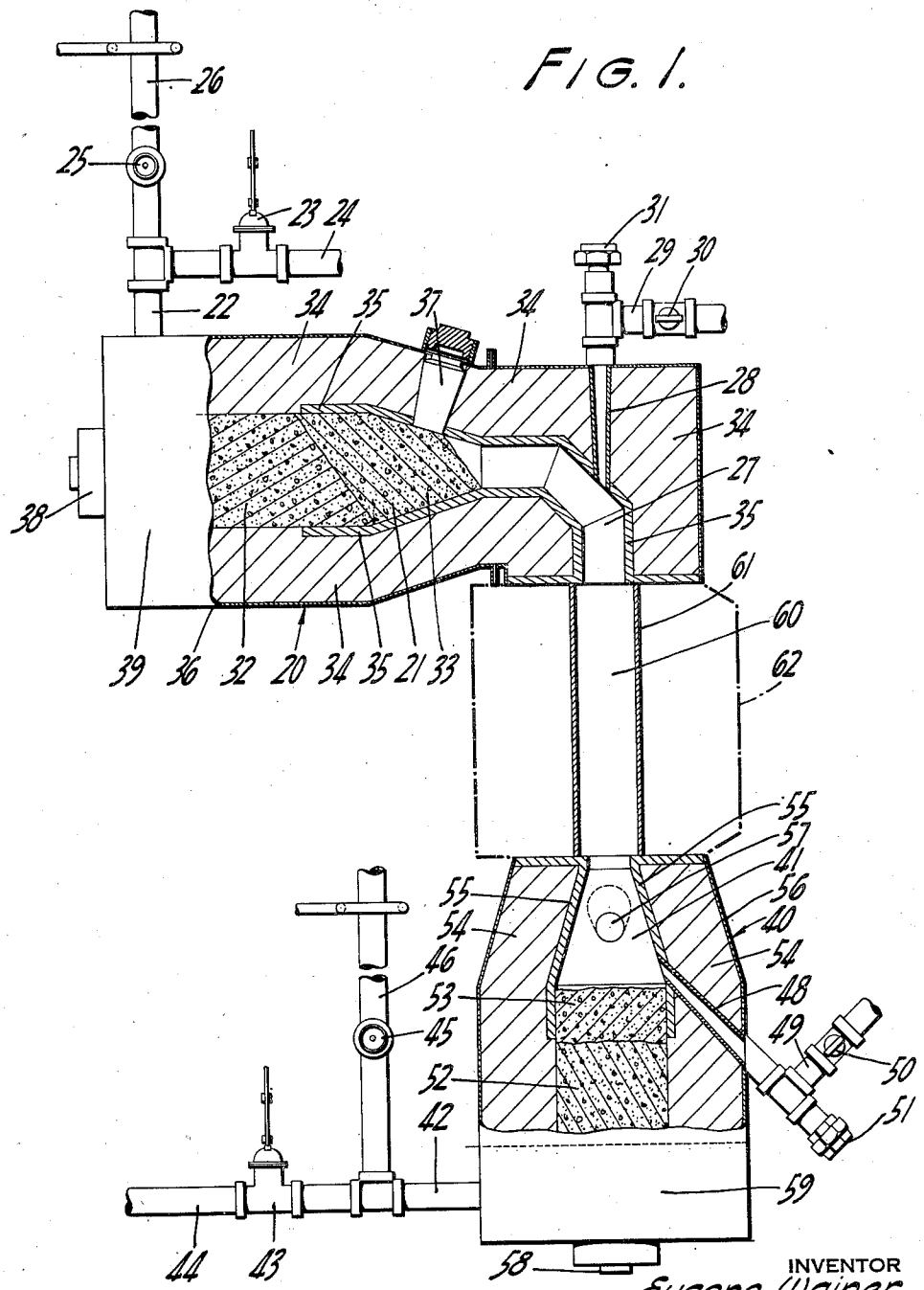
April 30, 1946. E. WAINER 2,399,609

FURNACE

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FIG. 1.



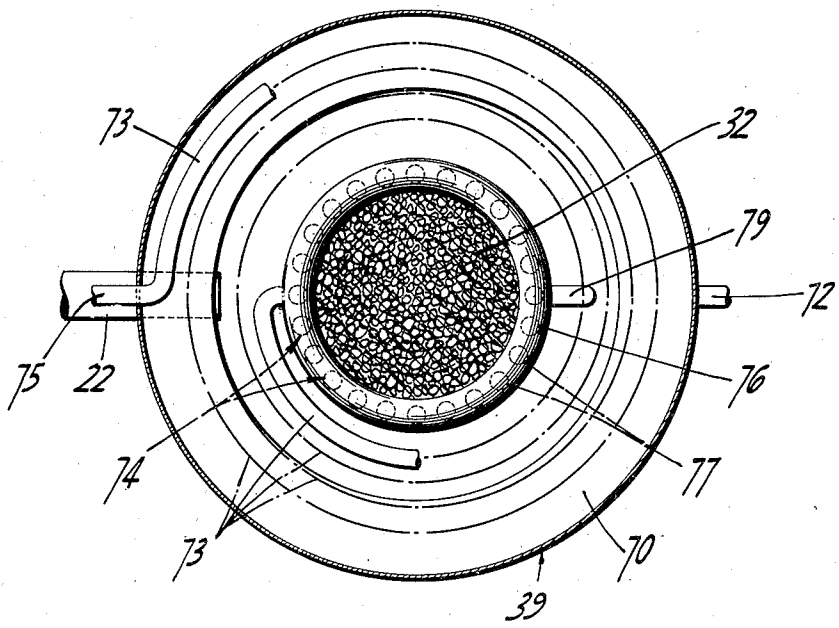
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FURNACE

