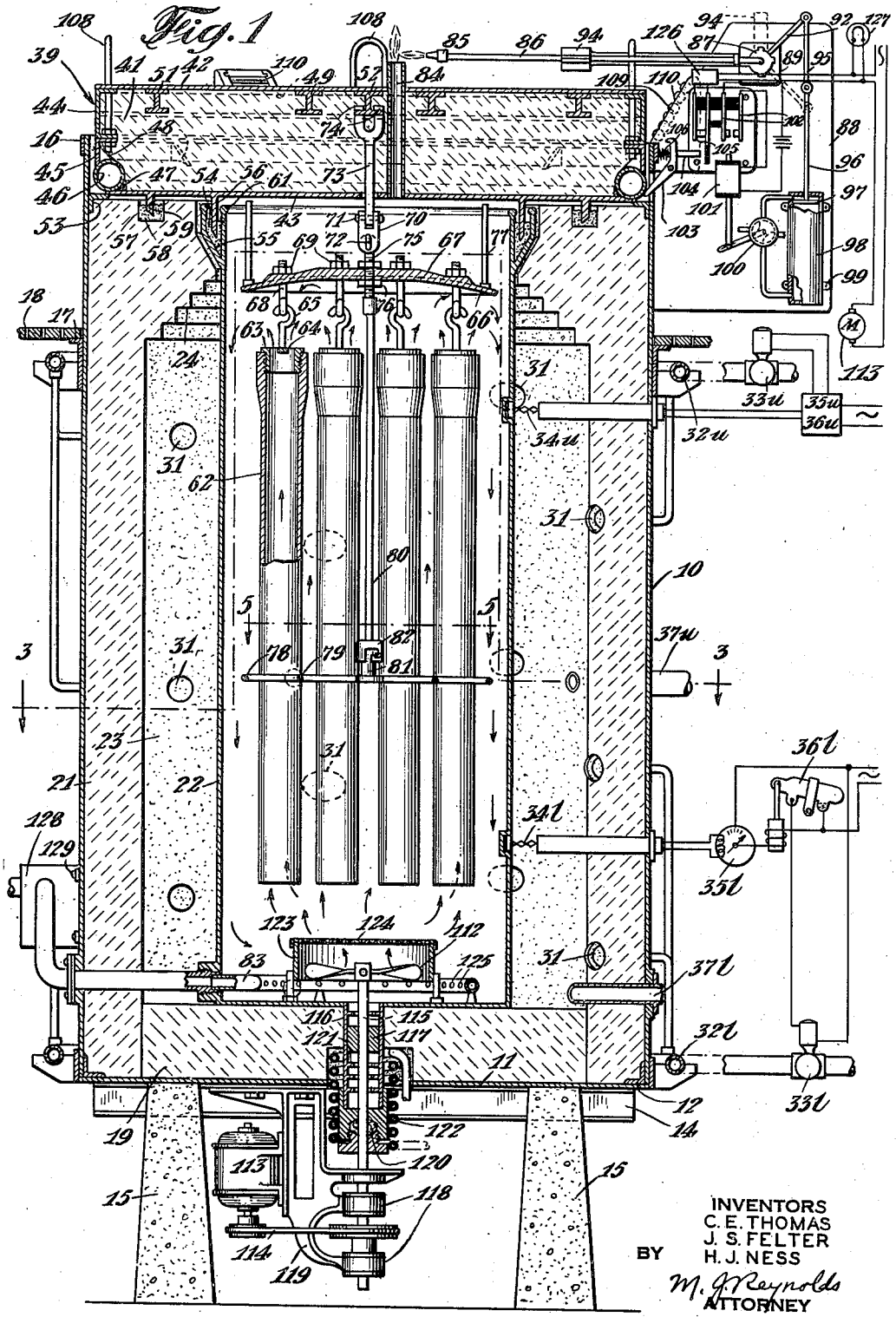
Dec. 14, 1948. C. E. THOMAS ET AL 2,456,469

