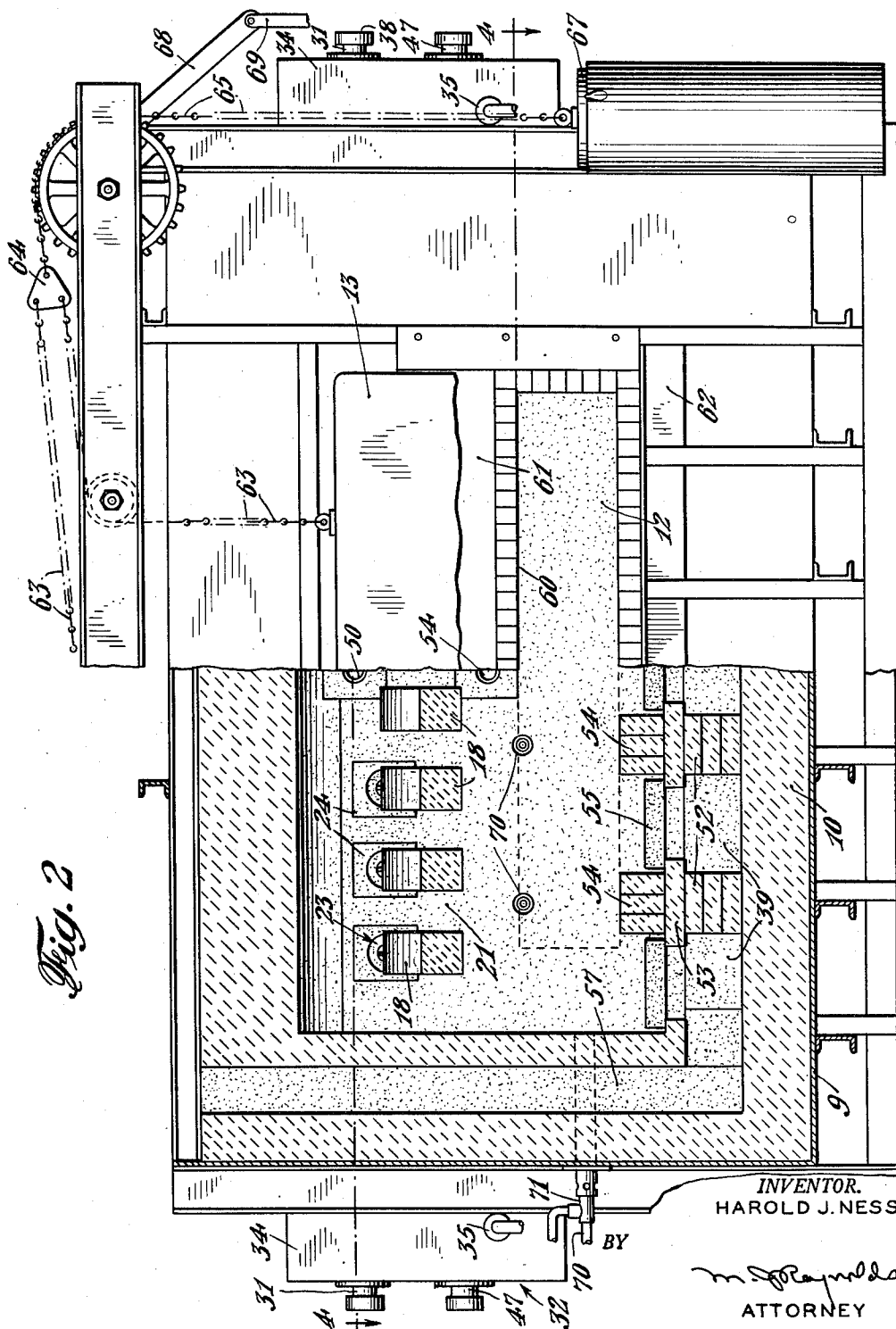
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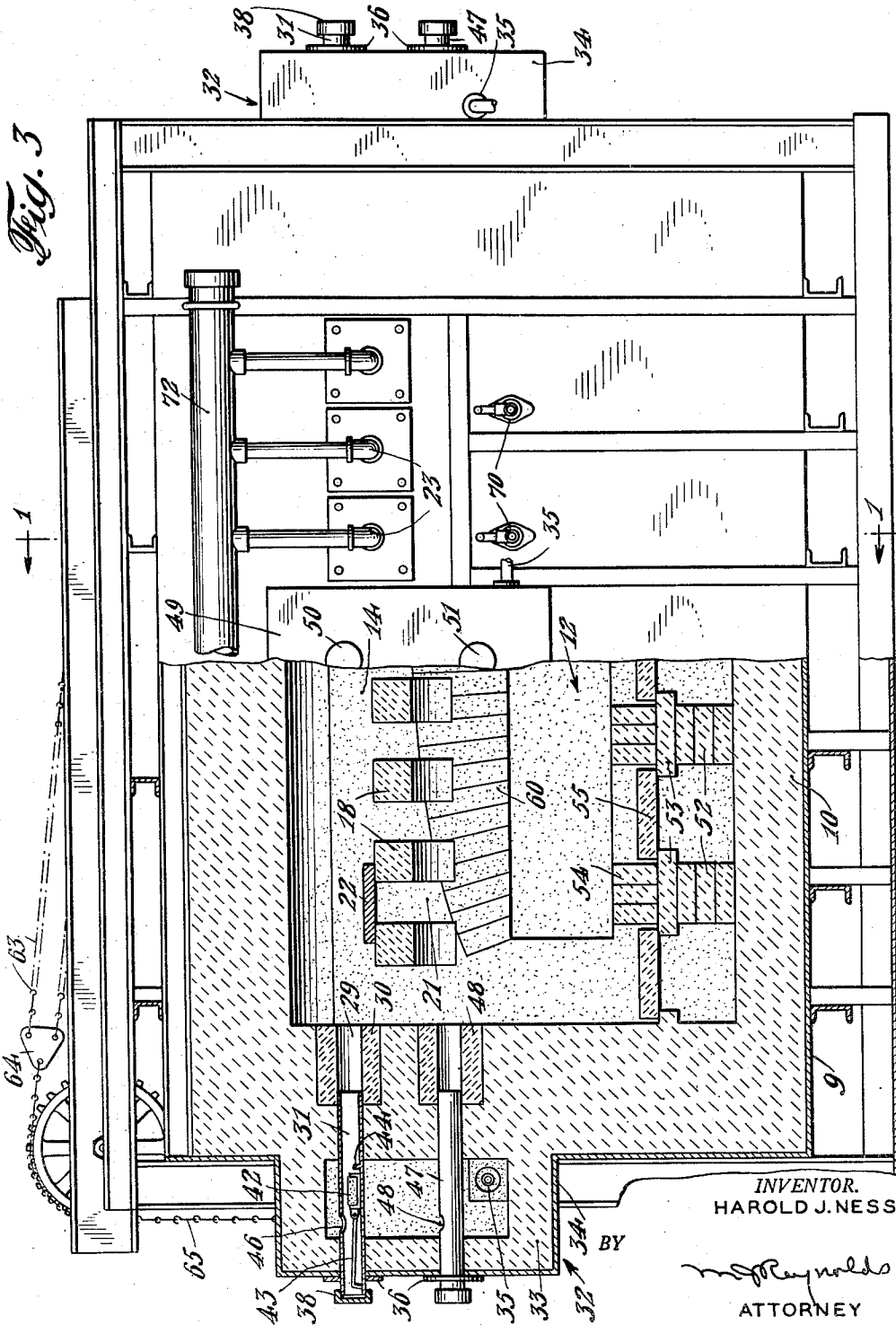
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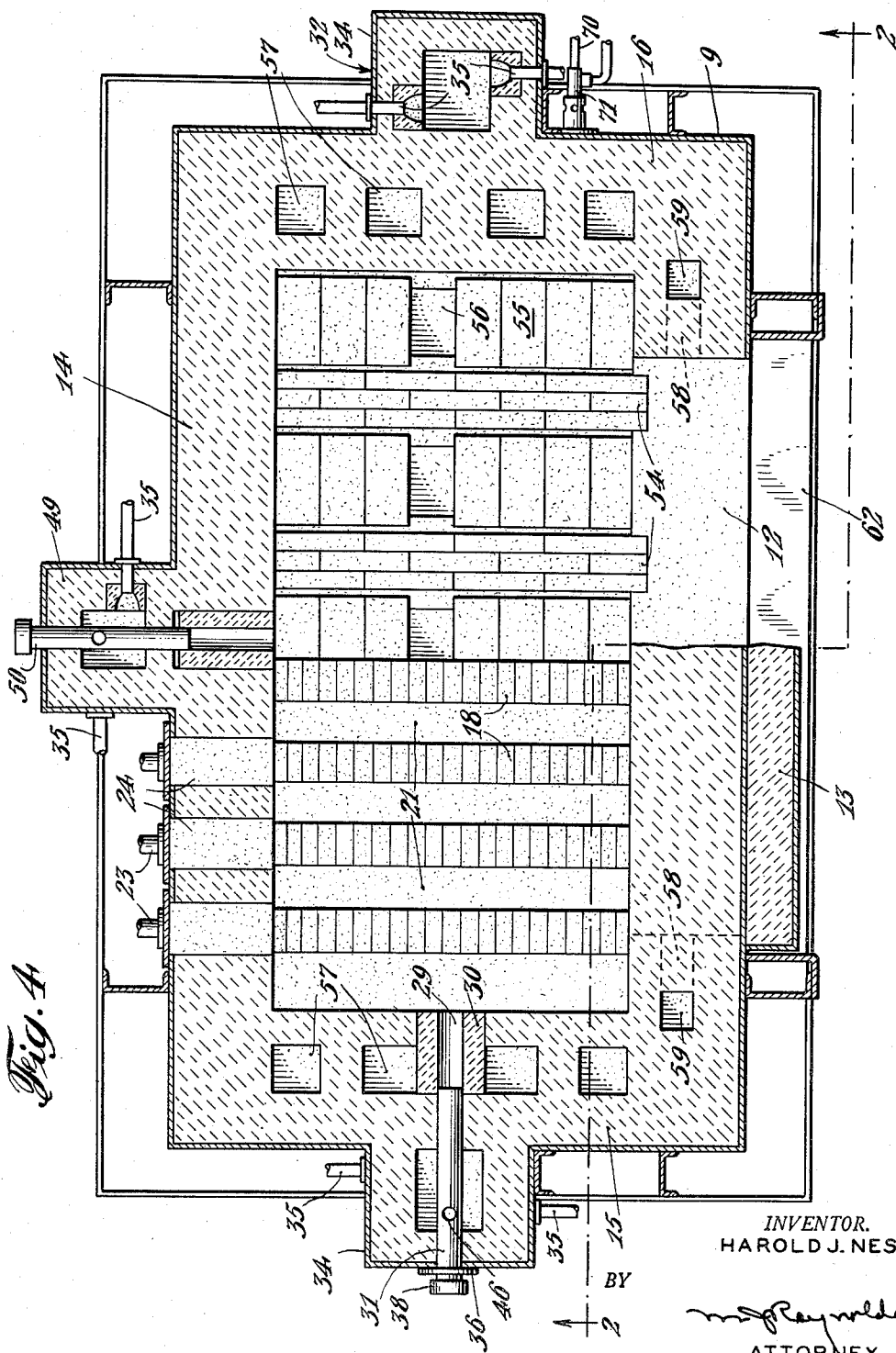
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Fig. 5