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FIG. 3.



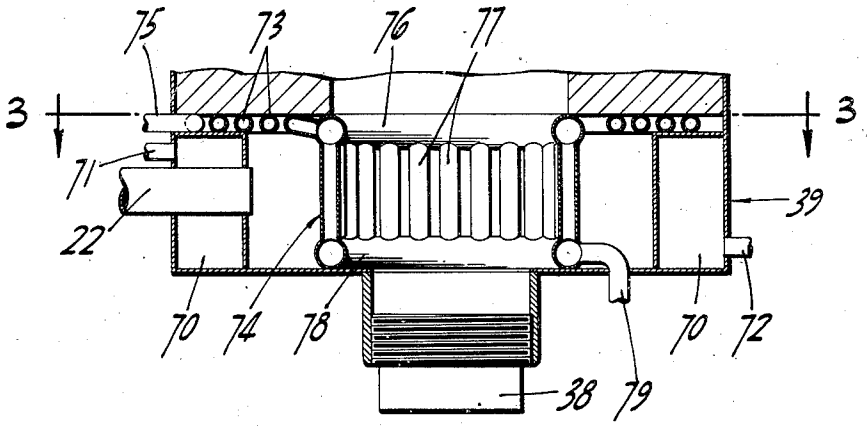


FIG. 2.

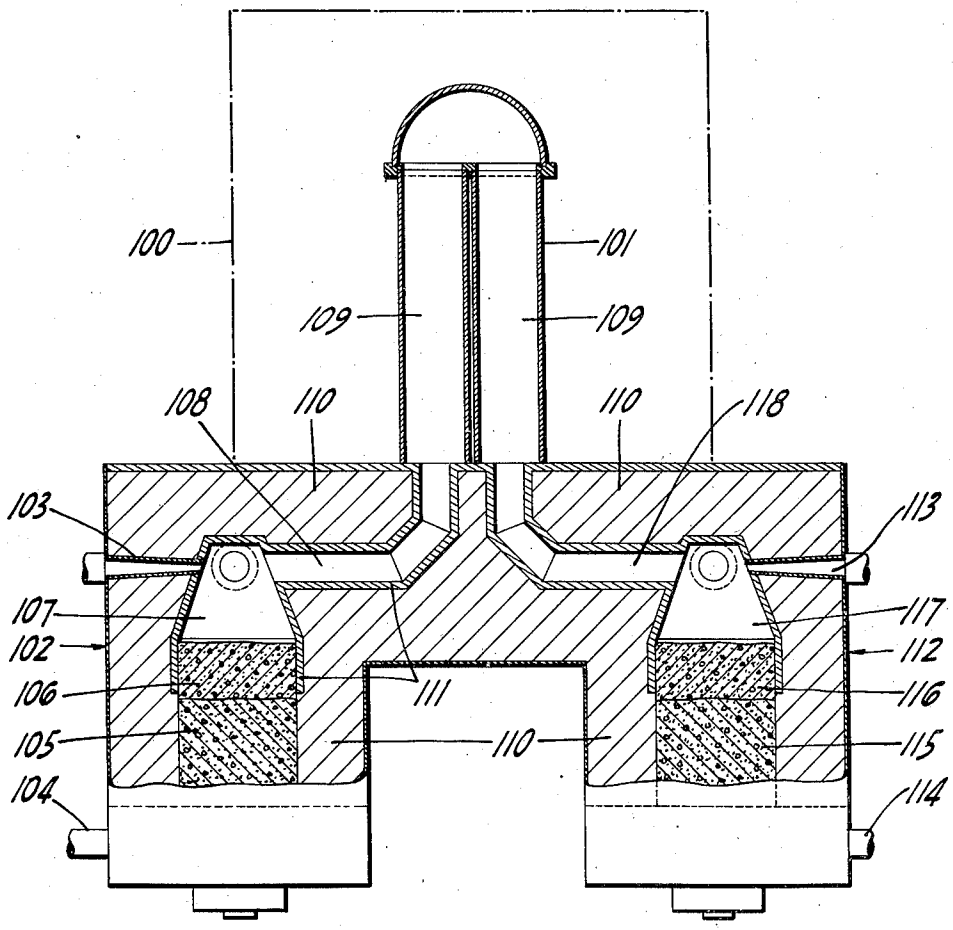
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FIG. 4.



