

[54] HEAT TREATMENT

[75] Inventor: Charles S. Flynn, Muskegon, Mich.

[73] Assignee: National Lumberman's Bank & Trust Company, as Trustee for Blu-Surf Thermo Engineering Trust, Muskegon, Mich.

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[51] Int. Cl. F27b 9/28

[58] Field of Search 263/3; 266/3; 34/155; 432/8, 59

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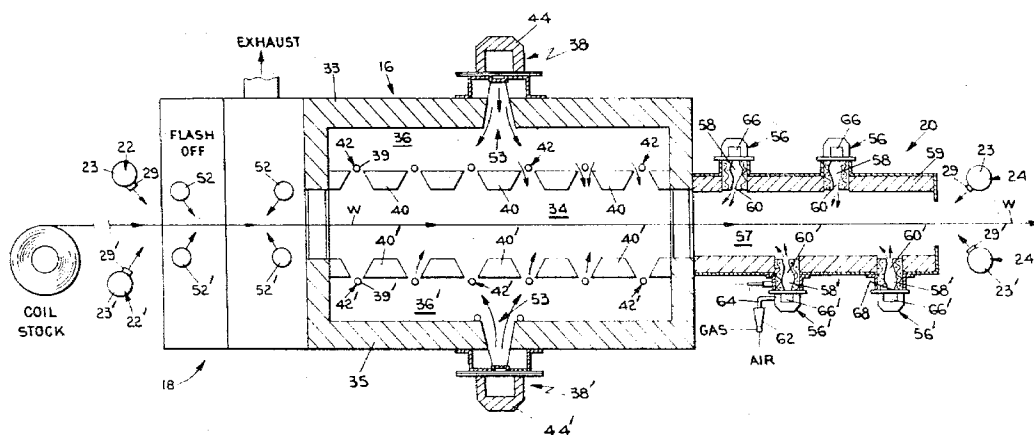
Primary Examiner—John J. Camby

Attorney—Price, Heneveld, Huizenga & Copper

[57] ABSTRACT

Apparatus for high-speed heat treatment of web stock, particularly coated metallic stock as supplied from a coil, moved in catenary configuration through the heat-treatment apparatus. The apparatus employs a plurality of high-velocity, combustion burner assemblies specially arranged in a plurality of heating zones through which the strip is moved. A plurality of heating sections using these burners usually includes a high-velocity section and a dynamic flow section. Frequently included is a flash-off section to remove volatiles. Special air curtains at the ends of the apparatus serve to close the entry and exit and also remove the cold incoming boundary layer from the stock thereby allowing more efficient operation, and the hot outgoing boundary layer to assure rapid cooling.