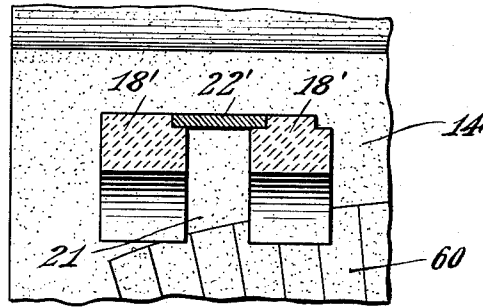


Fig. 6

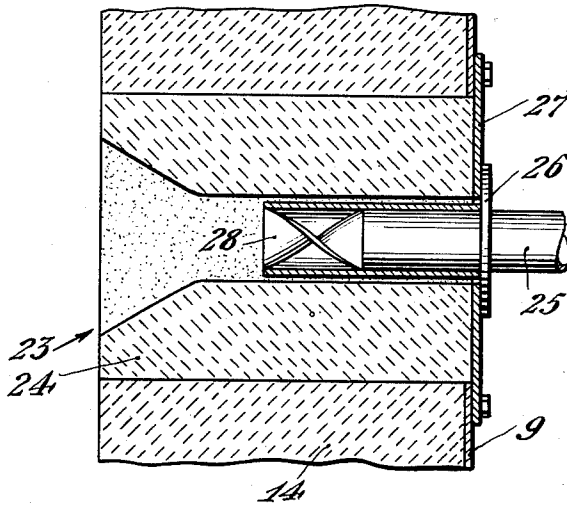
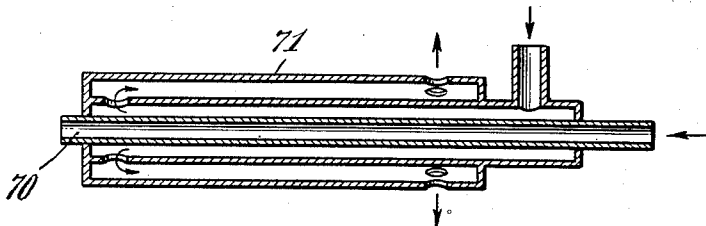


