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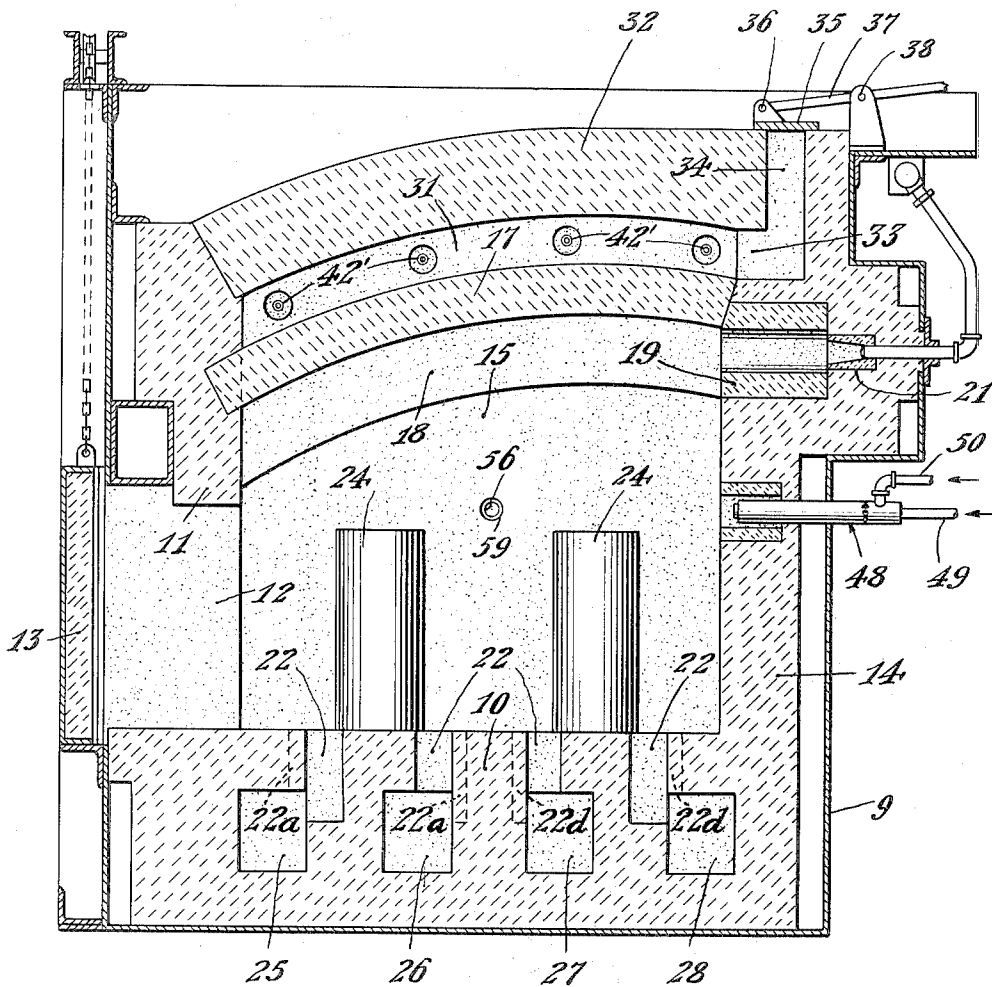
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Fig. 1