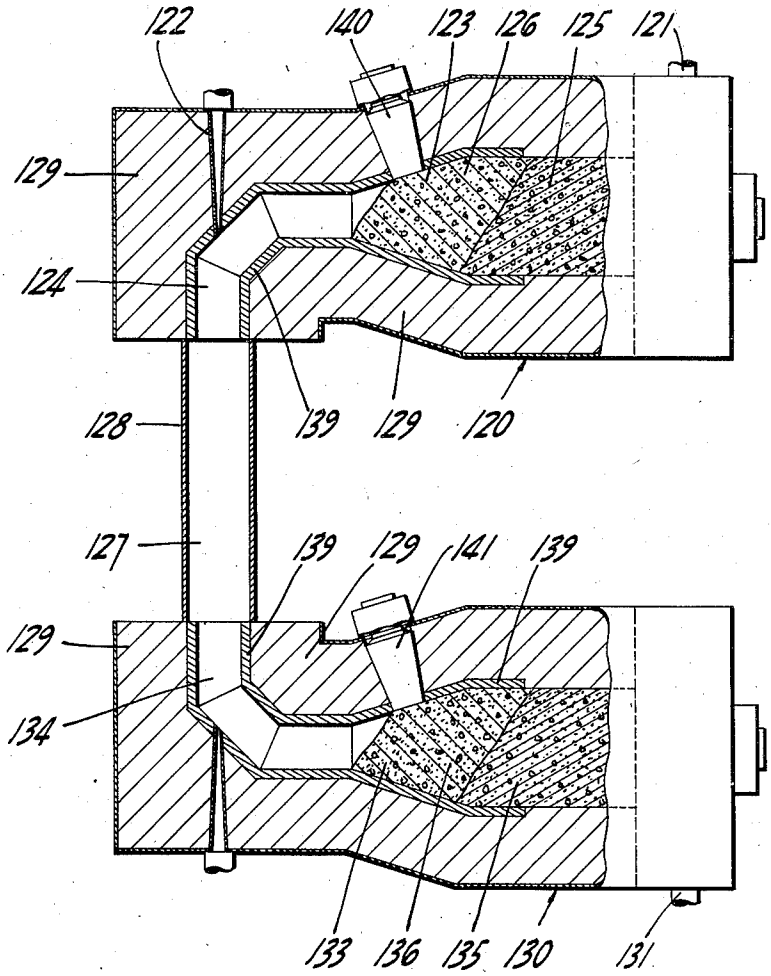
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FIG. 5.



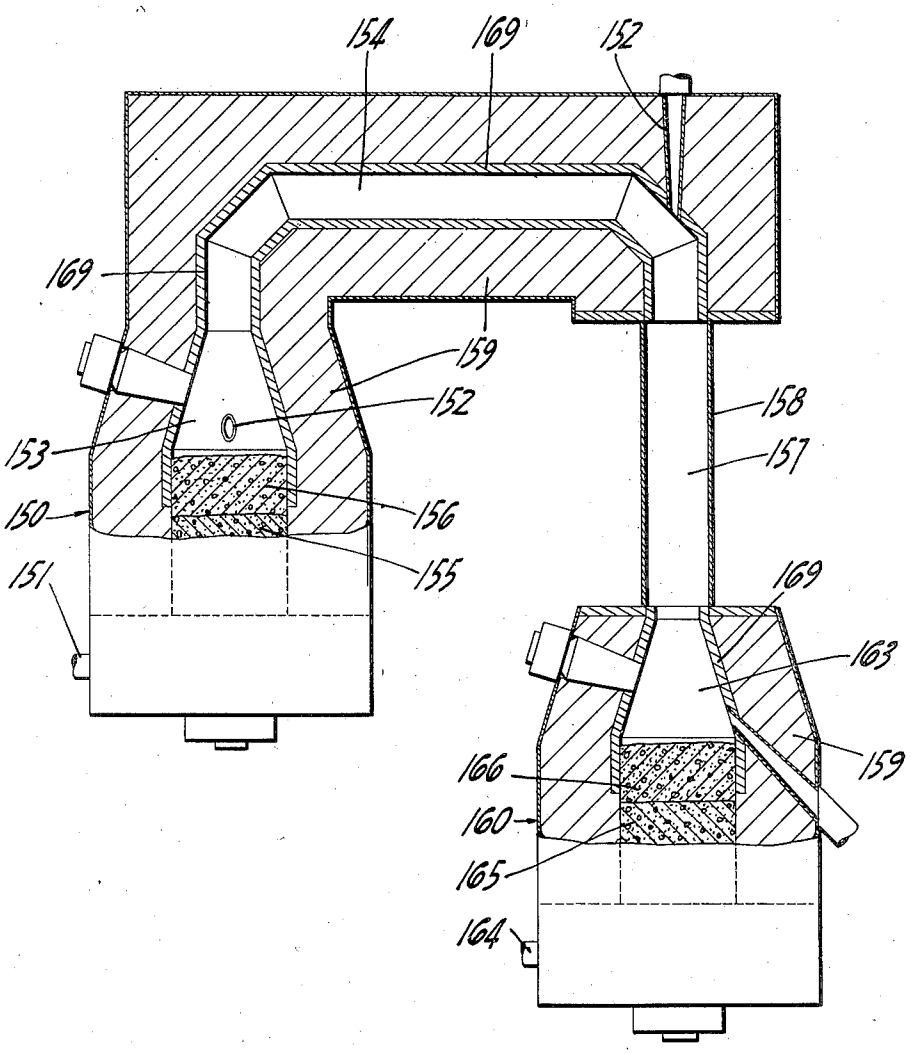
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FIG. 6.



