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FI RING OF GRINDING WHEELS AND THE LIKE IN A TUNNEL FURNACE

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FI G. 4

FI G. 5

FIG. 6

FI G. 7

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A further object is to provide a novel and improved batteless kiln for heat treatment of porous vitreous-bonded articles in which warm-up time is advantageously reduced and in which needs for kiln furniture and auxiliary support provisions designed to reduce article distortions are obviated.

Still further, it is an object to automate and improve the speed and quality of firing of discrete permeable articles, by simultaneously permeating and supporting such articles with high-temperature gases, and by a self-regulation of the rate at which such articles are floated across a furnace hearth.

By way of a summary account of practice of this invention in one of its aspects, a kiln for the heat treatment of porous ceramic-bonded flat ceramic grinding wheels is constructed with an elongated refractory hearth having numerous small and well-distributed openings extending between its upper and lower surfaces, the upper surface being planar and very slightly inclined downwardly from an inlet to an outlet end of the kiln. Refractory material above and alongside the hearth defines a tunnel-like chamber through which the articles are to be passed for heat treatment. Hot gases, preferably derived directly from combustion within another portion of the kiln structure, are forced through the hearth openings and into the tunnel, from whence they may be recirculated and/or exhausted, the tunnel and recirculation passages having relatively large cross-sections which prevent excessive friction losses and admit of high-velocity flow of the hot gases up through the hearth openings. At the inlet and outlet ends of the kiln, pressurized air-film support pads are positioned to feed and collect, respectively, the articles being processed through the kiln tunnel. Beyond the outlet end of the kiln, an external conveyor driven positively at a low speed collects and transports the articles which have been heat-treated in the kiln, and, by virtue of its predetermined low speed, prevents passage of articles through and their egress from the kiln at a rate any higher than that governed by the external conveyor.

Although the aspects of this invention which are believed to be novel are set forth in the appended claims, additional details as to preferred practices of the invention and as to the further objects, advantages and features thereof may be most readily comprehended through reference to the following description taken in connection with the accompanying drawings, wherein:

FIGURE 1 is a side view, partly in cross-section, of a preferred embodiment of a batteless kiln in which teachings of the present invention are practiced;

FIGURE 2 is a transverse cross-section of an improved kiln taken along section line 2—2 in FIGURE 1;

FIGURE 3 is a transverse cross-section of an improved kiln taken along section line 3—3 in FIGURE 1;

FIGURE 4 illustrates a cross-sectioned fragment of a hearth and kiln tunnel, together with a gas-supported grinding wheel and symbols characterizing the flow of hot gases;

FIGURE 5 portrays a fragment of a refractory hearth, for a batteless kiln, wherein the multitudinous gas flow passages are formed by drilled holes;

FIGURE 6 depicts graphically the theoretical and practical temperature conditions existing within various zones of a kiln such as that represented in FIGURE 4;

FIGURE 7 comprises a schematic illustration of a portion of an alternative kiln structure and its associated gas-circulation system.

The furnace arrangement illustrated in FIGURES 1 through 3 includes an insulated kiln structure 8 in which a heating chamber in the form of an elongated tunnel 9 extends from an inlet 10, where articles 11 are admitted into the tunnel, to an outlet 12, where these discrete articles are discharged after being heat-treated. The articles...
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The abrasive grinding wheels of generally flat annular configuration, in various sizes, having abrasive granules which are to be integrated by ceramic bonding induced by firing. Typically, the volumes of such wheels are about 35% pores, multitudes of which bring the opposite sides of the flat wheels into communication with one another through tortuous paths. Tunnel 9 is lined with dense refractory members 13-15 along the top and sides, except at the sites of laterally-extending gas-circulating passageways 16 and 17 and its lower surface is formed by a special gas-permeable hearth 18. As discussed more fully hereinafter, the height of tunnel 9 is sufficient, in relation to the width of its hearth 18, to provide more low-loss flow of gases which are forced upward through the hearth under pressure.