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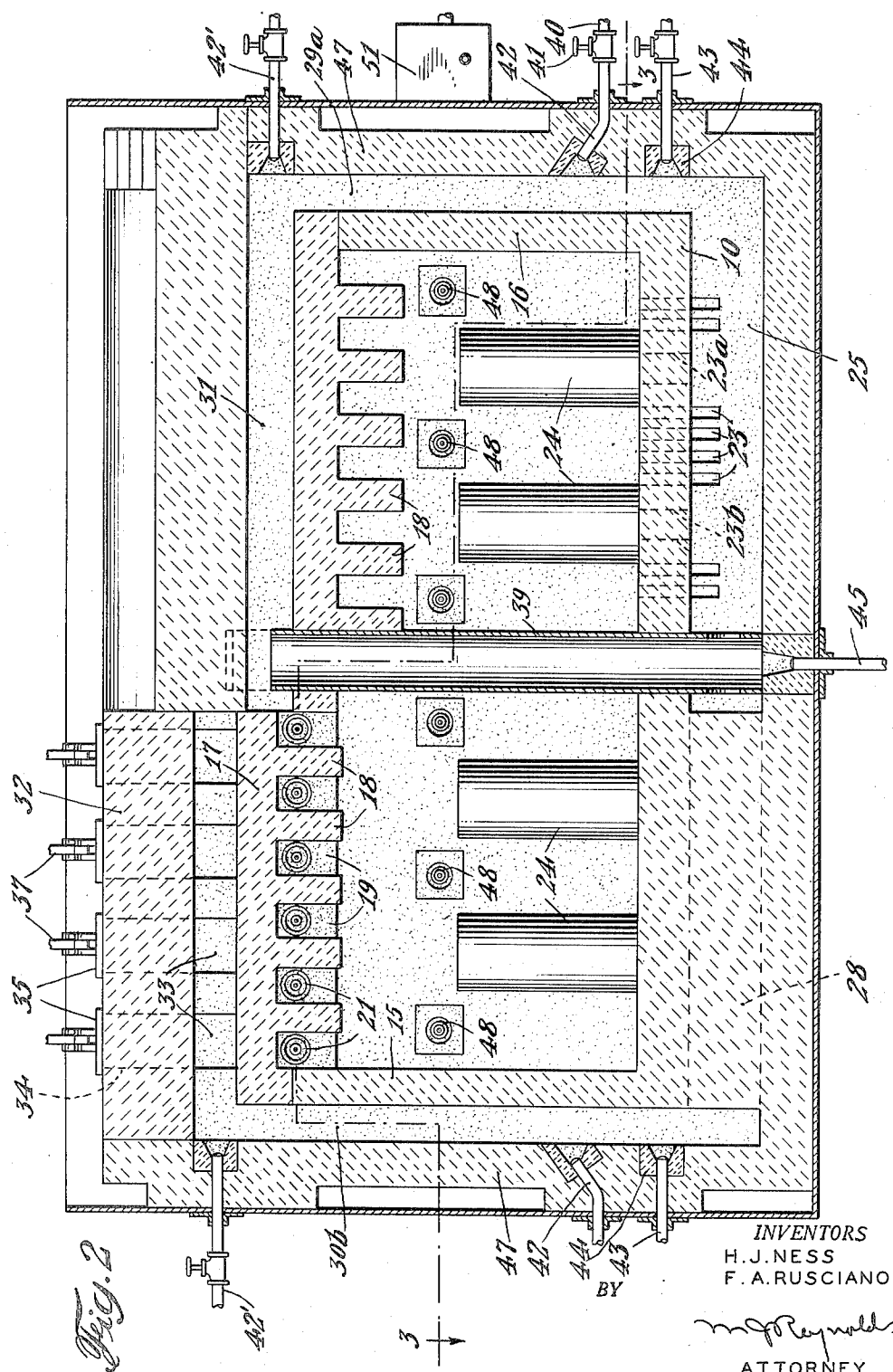
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Filed Nov. 10, 1951