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UNITED STATES PATENT OFFICE

2,399,609

FURNACE

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Application October 11, 1941, Serial No. 414,654

5 Claims. (Cl. 263—10)

This invention relates to high temperature recuperator furnaces, and more particularly to such furnaces in which the products of combustion do not come into direct contact with the material being heated.

In recent years, electric furnaces of all kinds have come into extensive use for the treatment of materials at high temperatures. These furnaces are of the arc type, the resistance type and the induction type. One outstanding advantage of such furnaces over those which employ solid, liquid or gaseous fuel has been that they can be used for the treatment of materials of all kinds without subjecting such treated materials to the action of gaseous products of combustion passing over the materials. On the other hand, electric furnaces are subject to the disadvantage that the cost of current to produce a given heating effect far exceeds the cost of the usual gaseous, liquid and solid fuels required to produce the same heating effect. A need has therefore long been felt for a practical type of furnace or heating unit which will secure the advantages of electric furnaces for high temperature work, but which will use solid, liquid or gaseous fuels, with the consequent great saving in operating costs. It has been known, of course, to secure these advantages in relatively low temperature work or medium temperature work. Thus, coal, oil or gas heated boilers of one type or another, for heating water, etc., have been known for hundreds of years. Similarly, at medium temperatures retorts and other containers of various kinds have been employed for holding materials to be heated. At very high temperatures, however, such as in excess of 1800° C., these expedients fail, both because of the difficulty of securing such high temperatures, and because the materials used to separate the substances being heated from the gaseous products of combustion melt or otherwise decompose or break down under the influence of high temperatures.

It is therefore an object of this invention to provide a commercially practical type of furnace or heating apparatus suitable for high temperature work, employing fluid fuel. It is another object to provide such a furnace in which the gaseous products of combustion do not come into contact with the material being treated. It is a further object to provide such a furnace or heating apparatus which is compact and which can be easily combined with any desired type of chamber containing the material being heated. Other objects will appear hereinafter.

In the drawings:

Figure 1 is a front elevation, with parts in cross section, of a preferred form of furnace according to the invention. Figure 2 is a cross section, on a larger scale and in more detail than in Figure 1, of the cooling apparatus for the exit gases employed in the furnace of Figure 1. Figure 3 is a view taken along the line 3—3 of Figure 2. Figures 4, 5 and 6 are front elevations, partly in cross section, of modified forms of furnace, corresponding to Figure 1.

Referring to Figure 1, the present novel type of furnace or heating apparatus is composed of two stoves or burning units indicated generally at 20 and 40, respectively, which may conveniently be of substantially similar size and shape. The burning unit 20 is composed of a central chamber 21, which is partly cylindrical and partly conical in shape. A pipe 22 serves as a means both for introducing air or other oxygen-containing gas (such as pure oxygen), which may be under forced draft, to support combustion within the chamber 21, and also for withdrawing spent products of combustion from the burning unit 40, as hereinafter pointed out. When pipe 22 is used for introducing air or other oxygen-containing gas, a valve 23 communicating with a supply conduit 24 for air or other oxygen-containing gas is kept open, while a valve 25 communicating with a water-cooled chimney 26 is kept closed. When pipe 22 is used for withdrawing spent products of combustion, valve 25 is open while valve 23 is closed. At its opposite end, the chamber 21 forms a cylindrical passageway 27, which turns at right angles and then in turn communicates with a passageway 60 which forms a continuation of the passageway 27.

Also communicating with the portion 27 of chamber 21 is a nozzle 28, preferably made of zircon, serving to direct gas or other fluid fuel under pressure from the supply pipe 29 into the chamber 21, the supply of gas being controlled by the valve 30. A sighting glass 31 of "Pyrex" or similar high temperature resistant glass may be provided for observing the combustion within the chamber 21, which occurs when gas from the nozzle 28 comes in contact with air from the supply line 24. Combustion thus occurs in the end of chamber 21 adjacent to passageway 27, and the hot products of combustion pass thence successively through passageways 27 and 60.