Parallel sides 13 and 15 of narrow tunnel 9 restrict lateral movement of the articles 11, and are preferably spaced only slightly in excess of the diameter of the largest wheels which are to be heat-treated, as is represented in FIGURES 2 and 3. Both the heat-treating and a fluid suspension of all the articles in the kiln are effected by hot gases forced through the hearth from below. For these purposes, the refractory hearth is preferably formed with many uniformly distributed substantially vertical drilled holes 19, shown in FIGURE 5, which, in a typical case may be about one-sixteenth inch in diameter and may have spacings 20 and 21 of about one-fourth inch. Hot gas flowing upwardly through these holes is distributed substantially uniformly along the lower surface of hearth 18, where it will tend to suspend the wheels 11 stably a small distance (such as one-sixty-four inch) above the hearth and will, simultaneously, in part permeate the porous grinding wheels. Gas pressures of about two to four inches of water, and not in excess of about six inches of water, are sufficient to develop the desired effects.

The particular furnace chosen for illustration includes a single combustion chamber, 22 (FIGURES 1 and 3) fired by a gas burner 23 fed by flammable gas or gases, such as a flammable gas and air, which are under high enough pressure to produce the desired two-to-four inches of water pressure associated with the forced flow of hot gas through hearth openings 19. Hot pressurized gas resulting from combustion in chamber 22 is passed directly to a distribution chamber 24 formed directly below one portion of the hearth, this portion corresponding to a high-temperature firing zone within the kiln. Length and position of this zone may be adjusted by sliding the dense refractory end walls or baffles 25 and 26 lengthwise of the furnace, to desired positions governing the length and orientation of the chamber 24. The floor and sides of chamber 24, and of other like chambers 27, 28, 29 and 30 in the furnace, are lined with dense refractory material 31, as are also the inner walls of combustion chamber 22. When the high-temperature gas from the combustion chamber has served to suspend and fire the articles passing over the zone of the hearth above chamber 24, it is removed from the tunnel 9 through the laterally-extending passageways 16 and 17 which are disposed one beyond each of the two longitudinal extremities of the firing zone. These removal passageways direct the hot gas into one or more insulated plenum chambers, such as chambers 32 and 33 appearing in FIGURES 2 and 3, respectively, from whence there may be a partial exhaust through ducts 35, 36, 37 and 38 into the chambers 27-30, respectively, underlying other portions of hearth 18. High-pressure fans 39-42, respectively, assist in these recirculations, and in certain mixing operations, and ensure that substantially the same volume of gas flows over those portions of the hearth above chambers 27-30 as occurs above highest-temperature chamber 24. The recirculation couplings from the plenum chambers may establish various fluid flow circuits designed to yield different prescribed temperatures in the furnace zones overlying the gas distribution chambers 27-30, the arrangement which appears in FIGURE 2 being a representative one. There, the insulated ducting 43 conveys hot gases from plenum chamber 33 to the inlet 44 of the high-speed high-temperature centrifugal fan 41, under control of valve 45, and ambient air is simultaneously drawn from the fan inlet 44 by ducting 46, as regulated by a valve 47. Depending upon the valve settings, the pressurized gas mixture flowing in fan outlet duct 37 feeding chamber 29 may be adjusted to have a desired temperature required for heat treatment of the articles as they pass through the tunnel zone above distribution chamber 29, without involving another combustion chamber. Similar mixings and regulations are produced in substantially the same way for supply of gas at various temperatures to the other distribution chambers, and, in some zones, such as that above chamber 30, externally-admitted air alone may be supplied in some instances.