Fig. 7



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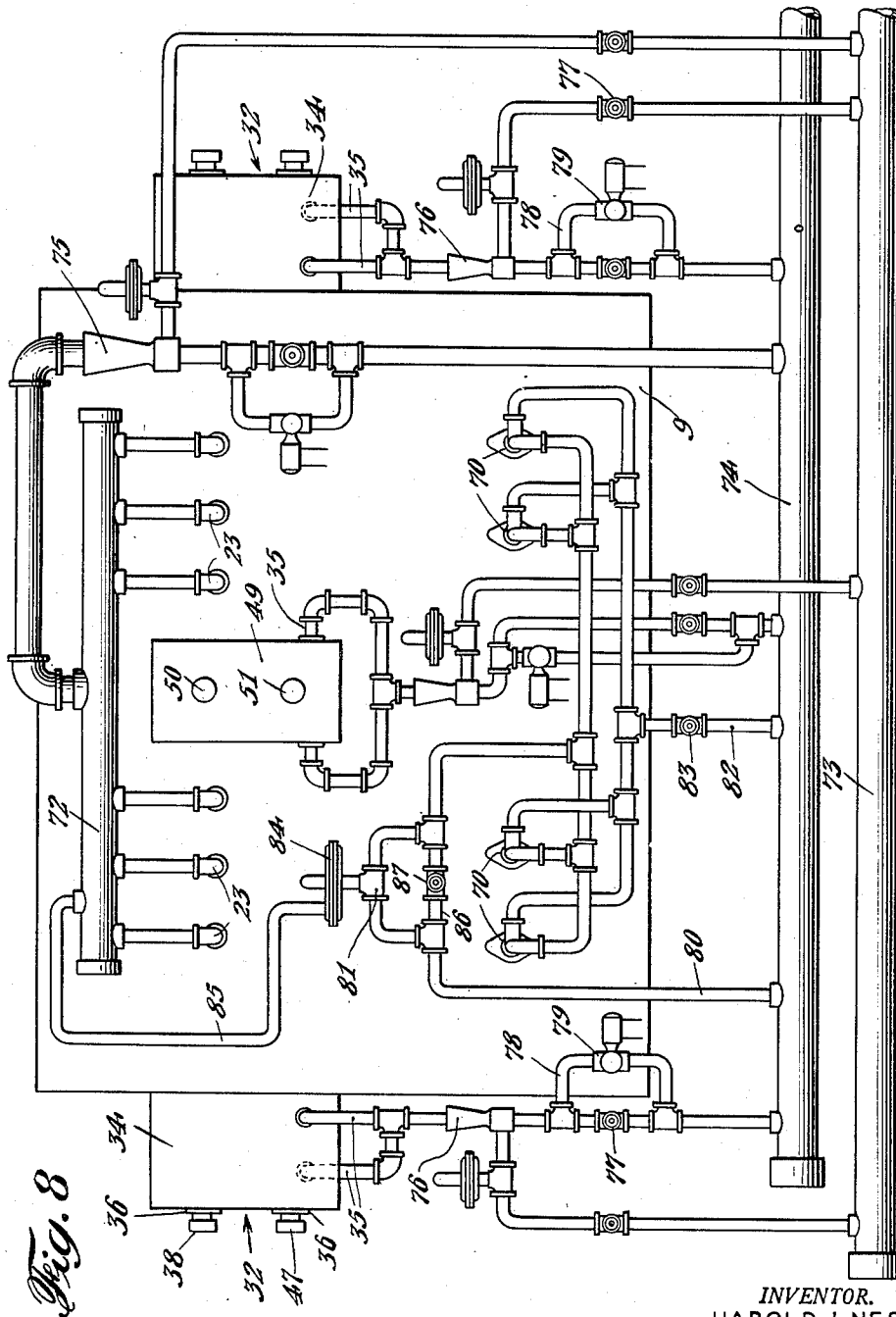


Fig. 8

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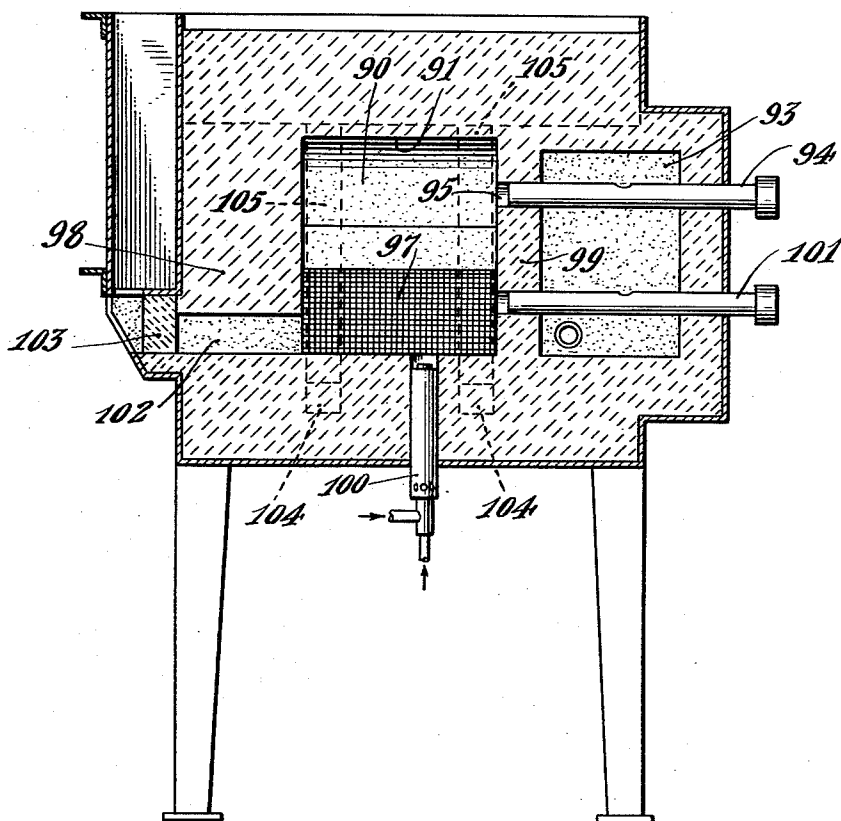
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Fig. 9



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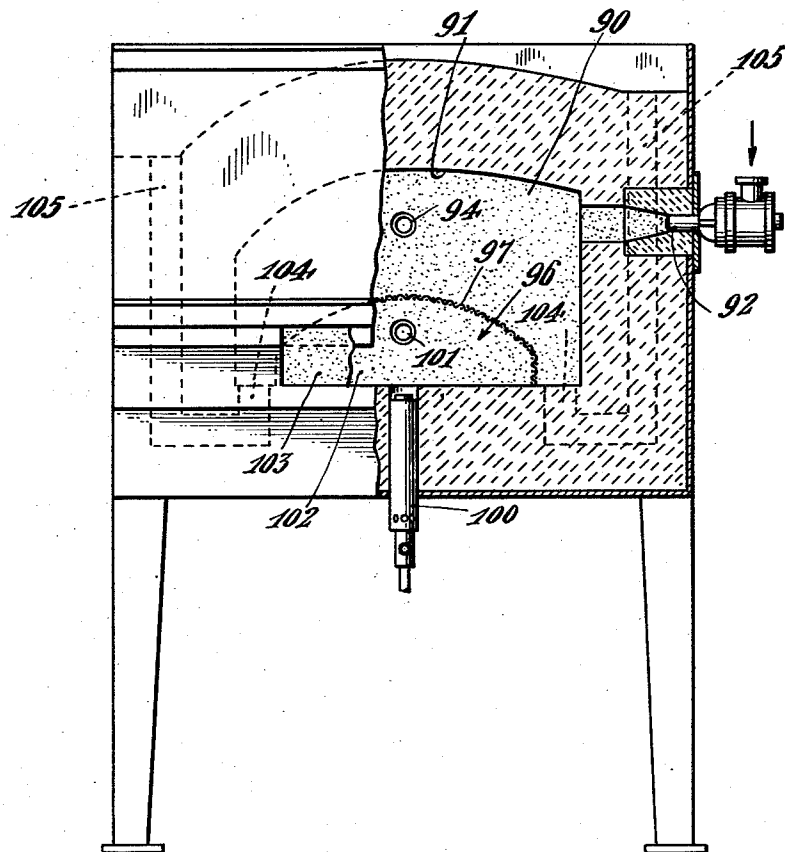
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Fig. 10



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PROCESS AND APPARATUS FOR CARBURIZING

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Application November 29, 1951, Serial No. 258,971

15 Claims. (Cl. 148—16.5)

This invention relates to industrial furnaces for the heating of metal parts and more particularly to direct fired combustion type furnaces in which the parts to be heated are surrounded by the products of combustion.