METALLURGICAL FURNACE

Filed June 10, 1943

4 Sheets-Sheet 1

Fig. 1



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METALLURGICAL FURNACE

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Fig. 2

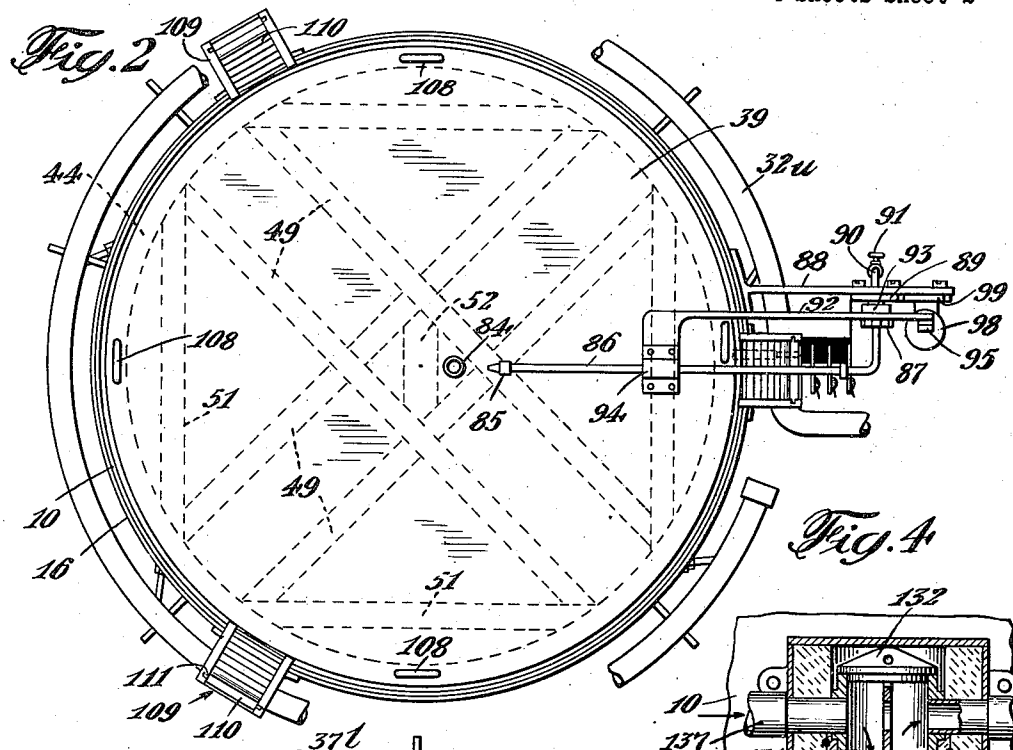


Fig. 4

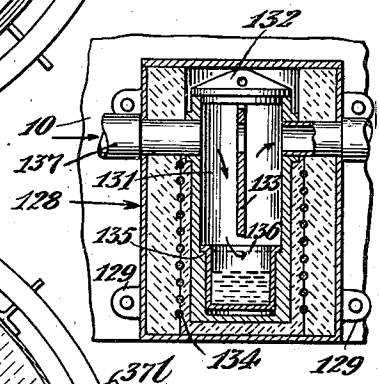


Fig. 3

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METALLURGICAL FURNACE

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Fig. 6

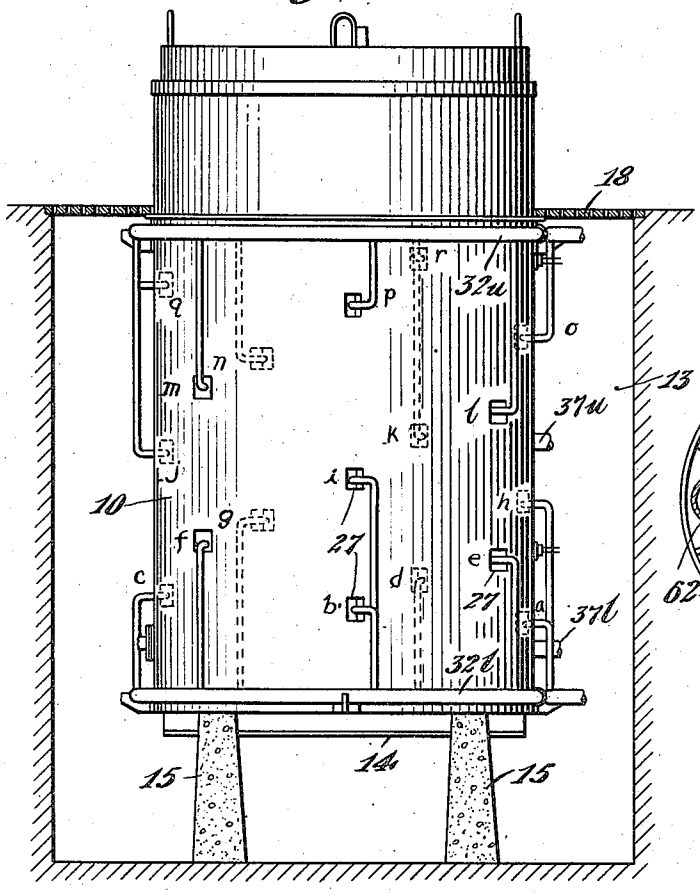


Fig. 5

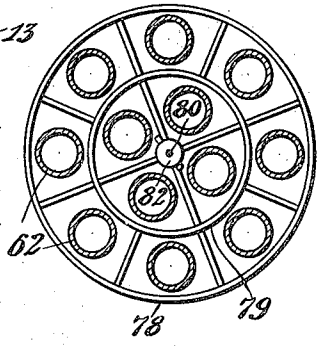
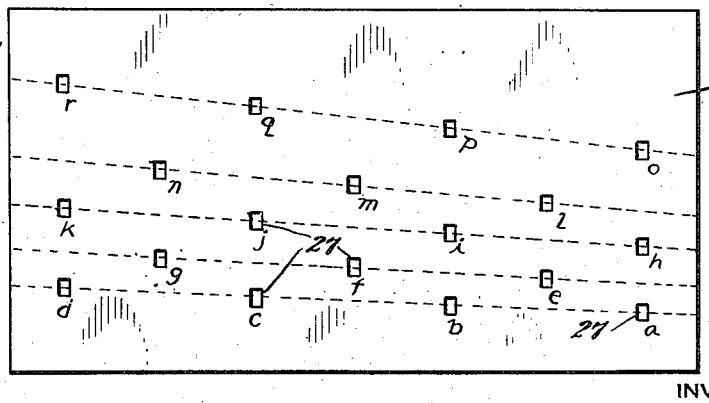


Fig. 7



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METALLURGICAL FURNACE

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Fig. 8

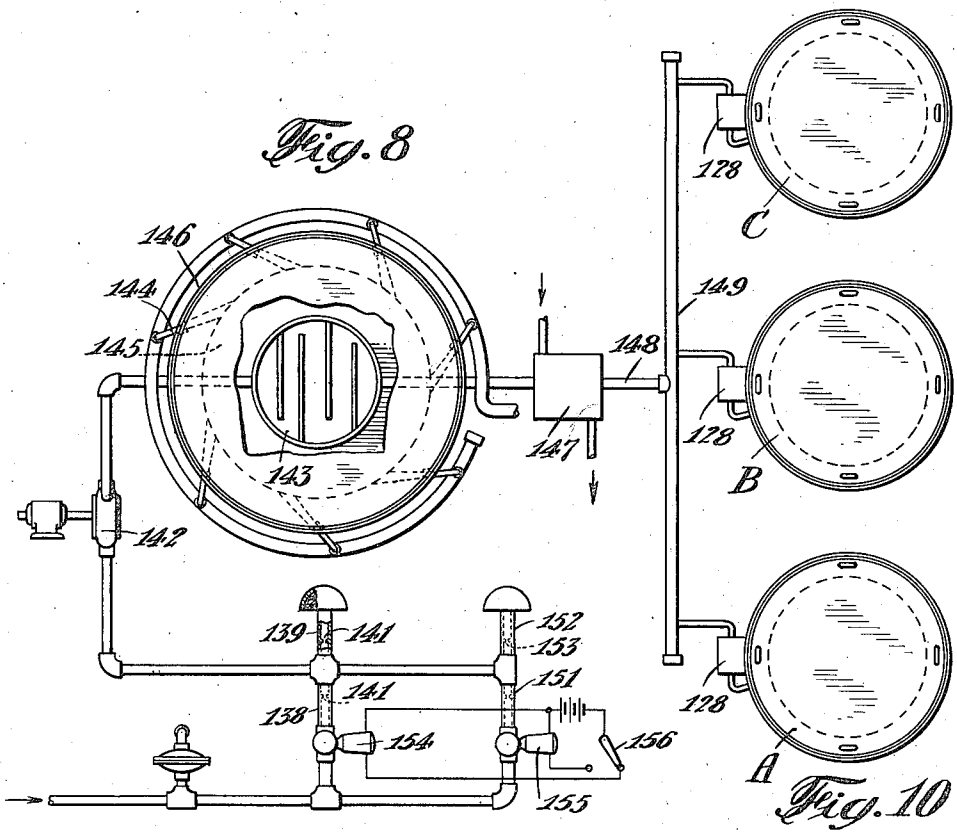


Fig. 10

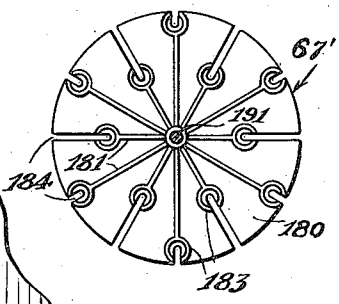


Fig. 9

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Patented Dec. 14, 1948

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UNITED STATES PATENT OFFICE

2,456,469

METALLURGICAL FURNACE

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Application June 10, 1943, Serial No. 490,256

25 Claims. (Cl. 263—40)

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This invention relates to metallurgical furnaces and more particularly to furnaces of the pit or vertical type employing a closed muffle for the work to be heated.

The invention is described with particular reference to a controlled atmosphere furnace in which the muffle is provided with a metallic vapor atmosphere which may be either neutral to the work parts or carburizing, as desired, although it is to be understood that certain features of the invention are applicable to other types of furnaces.

The preferred embodiment of the invention described herein comprises a vertical muffle or heat treating chamber adapted to be heated by external means. The heating means may comprise electrical heating units, but preferably the muffle is surrounded by a combustion chamber having walls of refractory insulating material through which suitable burners extend for the combustion of an oil or gas fuel. The refractory walls of the combustion chamber are preferably arched or corbelled at the top to form a substantially closed combustion chamber. The muffle, however, is open at the top and is normally closed by a removable cover which forms a gas-tight seal with the upper end thereof. This cover affords access to the muffle for introduction therein or the removal therefrom of the work to be treated.

Heretofore, in furnaces of the open-top vertical muffle type, it has been customary to support the cover of the muffle either on the open end of the muffle directly in the heated area of the furnace or directly on the refractory brickwork surrounding the muffle. Both of these means of supporting the cover are objectionable. When the cover rests directly on the top of the muffle, it imposes a severe load on the hot muffle, particularly since the cover must be heavy in order to provide the necessary heat insulation for the top of the furnace. The walls of the muffle, at the elevated temperatures at which they are operated, often near the melting point thereof, have little strength, and therefore in order to support the weight of the cover must be made many times heavier than would otherwise be required. Since the muffle is ordinarily made of expensive heat resisting metal, such as nickel or nickel-chromium alloy, to withstand the corrosive effect of the combustion gases, the increase in weight is of prime importance. Moreover, at the higher temperatures prevailing in the furnace, the walls of the muffle tend to sag or distort under the weight of the cover, and the life of the muffle is materially shortened.