Upstanding brackets 48 and 49 are adjustably slidable lengthwise of the furnace structure, to permit adjustment of the lengths of zones associated with gas-distribution chambers 28-30, in the same manner as brackets 25 and 26. Thermal insulation 50 surrounds those portions of the structure where heat losses are to be minimized, and external steel cladding 51 provides an outer enclosure. Preferably, the top section of the kiln is separately secured to the bottom section by fasteners 52, and lifting lugs 53 facilitate removal of the top for exposure of the tunnel 9, as needed for replacement of parts or for insertion of baffles within the tunnel itself to further control the gas flow characteristics within the tunnel, if desired. Conventional instruments 54 on an associated control panel 55 provide indications and/or control over temperature, pressure, and gas velocities at sites of interest within the kiln structure. The elongated hearth and nearby parts of refractory material enclosing the gas-distribution chambers below the hearth would normally be susceptible to damage as they undergo extreme variations in temperature, and the illustrated kiln is therefore specially arranged to provide compensation for thermal expansions and contractions. For purposes of such compensation, the parts most susceptible to damage are held together at all times by compression forces exerted by the external yeldable load springs 56 and 57 (FIGURE 1), disposed respectively at different ends of the kiln. Two associated U-shaped yokes, 58 and 59, respectively, are secured in place outside the kiln and restrain the two springs in relation to the housing for the furnace. Pressure plates 61 and 62 transmit the compressed spring forces to the fitted refractory parts 31 of the gas distribution chambers 24 and 27-30, and thus the sections of hearth 18 cemented atop the sides of these chambers are also compressed by the same forces. Hearth 18 is preferably fabricated in relatively short sections, about one and one-half feet in length, which are abutted end-to-end in forming the elongated hearth structure. The aforementioned cementing and the spring loading both contribute to gas-tightness of the joints between parts exposed to pressurized high-temperature gases. Other external loading mechanisms, such as air cylinders, may be employed in place of the spring-loading units, although the latter are presently preferred.

The top planar surface of hearth 18 is oriented with a slight downward inclination from the horizontal (example: one degree), from the inlet 10 to the outlet 11. This inclination assures that the gas-suspended abrasive articles being heat-treated in the tunnel kiln will be influenced to move slowly toward the outlet, in response to gravitational effects. Even this low natural rate of movement is not slow and precise enough for the firing and heat-treating purposes, however, and, for purposes of avoiding the disadvantages associated with a very long kiln or with regulating mechanisms inside the kiln tunnel, the natural rate of article movement is instead re-
tarded and accurately controlled by the linear surface speed of an external conveyor 62 disposed downstream beyond the outlet 11 (FIGURE 1) in alignment with the tunnel 9. This conveyor is shown in the form of a roller-supported continuous belt 63 driven at a slow linear speed by a speed-regulated motor 64; articles which leave the kiln 12 tunnel encoder and are picked up by the conveyor belt, wherein their linear speed become that of the conveyor. Travel of the discrete articles (wheels) to the rear of those on the conveyor is then impeded, due to their light touching abutment as shown in FIGURE 1. Contact between the articles does not involve appreciable force, such that they do not tend to distort even in the firing zone where they may be in a somewhat softened condition. At the start of furnace operation, the tunnel may first be at least partly filled with "dummy" or expendable articles, to provide the needed restraint against excessive speed of rotation of the newly-processed articles through the kiln. Inclined roller feeder mechanism 65 upstream of the kiln recirculates the wheels to be processed, from an operator or automatic dispenser, and delivers them to the kiln. Two auxiliary external gas-support feeders or air slides, 66 and 67, are disposed immediately adjacent the inlet and outlet, respectively, of the kiln tunnel, evenly with the height.