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Sept. 18, 1956

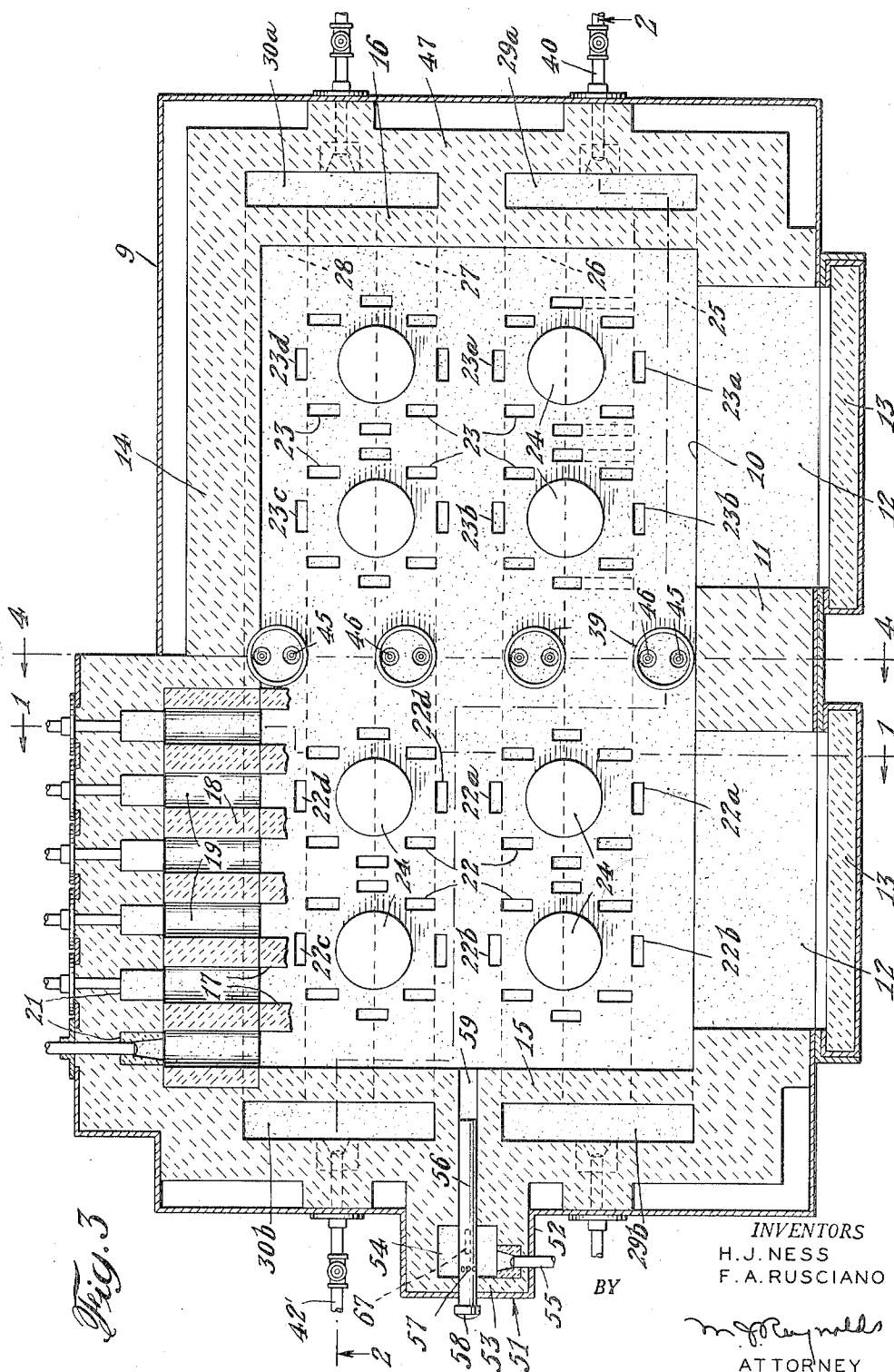
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2,763,476

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Filed Nov. 10, 1951

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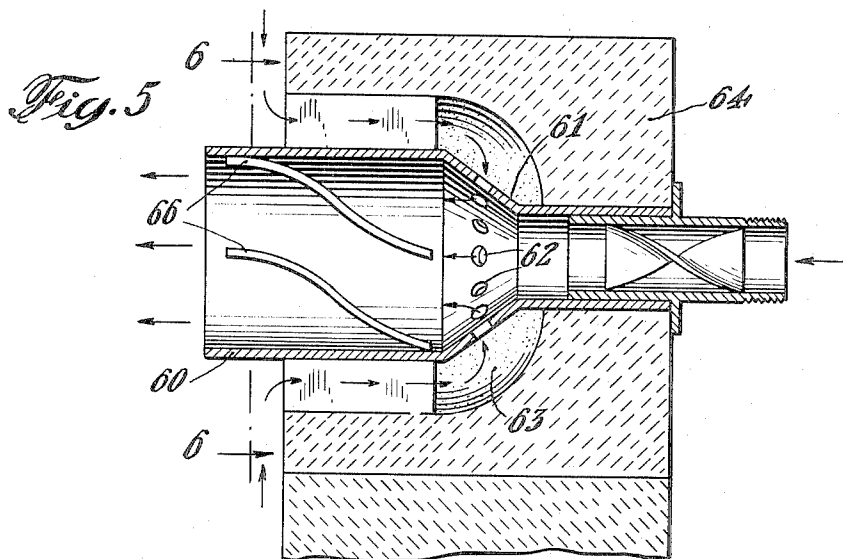
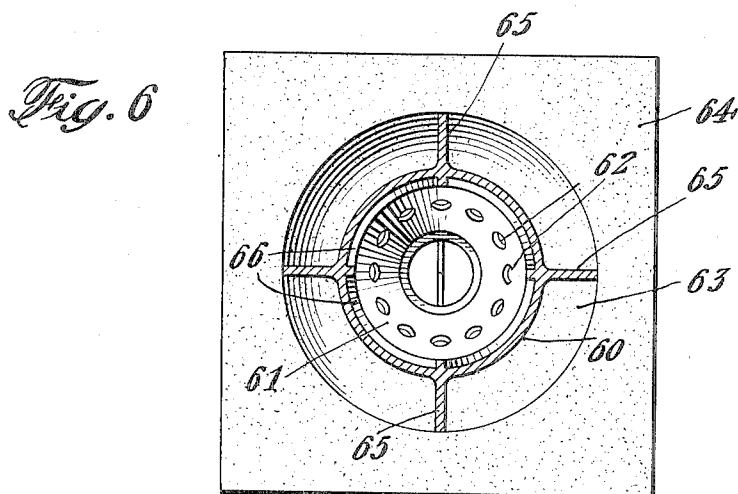
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TWO STAGE COMBUSTION FURNACE