14 Claims, 4 Drawing Figures



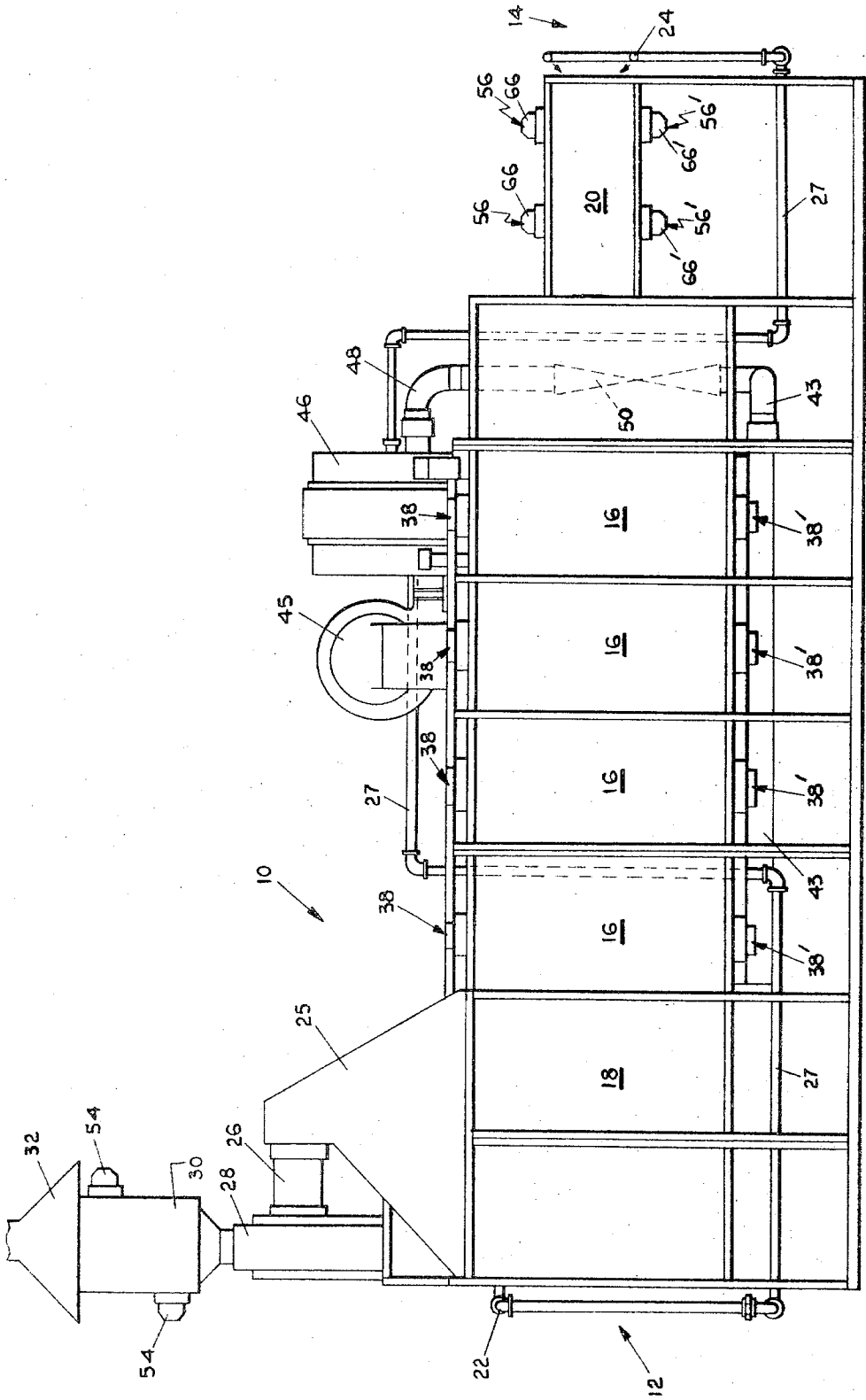


FIG. 1

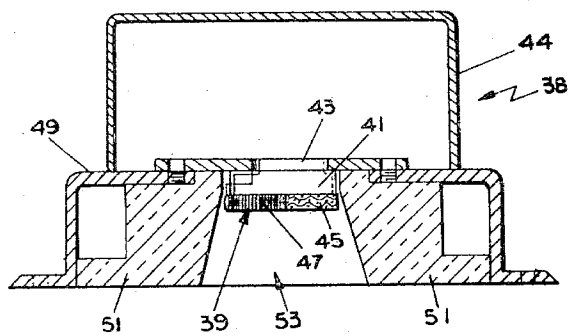


FIG. 4

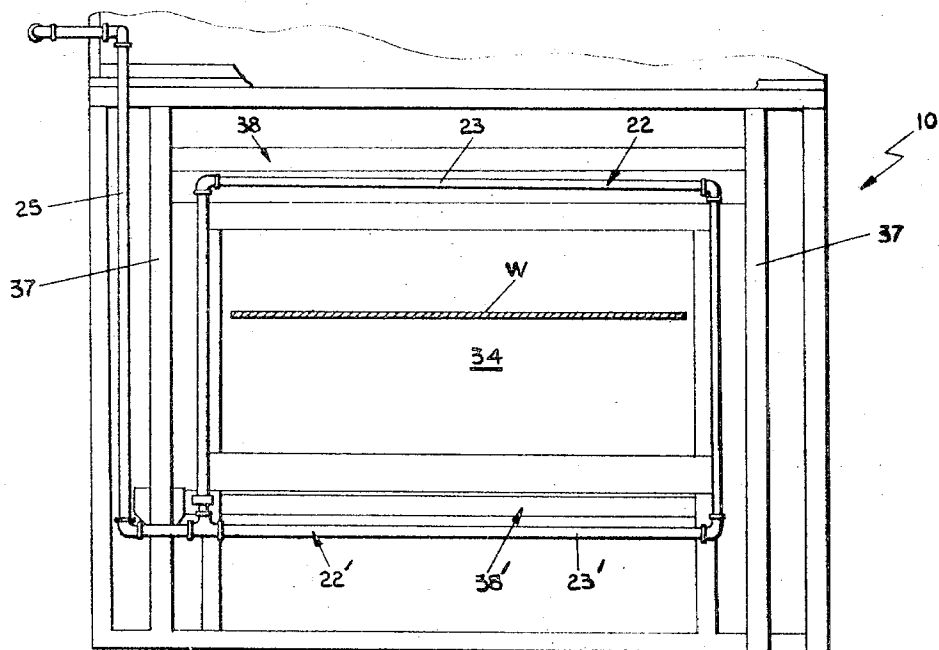


FIG. 2

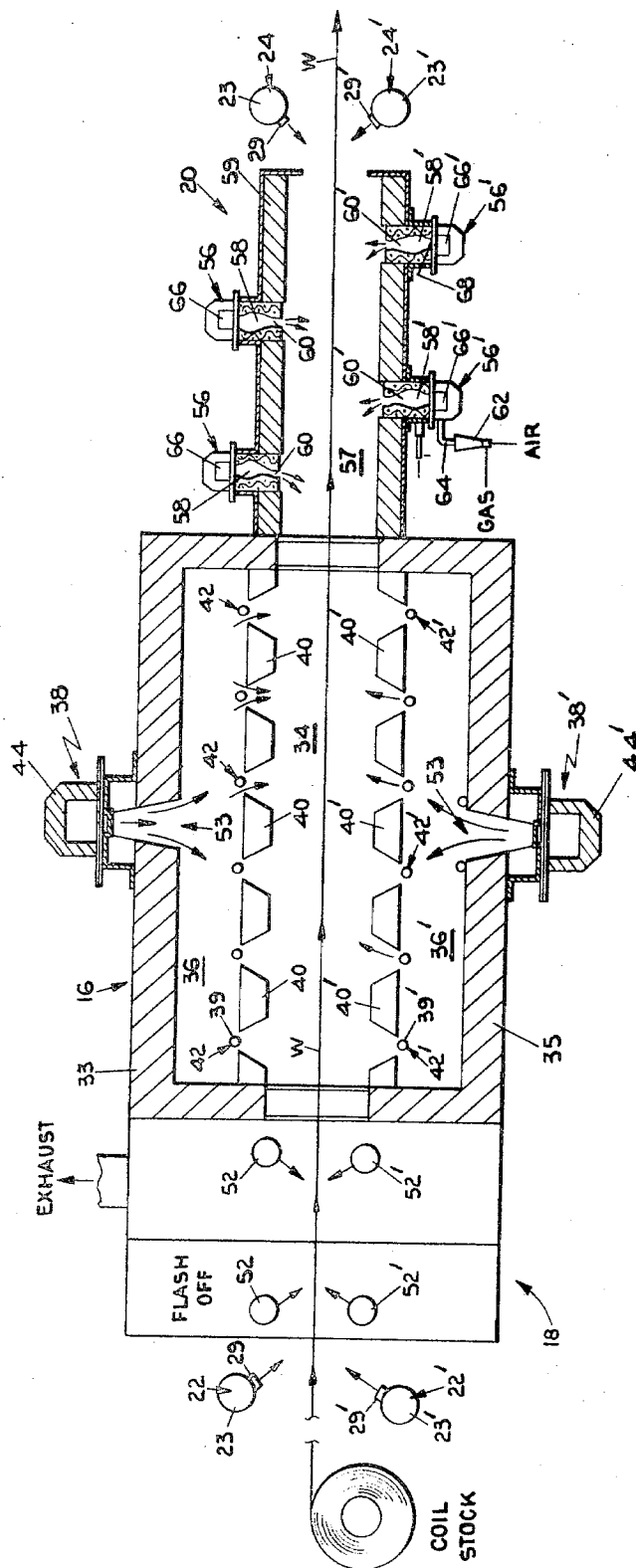


FIG. 3

HEAT TREATMENT

BACKGROUND OF THE INVENTION

In recent years, there have been more and more applications where raw materials are painted or otherwise treated before the finished product is formed. Typical of this is the painting of sheet metal prior to die forming it. To do this, a good coating is required that is durable enough to withstand acids, caustics and, in addition, must be highly abrasive and chip resistant. In many cases, paint containing epoxy-type compounds is used. The advantages of coating the geometrically plain stock rather than the geometrically complex final products are obvious. This also allows the inside of the product to be completely coated and protected.

Presently, the high cost of these coatings is offset by the ease of handling and high speed at which the finished product can be formed in only limited areas, however. Due to these high costs, the applications utilizing this technique have been limited. The equipment is expensive and the coatings require temperatures in the range of 250° to 500° F. The finish must be completely and evenly distributed and very carefully and closely controlled. After the coating is applied, the surface cannot be touched until after it has been properly cured as by heat treatment. In the case of coating long strips of stock, as for example, from a roll of coiled steel, the length of the treating oven is the crucial factor that determines the speed at which the coating can be applied because it is strictly controlled by the catenary or sag of the material as it is drawn through the oven. In presentday equipment, the time that the material must be subjected to the heat treatment limits the production to approximately 100-150 feet per minute. This limiting factor renders the process of "coating prior to forming" economically unfeasible for most mass production systems, e.g., automobile manufacture. However, by the present invention, the heat treatment can actually be accomplished in less than one-third of the time previously required therefore increasing the rate of production approximately three times with the resultant corresponding reduction in costs. Such a drastic improvement has resulted in the process being economically feasible for mass production system such as automobile manufacture such that at least one of the major United States automobile manufacturers is now adapting its manufacture to this system by using the invention herein.