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If the cover is extended over the muffle so as to rest on the surrounding brickwork, another difficulty is encountered, namely, the chipping and wearing away of the upper surface of the brickwork by the frequent removal and replacement of the heavy cover for unloading and loading of the furnace. Furthermore, in order to give the side walls sufficient strength to resist the impact and the weight of the cover, it is necessary to construct the same of dense, hard burned brick which has relatively poor insulating properties compared with the lighter, more porous insulating brick.

In accordance with the present invention, the furnace cover or roof is supported entirely independently of and out of contact with both the muffle and its surrounding brickwork and on a cool part of the furnace structure. The cover support is maintained at a relatively low temperature by its position remote from the heated chambers of the furnace, and by providing maximum heat insulation therebetween. Suitable heat seals may also be located between the furnace chambers and the cover support. Since the cover support is retained at normal temperature, it retains its normal strength and therefore need not be made unduly heavy. Moreover, the cover may be made sufficiently strong to permit the parts to be heated to be suspended entirely therefrom rather than to be supported in the customary manner by the muffle. Thus, by carrying the weight of both the cover and the furnace load independently of either the muffle or its surrounding brickwork, the former may be formed of thin walled stock and the latter of light, porous brick of high insulating value.

A gas seal, comprising cooperating parts of the cover and muffle, may be provided to isolate the muffle chamber completely from the combustion chamber.

In accordance with another feature of the invention, guide means is provided for centering the cover and guiding it to its seat during replacement thereof during the reloading operation.

As heretofore stated, the muffle is provided with a metallic vapor atmosphere such as disclosed in patent to H. J. Ness, No. 2,181,093, granted November 21, 1939, and this atmosphere may be either neutral or carburizing to the work to be treated, as desired, as fully disclosed in Patent No. 2,394,002 of H. J. Ness, granted February 5, 1946. Briefly, this atmosphere is produced by passing a carrier gas, such as results from a com-

bustion or cracking of an air and gas mixture, over suitable lithium compounds maintained at an elevated temperature whereby the carrier gas absorbs a portion of the vapor given off by the lithium compound This lithiated gas is introduced into the muffle and is circulated therethrough in contact with the work in any suitable manner, as by a fan or blower. This atmosphere may be either neutral to the work or carburizing, depending upon the nature of the carrier gas. In order to prevent the muffle atmosphere from being driven from the muffle when the cover is removed, suitable control means is arranged to be operated by removal of the cover to interrupt the operation of the circulating means and by replacement of the cover to restart the operation thereof.

Numerous other features of the invention will be apparent as the description proceeds.

As will be evident from the foregoing, one of the principal objects of the invention is to provide a furnace of the type described, in which there will be no load upon the muffle or upon the refractory furnace walls, thereby permitting the muffle to be made of thin walled alloy and the furnace walls to be made of light, porous brick of high insulating value.

Another object is to prevent damage to the muffle or to the furnace walls due to frequent removal of the cover and the charge from the furnace and the replacement of the cover and insertion of a new charge within the muffle.

Another object of the invention is to support the work to be heated independently of its containing muffle or of the refractory furnace walls.

Another object is to facilitate the loading and unloading of the furnace so that these operations may be conducted quickly and conveniently and with a minimum of heat loss from the furnace.

Still another object is to support the work parts in the furnace out of contact with the walls thereof and with each other whereby there will be no local hot or cold spots on the work and whereby the furnace atmosphere will have free access to all parts of the work.

Another object is to preclude the presence of pockets of trapped air in the work parts, carried into the furnace thereby.

Still another object is to provide a furnace in which any air entering into the furnace during loading or carried into the furnace by the work parts, will be rendered nonoxidizing to the parts by chemical reaction with the furnace atmosphere.

Another object is to provide a progressively advancing oxygen fixation front from the inlet of the protective atmosphere to the muffle outlet, following the introduction of a load of work parts into the muffle.

Another object is to provide a muffle furnace of the pit type heated by an external combustion chamber in which leakage of the products of combustion from said chamber into the muffle will be prevented.

Another object of the invention is to provide a suitable seal containing displaceable material for the top of the muffle and to facilitate the displacement of said material during the sealing operation.

Another object is to provide a cool zone of support for the removable cover and for the work parts.

A still further object is to provide an even and uniform heating of the muffle.

Still another object is to provide a novel arrangement of burners for the combustion chamber whereby maximum spacing therebetween and a minimum of impingement of the products of combustion on the muffle walls will be obtained.

Other objects and advantages will hereinafter appear.

The invention will be better understood by reference to the accompanying drawings, wherein:

Fig. 1 is a vertical sectional view of a pit type furnace embodying a number of features of the present invention, taken on the line 1—1 of Fig. 3;

Fig. 2 is a plan view of the furnace showing the removable cover thereof;

Fig. 3 is a sectional view on the line 3—3 of Fig. 1, showing the arrangement of the burners for the combustion chamber and the atmosphere inlet for the muffle;

Fig. 4 is a sectional view on the line 4—4 of Fig. 3, showing the lithium generator employed therewith for conditioning the furnace atmosphere;

Fig. 5 is a sectional view on the line 5—5 of Fig. 1, showing the work parts and work retaining ring;

Fig. 6 is an elevational view of the furnace, showing the arrangement of the burners and the manifolding thereof;

Fig. 7 is a developed view of the furnace shell on a reduced scale, showing the arrangement of the burners;

Fig. 8 is a layout view, showing the arrangement of a number of furnaces of the type shown in Fig. 1 in connection with a common carrier gas generator;

Fig. 9 is a sectional view of a modified form of cover and work support; and

Fig. 10 is a plan view of the work support of Fig. 9.

In Fig. 1 there is shown a furnace comprising an outer steel shell 10 of cylindrical form having its lower portion closed by a plate 11 welded thereto. A reinforcing annular angle 12 is also welded to the juncture of the shell 10 and bottom plate 11. The shell is supported within a pit 13 (Fig. 6) upon suitable beams 14 carried upon a number of columns 15. A reinforcing ring 16 is welded about the open upper end of the shell 10, and an annular angle 17 is welded to the shell at the floor level to serve as a support for the grating 18 forming a cover for the pit 13.

The shell 10 is lined with refractory brickwork composed of a base 19 of hard burned brick and a side wall 21 of a light, porous brick of high insulating value. A cylindrical muffle 22 is disposed centrally within the brickwork, resting directly upon the hard burned brick base 19 and spaced from the side wall 21 to form a combustion chamber 23, and the side wall 21 is corbelled at 24 to meet the muffle 22, to form a roof for the combustion chamber. A number of burners 25, Fig. 3, extending tangentially through the side wall 21 are arranged on an ascending helical line of increasing pitch, Fig. 6, whereby the greatest concentration of burners occurs near the base of the combustion chamber with a progressively greater spacing between the burners upwardly, thus compensating for the increased heat at the top of the muffle due to the tendency of the heated gases to rise in the combustion chamber, and thus maintaining the muffle 22 at a substantially uniform temperature throughout its length. The circumferential spacing of the burners is such that the burners located on one turn of the helical line are

positioned circumferentially intermediate those on adjacent turns. One arrangement of the burners is shown in the developed view of the shell 10 in Fig. 7, in which burners are indicated by the letters *a* to *r*. The spacing between burners of each turn is such that there will be an odd number of burners in each two turns of the helix. This arrangement enables maximum spacing between the burners of adjacent turns to be obtained, which promotes better bonding of the wall and reduces the danger of weak vertical zones therein, particularly adjacent the base where the spiral is relatively flat and the vertical spacing between burners is small. It also promotes a more continuous spiraling and swirling movement of the combustion gases and reduces impingement of the gases on the outer wall of the muffle 22, thus preventing localized hot spots in the muffle and the disintegrating effect which direct impingement of the combustion gases has on the muffle wall due to surface combustion on the wall of the muffle.