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Application November 10, 1951, Serial No. 255,774

7 Claims. (Cl. 263—2)

This invention relates to an industrial furnace and more particularly to a furnace in which the work is heated directly in the products of combustion of the heating fuel. The invention is of primary importance with furnaces operating at 2000° F. or higher but its use is not limited to such high operating temperatures.

One of the objects of the invention is to provide a furnace in which work may be heated to a high temperature directly in the products of combustion of the heating fuel and without detrimental scaling thereof.

Another object is to obtain a gaseous furnace atmosphere by direct reaction of fuel and air in the heating chamber of the furnace in such manner as to obtain a predetermined ratio of the constituents of the gaseous reaction products which is protective in nature to the work to be heated and further to maintain a temperature and heating rate in the furnace materially higher than that normally obtainable with said predetermined ratio of gaseous constituents.

Still another object is to obtain, in an economical manner, a high temperature furnace atmosphere having non-scaling or substantially non-scaling properties.

A still further object is to produce a combustion furnace atmosphere which will have a high carbon-monoxide and high hydrogen content without sacrificing fuel economy.

Other objects and advantages will hereinafter appear.

Heretofore, in the operation of industrial furnaces at high temperatures, as for instance in the heating of billets, it has been necessary, in order to obtain the requisite temperature and heating rate, to employ highly oxidizing combustion reactions in the furnace chamber. The resulting products of combustion have a high carbon-dioxide content relative to the carbon-monoxide content and are extremely scaling in nature. If a richer fuel to air ratio is employed, sufficient to materially reduce the scaling nature of the atmosphere, the temperature and heating rate obtainable in the furnace chamber is sharply reduced, usually below that required for the heating operation and in any event with a prohibitive increase in fuel consumption.

The present invention overcomes this difficulty and permits a high temperature and fast heating rate to be obtained with a low carbon-dioxide to carbon-monoxide ratio of the furnace gases and with an efficient utilization of the heating fuel.

Briefly, the invention comprises the reaction of an air-fuel mixture in the furnace chamber, the mixture having such proportions as to produce, when the reactions are completed and stabilized, a carbon-dioxide to carbon-monoxide ratio which is below the oxidizing ratio of these gases at the operating temperature of the furnace. The air-fuel mixture may be of a rich exothermic nature or it may even be endothermic, but in either case the resulting reaction products will have a high hydrogen and incompletely consumed carbon and hydrocarbon content. Consequently it will still contain a considerable amount of potential heat energy. Such a rich furnace gas, if produced by exothermic reactions, can impart only limited heat to

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the work and may be incapable of producing and maintaining the desired temperature and heating rate in the furnace. If the reactions are endothermic, they will, of course, absorb heat from the furnace chamber.

By way of example, if a fuel such as natural gas having a B. t. u. content of about 1000 per cu. ft. is employed, mixed with air to produce a rich exothermic reaction having a carbon-dioxide to carbon-monoxide ratio of about 0.3 and a carbon-monoxide content of about 10%, only about 60% of the heating value of the fuel will be utilized and the reaction products will still have about 400 B. t. u. per cu. ft. of the entering gas still available. If an endothermic mixture is employed, the reaction products may have a B. t. u. value in excess of 1000. If such furnace gases were exhausted directly from the furnace, it would result in an extremely high fuel consumption or low heating efficiency, but of even more importance, it would not be possible to operate the furnace at the desired temperature with the low carbon-dioxide content necessary to the prevention of scale and decarburization of the work.