One of the objects of the invention is to prevent or reduce to inconsequential amounts the oxidation or scaling of both ferrous and non-ferrous metals, and the decarburization of ferrous metals, which is inherent in prior art processes of heating such metals directly in combustion gases.

Another object is to provide a gaseous atmosphere in a direct fired furnace in which accurate control of the carbon content of ferrous metals heated therein may be obtained.

Another object is to provide such a gaseous atmosphere in which the carburizing potential of the atmosphere may be controlled so as to be neutral to steel of any particular carbon content or carburizing to such steel in selective amounts.

A still further object is to provide such an atmosphere in which a coating material will be deposited or formed on the work in controlled amounts during heating thereof and which will serve as a lubricant for subsequent working operations such as pressing, piercing, rolling, forming, or extrusion of the metal.

Still another object is to provide a combustion furnace atmosphere employing lithium as a conditioning medium, in which the conditioning of the combustion gases is completed and an equilibrium condition established prior to contact of the combustion gases with the work to be heated.

A further object is to provide controlled circulation of the combustion gases in contact with the work thereby to obtain uniformity in the protection from scaling and decarburization of the work or in the carburization thereof.

Another object is to provide partial segregation of the work from the exothermic gas reactions and to obtain gas reactions at or adjacent the work of or closely approaching an endothermic nature.

Still another object is to provide a combustion type furnace in which an increased uniformity of heating of the work is obtained and in which a large proportion of the heat supplied to the work is radiant.

Other objects and advantages will hereinafter appear.

In a copending application, Serial No. 139,906, filed January 21, 1950, now Patent No. 2,706,110, issued April 12, 1956, and entitled "Combustion Furnace," I have disclosed a directly fired furnace for the heating of metals employing lithium as a conditioning medium, in which scale-free heating is obtained. The present application is an improvement, for certain usages, over the furnace of the aforesaid application. In said prior application I pointed out the necessity of obtaining substantially complete reaction of the combustible mixture prior to the introduction of a lithium containing vapor into contact therewith and accomplished this objective by utilizing special burners in which the reactions were

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completed substantially in the burner block so that the products of combustion entered the furnace chamber at substantially their maximum heat energy level. The gases were then brought into immediate contact with the lithium vapor for reaction therewith, these reactions being carried out in a part of the heating chamber somewhat remote from the work. I have now found that increased effectiveness of the lithium-combustion gas reactions can be obtained by delaying the passage of the lithium-combustion gas mixture to the work and by increasing the area of contact and scrubbing action of the hot brickwork over which the mixture passes in its travel to and over the work. It is not known whether the brickwork acts catalytically to accelerate the lithium-combustion gas reactions or mechanically to break up the gas stream and produce a more intimate mixture between the lithium vapor and the gaseous products. It is believed, however, to be the former. As a result of the more complete reactions, the combustion gases are rendered more neutral toward the work and by means of supplemental raw hydrocarbon additions to the furnace adjacent the work, an atmosphere condition may be established about the work which is in balance with the carbon content of a particular steel or, if desired, carburizing to it.

In a preferred embodiment of my invention I provide a reaction chamber which is separate from the heating chamber, the combustion products passing from the reaction chamber into the heating chamber in transit to the exhaust vents. The furnace burners fire directly into the reaction chamber and are preferably of a type in which the burning is substantially completed in the burner block. The lithium conditioning medium in the form of a vapor is introduced into the burner products and reacted therewith in the reaction chamber to such a degree that an equilibrium condition is established in the products of the reaction prior to entrance of the gases into the work or heating chamber. The establishment of this equilibrium condition is dependent upon the size of the reaction chamber whereby the gases are delayed before entering the work chamber, in order to provide a time factor to permit completion of the reactions. The configuration or construction of the reaction chamber is also important in establishing the equilibrium of the lithium-combustion gas reactions, by providing an extended area of hot surfaces and a tortuous path to effect intermixing and scrubbing of the gases during the reaction period so as to accelerate the same.

The reaction chamber may conveniently be formed by an arch or refractory partition extending across the furnace so as to divide the latter into two separate compartments, the partition having passageways for the gases therein between the reaction and work chambers. This partition, in addition to providing the delayed passage of the combustion gases into the work chamber, serves to extract a portion of the heat from the gases and by virtue of its relation to the work, to heat the latter by radiation. This feature is of importance in the production of a carburizing or carbon equalizing condition adjacent to the work, as will more fully appear. To further aid in this regard the floor of the furnace is also chambered to enable the exhaust gases to pass therethrough and under whereby to extract further heat from the gases and to conserve and utilize such heat to further heat the work by radiation. The substantially solid side walls form further radiating surfaces, all of said walls being relatively closely spaced to the work to enhance the radiant heating of the load by the law of inverse squares.

The carburizing or carbon equilibrium condition is produced in the working chamber of the furnace by the endothermic reaction of a raw or rich carbonaceous fuel in the chamber in contact with the work, such carbo-

naceous fuel being introduced into the chamber in such manner as to overlay or envelop the work. The term "carbonaceous material" as used herein includes any carbon containing compound or mixtures containing one or more carbon containing compounds, which material will not of itself support combustion and which will decompose endothermically to produce nascent carbon. By way of example, such materials include hydrocarbons and hydrocarbon derivatives, such as alcohols and aldehydes, whether liquid, gaseous or solid, and compounds of hydrogen, carbon and oxygen, among which are petroleum oils and their distillation products; hydrocarbons of the methane series, such as methane, propane and butane, the lighter alcohols, as ethyl, methyl and propyl and their aldehydes, manufactured gas, such as city gas, and numerous others. However, for economy and convenience I prefer to employ one of the liquid or gaseous fuels in common use in the location, such as light or heavy fuel oil, city gas, natural gas, or propane. This carbonaceous material is reacted in part by contact with the hot combustion gases from the reaction chamber, in part from contact with the heated work, and in part by radiation from the furnace walls. However, since these reactions are partly endothermic in nature, a layer of a carbon rich gas is produced about the work, the carburizing potency of which may be controlled by the quantity and character of the raw carbonaceous material admitted to the chamber and may be regulated so as to be either in substantial balance with the carbon content of a particular steel or carburizing to it.

The carburizing efficiency of the gas is greatly increased by the actual cracking of this gas in contact with the hot work. However, since this action extracts heat from the work and further since the endothermic gases about the work serve to some extent to isolate the work from the hot combustion gases, the importance of the radiant heat from the walls, floor and roof of the chamber becomes evident. The provision of a separate reaction chamber permits the walls of the heating chamber to be closely spaced to the work since the combustion space, usually required in the heat chamber itself, is provided by the reaction chamber.