Each of the burners 25, as shown in Fig. 3, is secured by a burner bracket 26 to an angled recess 27 formed in the shell 10. The burner extends through the wall of the recess 27, and through a hard burned brick 28, terminating in a molded refractory burner block 29 which forms an outwardly flaring burner tunnel 30 connecting with a passage 31 in the refractory side wall. The angle of the burner and the burner tunnel is such that its axis is substantially tangent to the mid-circumference of the combustion chamber, thereby permitting the combustion gases to swirl around the combustion chamber with a minimum of interference from the walls of the combustion chamber and with a natural flow into the gas stream issuing from the next adjacent burner. The movement of the gases is thus augmented by the gases issuing from each suceeding burner, producing a smooth spiral flow of considerable velocity around the outer wall of the muffle 22. Due to centrifugal action, the gases scrub the inner wall of the brickwork, which aids in the extraction of the heat from the gases and a uniform heating of the muffle by radiation from the hot brickwork.

The burners 25 are provided with a combustible mixture of air and gas from a pair of manifolds 32U and 32L (Figs. 1, 2, 3, and 6) disposed about the shell 10 and supported thereon by suitable brackets. The upper manifold 32U serves the burners in the upper half of the furnace, and the manifold 32L serves the lower group of burners. Each manifold is provided with an electrically operated supply valve 33U and 33L, which is controlled by an individual pyrometer 34U and 35L, located in the zone serviced by the respective manifold through adjustable galvanometer switches 35U, 35L and mercury switches 36U, 36L. Thus, the upper and lower zones of the furnace are separately controlled to aid in maintaining a uniform temperature throughout the length of the muffle. The products of combustion are exhautsed from the chamber 23 by two sets of exhaust ports 37U and 37L, the former consisting of three ports located just below the upper group of burners and the latter, as best shown in Fig. 3, consisting of three ports located just below the lower set of burners. Each exhaust port is formed of a heat resisting alloy tube extending through the brickwork and serving to conduct the gases to a suitable stack or ventilator, not shown. The provision of a separate set of exhaust ports for each of the sets of burners also aids in maintaining a uniform temperature within the muffle, since the two sets of burners will operate on different "off" and "on" time intervals under their individual controls.

The open upper end of the muffle 22 is closed by a removable cover 39 comprised of a metal shell containing refractory heat insulation 41. The shell is formed by two spaced discs or plates 42 and 43 separated by an annular ring formed of a channel member 44, an angle 45, and a tube or pipe 46, each welded to its adjoining member. An annular angle 47 welded to the pipe 46 forms a seat for the lower plate 43, which is of heat resisting alloy. A number of gusset plates 48 are welded between the pipe 46 and the angle 45 to reinforce the same and to absorb any shock imparted thereto by the cover centering means during the lowering of the cover to its seat. This centering means will be described subsequently. The cover is reinforced by four substantially diagonal I-beams 49 subtended by four I-beams 51. A short section of I-beam 52 extends between the intersections of the I-beams 49. All of these reinforcing beams are welded to each other and to the channel member 44 and are for the purpose of providing a strong, rigid structure from which the heavy work parts to be treated may be suspended within the muffle, as will hereinafter appear.

The cover 39 with the work parts to be suspended therefrom is supported independently of the muffle 22 and the brick side wall 21 at a part of the furnace which is maintained at a relatively low temperature. For this purpose an annular angle 53 is welded to the interior of the shell with its upper face slightly above the top of the brick side wall 21 and the muffle 22, thereby maintaining a space between the bottom cover plate 43 and these members when the cover is resting upon its seat 53. Thus, neither the cover 39 nor the work parts can impose any load on the muffle or on its surrounding brickwork or effect any damage thereto. As a consequence, the muffle 22 may have a relatively thin wall, sufficient only to support its own weight when heated. This results in a large saving of metal and a substantial economy in construction cost. It also promotes more rapid heat transfer from the combustion gases in the outer chamber 23.

In order to seal the interior of the muffle 22 from the combustion chamber 23, an annular trough 54 is formed at the upper end of the muffle in which a suitable displaceable sealing material 55 may be contained. Preferably this material is granular chrome ore, substantially free of powder and of a sufficient size to have a low angle of repose, so as to prevent packing and to permit ready displacement thereof, although beach sand or other suitable refractory sealing material may be used. An annular fin or ring 56, depending from the cover plate 43, is provided for entry into the trough 54 to complete the seal. This ring 56 is beveled at its lower edge to facilitate displacement of the sealing material.

A similar seal, comprising an annular trough 57 formed in the brick side wall 21, a sealing medium 58, and a cooperating depending sealing ring 59 provide a heat seal to isolate the cover supporting ring 53 from the combustion gases. The depending length of the sealing rings 56 and 59 is such that they engage in the troughs 54 and 57 only after the cover 39 has progressed into the extended upper end of the shell 10 a short distance, thus insuring correct centering

of the cover over the muffle and proper alignment of the sealing rings over their respective troughs before entry of the rings into the troughs. Possible damage to the sealing rings, or to the muffle, or the brickwork, by accidental engagement of the sealing rings therewith is thus prevented. In order that there will be no sudden shock imparted to the muffle 22 by the sealing ring 56, transmitted through the sealing material 55, should the cover be lowered to its seat at an abnormal rate, the outer sealing ring 59 is made of considerably greater wall thickness than the ring 56 which, together with its greater diameter, gives it a much larger area of contact with the sealing material than has the inner ring 56. The shock of a sudden movement of the cover to its seat will, therefore, be taken up primarily by the outer ring. To stiffen the upper end of the muffle 22 and protect it from accidental knocks, as from the work parts, if improperly loaded, and to retain the sealing medium therein, a beading 61 is formed about the upper end of each wall of the trough 54.

The parts to be treated are shown in Fig. 1 as comprising tubular blanks 62 for use in the production of steel propeller blades for aircraft. These blanks are threaded at their upper ends for subsequent attachment to the propeller hub and these threads are utilized to suspend the blanks within the muffle 22. For this purpose a hollow plug 63, having apertures 64 therein and a hook 65 formed thereon, is threaded into the blanks. The apertures 64 are provided for the escape of the air contained within the tubes when first loaded into the furnace and for circulation of the protective furnace atmosphere therethrough during the heat treatment, as will hereinafter appear. The blanks 62 are suspended from a plate 66 having stiffening ribs 67 cast thereon and provided with a group of depending hooks 68 secured thereto, as by means of nuts 69, for interengagement with the hooks 65. The plate 66 extends to adjacent the side wall of the muffle 22 and its lower surface is concave so that it will serve as a baffle to direct the muffle atmosphere in a circulatory path, as will hereinafter appear. It is carried by the cover 39 through a quickly detachable universal coupling comprising a double shackle member 70 having its pins 71 and 72 disposed at right angles. The shackle is secured by its upper pin 71 to a rod 73 fixed to the cover I-beam section 52, as by bolts 74, and the baffle plate 66 is suspended therefrom by a rod 75 passing loosely through the plate 66 and having a nut 76 on its lower end. The shackle pin 72 is removable and passes through the eyes of the shackle and rod 75. In order to limit swinging of the plate 66 on the shackle bolts, a number of upstanding posts or lugs 77 are provided on the plate 66 extending to adjacent the cover 39. Swinging of the blanks 62 on the hooks 68 is prevented by concentric retaining rings 78 and 79, Fig. 5, removably carried by a depending rod 80 rigidly secured to the under side of the plate 66. The ring structure is spidered to a sleeved hub 81 having a pin and bayonet connection to a sleeve 82 carried by the rod 80. Thus, after the blanks 62 have been secured to the plate 66 externally of the furnace, the retaining ring structure is slipped up over the ends of the tubes and fastened in place by the sleeve 82.