Most of the remaining space in the chamber 21 between the nozzle 28 and the pipe 22 is filled with irregular refractory particles or lumps 32

and 33, which conveniently may average ½ to 1 inch in size. These lumps advantageously fill about half the space or more between the beginning of the passageway 27 and the end of the chamber 21 adjacent the pipe 22. The lumps 32 adjacent the pipe 22 are composed of the highly refractory material zircon (zirconium silicate), while the lumps 33 furthermost from pipe 22 are composed of the even more refractory material zirconium dioxide (zirconia), for reasons hereinafter pointed out. Because of the horizontal orientation of the chamber 21, the dividing line between lumps 32 and 33 and also the free surface of the lumps 33 assumes an inclined position.

The walls of the chamber 21, including the passageway 27, are composed mainly of zircon, as indicated at 34. Conveniently the walls are made out of prefabricated blocks or bricks of suitable size and shape which may be tongued and grooved to fit tightly and sealed with zircon cement. The portions of the chamber 21 which are subjected to the highest temperatures, including the passageway 27, are provided with a lining 35 of zirconium dioxide such as of the semi-vitreous tile-link type. Finally, the entire structure may, if desired, be backed up with insulating firebrick of the fireclay type (not shown), although normally this is not necessary. To hold the structure together, a cast iron shell 36 may be provided. To secure access to the interior of the chamber 21, there is provided a removable plug 37 of zircon in one wall of the chamber, adjacent the passageway 27, and a removable cast iron plug 38 in the end of the chamber adjacent the pipe 22. Spent and dirty lumps 32 and 33 may thus be removed by removing plug 38, and fresh lumps 32 and 33 inserted by removing plug 37. Similarly, the chamber 21 may be cleaned at periodic intervals, as desired, after removing plugs 37 and 38. The plug 38 may if desired be provided with a valved passageway (not shown) for removing water condensing within the chamber 21.

At the end of chamber 21 adjacent pipe 22 is a cooling unit indicated generally at 39. This can be understood more easily by reference to Figures 2 and 3 of the drawings. It consists of three separate units, that is, an external cooling ring 70, a spiral loop of pipe 73, and a squirrel cage grate 74. The cooling ring 70 has its own water supply line 71 and water outlet 72. Spiral loop 73 and squirrel cage grate 74, however, are connected in series. Cooling water comes in through supply line 75, passes through the successive spirals of spiral loop 73, and then into the circular pipe 76 of squirrel cage grate 74. From pipe 76 the water passes through straight pipes 77 connecting circular pipe 76 with a second circular pipe 78. Thence the cooling water finally passes out through outlet pipe 79. The interior of the squirrel cage grate 74 is filled with lumps 32, not shown in Figure 2.

The cooling unit 39 may be dispensed with entirely, if desired. Ordinarily this will require a chamber 21 of great length, in order that the exit gases may be cooled to the proper degree. Since this sacrifices the desirable feature of compactness to some extent, it is generally preferred to include the cooling unit. In actual operation, the unit 39 may also be and preferably is employed as a source of hot water or steam for other uses; and this constitutes one of the advantages of the use of this cooling unit.

The stove or burning unit 40 is constructed in a fashion very similar to that of unit 20. Central chamber 41 is very similar to chamber 21, except that its upper conical portion communicates directly with passageway 60 instead of through a bent passageway. Pipe 42 serves as a means both for introducing air, which may be under forced draft, to support combustion within chamber 41, and for withdrawing spent products of combustion from the burning unit 20, as hereinafter pointed out. Pipe 44, chimney 46, and valves 43 and 45 are connected with pipe 42 in the same manner and for the same purposes as the similar elements 24, 26, 23 and 25, respectively, in unit 20. Similarly nozzle 48, supply line 49, valve 50, and sighting glass 51 serve the same purposes as similar elements 28, 29, 30 and 31, respectively, of unit 20. The dividing line between lumps of zircon 52 and lumps of zirconium dioxide 53, and also the free surface of lumps 53, are in this case level or horizontal, since chamber 41 is oriented vertically. The zircon walls 54, zirconium dioxide lining 55, iron shell 56, plugs 57 and 58 and cooling unit 59 are constructed similarly to the corresponding elements 34, 35, 36, 37, 38 and 39 of unit 20.

Both units 20 and 40 are preferably of generally cylindrical or circular shape, since the problem of placing and welding into place sheet iron shells 36 and 56 is thereby simplified. Furthermore, the interiors of the units preferably should be free from corners or cut backs, or should be otherwise streamlined to prevent erosion by whirlpools or eddies of flames at very high temperatures.