The lithium compound vapor added to the reaction chamber, in addition to rendering the products of combustion non-oxidizing to the work, also serves to deposit on the work a very thin layer of a lithium compound, which, as pointed out in my aforesaid application, serves as a lubricant for the work in subsequent mechanical operations. It is desirable, however, in certain operations to separately lithiate the raw gas additions and to augment the coating on the work, and I have found that this is most readily accomplished by supplying an additional amount of lithium compound vapor into the furnace close to the work.

The invention will best be understood by a detailed description of a preferred embodiment of the invention, taken in connection with the accompanying drawings, in which:

Fig. 1 is a vertical sectional view of a billet heating furnace embodying the present invention;

Fig. 2 is a view of the furnace partly in front elevation and partly in section on the line 2—2 of Fig. 4;

Fig. 3 is a view of the furnace partly in rear elevation and partly in section on the line 3—3 of Fig. 1;

Fig. 4 is a view of the furnace, partly in plan and partly in section, on the line 4—4 of Fig. 2;

Fig. 5 is a fragmentary view showing a modified form of arch structure;

Fig. 6 is a detail sectional view of a main furnace burner;

Fig. 7 is a sectional view, on an enlarged scale, of the supplemental raw fuel inlet;

Fig. 8 is a rear view of the furnace showing the piping and valving arrangements of the furnace;

Fig. 9 is a side elevation partly in section of a modified form of furnace embodying the invention; and

Fig. 10 is a front view partly in section of the furnace of Fig. 9.

Referring first to Fig. 1 I have shown a billet heating furnace comprising an external metal shell 9 containing a refractory lining comprising a base 10, a front wall 11 having an opening 12, closed by a door 13, a solid rear wall 14, end walls 15 and 16 (Fig. 4), a roof 17 and an intermediate arched portion 18 forming an upper reaction chamber 19 and a lower work chamber 20.

The arched portion 18 is not continuous longitudinally of the furnace but is divided into a series of arches with intermediate passageways 21, as shown in Figs. 3 and 4. This construction is preferred over the usual checkerboard type of perforated arches for the reason that it permits certain of the passageways 21 to be closed by overlaying the same with an arcuate metal plate 22, inserted up through the passageways, whereby the circulation of the gases from the upper reaction chamber to the heating chamber may be varied in order to obtain the most advantageous arrangement for proper conditioning of the gas and to obtain uniformity in the heating of the work. If desired, as shown in the modification of Fig. 5, the arches 18' may have a stepped or shouldered upper face to support loose refractory bricks, or slabs, 22' variably positioned to control the passage of combustion gases into the heating or work chamber 20.

The roof 17 preferably is also formed of a refractory arch for structural reasons and to enhance the scrubbing of the products of combustion.

The burners 23 for supplying the heat to the reaction chamber 19 are arranged in a horizontal row on the rear wall of the furnace and preferably are of a type in which the combustion reactions are substantially completed in the burner blocks. The burners, shown in detail in Fig. 6, comprise the refractory blocks 24 set into the rear wall 14 of the furnace and apertured to receive the burner nozzle 25, secured by a flange 26 to a plate 27, in turn secured to the furnace shell 9 and serving to cover square apertures in the shell by which the block 24 may be removed for repair or replacement. A spiral insert 28 in the bore of the burner nozzle serves to deflect and break up the burning air-fuel mixture issuing from the nozzle and to assist in the rapid combustion thereof. Obviously other forms of burner construction may be employed which will handle the large volume of gas required in the heating of furnaces of the high temperature type, the prime consideration being the rapid and substantially complete combustible reaction of the fuel and air mixture by the time the products of combustion enter into the reaction chamber 19, or at least before they contact the lithium vapor introduced into the reaction chamber through the inlets 29 (Fig. 1). This completion of the combustion reactions prior to the mixture of the lithium vapor therewith is an important step in the creation of a non-oxidizing condition in the work chamber, the second important step being, as heretofore stated, the complete reaction of the lithium vapor with the products of combustion prior to the entrance of the gases into contact with the work.

The lithium vapor inlets 29 are disposed in each end of the furnace above the arches 18 and comprise (Fig. 3) an apertured refractory 30 communicating with a vaporizing tube 31 of suitable heat resisting alloy extending through a combustion chamber 32 formed of suitable refractory 33 contained within a metal shell 34 forming an extension of the furnace shell 9, at each end of the furnace. One or more burners 35 fire into the chamber 32 at the lower part thereof so as to maintain the tube 31 at a temperature above the melting point of the lithium compound adapted to be contained within the tube.

As shown in Fig. 3, the tube 31 is connected to the shell 34 by a flange 36 and is provided externally of the shell with an extension having an open end adapted to be closed by a cover 38.

The lithium compounds are inserted into the vaporizing tube 31 in the form of a compressed or fused cake dis-

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posed within an open boat 42 secured to the end of a draw rod 43 and engageable with a lug 44 in the tube 31 so as to accurately position the boat within the tube centrally of the combustion chamber 32. The charge placed within the boat 42 preferably comprises a mixture of lithium carbonate and lithium chloride in the proportion of 60% of the former and 40% of the latter. Other compounds of lithium and other proportions may be employed.

Any suitable neutral carrier gas may be introduced into the vaporizing tube for the purpose of entraining the vapors liberated from the molten lithium and carrying them into the furnace, but I prefer to employ the products of combustion of a suitable fuel such as oil, city gas, natural gas, propane, etc. In practice I have found that the products of combustion in the chamber 32 may be employed, and for this purpose an aperture 46 is provided in the tube 31 communicating with the chamber 32. The opening 46 is disposed to the side of the boat 42 away from the furnace so that the combustion gases sweep over the lithium compound contained therein in passing into the reaction chamber 19 of the furnace.

The use of the products of combustion from the chamber 32 as a carrier gas for the lithium compounds has a number of advantages over the previously employed arrangements in which either a separate gas generator is employed or a portion of the gas in the main furnace is recirculated through the vaporizer tube 31, as shown in my aforesaid application Serial No. 139,906. The present arrangement eliminates the need for cooling, dehydrating and pumping of the gas, together with all of the external piping connections, cooling water supply, and electrical connections to the pump motor. It also avoids exhausting the combustion gases from the chamber 32 into the room since these gases are vented through the furnace itself. Moreover, a smaller chamber 12 may be employed with less fuel consumption than when a cold carrier gas is passed through the tube 31 and the heat generated in the vaporizing chamber is, except for loss through the vaporizer chamber walls, all added to the main furnace chamber. The avoidance of a temperature differential between the inside and outside of the alloy tube 31 and between the front and rear ends thereof also results in much longer life for the tube and, since there is no chilling effect of cold gases on the lithium compound, a lower temperature may be employed in the vaporizing chamber.

The amount of lithium compound employed is extremely small and may be regulated by the temperature of the combustion chamber 32 through suitable pyrometer control, as is well known in the art. However, where the products of combustion of the chamber 32 are vented over the lithium compounds within the tube 31, it is desirable to have a relatively small variation in burner consumption whether the burners are on or off of control. For this reason the gas and air supply to the burners 35 is adjusted just below the minimum requirement to maintain the chamber up to the required temperature, say 1640° F., when the burners are on control. This insures an adequate minimum flow of gas over the lithium compounds at all times.