A protective atmosphere is introduced into the muffle 22 under slight pressure through a conduit 83 and is exhausted therefrom by a vent 84 extending through the cover 39. The escaping gases are ignited by a pilot burner 85 carried by a pipe 86 extending over the cover 39. The pipe 86 is threaded in the elbow of a swivel coupling 87 bolted through a squared flange 89, to a bracket 88 carried by the furnace shell. The coupling 87 communicates with a gas supply conduit 90, Fig. 2, having a suitable valve 91 for regulating the length of the pilot flame. The burner 85 is adapted to be moved away from the cover 39 and back into position to re-ignite the vented gas, upon the removal and displacement of the cover, by a lever 92 pivoted on the sleeve section 93 of the coupling and clamped at 94 to the pipe 86. The outwardly extending end of the lever 92 is pivotally connected by a link 95 to the plunger rod 96 of a piston 97 contained within the cylinder 98 secured to the bracket 88 by the lugs 99. Air under pressure is admitted alternately above and below the piston 97 by a reversing valve 100 operated by a solenoid 101 controlled by a switch 102 in accordance with the position of the cover 39. A switch operating lever 103 pivoted on the bracket 88 has one end extending through the shell 10 into the path of the cover 39 so that with the cover in closed position the lever will be depressed and its outwardly extending arm will be held out of engagement with the contact arm 104. Therefore, contacts 102 will remain open and contacts 105 will be closed. In this condition of the switch, solenoid 101 will be de-energized, and the reversing valve 100 will be so positioned as to admit air to the under side of the piston 97 whereby to retain the piston in its uppermost position so that the pilot burner 85 will be located over the cover 39 of the furnace in position to keep the exhaust gases from the furnace ignited. However, upon the initial movement of the cover upwardly, lever 103 will rock under action of the spring 106 to close contacts 102, and energize the solenoid 101 so as to reverse the valve 100. Air pressure will then be applied above the piston 97 to draw the link 95 downward, and thus rock the lever 92 and pipe 86 to the vertical dotted line position away from the cover 39. On return of the cover 39 to its seat, the reverse action occurs, and the pilot burner is returned to its horizontal position over the furnace to reignite the gases escaping from the vent 84. Since the vent 84 is disposed substantially centrally of the cover, the pilot flame will ignite the escaping gases irrespective of the angular position of the cover on its seat; thereby no indexing of the cover is required. With a commercial size furnace, the pipe 86 will be sufficiently long to elevate the burner above the floor at such height as to produce no hazard. It will be understood that the pilot burner will be pivoted at the side of the shell 10 remote from the direction of loading and unloading of the muffle.

The loading and unloading of the furnace is effected by a traveling crane or hoist having a chain gear which engages the cover 39 by means of four eyes 108 suitably anchored to the lower flange of the channel frame member 44. The operation of unloading the furnace comprises the lifting of the cover and its load of work parts vertically so that the work parts clear the top of the furnace and a lateral movement of the cover to a point where the work parts may be lowered between a pair of suspended rails upon which the plate 66 may rest. With the load thus removed from the cover 39, the shackle pin 72

may be removed and the cover positioned over another plate 66 carrying a cold load. The shackle pin is reinserted and the cover and cold load conveyed to a point vertically above the muffle 22 and then lowered in place. In order to center the cover in the shell 10 and align the sealing rings 56 and 59 with their troughs, a number of centering guides 109 are secured to the upper edge of the furnace shell. Each of the guides 109 comprises a U-shaped bracket, the upper edges of which slope outwardly from the cover, and a series of needle rollers 110 loosely journaled in grooves 111 in the opposite arms of the bracket. The brackets are secured to the shell in any suitable manner, as by welding. In lowering the cover into position, should it be slightly off center, the annular pipe 46, which has a relatively large radius, will engage one or the other of the guides to give it the required lateral movement to center it with respect to the muffle and enable it to pass freely into the furnace opening.

To promote the circulation of the atmosphere through and around the blanks, a fan 112 is provided in the base of the muffle, driven from a suitable motor 113 by means of a belt 114 and a shaft 115. The shaft 115 extends through a tubular extension 116 of the muffle 22 and is provided with a pressed graphite bearing 117 within the tube 116 and with a pair of ball or roller bearings 118 carried by a bracket 119 secured to the bottom plate 14 of the furnace. The tube 116 is sealed by a gland 120 and is provided with a number of heat insulating disks 121 for baffling the flow of hot gases through the tube 116 and for conducting the heat away from the shaft 115 and the gland 120. If desired, the gland may be cooled by either an air stream or by circulating water thereabout, as by the coil 122. A tubular fan housing 123 elevated from the floor of the muffle on legs or brackets surrounds the fan 112 and tends to direct the atmosphere stream upwardly through and around the work parts 62. It is covered with a wire mesh 124 to diffuse the gases and prevent injury to the fan by any work parts or other objects dropped into the muffle accidentally.

The atmosphere forced upwardly by the fan through the center of the muffle into and around the tubes 62 is deflected at the top of the muffle by the baffle plate 66, passing towards the side wall of the muffle and sweeping down over the heated surface thereof in a vertical circulatory path. A portion of the atmosphere passes around the edge of the plate 66 and escapes through the vent 84, where it is ignited. The burning gases at the vent 84 serve as an indication of the condition of the muffle atmosphere, burning with the characteristic scarlet color of lithium when the atmosphere is properly conditioned. The opening through the vent 84 is of such size as to maintain a slight pressure within the muffle.

The operation of the fan 112 is controlled by the removal and replacement of the cover 39 through the switch contacts 105 operated by the switch lever 103. With the cover in position, the contacts 105 will be closed and the motor circuit completed, but upon removal of the cover these contacts will be opened to quickly interrupt the motor circuit and stop the operation of the fan so that the hot atmosphere in the muffle will not be driven up about the sides of the cover as it is lifted from its seat. The fan then remains out of operation throughout the entire unloading and reloading operation.

The inlet conduit 83 for the muffle atmosphere encircles the fan housing 123 below the lower edge thereof. It is provided with a series of slots 125 on its inner face for the admission of the protective gas into the muffle, radially in the direction of circulation of the muffle atmosphere as produced by the fan 112 when it is in operation. In addition to providing a uniform distribution of the lithiated gas to the blower, the extension of the conduit 83 through the combustion chamber 23 and in a long path in the base of the muffle enables the incoming gas to be brought up to the muffle temperature before issuing into the muffle. This preheating of the lithiated gases promotes the reaction of the lithium with the combustion products in accordance with the equations set forth hereinafter.

By virtue of the quickly detachable coupling 72 whereby the complete load may be detached from the cover and a new load quickly secured thereto, the unloading and loading period may be very brief, thereby preventing substantial heat loss from the furnace. However, the removal of the cover permits the external air to enter into the muffle 22, and a substantial volume of air is also carried into the muffle within the tubular work parts. To expedite the removal of the air from the muffle and for the fixation of the oxygen contained therein, by the protective atmosphere introduced into the base of the muffle, it is preferable to retain the blower at rest for a short period after the cover has been replaced. For this purpose the switch contacts 105, which are closed by the replacement of the cover, do not immediately energize the motor, a delay being introduced by a time delay switch 126 such as an electric timer or a dashpot relay, thus holding the blower circuit open for a sufficient period to substantially rid the muffle of the air or oxygen therein. The time delay switch 126 may be adjusted so that its contacts will not close until after the tell-tale scarlet flame appears at the vent 84.