These air slides, which may have substantially horizontal or approximately inclined upper surfaces, serve to maintain the wheels suspended on air at substantially the same gas-suspension height to which they are elevated within the kiln (i.e., preferably about one-sixty-fourth inch). Lateral guides, such as the guide plates 68 and 69, confine the transported articles to the feeder mechanism, air slides, and conveyor. Each of the slides includes a top planar-surfaced plate which is perforated generally in accordance with the perforation pattern of hearth 18, and is supplied with pressurized air from beneath by a source (not shown) connected with a gas-distribution chamber below the plate. These air slides tend to maintain a uniform continuous pattern of upward fluid flow which will not become discontinuous at the kiln inlet tunnel, thus this uniformity reduces the possibilities that the discrete articles will be upset by the pressurized fluid upon entering or leaving the kiln tunnel, and the shielding air curtain produced by the external airslides also suppresses tendencies of the heated gases to escape from the tunnel end openings. Where found desirable, heat losses may also be suppressed through use of partial end closures 70 and 71 for the tunnel inlet and outlet. Firing times of the order of about eighteen to thirty-two hours have been common in the vitreous bonding of ceramic grinding wheels herefore. However, a kiln such as that illustrated in FIGURES 1-3 makes possible a dramatic and vastly improved total firing cycle of the order of less than about one-half hour. This reduction is principally the result of flow of the hot gases (example: temperatures to about 1300° C.) through the multitude of small openings in the porous article. As is represented by the arrows appearing in FIGURE 4, the hot pressurized gaseous combustion products forced through the uniformly-distributed openings 19 in hearth 18 travel at high velocity (example: about 50 ft./sec.) through the ¾-inch holes (area-average velocity being about 2.5 ft./sec.), and the flowing gas develops a fluid pressure pad under the porous wheel, lifting it in the process. In a wheel typically made of about 35% voids, with average pore diameters typically ranging from about 60-265 microns, a significant amount of hot gas flow occurs through the microns, and achieves outstanding uniform heat-exchange with the particles of which the wheel is largely composed, such that the desired firing temperature can be reached quickly and maintained without difficulty. The extremely fast heating rate which can be realized with the improved kiln is shown by the fact that a ceramic annular wheel 4 x ½ x ½ inches, having 35% voids, a grit size of 30, an average pore diameter of 264

microns, an average thermal conductivity of 1.1 Btu./hour-foot°F, and a permeability of 65 cubic feet/minute/foot²/inch thickness at a differential pressure equal to about 2 inches of water, can be expected to heat from room temperature to 1250° C, in about 5.4 minutes.

Even though this represents a high temperature gradient, the hot gas permeating the wheel body apparently acts to suppress thermal spalling. The time, t, in seconds, required to heat a porous ceramic body in the improved kiln is substantially as follows:

\[
T = \left( \frac{\rho_a}{\mu_a} \right) \left( \frac{1}{\mu_a} \right)^{1/2} \left( \frac{1}{\mu_g} \right)
\]

where:

- \(r_a\) = specific heat, solid, Btu./lb. °F
- \(c_{pg}\) = specific heat, gas, Btu./lb. °F
- \(\rho_a\) = density, solid, lbs./ft.³
- \(\mu_a\) = density, gas, lbs./ft.²
- \(\alpha\) = thickness, ft.
- \(\mu_g\) = gas velocity through pores, ft./sec.

It is found that the articles 11 tend to remain stably supported upon the gas cushion or pad produced immediately above the hearth, without excessive oscillation, and that tendencies toward lateral movement are suppressed by light contact made with the tunnel walls 13 or 15 (as portrayed in FIGURE 4) or with other adjoining articles in the kiln.