A second vaporizer tube 47, identical to the tube 31, passes through the combustion chamber 32 and terminates in an aperture in a refractory 48 disposed below the level of the arch 18 so as to discharge into the work chamber 20. The tube 47 also has an opening 48 into the combustion chamber 32 to permit the products of combustion of this chamber to serve as the carrier gas for this vaporizer tube. The apertures 48 and 46 should be of sufficient size to permit the products of combustion to be readily vented therethrough, the sum of the areas of these openings being equal, approximately, to the area of the vent normally required for the chamber 32. The purpose of the tube 47 is to increase the lithium supply to the work chamber both to provide atmosphere protection to the work and to augment the coating of lithium compounds formed on the work, as will more fully appear hereinafter.

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In furnaces of moderate length the provision of lithium vapor inlets at the opposite ends thereof will be sufficient to satisfactorily condition the combustion gases in the reaction chamber 18. In longer furnaces it may be desirable to add one or more additional lithium vaporizers and I have shown one such additional vaporizer 49 disposed centrally of the rear wall 14 of the furnace, and having a pair of vaporizing tubes 50 and 51 discharging above and below the arch 18, respectively.

The floor of the work chamber 20 is carried by a series of spaced brick pedestals 52 disposed in a number of transverse rows, the pedestals of each row being bridged by refractory slabs 53 upon which the transverse rows of work supporting rails or sills 54 are carried. Other slabs 55 are bridged across each adjacent pair of transversely extending slabs 53, certain of the slabs 55 being omitted to provide openings, as shown at 56 in Fig. 4, for the venting of the furnace gases through the floor. These gases pass through the openings 56 and thence transversely beneath the slabs 55 and longitudinally through the passageways 39 between the piers or pedestals 52 to the vertical venting stacks 57 disposed at each end of the furnace.

As will be evident from the construction described, by adjustment of the position of the vent openings between the slabs 55, the circulation of the furnace gases may be controlled to produce uniform atmosphere and heating conditions throughout the work chamber. This is highly desirable in order to obtain a uniform carbon potential at the work either for carburizing or carbon controlled heating.

As shown in Figs. 1 and 4, additional vents 58 extending from the base of the door passageway 12 to stacks 59 in the front wall 11 provide for a circulation of the furnace gases into the door passageway, thereby overcoming the normal cooling effect of the door and preventing contamination of the furnace atmosphere by restricting or opposing the seepage of air into the furnace around the door 13 and venting such air through the stacks 59.

The passageway 12, as will be clear from Fig. 2, extends across the major portion of the furnace and is bridged by a flat arch 60. A hollow rectangular structural member 61, which may be water cooled, is also bridged over the passageway 12 and serves as an abutment for the door 13, which in closed position is supported on an angle bracket 62 and is arranged to be raised by cables or chains 63 secured through a triangular load equalizer 64 to a chain 65 which passes over a sprocket 66 and is secured to a counterweight 67. The sprocket 66 has an operating arm 68 pivoted to a pull rod 69 operated in any suitable manner as by a lever or hydraulic cylinder (not shown).

In addition to the burners 23 and lithium vapor inlets 31 and 47, the furnace has another set of inlets 70 extending into the furnace through the rear wall 14 below the arch 18. These inlets 70 are for the admission of a raw hydrocarbon fuel into the work chamber, the purpose of which is to enrich the atmosphere of the work chamber in an amount to permit a desired carbon potential to be created about the work. The hydrocarbon fuel may be a liquid, solid or gaseous hydrocarbon, but for convenience I prefer, as stated, to employ a fuel gas such as natural gas, propane, city gas, or the like. This gas is introduced into the furnace adjacent the work so as to form a blanket or layer of gas which in general surrounds and envelopes the work. Its function is to break down endothermically in contact with or in close association with the work so as to produce a supply of available carbon either for carburizing the work or balancing the carbon level thereof so as to prevent decarburization of the work.

I believe it has not been possible heretofore to produce carburizing in direct fired furnaces due to the inability of producing a sufficiently high carbon potential in such furnaces. I am able to accomplish such carburizing, however, by virtue of a combination of contributing conditions, the most important of which is the use of

lithium vapor, whereby carburization may be effected at much lower carburizing potentials than is otherwise possible. This property of lithium is further increased by insuring the complete conditioning of the combustion gases prior to the entrance into the heating chamber; that is to say, in the reaction chamber. By virtue of the increased reaction time provided by the passage of the combustion gases through the reaction chamber, and the catalytic effect of the hot brickwork of this chamber on the lithium-combustion gas reactions, and particularly the intimate scrubbing action of the gases on this brickwork, the combustion gases attain their equilibrium values before entering the work chamber. These gases also give up a large proportion of their heat to the arch members 18 which thus serve as radiating surfaces for heating the work in the chamber 20. The same effect is produced by the floor refractories due to the venting of the gases under the floor. The combustion gases entering the work chamber are substantially neutral to the work providing the proper air-fuel ratio is maintained to the burners 23. This ratio should be such that the gases leaving the reaction chamber will have a CO_2/CO ratio of from 0.3 to 0.45 depending on the temperature of operation. The raw fuel added through the inlets 70 is relatively small in quantity, compared to that consumed in the burners 23, ordinarily up to 20% depending upon the temperature of the work heated. It is maintained in a relatively cool condition prior to entering the work chamber by the air-cooled jacket 71 (Fig. 7) about the inlet tubes 70 so that cracking of the fuel will not occur prior to its entrance into the chamber 20. The location of the inlets 70 is, as stated, closely adjacent to the work and spaced across the length of the rear of the furnace and at each end so as to permit all of the work to be substantially enveloped by this raw fuel before the former has had sufficient time to break down thermally. Due to the low available oxygen content of the gases from the reaction chamber 18, exothermic reactions with the added fuel can not be supported to any appreciable extent so that the latter in large part break down endothermically, obtaining heat for this purpose in part by intermingling with the lithiated products from the reaction chamber, in part by contact with the hot work, and in part by radiation from the furnace walls. This latter effect causes a gas having a positive carbon potential to be created at the surface of the work, the potency of which can be readily controlled by the volume and the carbon availability of the raw fuel admitted over the work. This endothermic gas is of course diluted by the exothermic gas but, since the latter is substantially neutral in character, its only effect is to render the endothermic gas less potent. Thus by adjustment of the relative volumes of the exothermic and endothermic gases, any desired carburizing potential may be produced at the work. The radiant effect of the hot arch and floor is responsible in a large degree for the maintenance of the proper temperature of the work, serving to replace in a considerable measure the heat absorbed thereby in the endothermic cracking of the raw fuel, it being understood that the work is more or less isolated from the exothermic gases by the raw gas layer. It is partially because of this partial isolation of the work that renders it desirable to add additional lithium compound into the work chamber over the work in such manner that it will mingle with and be carried to the work by the raw fuel so as to deposit thereon in a thin adherent coating. This coating not only prevents any oxidizing reactions from occurring on the surface of the work but appears to facilitate the carburizing reactions, perhaps due in part to the oxide-free surface produced and in part to the catalytic action of lithium in facilitating the cracking of the raw fuel. In any event the presence of lithium vapor adjacent the work appears to lower the CO_2/CO ratio obtained in the endothermic gases and enhances and stabilizes the proc-

ess whereby greater uniformity and control of the carburizing potency of the atmosphere is achieved. As a coating on the work it serves in addition to protect the same from oxidizing in the air during cooling of the metal and further acts as a lubricant during mechanical hot or cold working.