The restoration of the desired protective atmosphere in the muffle is not dependent upon the physical displacement of the air by the incoming gas, but primarily upon a chemical fixation of the oxygen and water vapor content, the latter effect being obtained from the lithium introduced therein. Lithium has a strong affinity for oxygen and permeates the muffle chamber, penetrating into the interior of the tubes 62 and chemically uniting with any oxygen or water vapor therein to fix the same, as will presently appear. As stated, when the cover 39 of the furnace is removed, the lithiated atmosphere in the muffle escapes and is replaced by air. The fan 112 is at rest at this time, and the lithiated gases issuing from the apertures 125 in the conduit 83 into contact with this air burn in the base of the muffle. When the cover 39 is first replaced, the fan is still retained at rest, but as the oxygen adjacent the apertures 125 is consumed the incoming lithiated gases, which are only partially combusted, spread out radially and upwardly from the conduit 83, forming a substantially continuous atmosphere front which progresses upwardly, displacing a part of the air through the vent 84 and consuming the oxygen in contact therewith as it advances upwardly. The oxygen is in part converted by the CO and H_2 of the incoming gases to CO_2 and H_2O, and these together with any remaining oxygen are fixed by the lithium of the carrier gas. By retaining the fan 112 at rest during this cleaning up period, this combined flame propagation and oxygen fixation front is

permitted to advance upwardly of the muffle without intermixing of the air and the carrier gas, with a progressive fixation of the oxygen and water vapor content of the air as this oxygen fixation front advances.

When the lithiated gases reach the top of the muffle and start escaping from the vent 84, they will be ignited by the pilot burner 85, and this flame will gradually assume a rich scarlet color, indicating that the muffle has been entirely freed of any unfixed oxygen. When this scarlet flame appears, the fan 112 may be started, and the dashpot relay 126 may be adjusted to provide a time delay sufficient for this purpose.

In order that the furnace attendant will know when the fan 112 is operating, a signal lamp 127 is provided mounted at any suitable position, either on the furnace or on the control panel, operated in parallel with the fan motor 113.

The inlet pipe 23 for the muffle atmosphere extends from a lithium generator 128 suitably secured to the outer wall of the furnace, as by lugs 129. As shown in Fig. 4, this generator comprises a metal chamber 131 having a removable cover 132 from which a plate 133 depends. Around the chamber 131 is disposed an electrical heating coil 134 contained within suitable refractory insulation, and within the chamber there is a central cylindrical recess 135, in which is supported a metallic cup 136 containing suitable lithium compounds. A carrier gas is admitted into the lithium generator through a conduit 137, this carrier gas being deflected by the partition plate 133 over the cup 136 and thence by way of the conduit 83 into the muffle 22.

The carrier gas may be a non-oxidizing medium, such as nitrogen or hydrogen, although a gas resulting from the combustion or cracking of a liquid or gaseous fuel is preferred. Air may also be employed as a carrier gas, if desired, since the lithium fixes the oxygen therein. However, the use of air as a carrier gas requires the consumption of a greater quantity of lithium and is not preferred. Fig. 8 shows apparatus for producing a suitable carrier gas by the combustion of an air and gas fuel. Hydrocarbon gas, such as butane, propane, or natural gas, supplied from a conduit 138, and air drawn in through a conduit 139, each provided with an apertured plate or disc 141 for metering the proportion of each, are forced under slight pressure by a pump or blower 142 into a closed cracking chamber 143. The chamber 143 is heated by a series of burners 144 extending tangentially into the combustion chamber 145 of a furnace 146 in which the chamber 143 is contained. The ratio of the hydrocarbon gas to air is dependent upon the analysis of the former, and the purpose for which the muffle chamber is to be used. For the heat treating of metals, where a neutral atmosphere is desired, we prefer to employ a ratio of approximately 1 part of propane to 18 parts of air, whereas for carburizing a ratio of 1 part of propane to from 4 to 12 parts of air may be used, depending upon the analysis of the gas and the type, analysis and quality of the carburized case desired.

The furnace 146 may be of similar construction to the furnace of Fig. 1, with the closed cracking chamber 143 substituted for the muffle 22. The burners 144 are supplied with fuel and air from an independent source to provide heat of approximately 1800° to 1900° F. for cracking of the gases in the chamber 143, as fully described in Patent No. 2,346,698 of H. J. Ness, granted April 8, 1944, and entitled "Controlled atmosphere furnace." The cracked gases from the chamber 143 are passed through a condenser 147 where they are cooled and the major portion of the water is removed. A condenser suitable for this purpose is shown in the Patent No. 2,394,002 of H. J. Ness, previously referred to. The cooled and partially dried gases are conducted by a conduit 148 to a manifold 149 from which it is distributed to the lithium vaporizing chambers 128 of a number of treating furnaces A, B and C, similar to the furnace of Fig. 1. As stated, this gas in passing through the chamber 131 picks up the vapor emanating from the lithium compound in the cup 136 and carries it into the muffle 22.

The preferred charge within the cup 136 comprises a mixture of lithium carbonate and lithium chloride in the proportion of about 60% of the former and 40% of the later, by weight, which has been fused together at a temperature of about 1800° F. With a fused mixture of these proportions, sufficient vaporization occurs at a temperature of about 1300° F. to create an appreciable lithiated muffle atmosphere, although higher temperatures may be employed depending on the amount of lithium desired in the atmosphere. The amount of lithium salt required to produce a non-oxidizing and non-decarburizing and non-staining atmosphere in the muffle 22 is very small. With a muffle heated to 1400° F. and having a volume of approximately 100 cubic feet and provided with a mixture of air and gas entering the gas generator at the rate of about 1200 cubic feet per hour, a 7 to 8 ounce charge of lithium salts composed of 40% lithium chloride and 60% lithium carbonate, heated in the vaporizer to a temperature of 1800° F., will supply sufficient lithium to the atmosphere within the muffle to maintain the same for a period of 12 hours or more in a condition which is neutral to steels or other metals so that neither oxidation, nor decarburization, nor stainining thereof will occur. While it is desirable to maintain the charge in the vaporizing chamber 131 at a temperature of at least 1800° F. for the salt mixture specified, the muffle 22 may be operated at temperatures ranging from 450° F. up to the maximum temperature that the muffle will withstand.

While the exact nature of the chemical reactions occurring in the charge in the cup 136 or between the generated vapors and the combustion gases from the cracking chamber 143 is not fully known, the following explanation is supported by a large amount of experimental evidence.

The lithium chloride within the cup at the temperature prevailing therein is reduced to lithium metal by reaction with the hydrogen of the carrier gas in accordance with the equation

$$2LiCl + H_2 = 2Li + 2HCl$$

The hydrochloric acid so formed then reacts with the lithium carbonate or any lithium oxide in the cup to produce additional lithium chloride as follows:

$$2HCl + Li_2CO_3 = 2LiCl + H_2O + CO_2$$

$$2HCl + Li_2O = 2LiCl + H_2O$$

The lithium chloride formed by the above conversion reacts with hydrogen, as set forth above, to liberate a vapor of lithium metal.

In this manner the lithium carbonate is gradually converted to the chloride and thus to the metal, as the process proceds. The proportion of 40% lithium chloride and 60% lithium carbonate appears to be so balanced as to render the

rate of conversion substantially proportional to the rate of dissipation of the lithium vapor into the furnace atmosphere, whereby the liberation of lithium vapor continues at a substantially uniform rate until the charge in the cup is almost entirely consumed. The material leaving the charge in the cup 136 and entrained by the combustion gas thus appears to be the vapor of lithium metal with possibly some lithium oxide. The lithium oxide, if any, reacts with the carbon monoxide in the carrier gases to liberate lithium metal in accordance with the equation:

$$2Li_2O + CO = Li_2CO_3 + 2Li$$

The lithium is thus freed to combine with any oxygen in the furnace from whatever source, and the lithium carbonate of the above reaction is again broken down thermally within the furnace to lithium oxide, liberating carbon dioxide, or by reaction with hydrochloric acid gas, to produce lithium chloride, which by further reaction with hydrogen is reduced to lithium metal. These reactions are then repeated with the lithium oxide so formed.