The tube or wall 61 of the passageway 60 is constructed of zirconium dioxide of relatively thin cross section. It may be built up of individual sections of tile suitably cemented together with zirconium dioxide cement, or cast in a single piece. It should be of relatively dense structure, so that it is as impervious as possible to the gaseous products of combustion going through the passageway 60, and also so that heat may be conducted as efficiently as possible to the exterior surface of the tube 61. For strengthening purposes, the tube 61 may if desired rest in suitable recesses (not shown) in the refractory linings 35 and 55. The tube 61 may be of any desired cross section, such as circular, elliptical, square, rectangular, etc., and may be straight or curved, or of constant or variable cross section, but preferably is cylindrical in shape.

The exterior surface of the tube 61 forms the actual heat-giving source of the furnace according to the present invention. It communicates the heat by radiation to a chamber 62 containing the material to be heated. This chamber may be of any suitable size, shape, or form depending upon the material being heated, the temperatures desired, the length of the tube 61 and other factors. In the form shown in Figure 1, it is indicated as a chamber about 3 feet high and 3 feet wide, but wide variations from this are of course permissible. The chamber 62 is also preferably completely surrounded with suitable refractory insulating walls (not shown) of any required thickness, to prevent or minimize heat losses. Chamber 62 may also be provided with doors or other openings, thermometers, sight glasses, etc., also not shown.

In addition to or in place of the means shown, other expedients may be employed to increase the efficiency of heat transfer, to insure safety of operation, etc. Thus, the tube 61 may be filled with checkerwork or suitably supported lumps of zirconium dioxide to slow down the velocity

of travel of the products of combustion passing through the tube. Suitable cooling means may be combined with any excessively hot regions that develop. Instead of a single nozzle 28 or 48, a plurality of nozzles radially disposed about the circumference of the chambers 21 or 41 may be employed. Instead of gaseous fuel, liquid fuel with suitable modification of the nozzles may be used. An auxiliary unit similar to burning units 20 and 40 could be provided for preheating the gaseous fuel. Alternatively, gaseous fuel could be introduced through pipe 22 and air through nozzle 28. Still another alternative would be to divide the mass of zircon and zirconium dioxide lumps by means of a longitudinal partition, introduce air on one side of the partition by means of pipe 22 and gaseous fuel on the opposite side of the partition by means of a similar pipe entering the chamber 21 in a diametrically opposite position. Thus, both air and gaseous fuel would be preheated by passing through the mass of lumps and burn in the space beyond such lumps.

The furnace is operated as follows: Valves 43, 50 and 25 are opened, while valves 45, 23 and 30 are closed. Air and gas are thus caused to simultaneously enter chamber 41. Combustion is then initiated in the upper part of chamber 41 such as by means of an electric or cerium spark. The hot products of combustion pass through the passageway 60, causing heat to be radiated from the exterior surface of tube 61. Thence the hot products of combustion pass into chamber 21 and successively through lumps 33 and 32 and out through pipe 22 and chimney 26, being cooled by means of cooling unit 39. In this fashion, the temperature of lumps 33 and 32 is raised to a high point, lumps 33 being hotter than lumps 32 because the hot products of combustion pass through the former first.

When the temperatures of lumps 32 and 33 are raised to the required degree, valves 43, 50 and 25 are shut while valves 45, 23 and 30 are opened, these operations being effected by suitable thermostatic controls, if desired. When this is done, air passing from pipe 22 through lumps 32 and 33 are heated thereby to a high degree, so that when the air mixes with gas from nozzle 28 in passageway 27 combustion takes place instantly without any externally applied heat. Also as a result thereof, the hot products of combustion reach a much higher temperature, and the heat radiation from the exterior surface of tube 61 is greatly increased. The hot products of combustion pass successively down through lumps 53 and 52 and out through pipe 42 and 46, being cooled by means of cooling unit 59. The temperature of lumps 53 and 52 is thus raised to a high point. When the required temperature of lumps 53 and 52 is reached, the cycle is again reversed, and this is repeated as often as is desired, to secure the required temperature in chamber 62. Each time the cycle is reversed, the temperature of chamber 62 increases until equilibrium is reached.

It will be seen that, by the practice of the present invention, the heat resisting qualities and other high temperature characteristics of zircon and zirconium dioxide are utilized to the highest degree. In particular, construction of the tube 61 out of zirconium dioxide enables chemical reactions of all sorts to take place at high temperatures in the chamber 62 without appreciably affecting the zirconium dioxide. Reactions under high pressure can be made to take place in chamber 62 by suitably balancing the pressure in passageway 60. This can be done, for example, by suitably increasing the pressure of the entrant air and gases and the exiting products of combustion. In addition, the use of combinations of zirconium dioxide joined to refractory insulating zircon ware enables the relative cheapness, high temperature resistant qualities and heat insulation properties of the latter to be combined with the characteristic of the former of being able to resist still higher temperatures.

The form of furnace illustrated in Figure 1 is particularly advantageous because it enables gases to be conducted most directly from the combustion chamber to the passageway 60. Also, the furnace may be used either with a horizontal or a vertical tube 60, merely by turning the entire apparatus over on its side so that unit 20 becomes vertical and unit 40 horizontal.