The graphical representation in FIGURE 6 characterizes temperature conditions, in °C x 100, within the muffle or kiln tunnel of a furnace such as that depicted in FIGURES 1-5, plotted against tunnel length in feet. Curve 72 illustrates the levels of gas temperatures in the various tunnel zones, while curve 73 approximates the temperatures of the wheels 11 being processed. In the first zone, for example, which corresponds to that immediately above gas-distribution chamber 27, the forced-gas temperature is at a substantially constant temperature of about 800° C, and an article 11 is gradually brought up to nearly that temperature (to avoid an excessive temperature gradient) in slowly traveling the distance of about one and one-half feet through which that zone extends. The second zone exhibits the highest gas temperature, about 1200° C., needed for vitreous bonding or firing, and the article there travels above gas-distribution chamber 24 for a distance of about two feet, during which travel it is brought to and then maintained for a predetermined time at the maximum 1200° C. temperature. The third zone, above chamber 28, is relatively short (about one-half foot) and at a relatively low gas temperature (about 200° C.), such that the processed wheel temperature there begins to drop rapidly. In the fourth and fifth zones (above gas-distribution chambers 29 and 30, respectively), the gas temperatures are at levels designed to regulate the rate of wheel cooling, without inducing unwanted residual stresses or strains. Depending upon the chemical and physical characteristics of the articles being heat-treated, the temperatures and durations (i.e., zone lengths) of the treatments may be varied to meet different requirements. The rate at which the discrete porous articles travel through the 7+ foot length of kiln tunnel, for the case represented in FIGURE 6, is intended to be about one-third foot per minute, such that about six minutes is actually spent within the second (firing) zone. Linear speed of the speed-regulating conveyor belt 65 is thus set at the very low rate of one-third foot per minute; other speeds are of course permissible, although the lengths of kiln zones and linear speed are interrelated in each design. From the aforementioned measurements, it should be evident that the furnace in FIGURE 1-3 is remarkably small, moreover, its production rate is remarkably high, with each article being fully processed in about merely 22½ minutes. Fuel costs are very low, in part because warm-up time is so short where the hot gaseous combustion products themselves efficient.
ly permeate the articles to cause the desired heating effects; by way of example, total fuel costs for the heat-treatment of a single grinding wheel may be reduced to less than one-half cent. Advantages are realized not only in the firing but also in the rapid cooling by the permenting gases. Temperatures are lowered quickly and with high efficiency and uniformity, thereby importantly reducing the furnace size and processing times. The rather even flow of cooling gases through the porous wheel material tends to minimize occurrence of sharp temperature gradients which can be responsible for unwanted residual strains; safer wheels result from this improved processing.

In FIGURE 7 the gas flow circuitry for one preferred embodiment of the invention is represented schematically; where appropriate, the same reference characters used in connection with the embodiment of FIGURES 1–3 are applied to the same or functionally equivalent parts of the furnace, with a distinguishing single-prime accent being added. Hot gases from interconnected plenum chambers 32' and 33' are shown to be recirculated through all of the gas-distribution chambers 24' and 27'–30', via conduits 74 and 75, to conserve heat losses and fuel consumption in the system. Compressed air from supply line 76 is delivered to venturi-injectors 77–81 serving each of the gas-distribution chambers 24' and 27'–30', respectively, and the pressurized air entrains air at room temperature and pressure to these injectors by line 82. Such injectors, which are of a known construction, serve to bring the required volumes of room-temperature air to the various chambers at pressures and velocities needed for purposes of penetration and flotation or suspension of the processed porous articles. These injector mechanisms avoid the need for fans. In addition, the injector 77 is supplied with fuel (either gases or liquid) from fuel supply line 83, and the resulting entrainment provides a combustible mixture suitable for burning in a combustion chamber (not illustrated) before the resulting high-temperature gaseous combustion products reach the gas-distribution chamber 24' underly ing the hottest or "firing" zone of the kiln.

Articles which are generally flat and of relatively broad surface area, such as grinding wheels and tires, are best supported and fired using the apparatus and techniques which have been thus far described. However, other small flat items, and articles such as dinner-ware pieces which have a convex closed configuration, can also be successfully floated for heat-treatment. In other instances, where small articles are themselves shapes which are not stably supported by flow of hot gases, they may instead be supported indirectly upon porous pallets or "boats" designed for that purpose; such re-usable boats are preferably thin and substantially flat, such that they will contribute little mass and will float well while also permitting the hot gases to penetrate and reach the smaller boat-supported articles. For some purposes, such as processing of articles having curved lower surfaces, the hearth may have an upper surface which is curved or otherwise depressed, as viewed in the transverse direction, rather than being flat. Hearths may be made of naturally porous material, rather than artificially-perforated material, although the latter is presently preferred. Where kiln lengths are likely to be very great, the elongated hearth and associated tunnel may be arranged sinuously, rather than wholly linearly, to conserve space.