Reference has been made herein to supplying of air and fuel to the burners 23 and 35, and fuel and cooling air to the raw gas inlets 70. In Fig. 8 I have shown the piping and valving arrangements for this purpose. The main burners 23 are supplied with gas and air from a manifold 72 connected to the gas and air supply lines 73 and 74 respectively through a venturi mixing valve 75, under pyrometer control as is well known in the art. The burners 35 of the vaporizing chambers 32 and 49 are similarly supplied with gas and air from the supply lines 73 and 74 through the venturi mixers 76. A hand valve 77 in the air line is ordinarily adjusted to maintain a flow of air and gas to the burners 35 slightly less than required to keep the vaporizing chambers up to the desired temperature and supplemental air is provided through the bi-pass 78, under control of the pyrometer controlled valve 79, when the vaporizer temperature drops below the desired minimum.

Fuel for the raw gas addition tubes 70 is also supplied from the main fuel line 73 through conduit 80 and a diaphragm controlled valve 81, and cooling air for the tubes is supplied from the air line 74 by way of conduits 82 and valve 83. The diaphragm valve 81 is for the purpose of maintaining in the furnace the proper proportion of raw gas from the tubes 70 and combusted gas from the burners 23, irrespective of changes in the pressure in the burner manifold 72. This constant proportion is obtained by connecting one side of the diaphragm 84 of valve 81 to the manifold 72 by the conduit 85 whereby the valve 81 opens and closes proportionally to increased and decreased gas pressure in the manifold 72. A bi-pass 86 containing a manual valve 87 permits the raw gas flow to be controlled separately from the valve 81.

While the invention has been described in connection with the well known overfired type of furnace structure, it is to be understood that it is not limited to furnaces of this type but may be embodied in form of furnace in which separate exothermic and endothermic reaction zones may be satisfactorily maintained. In the modification of Figs. 9 and 10 I have shown another form of furnace for effecting this result.

The furnace chamber 90 of Figs. 9 and 10 is shown as substantially rectangular in shape and having an arched roof 91 with one or more burners such as 92 firing thereinto against the arch so as to obtain the scrubbing effect of the hot brickwork on the combustion gases. A lithium vaporizer 93 of similar construction to that shown in Fig. 3 is built into the rear of the furnace and the products of combustion thereof pass through the vaporizing tube 94, over the molten lithium compounds contained therein and thence into the combustion chamber at 95, in the path of the gases issuing from the burner 92. The upper part of the furnace chamber serves as a reaction chamber for the completion of the reactions between the burner products and the lithium vapor and is of sufficient size to permit these reactions to be completed therein. The work chamber 95 is formed adjacent the floor of the furnace and is separated from the reaction chamber by an arch 97 composed of mesh or perforated heat resisting alloy such as a nickel chrome alloy, and extends between the front and rear walls 98 and 99, respectively, of the chamber 90.

Raw or unburned hydrocarbon fuel is admitted into the work chamber 96 by means of a conduit 100, and lithium compound vapor is supplied thereto by a second vaporizing tube 101. The work is inserted into and removed from the chamber 96 through a horizontal slot 102 in the forward wall 98, the slot 102 being closed by

a suitable door, if desired, or of loose refractory as shown at 103.

The furnace gases are exhausted from the reaction chamber through vents 104 disposed in the floor at each corner of the chamber and in communication with the vent stacks 105.

By virtue of this arrangement, heat is supplied by exothermic reaction of the combustible mixture supplied to the burners 92 and a carburizing gas is produced around the work by endothermic cracking of the raw fuel supplied by the conduit 100. The alloy arch serves to partially isolate the endothermic gas from the exothermic while permitting the former to pass through the interstices and thus to the vents. The heat for effecting the endothermic reactions is supplied in part from radiation from the arch 91, in part from contact with and radiation from the alloy arch 97, which in turn is heated by contact with the combustion gases, and in part by contact with the hot work. There is also some intermingling of combustion gas with endothermic gases within the chamber 96, the amount of such intermingling depending upon the quantity of raw fuel admitted to the chamber, and the size and number of openings in the alloy arch. In practice I have found that a wire mesh having an opening of from $\frac{1}{4}$ " to $\frac{3}{8}$ " is satisfactory. Finer meshes, while permitting a carburizing potential to be maintained in the work chamber, are not sufficiently rugged to give a long useful life and are not necessary to effect the desired results. Moreover, a mesh having a substantial amount of metal surface is advantageous for absorbing heat from the exothermic gases and conveying it to the contained endothermic gas.

Control of the carburizing potential is obtained by the quantity and nature of the hydrocarbon fuel supplied to the work chamber and may best be determined empirically for any particular furnace. In the furnace shown ordinary city gas having a 550 B. t. u. content was satisfactorily employed for obtaining carbon potentials below the eutectic, whereas a richer gas, such as propane gas, produced hypereutectoid carburizing; the quantity of raw fuel being of the order of magnitude of 10% of the fuel consumption of the burners 92.

Obviously other forms of furnaces and furnace appurtenances may be employed to obtain the combined exothermic heat producing and endothermic controlled carbon potential conditions in the furnace, and therefore I do not desired to be limited to the illustrative embodiments of the invention herein shown and described but contemplate all manner and means of accomplishing the desired result coming within the scope of the appended claims.

What I claim is:

1. In a combustion furnace for metal heating, the combination of a work heating chamber, a combustion chamber, a partition separating said combustion chamber from said work chamber, said partition having openings therein for passage of products of combustion from said combustion chamber into said work chamber, burner means for said combustion chamber, means for supplying a combustible mixture of air and fuel to said burner means, said burner means and said combustion chamber being of related capacity so that the gaseous reactions will be completed and stabilized prior to passage thereof into said work chamber, means for admitting a raw gas into said work chamber, and means for producing a vapor of a lithium compound and for separately admitting the same into said combustion chamber and into said work chamber.

2. In a combustion furnace for metal heating, the combination of a work heating chamber, a combustion chamber, an arched partition separating said combustion chamber from said work chamber, said partition having openings therein for passage of products of combustion from said combustion chamber into said work chamber, burner means for said combustion chamber, means for supplying

a combustible mixture of air and fuel to said burner means said burner means being disposed to direct the burner products into scrubbing contact with said arched partition, said burner means and said combustion chamber being of related capacity so that the gaseous reactions will be completed and stabilized prior to passage thereof into said work chamber, and means for producing a vapor of a lithium compound and for admitting the same into said combustion chamber.

3. In a combustion furnace for metal heating, the combination of a work heating chamber, a combustion chamber, a series of arched sections forming a partition separating said combustion chamber from said work chamber and constituting one wall of each of said chambers, said arched sections being spaced apart to form openings therebetween for passage of products of combustion from said combustion chamber into said work chamber, burner means for said combustion chamber, means for supplying a combustible mixture of air and fuel to said burner means, said burner means and said combustion chamber being of related capacity so that the gaseous reactions will be completed and stabilized prior to passage thereof into said work chamber, means for admitting a raw gas into said work chamber, and means for producing a vapor of a lithium compound and for separately admitting the same into said combustion chamber and into said work chamber.