The invention, therefore, in one of its aspects utilizes the high residual B. t. u. content of the gases in the heating chamber in such a manner as, first, to assist in the completion and stabilization of the primary reactions in the chamber and, secondly, to impart its heat to the chamber without disturbing the low carbon-dioxide to carbon-monoxide ratio created by such primary reactions, whereby the requisite temperature, heating rate and fuel efficiency will be attained.

The manner in which this result is accomplished will best be understood by reference to the accompanying drawings, in which:

Fig. 1 is a vertical sectional view, taken on the line 1—1 of Fig. 3, of a billet heating furnace embodying the present invention;

Fig. 2 is a vertical sectional view of the furnace, taken on the line 2—2 of Fig. 3;

Fig. 3 is a horizontal sectional view of the furnace, taken on the line 3—3 of Fig. 2;

Fig. 4 is a vertical mid-sectional view, taken on the line 4—4 of Fig. 3.

Fig. 5 is a vertical sectional view of a preferred form of burner for the furnace shown; and

Fig. 6 is a sectional view taken on the line 6—6 of Fig. 5.

Referring first to Fig. 1, we have shown a furnace comprising an external rectangular metal shell 9, within which the work heating chamber is contained, the latter being defined by the refractory floor 10, a front wall 11 having two spaced openings 12 therein (Fig. 3), arranged to be closed by individual doors 13, a rear wall 14, end walls 15 and 16 (Fig. 2), and an arched roof 17. The roof 17, as shown in Fig. 2, has a plurality of spaced, depending arch sections 18 forming narrow arcuate channels 19 therebetween and the wall 14 is provided with a series of burners 21 in a position to fire into the channels 19 and against the face of the arch 17. The purpose of this structural arrangement will subsequently appear.

The floor 10 of the work chamber is provided with two main groups 22 and 23 (Fig. 3) of exhaust passages, each group having four sub-groups 22a, 22b, 22c and 22d; and 23a, 23b, 23c and 23d, respectively. Each of the sub-groups of exhaust passages is spaced about a central area upon which a billet 24 or other work piece is supported. The passageways of groups 22 and 23 communicate, below the floor, with a series of four horizontal exhaust tunnels 25, 26, 27 and 28, as shown in Fig. 1 and in dotted lines in Fig. 3. The tunnels 25 and 26 connect at each side of the furnace with vertical chambers 29a and 29b; and passageways 27 and 28 connect with similar vertical chambers 30a and 30b. Chambers 29a, 29b, 30a and 30b

constitute combustion chambers for the reaction products exhausted from the work chamber, and in turn they conduct the gases into a chamber 31 (Figs. 1 and 2) provided between the work chamber arch 17 and an outer refractory arch 32. Arch 32 has a number of laterally extending exhaust passages 33, at the rear of the furnace, leading into the vertical flues 34, by which the completely combusted gases are vented to the outer atmosphere. Each of the flues 34 is provided with a damper 35, pivoted at 36 to an operating lever 37, in turn pivoted at 38.

In addition to the vertical chambers 29a, 29b, 30a and 30b, the arch space 31 receives the exhaust gases from the heating chamber through a group of vertical radiant combustion tubes 39, extending through the work chamber between the exhaust tunnels 25 to 28 and the inter-arch chamber 31. The tubes 39 are preferably composed of a refractory material, such as silicon carbide.

As indicated, the purpose of the vertical chambers 29a, 29b, 30a, 30b, radiant tubes 39 and inter-arch chamber 31 is to provide for the further combustion of the gases vented from the work chamber and to extract the residual heat energy therefrom and impart it to the work heating chamber. For this purpose supplemental air is added to these gases through suitable nozzles directed into the chambers 29a, 29b, 30a, 30b and tubes 39. Referring again to Fig. 2, the chambers 29a and 29b are each shown as being provided with an air inlet conduit 40, having a control valve 41 for regulating the admission of supplemental air to a nozzle 42, directed obliquely into the lower end of the chambers 29a and 29b. A similar nozzle 42' supplies air to the exhaust gases as they enter the inter-arch chamber 31. The amount of air supplied by the nozzles 42 and 42' is controlled to effect complete combustion of the gases vented from the heating chamber. A pilot burner 43, supplied with a combustible mixture containing an excess of oxygen, preferably of about 20%, also extends into each of the chambers 29a and 29b, for the purpose of insuring ignition of the air-gas mixture in the chamber. Burner 43 is provided with a conventional burner block 44. Chambers 30a and 30b are provided with similar air and pilot burner nozzles.