Other forms of furnaces may also be used, which secure additional advantages at the expense of certain disadvantages. Thus the form shown in Figure 4 has the advantage that the chamber 100 (corresponding to the chamber 62), in which the material to be heated is placed, may be built up and taken down with the greatest ease. Also the U-shaped tube 101 (corresponding to the tube 61) offers a somewhat larger surface area, thus increasing the radiation surface.

In this form of furnace, the lower parts of the burning units or stoves 102 and 112 are constructed exactly the same as in unit 40. Gas is supplied through the nozzles 103 and 113, respectively, and air through the pipes 104 and 114, respectively, these pipes (as with pipes 22 and 42) also serving to withdraw spent products of combustion. Thus, in one cycle air from pipe 104 and gas from nozzle 103 both pass into central chamber 107, the air passing successively through zircon lumps 105 and zirconium dioxide lumps 106. After the air and gas are burned, the spent products of combustion pass through passageway 108 and passageway 109 defined by tube 101. Thence the products of combustion pass out through passageway 118 into chamber 117, and then down successively through zirconium dioxide lumps 116 and zircon lumps 115 and out through pipe 114. The cycle is reversed exactly as with the apparatus of Figure 1. As with the apparatus of Figure 1, the walls 110 of the furnace are composed of zircon, the hottest portions 111 being provided with a lining of zirconium dioxide.

In the form of furnace shown in Figure 5, both burning units or stoves 120 and 130 lie in a horizontal position. Otherwise, the operation is exactly the same as in the forms shown in Figures 1 and 4. In one cycle, air from pipe 121 and gas from nozzle 122 both pass into passageway 124 forming a continuation of central chamber 123, the air passing successively through zircon lumps 125 and zirconium dioxide lumps 126. After the air and gas are burned, the spent products of combustion pass into passageway 127, so as to cause heat to be radiated from the exterior surface of the tube 128. Thence the products of combustion pass out through passageway 134 into chamber 133, and then down successively through zirconium dioxide lumps 136 and zircon lumps 135 and out through pipe 131. The cycle is reversed exactly as with the apparatus of Figure 1. As with the apparatus of Figure 1, the walls 129 of the furnace are composed of zircon, the hottest portions 139 being provided with a lining of zirconium dioxide. The plugs 140 and 141 are pro-

vided for easy access to chambers 123 and 133 respectively.

In the form of furnace shown in Figure 6, both burning units or stoves 150 and 160 lie in a vertical position. Otherwise, the operation is exactly the same as in the forms shown in Figures 1, 4 and 5. In one cycle, air from pipe 151 and gas from nozzle 152 both pass into passageway 154 forming a continuation of central chamber 153, the air passing successively through zircon lumps 155 and zirconium dioxide lumps 156. After the air and gas are burned, the spent products of combustion pass into passageway 157, so as to cause heat to be radiated from the exterior surface of tube 158. Thence the products of combustion pass directly into chamber 163, and then down successively through zirconium dioxide lumps 166 and zircon lumps 165 and out through pipe 164. The cycle is reversed exactly as with the apparatus of Figure 1. As with the apparatus of Figure 1, the walls 159 of the furnace are composed of zircon, the hottest portions 169 being provided with a lining of zirconium dioxide.

From the above description, it will be seen that the present type of furnace is admirably suited for performing all sorts of reactions at high temperatures, where electric furnaces were formerly required. Thus it may be used for the preparation of ferro alloys, fused alumina, fused quartz, fused slags, calcium carbide, carbon bisulfide, carbon tetrachloride, magnesium metal or any reaction requiring a temperature of 1800° C. or over and which may or may not require atmosphere control. In addition to the numerous advantages pointed out previously, it provides for ease of cleaning, complete atmosphere control, rapidity of change from one reaction to another, and numerous other advantages.

As many variations may be made within the scope of this invention it is not intended to be limited except as defined by the appended claims.

What is claimed is:

1. A high temperature recuperating furnace, capable of generating temperatures in excess of 1800° C., comprising a pair of burning units and a closed passageway connecting said burning units; at least a part of said passageway being enclosed only by a tube essentially of zirconium dioxide, the exterior surface of said tube constituting a heat radiating surface for the heating of substances placed in proximity therewith; each of said burning units comprising a central chamber containing lumps of zirconium dioxide, a conduit for oxygen containing gas, a conduit for fluid fuel, each of said conduits communicating by separate means with the portion of said central chamber between said tube and the free surface of said lumps, at least one of said conduits communicating with said first named portion through a portion of said central chamber occupied by said lumps, and a conduit for waste gases communicating with said first named portion through said second named portion of said central chamber; one of said burning units acting as a unit for supplying hot gaseous products of combustion to the interior of said closed passageway while at the same time the other of said burning units acts as a unit for withdrawing said hot gaseous products of combustion from the interior of said closed passageway, each of said units being adapted to interchangeably act as a supplying unit and as a withdrawing unit.