4. In a combustion furnace for metal heating, the combination of a work heating chamber, a combustion chamber, a partition separating said combustion chamber from said work chamber and forming one wall of each of said chambers, said partition having distributed openings therein for passage of products of combustion from said reaction chamber into said work chamber, burner means for said combustion chamber, said burner means and said combustion chamber being of related capacity so that the gaseous reactions will be completed and stabilized prior to passage thereof into said work chamber, means for admitting a raw gas into said work chamber, means for producing a vapor of a lithium compound and for separately admitting the same into said combustion chamber and into said work chamber and means for variably closing said openings, whereby to control the passage of said reaction products into said work chamber.

5. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, an endothermic reaction chamber, a partition intermediate said chambers and forming a common wall thereof, said partition serving to absorb heat from said exothermic reactions and to impart said heat radiantly to said endothermic reaction chamber, means for supplying a carbonaceous material to said endothermic reaction chamber which is capable of reacting endothermically by absorption of heat from said endothermic reaction chamber, means for passing the reaction products from said exothermic combustion chamber into said endothermic reaction chamber for admixture with said endothermic reaction products, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

6. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, means for adding a lithium compound to said chamber, an endothermic reaction chamber, a partition intermediate said chambers and forming a common wall thereof, said partition serving to absorb heat from said exothermic reactions and to impart said heat radiantly to said endothermic reaction chamber, means for supplying a carbonaceous material to said endothermic reaction chamber which is capable of reacting endothermically

by absorption of heat from said endothermic reaction chamber, means for maintaining said carbonaceous material below its endothermic reaction temperature during its passage into said chamber, means for passing the combustion products from said exothermic reaction chamber into said endothermic reaction chamber for admixture with said endothermic reaction products, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

7. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, an endothermic reaction chamber, a partition intermediate said chambers and forming a common wall thereof, said partition serving to absorb heat from said exothermic reactions and to impart said heat radiantly to said endothermic reaction chamber, means for supplying a carbonaceous material to said endothermic reaction chamber which is capable of reacting endothermically by absorption of heat from said endothermic reaction chamber, means for passing the reaction products from said exothermic combustion chamber into said endothermic reaction chamber for admixture with said endothermic reaction products, means for separately adding lithium compounds in vapor form to each of said chambers, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

8. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, an endothermic reaction chamber, an apertured partition intermediate said chambers and forming a common wall thereof, said partition serving to absorb heat from said exothermic reactions and to impart said heat radiantly to said endothermic reaction chamber, and to permit the passage of gases from said exothermic combustion chamber to said endothermic reaction chamber, means for supplying a carbonaceous material to said endothermic reaction chamber which is capable of reacting endothermically by absorption of heat from said endothermic reaction chamber, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

9. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, an endothermic reaction chamber, a reticulated partition intermediate said chambers, said partition serving to permit the passage of gases from said exothermic combustion chamber to said endothermic reaction chamber, means for supplying a carbonaceous material to said endothermic reaction chamber which is capable of reacting endothermically by absorption of heat from said endothermic reaction chamber, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

10. In a combustion furnace for metal heating, the combination of an exothermic combustion chamber, means for supplying air and fuel thereto in proportion to react exothermically therein to produce hot reaction products, an endothermic reaction chamber, an apertured partition intermediate said chambers and forming a common wall thereof, said partition serving to absorb heat from said exothermic reactions and to impart said heat radiantly to said endothermic reaction chamber, and to permit the passage of gases from said exothermic combustion chamber to said endothermic reaction chamber, means for supplying a carbonaceous material to said

endothermic reaction chamber which is capable of reacting endothermically by absorption of heat from said endothermic reaction chamber, means for separately adding lithium compounds in vapor form to each of said chambers, means in said endothermic reaction chamber for supporting work to be heated and means for venting the gaseous products from said endothermic reaction chamber.

11. The method of heating metal in the work chamber of a metal heating furnace and producing a gaseous atmosphere therein, comprising exothermically reacting air and a hydrocarbon fuel externally of said chamber to produce hot gaseous reaction products, adding lithium carbonate to said hot reaction products, introducing the hot lithiated reaction products into the chamber to impart heat thereto, adding an unreacted hydrocarbon gas to said chamber and utilizing said heat to raise the temperature of said metal to the desired degree and to endothermically crack said unreacted hydrocarbon gas to produce nascent carbon in said chamber.

12. The method of heating metal in the work chamber of a metal heating furnace and producing a gaseous atmosphere therein, comprising exothermically reacting air and a hydrocarbon fuel externally of said chamber to produce hot gaseous reaction products having a CO/CO₂ ratio between 0.3 and 0.45, adding lithium carbonate in vapor form to said hot reaction products, introducing the hot lithiated reaction products into the chamber to impart heat thereto, adding an unreacted hydrocarbon gas to said chamber and utilizing said heat to raise the temperature of said metal to the desired degree and to endothermically crack said unreacted hydrocarbon gas to produce nascent carbon in said chamber.

13. The method of heating metal in the work chamber of a metal heating furnace and producing a gaseous atmosphere therein, comprising exothermically reacting air and a hydrocarbon fuel externally of said chamber to produce hot gaseous reaction products, adding lithium carbonate to said hot reaction products, introducing the hot lithiated reaction products into the chamber to impart heat thereto, adding an unreacted hydrocarbon gas to said chamber, utilizing said heat to raise the temperature of said metal to the desired degree and to endothermically crack said unreacted hydrocarbon gas to produce nascent carbon in said chamber and adding additional lithium carbonate in vapor form to said chamber.

14. The method of heating metal in the work chamber of a metal heating furnace and producing a gaseous atmosphere therein, comprising exothermically reacting air and a hydrocarbon fuel externally of said chamber to produce hot gaseous reaction products, adding lithium carbonate to said hot reaction products, introducing the hot lithiated reaction products into the chamber to impart heat thereto, adding an unreacted hydrocarbon gas to said chamber, utilizing said heat to raise the temperature of said metal to the desired degree and to endothermically crack said unreacted hydrocarbon gas to produce nascent carbon in said chamber, flowing said products into contact with said metal and then venting the same from said chamber, the aggregate volume of said exothermic and endothermic reaction products being sufficient to maintain continuously a positive gas pressure in said chamber.

15. The method of heating steel in the work chamber of a metal heating furnace and producing a carburizing gaseous atmosphere therein, comprising exothermically reacting air and a hydrocarbon fuel externally of said chamber to produce hot gaseous reaction products, adding lithium carbonate to said hot reaction products, introducing the hot lithiated reaction products into the chamber to impart heat thereto, adding an unreacted hydrocarbon gas to said chamber and utilizing said heat to raise the temperature of said steel to the carburizing range and to endothermically crack said unreacted hydrocarbon gas to produce nascent carbon having a positive

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carburizing potential to said steel in said chamber, flowing said products into contact with said steel and then venting the same from said chamber, the aggregate volume of said exothermic and endothermic reaction products being sufficient to maintain continuously a positive gas pressure in said chamber. 5

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