The tubes 39 are also each equipped with a supplemental air supply nozzle 45 and a pilot burner 46 (Fig. 4), extending vertically upward through the base of the furnace. It will be noted that the tubes 39 extend across the tunnels 25 to 28 and are supported upon the burner blocks of burners 45, being apertured to receive the exhaust gases from these tunnels. The purpose of this construction is to preclude burning of the exhaust gases in the tunnels by infiltration of air from the nozzles 45.

It will be apparent that the gases burned in the chambers 29 and 30 and in the radiant tubes 39 pass upwardly into the inter-arch chamber 31 and then rearwardly to the vents 34. The distribution of the gases over the arch 17 may be controlled by suitable adjustment of the various dampers 35 so as to produce substantially uniform heating of the arch.

It will be understood that while the air-fuel mixture supplied to the heating chamber, due to its deficiency in air, may be incapable of burning at a high temperature, there is no such inherent restriction on the flame temperature of the gases combusted in the chambers 29, 30, tubes 39 and inter-arch chamber 31, so that the tubes 39, side walls 15 and 16, and arch 17 may be heated to a temperature several hundred degrees higher than that obtainable in the heating chamber solely by the partial combustion of the rich mixture therein. To facilitate the transfer of this heat to the heating chamber the walls 15, 16 and arch 17 are preferably composed of a hard burned refractory, such as fire clay or silicon carbide, which has a relatively high coefficient of heat conduction and radiation. Refractory brick of this type has a heat conductivity of from 8 to 10 B. t. u. per hour per sq. ft. per degree Fahrenheit at 1000° F. Contrariwise, to prevent conduction and radiation losses from the furnace and to force the heat to

these inner walls, the external walls 47 and outer arch 32 are composed, at least in part, of a refractory having a low coefficient of conduction, such as a porous insulating brick, having a conductivity of from 1 to 2 B. t. u. per hour per degree Fahrenheit at 1000° F.

The combustion of the rich exhaust atmosphere of the heating chamber in the inter-wall combustion chambers and in the radiant tubes 39 serves several important purposes. It makes the residual heat energy in the work chamber exhaust gases available for additional heat input into the work chamber, thus effecting an economy in the fuel consumption; it consumes the high carbon-monoxide and hydrogen content of the work chamber gases and thus eliminates a hazard to the health and safety of the furnace operators; it prevents the subsequent burning of these gases in the building ventilating system and so facilitates the disposal thereof; it drives the temperature of the work chamber up above that obtainable by the reactions produced in the chamber itself and thus makes it possible to employ inherently low temperature, rich reaction products in the work chamber for the protection of the work, and at the same time to operate the work chamber at a much higher temperature than would otherwise be possible with such a gaseous atmosphere; and it serves to heat the arch 17 and spaced depending arch members 18 to a temperature above the reaction temperature of the mixture supplied to the burners 21. This latter effect is an important feature of the invention since it facilitates the reactions in the work chamber and permits air-fuel mixtures to be employed which approach or even include the endothermic range. These reactions are further facilitated by the channeled arrangement of the arch members 18 whereby severe scrubbing of the entering mixture occurs on the hot surfaces of the arch 17 and depending members 18. The non-scaling nature of the resulting gaseous products is dependent in a large measure on the extent to which these reactions are completed and stabilized in the upper part of the heating chamber, that is, before they come into contact with the work. The catalytic effect of the hot brick work resulting from the scrubbing referred to above promotes the completion of these reactions, whether they be endothermic or exothermic.

In some cases it may be preferable to supply a fuel-air mixture to the burners 21 which will produce a carbon-monoxide content somewhat lower than is desired at the work, and to increase this content by the subsequent addition of raw gas to the furnace at a point where the primary reactions have been completed. For this purpose the furnace is provided with a number of gas addition tubes 48 entering the heating chamber below the arch 17. The tubes 48 are supplied with any suitable raw gas or a rich endothermic mixture of fuel and air by conduits 49, suitably valve controlled. The gas admitted by the tubes 48 will be cracked endothermically to liberate nascent carbon and hydrogen in contact with the work, and these elements by virtue of their strong reducing tendency serve to reduce or prevent the formation of scale on the work or, if desired, may be supplied in sufficient quantity to produce carburization of the work surface. The free carbon released by the cracking down of this gas further reduces the carbon-dioxide to carbon-monoxide ratio of the work chamber gases.