It should be noted that, although the major portion of the water vapor is removed by the condenser 147 from the carrier gas introduced into the muffle, upon reheating of these gases to the muffle temperature further reactions occur in the gas mixture, causing the formation of additional quantities of water vapor. The addition of the lithium vapor to the muffle gases has the effect of either reducing any water vapor which so forms at the instant of formation or precludes the formation thereof by interaction with the oxygen before it has an opportunity to combine with the hydrogen to form water vapor. Due to the much smaller amount of water vapor which is formed by reaction within the muffle or within the conduits leading thereto, as compared with the amount which would be present in the absence of the condensing apparatus, the amount of lithium required to reduce or prohibit the formation of such water vapor is extremely small. This is true both when employing a heat treating mixture and a carburizing mixture within the muffle. In both cases the parts treated are neither oxidized, discolored, or stained in any manner by the atmosphere and come out of the furnace in a bright and clean condition.

The lithium, in addition to protecting the parts from oxidation or decarburization in the case of the heat treating atmosphere, also serves in the case of the carburizing atmosphere to accelerate carburization to such an extent that penetration of carbide is obtained with a much less concentrated hydrocarbon atmosphere than heretofore. For instance, in ordinary gas carburization employing hydrocarbon gases such as propane, it is the practice to employ approximately one part of propane to two parts of air in order to obtain carburization at a rate which is sufficiently fast to render the process commercially practical. Mixtures of such concentration, however, are sooty in nature and deposit large quantities of carbon or soot upon the parts, forming hard carbon scales thereon. As previously stated, in the presence of lithium, a mixture of one part propane to from 4 to 12 parts of air may be employed, which dilution produces a mixture which is substantially completely free of soot. The rate of carburization at such dilutions is much higher than that which is obtained with the ordinary carburizing mixture of two parts air to one part propane, and is of the order of .02 inch for the first hour and .01 inch for each succeeding hour at temperatures ranging from 1650° F. to 1700° F. Rapid carburization, at the ratio of gas and air specified, is also obtained at temperatures as low as 1500° F. This rapid carburization and effectiveness of the atmosphere at low temperatures is believed to result from the fact that the surface is maintained in a clean condition at all times during the carburizing process, and the oxidizing and deoxidizing phase of the usual carburizing equilibrium is eliminated. The ability to carburize at a rapid rate at temperatures between 1500° F. and 1600° F. is of considerable importance because steel in certain shapes tends to distort during carburization at higher temperatures. While we have referred to propane as the preferred carrier gas, it is to be understood that any type of carburizing gas may be employed.

It is to be understood that the furnace disclosed may be employed for either carburizing or heat treating merely by changing the proportion of air to hydrocarbon gas introduced into the cracking chamber 143. In case of heat treating furnaces alone, the cracking chamber 143 is not necessary, since the composite gas mixture may be burned directly in the combustion chamber 145 and exhausted therefrom into the manifold through the drying apparatus 147.

In order to enable the furnaces A, B and C to be used selectively for either heat treating or carburizing, a second set of gas and air inlet conduits are provided, the aperture plates 141 of one set being adjusted for a neutral gas atmosphere and the aperture plates 153 of the other set being adjusted for a carburizing gas atmosphere. Valves 154 and 155 in the gas inlets 138 and 151 are operated electrically by a control switch 156 whereby selective control of the muffle atmosphere is obtained.

In Figs. 9 and 10 there is shown a modified form of cover and work support. In this form the cover is composed of two annular channel members 157 and 158 welded together, with reinforcing pairs of crossed I-beams 159 and 161. The ring of channel members in this modification is of a diameter somewhat less than that of the outer wall 24 of the brickwork, to thereby reduce the weight of the cover, and the I-beams 159–160 extend beyond the cover and rest on the cold angle ring 162 carried at the top of the shell 10. The outer sealing ring 59' depends from an annular plate 163 secured to the channel 157 by screws 164 and the heat resisting alloy bottom cover plate 165 rests freely on the plate 163 so that it is free to expand outwardly and contract under changes in temperature in the furnace. It is loosely supported at the center by a shoulder 166 on a hanger rod 167 secured by nuts to a channel member 168 welded between the I-beam 159 and a second parallel I-beam, not shown. The hanger rod is pivoted to the double shackle member 70, as in Fig. 1. The plate 165 has a rod 169 rigidly secured thereto which projects loosely up through the top cover plate 42', and at its upper end the rod has a right angled bracket 171 clamped thereto, carrying an electric vibrator comprising a magnet 172 secured to the vertical arm of the bracket and a cooperating armature 173 mounted on the horizontal arm through a leaf spring 174. The magnet 172 is provided with a sharp, pulsating current from a 60 cycle source, as through an electronic converter, or as shown through a steep wave front transformer 175 having a reduced section in its magnetic path to produce rapid saturation and,

hence, a sharply peaked secondary voltage, the effect of which is accented by a tuning condenser 176 across the secondary winding. The rapid vibrations of the armature 173 are communicated through the rod 169 to the plate 165, and thence to the sealing ring 56' and to the sealing material 55 adjacent thereto, causing the latter to become fluid and enabling the sealing ring to readily penetrate the same as the cover is lowered to its seat. A switch 177 in the vibrator circuit permits the vibrator to be operated only during the cover opening and closing operations. The switch 177 is normally open but is arranged to be operated by a slide 178 extending through a slideway in a block carried by the furnace shell 10 into the path of the ring 179 which encircles the outer end of the I-beams 159. Consequently as the rings 56' and 59' approach the sealing medium in their associated troughs, the slide 178 is engaged by the ring 179 and cammed outwardly thereby to close the vibrator vircuit. This circuit remains closed until the sealing rings are substantally fully engaged in the sealing medium and the cover fully seated upon the support 162 whereupon the slide is released to open the vibrator circuit.

In Figs. 9 and 10 a modified form of work holder and baffle plate 67' is shown, comprising a disc 180 having a series of radial ribs 181 thereon extending outwardly from the hub 182 to a series of work holding cups 183. Slots 184 extend inwardly from the periphery of the disc into the cups. The blank holders 185 each comprise an apertured plug 186 threaded to the blanks 62 and having a shank 187 terminating in a ball 188 adapted to fit within the cups 183 when the shank 187 is passed through the slots 184, thus providing a universal connection with the holding disc 180 and permitting the tubes 62 to hang vertically irrespective of the angular position of the disc.

The disc 180 rests on an enlarged portion 189 of the stud 191 by which it is carried from the shackle 70 by the removable pin 72. The lower end of the stud 191 has a cylindrical recess 192 therein adapted to receive a vertical stanchion or post, not shown, to support the disc and its load of work parts when it is removed from the furnace for cooling. The furnace of Fig. 9 is otherwise similar to that shown in Figs. 1 to 4.

It will be understood, of course, that many modifications and alterations of the structure shown and described may be made without departing from the essential attributes of the invention, and all such changes are contemplated as coming within the scope of the appended claims.

What is claimed is:

1. A furnace comprising a vertical heat treating chamber having an open top, heating means for said chamber, a removable closure member for said chamber, means for supporting said closure member on said furnace structure independent of said heat treating chamber and a plurality of concentric gas seals between said heat treating chamber and said supporting means, one of said seals being disposed between said heating means and said supporting means and another of said seals being disposed between said heat treating chamber and said heating means.

2. A furnace comprising a heating chamber, a muffle disposed in said heating chamber and having an open top, a closure member for said muffle, means carried by said closure member for forming a gas seal between said heating chamber and said muffle, a support for said closure member disposed remote from the heating chamber and a heat seal between said heating chamber and said support adapted to be closed by said closure member.

3. A furnace comprising a heating chamber, a muffle disposed in said heating chamber and having an open top, a closure member for said muffle, means carried by said closure member for forming a gas seal between said heating chamber and said muffle, a support for said closure member disposed remote from the heating chamber, a heat seal between said heating chamber and said support adapted to be closed by said closure member, and work supporting means carried by said closure member.