2. A high temperature recuperating furnace, capable of generating temperatures in excess of 1800° C., comprising a pair of burning units and a closed passageway connecting said burning units; at least a part of said passageway being enclosed only by a tube essentially of zirconium dioxide, the exterior surface of said tube constituting a heat radiating surface for the heating of substances placed in proximity therewith; each of said burning units comprising a central chamber containing lumps of zirconium dioxide, a conduit for oxygen containing gas, a conduit for fluid fuel, each of said conduits communicating by separate means with the portion of said central chamber between said tube and the free surface of said lumps, at least one of said conduits communicating with said first named portion through a portion of said central chamber occupied by said lumps, a conduit for waste gases communicating with said first named portion through said second named portion of said central chamber, and the interior surface of said first named portion being essentially of zirconium dioxide; one of said burning units acting as a unit for supplying hot gaseous products of combustion to the interior of said closed passageway while at the same time the other of said burning units acts as a unit for withdrawing said hot gaseous products of combustion from the interior of said closed passageway, each of said units being adapted to interchangeably act as a supplying unit and as a withdrawing unit.

3. A high temperature recuperating furnace, capable of generating temperatures in excess of 1800° C., comprising a pair of burning units and a closed passageway connecting said burning units; at least a part of said passageway being enclosed only by a tube essentially of zirconium dioxide, the exterior surface of said tube constituting a heat radiating surface for the heating of substances placed in proximity therewith; each of said burning units comprising a central chamber containing a plurality of layers of lumps, the layer nearest said tube being composed essentially of zirconium dioxide and another of said layers being composed essentially of zircon, a conduit for oxygen containing gas, a conduit for fluid fuel, each of said conduits communicating by separate means with the portion of said central chamber between said tube and the free surface of said lumps, at least one of said conduits communicating with said first named portion through a portion of said central chamber occupied by said lumps, a conduit for waste gases communicating with said first named portion through said second named portion of said central chamber, the walls of said central chamber being composed principally of zircon but being provided at said first named portion with a lining essentially of zirconium dioxide; one of said burning units acting as a unit for supplying hot gaseous products of combustion to the interior of said closed passageway while at the same time the other of said burning units acts as a unit for withdrawing said hot gaseous products of combustion from the interior of said closed passageway, each of said units being adapted to interchangeably act as a supplying unit and as a withdrawing unit.

4. A high temperature recuperating furnace, capable of generating temperatures in excess of 1800° C., comprising a pair of burning units and a closed passageway connecting said burning units; said passageway being enclosed only by a thin-walled tube essentially of zirconium dioxide, the exterior surface of said tube constituting a heat radiating surface for the heating of substances placed in proximity therewith; each of said burning units comprising walls composed

principally of zircon, a central chamber enclosed by said walls, a quantity of zirconium dioxide lumps within said chamber and having a free surface exposed in the direction towards said tube, a quantity of zircon lumps within said chamber and being covered by said zirconium dioxide lumps, a conduit and nozzle for introducing fluid fuel into a portion of said chamber between said tube and said free surface of the zirconium dioxide lumps, a conduit for introducing oxygen-containing gas into and for withdrawing waste gases from a portion of said chamber filled with said zircon lumps, a lining of zirconium dioxide in said first named portion of said chamber, and a cooling unit adjacent said second named portion of said chamber and also adjacent said second named conduit; one of said burning units acting as a unit for supplying hot gaseous products of combustion to the interior of said closed passageway, while at the same time the other of said burning units acts as a unit for withdrawing said hot gaseous products of combustion from the interior of said closed passageway, each of said units being adapted to interchangeably act as a supplying unit and as a withdrawing unit.

5. A high temperature recuperating furnace, capable of generating temperatures in excess of 1800° C., comprising a horizontally disposed burning unit, a vertically disposed burning unit, and a closed passageway connecting said burning units; said passageway being enclosed only by a thin-walled tube essentially of zirconium dioxide, the exterior surface of said tube constituting a heat radiating surface for the heating of substances placed in proximity therewith; each of said burning units comprising walls composed principally of zircon, a central chamber enclosed by said walls, a quantity of zirconium dioxide lumps within said chamber and having a free surface exposed in the direction towards said tube, a quantity of zircon lumps within said chamber and being covered by said zirconium dioxide lumps, a conduit and nozzle for introducing fluid fuel into a portion of said chamber between said tube and said free surface of the zirconium dioxide lumps, a conduit for introducing oxygen-containing gas into and for withdrawing waste gases from a portion of said chamber filled with said zircon lumps, a lining of zirconium dioxide in said first named portion of said chamber, and a cooling unit adjacent said second named portion of said chamber and also adjacent said second named conduit, one of said burning units acting as a unit for supplying hot gaseous products of combustion to the interior of said closed passageway while at the same time the other of said burning units acts as a unit for withdrawing said hot gaseous products of combustion from the interior of said closed passageway, each of said units being adapted to interchangeably act as a supplying unit and as a withdrawing unit.

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