In order to prevent premature cracking of these raw gas additions and the consequent deposition of soot in the tubes 48, they are preferably provided with a cooling jacket through which cooling air from a conduit 50 may be circulated.

In bringing the furnace up to heat, we prefer to utilize at the start an air-fuel mixture for the burners 21 which is readily combustible with a high flame temperature, as for instance, with natural gas, an air to fuel ratio of about 10 to 1. After the desired furnace temperature has been attained and before the work is placed in the work chamber, the air-fuel ratio is reduced either to the desired rich exothermic or endothermic range necessary to pro-

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duce the carbon-dioxide to carbon-monoxide ratio in the work chamber required for the protection of the work. As the air supplied to the main burners 21 is reduced, supplemental air is supplied to the nozzles 42 and 45 to initiate combustion in the inter-wall combustion chambers 29, 30 and 31 and tubes 39, so as to maintain the furnace at the desired operating temperature, it being understood, as heretofore stated, that this high temperature is maintained without increase in the abnormally low carbon-dioxide to carbon-monoxide ratio produced in the work chamber by the rich exothermic or endothermic reactions occurring therein. The raw gas additions are supplied only while the work is in the furnace.

While reference has been made, by way of example, to the use of natural gas, it is to be understood that any other suitable fuel, such as city gas, propane, butane, oil, or the like, may be employed both in the burners 21 and in the gas addition tubes 48.

To further assist in the combustion of the rich mixture supplied to the burners 21, the special construction thereof, as shown in Figs. 5 and 6, is preferred. Referring to these figures, the burner shell 60 is flared outwardly at 61 and the flared portion is provided with a number of apertures 62 communicating with a space 63 disposed between the shell 60 and the burner block 64 and having open access to the work chamber. The shell 60 extends outwardly beyond the face of the burner block and is supported in spaced relation to the burner block walls by radial fins 65. The inner face of the burner shell is provided with spiral fins 66 to increase the scrubbing effect of the incoming gases on the cylindrical wall of the shell. As a result of the expansion of the gases in the tapered section 61 of the shell, a venturi effect is produced which draws the gases from the work chamber through the space 63 and openings 62 into the burner shell. The extension of the shell 60 beyond the face of the block 64 causes these gases to be drawn along the hot walls of the rear face of the chamber rather than from the gases exiting from the burner shell. As a consequence these entrained gases are at the furnace temperature which, as explained, will be above the normal reaction temperature of the incoming air-fuel mixture. They therefore serve to heat the shell 60 and the incoming gases. This added heat promotes the reaction of the rich incoming mixtures and will even permit combustion of mixtures which by themselves do not generate sufficient heat to support combustion.

It will be understood that the process is not dependent upon the use of burners of the preheating type but may be employed with burners of conventional form; but the use of the burners shown in Figs. 5 and 6 permits the use of somewhat richer mixtures than is otherwise feasible and enables the reactions in all cases to be more nearly completed in the burner shell and this is a highly desirable feature. The shell 61 may be composed of a suitable heat resisting alloy but for high temperature operation we prefer to use a refractory such as silicon carbide.

The invention has been described particularly with reference to the obtaining of a low carbon-dioxide to carbon-monoxide ratio in the work chamber for protection of the work from scale. However, because of the large deficiency in oxygen in the chamber, the water vapor to hydrogen ratio of the gaseous reaction products will also be low and thus reduce the scaling tendency of the gases in this regard.

If it is desired to completely eliminate the oxidizing tendency of water vapor and thus eliminate this variable from consideration in the control of the furnace atmosphere, a small amount of the vapor of lithium may be introduced into the chamber. For this purpose there is shown a lithium generator 51 disposed at each end of the furnace shell. These generators each comprise a horizontal cylindrical extension 52 secured to the shell 9 and provided with a refractory lining 53 forming a combustion chamber 54. Extending axially through the cham-

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ber 54 is a heat resisting alloy tube 56 having an opening or openings 57 therein by which the products of combustion from the chamber 54 may pass into the interior of the tube 56. One end of the tube 56 extends outwardly from the shell 52 and is adapted to be closed by a cap 58. The opposite end of tube 56 extends into an aperture 59 in the furnace wall for conducting the gases into the heating chamber.