4. In a furnace structure, the combination of two co-operative chamber forming members movable into inter-engaging relation to form a closed chamber, a displaceable sealing medium carried by one of said members and engaged by the other to seal said chamber and means for vibrating one of said members to facilitate displacement of said medium.

5. In a furnace structure, the combination of two co-operative chamber forming members movable into inter-engaging relation to form a closed chamber, a displaceable sealing medium carried by one of said members and engaged by the other to seal said chamber, means for vibrating one of said members during the inter-engaging movement of said members and means for interrupting said vibrating means upon full engagement of said members.

6. A furnace comprising a heat treating chamber having a channel at its upper end for holding a displaceable sealing medium, a closure member for said chamber having a flange disposed in said sealing medium and removable for access to said chamber and means carried by said closure member adapted to vibrate the same to facilitate displacement of said sealing medium about said flange.

7. A furnace comprising a heating chamber having side walls, a muffle disposed within said chamber, a channel at the upper end of said side walls for holding a displaceable sealing medium, a channel at the upper end of said muffle for holding a displaceable sealing medium, a closure member for said chamber and muffle having depending flanges adapted to be disposed in said sealing mediums, and means carried by said closure member for vibrating said flanges to facilitate the displacement of said sealing medium thereabout.

8. A furnace comprising a heating chamber having side walls, a muffle disposed within said chamber, a channel at the upper end of said side walls for holding a displaceable sealing medium, a channel at the upper end of said muffle for holding a displaceable sealing medium, a closure member for said chamber and muffle having depending flanges adapted to be disposed in said sealing mediums, the flange associated with said first channel having a greater displacement than the flange associated with said second channel, whereby impact shock of said closure member will be received primarily by said side walls.

9. A furnace comprising a heating chamber having side walls, a muffle disposed within said chamber, a channel at the upper end of said side walls for holding a displaceable sealing medium, a channel at the upper end of said muffle for holding a displaceable sealing medium, a closure

member for said chamber and muffle having depending flanges adapted to be disposed in said sealing mediums, the flange associated with said first channel being adapted to engage its associated sealing medium prior to engagement of the flange associated with said second channel with its associated sealing medium, whereby impact shock of said closure member will be received primarily by said side walls.

10. A furnace comprising a heating chamber having an opening in its upper end, a closure member for said opening supported independently of said chamber, a bottom plate carried by said closure member adjacent the center thereof and having its outer edges free, said plate being exposed to the direct heat of said chamber and being free to expand laterally relative to said closure member.

11. A furnace comprising a heating chamber having an opening in its upper end, a closure member for said opening supported independently of said chamber, a bottom plate carried by said closure member adjacent the center thereof and having its outer edges free, said plate being exposed to the heat of said chamber and being free to expand laterally relative to said closure member, a channel disposed about the upper edge of said chamber for holding a displaceable sealing medium, and a flange depending from said plate for reception in said sealing medium.

12. A furnace comprising a heating chamber having an opening in its upper end, a closure member for said opening supported independently of said chamber, a bottom plate carried by said closure member adjacent the center thereof and having its outer edges free, said plate being exposed to the heat of said chamber and being free to expand laterally relative to said closure member, a channel disposed about the upper edge of said chamber for holding a displaceable sealing medium, a flange depending from said plate for reception in said sealing medium and means for vibrating said plate to facilitate entrance of said flange into said sealing medium.

13. A furnace comprising a combustion chamber, burners extending therein, a muffle having an open top disposed in said combustion chamber, a closure member extending over the top of said muffle and said combustion chamber, a support for said closure member disposed remotely from said combustion chamber, and means carried by said closure member for forming a gas seal between said muffle and said combustion chamber and between said combustion chamber and said support.

14. A furnace comprising a heating chamber having a removable cover, means for introducing a gaseous medium into said chamber, a conduit in said cover for egress of said medium, removable means positioned over said cover, adjacent to said conduit, for igniting the gaseous medium escaping therefrom, and means operated by the removal and replacement of said cover for moving said removable means to a position at one side of said cover and back to a position over said cover.

15. A furnace comprising a heating chamber having a removable cover, means for introducing a gaseous medium into said chamber, a conduit in said cover for egress of said medium, means positioned over said cover, adjacent to said conduit, for igniting the gaseous medium escaping therefrom, said last means being movable to a position at one side of said cover to permit removal of the cover, and means for retaining said means in each position.

16. A furnace comprising a substantially cylindrical shell, a refractory lining within said shell forming a chamber, heating means for said chamber, a substantially cylindrical muffle within said chamber, said muffle having an open top, a closure member extending over said muffle and said refractory lining, means carried by said shell for supporting said closing member out of contact with said refractory lining and said muffle, a work support carried by said closure member for suspending the work to be heated within said muffle and means for preventing gas transfer between said chamber and said muffle.

17. A furnace comprising a heat treating chamber having an opening therein for loading and unloading the furnace, a removable closure member for said opening, an inlet conduit for introducing a gaseous atmosphere into said chamber, a vent for said chamber, means for circulating said atmosphere within the chamber and means operated by said closure member for controlling the operation of said circulating means.

18. A furnace comprising a heat treating chamber having an opening therein for loading and unloading the furnace, a removable closure member for said opening, means for introducing a gaseous atmosphere into said heat treating chamber, means for circulating said atmosphere within the heat treating chamber and means operated upon the opening of said closure member to interrupt the operation of said circulating means and upon the closing of said closure member for restarting the operation of said circulating means.

19. A furnace comprising a heat treating chamber having an opening therein for loading and unloading the furnance, a removable closure member for said opening, means for introducing a gaseous atmosphere into said heat treating chamber, means for circulating said atmosphere within the heat treating chamber, means operated upon opening of said closure member to interrupt the operation of said circulating means and upon the closing of said closure member for restarting the operation of said circulating means, and means for delaying the restarting of said circulating means for a predetermined time after the closing of said closure means.

20. A furnace comprising a furnace casing having an opening therein, a heat treating chamber in said casing, a closure member for said chamber extending into said opening, means for circulating a gaseous medium in said chamber and means engageable by said closure member when in said opening for controlling said circulating means.

21. A furnace comprising a furnace casing having an opening therein, a heat treating chamber in said casing, a seat within said casing, a closure member for said chamber extending into said opening and resting on said seat, means for circulating a gaseous medium in said chamber and switch means engageable by said closure member on movement to and from said seat for controlling said circulating means.

22. A furnace comprising a heat treating chamber, heating means for said chamber, gas circulating means within said chamber, a drive shaft for said circulating means extending through a wall of said chamber, a tube surrounding said shaft and extending into said chamber, a seal for the outer end of said tube and gas flow retarding means in said tube between said seal and said chamber.

23. A metallurgical furnace having a heat treating chamber, heating means for said cham-

ber, means for introducing a gaseous atmosphere into said chamber, and a revoluble fan within said chamber for circulating said gaseous atmosphere, said gas introducing means comprising a conduit disposed about said fan and having inlets for directing the incoming atmosphere substantially in the direction of circulation of said atmosphere as produced by said fan and substantially uniformly with respect to the axis of said fan.

24. A furnace comprising an open top heat treating chamber, a removable closure member for said chamber, means for introducing a gas atmosphere into said chamber, circulating means for said gas, a baffle plate adjacent to and spaced from the top of said chamber and extending to adjacent the sides thereof for deflecting the gases towards the side of said chamber and means for supporting said baffle plate from said cover.

25. A furnace comprising an open top heat treating chamber, a removable closure member for said chamber, means for introducing a gas atmosphere into said chamber, circulating means for said gas, a baffle plate adjacent to and spaced from the top of said chamber and extending to adjacent the sides thereof for deflecting the gases towards the sides of said chamber, means for detachably supporting said baffle plate from said cover, and work holding means carried below said baffle plate.

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