It should be understood that the specific embodiments and practices herein described have been presented by way of disclosure rather than limitation, and that various modifications, substitutions and combinations may be effected without departure in spirit or scope from this invention in its broader aspects.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Furnace apparatus for heat-treatment of discrete porous articles such as thin grinding wheels and the like, comprising a thermally-insulated tunnel extending from an inlet to an outlet, a hearth forming the bottom of said tunnel and having a plurality of uniformly-distributed relatively small openings therethrough for conveying hot gases from below said hearth to the top thereof, means forcing hot gases upwardly through at least one portion of said hearth with pressure and velocity uniformly across said portion which stably suspend the discrete porous articles a short distance above the top surface of said hearth, said hot gas-forcing means including means burning fuel under high pressure conditions and means distributing the hot gaseous products of combustion from said burning means evenly below said one portion of said hearth, said burning means comprising a combustion chamber fired by a burner supplied with combustible fuel and an oxidizing gaseous medium under pressure, said distributing means comprising a gas-distribution chamber immediately below said portion of said hearth and conveying hot gases from said combustion chamber substantially uniformly to all of said openings in said portion of said hearth, means externally of said tunnel continuously regulating the linear speed of the gas-suspended articles through said tunnel and across said portion of said hearth, and means recirculating at least some of the hot gases from said tunnel through at least some of said openings in said hearth at pressure and velocity which stably suspend the discrete porous articles a short distance above the top surface of said hearth.

2. Furnace apparatus for heat-treatment of discrete porous articles, as set forth in claim 1, wherein said burner produces said hot gases at a temperature at least as high as the vitreous-bonding temperature of the porous articles, for firing thereof, wherein said hearth is formed of refractory material and internal surfaces of said combustion chamber and gas-distribution chamber are of refractory material, and wherein said gas-distribution chamber includes end walls movable longitudinally in relation to said hearth and tunnel to adjust the length of said portion of said hearth.

3. Furnace apparatus for heat-treatment of discrete porous articles, as set forth in claim 1, wherein said recirculating means comprises at least one further gas-distribution chamber immediately below another portion of said hearth adjoining said one portion, and means combining at least some of the hot gases from said tunnel with air and forcing the mixture into said further gas-distribution chamber and through the openings in said other portion of said hearth at said pressure and velocity which stably suspend the discrete porous articles.

4. Furnace apparatus for heat-treatment of discrete porous articles, as set forth in claim 3, wherein said recirculating means comprises at least two further gas-distribution chambers immediately below other portions of said hearth adjoining said one portion at different ends thereof, and wherein said gas-distribution chambers are pressurized by said combining and forcing means.

5. Furnace apparatus for heat-treatment of discrete porous articles, as set forth in claim 3, wherein said recirculating means includes at least one thermally-insulated plenum chamber, and means connecting said plenum chamber with said tunnel to receive hot gases therefrom, said hot gases being recirculated from said plenum chambers by said recirculating means.

6. Furnace apparatus for heat-treatment of discrete porous articles, as set forth in claim 4, wherein said recirculating means includes thermally-insulated plenum chamber means, means withdrawing hot gases from said tunnel at positions therealong each displaced from a different
end of said one portion of said hearth, and means applying the hot gases withdrawn from said tunnel to said plenum chamber means for recirculation therefrom.

7. Furnace apparatus for heat-treatment of discrete porous articles such as thin grinding wheels and the like, comprising
  a thermally-insulated elongated tunnel extending from an inlet to an outlet,
  an elongated hearth forming the bottom of said tunnel and having a plurality of uniformly-distributed relatively small openings therethrough for conveying gases from below said hearth to the top thereof, means forcing gases upwardly through said hearth throughout the length thereof with uniform pressure and velocity which stably suspend the discrete porous articles a short distance above the top surface of said hearth,
  said gas-forcing means including fuel-burning means forcing hot gases through at least one portion of said hearth at a temperature at least as high as the ceramic-bonding temperature for said articles, means externally of said tunnel continuously regulating the linear speed of the gas-suspended articles through said tunnel and across said portion of said hearth, means recirculating at least some of the hot gases from said tunnel through at least some of said openings in said hearth,
  said tunnel having at least one passageway extending laterally therefrom for recirculation of said gases, the side walls of said tunnel restricting lateral movement of the articles through said tunnel, the transverse cross-sectional area of said tunnel above the hearth and the articles suspended over the hearth promoting rapid flow of said gases through the tunnel to said passageway with low losses, at least one air-slide means externally of said tunnel in alignment with and adjacent to one end of said hearth,
  said air-slide means having a member the top of which is substantially coplanar with the top of said hearth and which has a plurality of uniformly-distributed relatively small openings therethrough for conveying gas from below to the top thereof, and means for forcing gas through said last mentioned openings in said member at pressure and velocity which stably suspend the articles at said short distance above the top of said member.