Lithium compounds are inserted into the vaporizing tube 56 in the form of a fused cake disposed within an open boat or container, indicated at 67, and more fully disclosed in copending application of H. J. Ness, Serial No. 139,906, filed January 21, 1950, and entitled "Combustion Furnace." This fused cake preferably comprises a mixture of lithium chloride and lithium carbonate in the proportion of 40% of the former and 60% of the latter.

The temperature of the vapor generator is preferably maintained at from 1400° F. to 1750° F. which is sufficient to create a substantial vapor pressure at the surface of the lithium compounds and enable a small amount thereof to be carried into the furnace by the combustion gases flowing thereover from the chamber 54.

It will be understood, of course, that variations may be made in the arrangement and construction of the various elements disclosed and in the manner of producing the furnace atmosphere without departing from the essential attributes of the invention, and therefore it is desired to include all such changes and modifications as come within the scope of the appended claims.

What is claimed is:

1. A furnace for the heating of metal comprising a first set of walls composed of a refractory material of good heat conductivity forming a work heating chamber, a second set of walls composed of refractory material of lower coefficient of heat conductivity spaced outwardly from said first walls to form external combustion chambers, means for introducing fuel and air into said work heating chamber for thermal reaction therein, means for venting the products of said reaction from said work heating chamber into said combustion chambers, means for adding air to said combustion chambers for producing combustion of said reaction products therein and venting means for said combustion chambers.

2. A furnace for the heating of metals comprising a floor, a set of side walls and a first arched roof, forming a work heating chamber, additional side walls and a second arched roof spaced from said first mentioned walls and roof, respectively, to form intermediate combustion chambers, means for introducing air and fuel into said work heating chamber at locations adjacent to said first arched roof for thermal reaction therein, means for venting the products of said reaction from said work heating chamber at locations adjacent to the floor thereof, into said combustion chambers, means for adding air to said combustion chambers for producing combustion of said reaction products therein, and venting means for said combustion chambers.

3. A furnace for the heating of metals comprising a floor, a set of side walls and a first arched roof, forming a work heating chamber, said arched roof having depending spaced arch members forming a plurality of channels, a second arched roof spaced from said first arched roof to form a combustion chamber therebetween, means for introducing air and fuel into said work heating chamber at locations adjacent to said first arched roof and within said channels, means for venting said work heating chamber at locations remote from said first roof, means for conducting the products so vented into said combustion chamber and means for adding air to said products to effect combustion thereof in said combustion chamber.

4. A furnace for the heating of metals comprising a set of walls including a roof forming a work heating chamber, burner means for firing into said chamber against said roof, a second roof spaced from said first roof to form a combustion chamber therebetween, means for

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venting said work heating chamber at one or more locations remote from said first roof, means for conveying the products so vented into said combustion chamber and means for adding air to said products to effect combustion thereof in said combustion chamber.

5. A furnace for the heating of metals comprising refractory walls forming a work heating chamber, means for introducing fuel and air into said work heating chamber for reaction therein, means for venting the products of said reaction from said chamber, radiant heating means having a combustion chamber isolated from said work heating chamber and in heat transfer relation thereto, means for conveying said vented reaction products to said combustion chamber and means for adding air to said products to effect combustion thereof in said combustion chamber.

6. A furnace for the heating of metals comprising walls forming a work heating chamber, means for introducing fuel and air into said chamber for thermal reaction therein, means for venting the products of said reaction from said chamber, other walls, including at least one of said first mentioned walls for forming a combustion chamber isolated from said work heating chamber, means for conveying the products of said reaction from said work heating chamber into said combustion chamber and means for adding air to said combustion chamber to effect combustion of said reaction products therein.

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7. A furnace for the protective heating of metal comprising refractory walls forming a work heating chamber, means for providing a protective atmosphere for metal to be heated in said chamber including means for reacting a mixture of fuel and air having insufficient air to produce complete combustion of said fuel, a combustion chamber isolated from said work heating chamber, means for venting said atmosphere from said work chamber into said combustion chamber, means for adding additional air to said vented atmosphere to produce substantially complete combustion of the fuel content thereof in said combustion chamber and means comprising a wall of said combustion chamber for supplying heat generated in said combustion chamber to the products of said reaction to assist in the completion and stabilization thereof.

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