8. Furnace apparatus for heat-treatment of discrete porous articles such as grinding wheels and the like, as set forth in claim 7, including two of said air-slide means, and means orienting each of said air-slide means adjacent a different one of said inlet and outlet of said tunnel.

9. Furnace apparatus for heat-treatment of discrete porous articles such as thin grinding wheels and the like, comprising
  a thermally-insulated elongated tunnel extending from an inlet to an outlet, an elongated hearth forming the bottom of said tunnel and having a plurality of uniformly-distributed relatively small openings therethrough for conveying gases from below said hearth to the top thereof, said small openings being about 1/8-inch in diameter and having their centers spaced apart about 1/4-inch, means forcing gases upwardly through said hearth throughout the length thereof with uniform pressure and velocity which stably suspend the discrete porous articles a short distance above the top surface of said hearth, said gas-forcing means including fuel-burning means forcing hot gases through at least one portion of said hearth at a temperature at least as high as the ceramic-bonding temperature for the articles, means externally of said tunnel continuously regulating the linear speed of the gas-suspended articles through said tunnel and across said portion of said hearth, and means recirculating at least some of the hot gases from said tunnel through at least some of said openings in said hearth by way of said gas-forcing means.

10. Furnace apparatus for heat-treatment of discrete porous articles such as thin grinding wheels and the like, comprising
  a thermally-insulated elongated tunnel extending from an inlet to an outlet, an elongated hearth forming the bottom of said tunnel and having a plurality of uniformly-distributed relatively small openings therethrough for conveying gases from below said hearth to the top thereof, said elongated hearth being formed of a plurality of contiguous sections of refractory material aligned in end-to-end relationship, loading means disposed externally of said tunnel yieldably compressing said aligned sections together continuously under conditions of thermally-induced expansions and contractions, means forcing gases upwardly through said hearth throughout the length thereof with uniform pressure and velocity which stably suspend the discrete porous articles a short distance above the top surface of said hearth, said gas-forcing means including fuel-burning means forcing hot gases through at least one portion of said hearth at a temperature at least as high as the ceramic-bonding temperature for the articles, means externally of said tunnel continuously regulating the linear speed of the gas-suspended articles through said tunnel and across said portion of said hearth, and means recirculating at least some of the hot gases from said tunnel through at least some of said openings in said hearth by way of said gas-forcing means.

11. Furnace apparatus for heat-treatment of discrete porous articles such as grinding wheels and the like, as set forth in claim 10, wherein said gas-forcing means includes a plurality of aligned refractory members forming multi-section upwardstanding walls and bottom walls of an elongated trough-shaped structure subdivided into separate gas-distribution chambers by movable partitions of refractory material extending transversely to the direction of elongation of said hearth, wherein said hearth sections are secured atop the said upwardstanding walls of said trough-shaped structure, and wherein said external loading means comprises movable pressure plate means at the ends of said trough-shaped structure for applying forces to each end thereof, rigid yoke means at each end of said trough-shaped structure fixed in relation thereto and respectively spaced in relation to said pressure plate means at said ends, and yeldable springs interposed between said yoke means and pressure plate means at said ends of said structure to compress said walls and hearth sections together in direction of said elongation thereof.

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