There are various types of coating that require different treatments. Some that are applied in liquid form require a flashoff time and then a baking process while others can be cured by preheating the metal and then applying the coating.

The present invention provides an apparatus for heat treatment of web stock such as, for example, sheet metal provided in a large coil. Stock is withdrawn from the coil and coated with a suitable coating material such as paint and then passed through the heat treatment chamber in a long continuous catenary web. The heat treatment apparatus of the present invention includes a plurality of modular sections arranged in tandem along the length of the web as it passes there-through.

Each of the modular units perform a particular function with respect to the heat treatment of a particular type of stock. In an application relating to the heat treatment of paint (e.g., epoxy type) applied to a web

of sheet metal, the heat treating apparatus utilizes the following modular units arranged in tandem: an exhaust or flash-off section, a dynamic-flow oven section, and a high-velocity section. The second and third sections employ special burners, specially arranged. Air curtains are provided at both ends, i.e., the inlet and the outlet end, of the apparatus to specially remove boundary layers as well as closing the ends, as will be more fully described hereinafter. If desired, a second dynamic-flow oven and high-velocity section together with an exhaust section may be provided to further treat the material. Actually, as many modular units as desired may be provided to treat the material although it is normally not necessary because of the extremely high efficiency of the invention.

Accordingly, it is a primary object of the present invention to provide a high-speed heat treatment apparatus for web stock.

It is another object of the present invention to provide a heat treatment apparatus utilizing special air curtain jets at the inlet and outlet ends of the apparatus to remove the boundary layer of air which follows the web to enhance the heating, and to remove the boundary layer of hot gases from the web to enhance cooling of the web stock.

It is another object of the present invention to provide a heat treatment apparatus which operates with extremely high efficiency and extremely rapidly, thereby rendering coating prior to forming economically feasible for many uses, and thus effecting great cost savings as well as enabling superior quality products.

These and other important objects and advantages of this invention will be readily understood by those skilled in the art upon reading the following specification with reference to the accompanying drawings in which:

FIG. 1 is a side elevation view of an apparatus incorporating the present invention;

FIG. 2 is an end view of the apparatus shown in FIG. 1 illustrating the inlet end;

FIG. 3 is a somewhat schematic elevational cross-sectional view taken along the length of the apparatus in FIG. 1; and

FIG. 4 is an enlarged sectional view of one of the burner assemblies.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and particularly to FIGS. 1 and 2, a representative heat treatment apparatus designated by the numeral 10 for the heat treatment of web stock is illustrated. Basically, the apparatus comprises an elongated tunnel having an inlet end 12 and an exit end 14. It has a plurality of functional heat treatment sections including a flash-off section 18, a dynamic-flow section 16, and a high velocity section 20. Air curtain mechanisms 22 and 24 are positioned at the inlet end and the outlet end of the tunnel respectively. Each of the sections may be of modular construction and conveniently assembled together to form a heat treatment apparatus including some or all of the above-mentioned sections of any desired length and arrangement depending upon the particular materials being heat treated. When, for example, heat treating paint substances on metallic stock, it is sometimes desirable to have all of the above-named sections, that is,

flash-off, dynamic-flow, and high-velocity, arranged together, with the dynamic flow section being the greatest in length so that a moving web passing therethrough is subjected to that particular treatment for the greatest length of time. The flash-off section 18 is provided with a hood 25 at the top thereof and is connected by conduit means 26 to an exhaust blower 28. Such removes the fumes and volatile substances from the stock and passes them through an after burner 30 vented to the atmosphere through an exhaust stack 32.

Referring now additionally to FIG. 3, the various sections of the heat-treatment apparatus will be described in greater detail. Normally, the web W moves along the central portion of the heat-treatment apparatus in an essentially horizontal plane realizing that it sags in catenary fashion when so supported only at its ends. The various sections of the apparatus operate above and below the web to simultaneously treat both surfaces. The upper portion of each section will therefore be described in detail, with like reference numerals bearing the (') designation being utilized to designate similar structure in the lower section.

As the web begins its travel through the apparatus, it first passes through the flash-off and exhaust section 18. The flash-off section 18 of the apparatus is located adjacent and ahead of the dynamic-flow section 16 and upstream thereof with respect to the movement of the web W. The flash-off section removes the volatile fumes which can sometimes be approximately 200 gallons per hour. The fumes are removed by passing the web through an exhaust plenum where the volatile fumes are removed by an exhaust blower. The removal of the fumes may be accelerated by a plurality of strategically placed air nozzles 52 arranged to direct a jet flow of air toward the surface of the web from above and below. In some cases, heated air from one of the heating sections may be diverted into the flash-off section to effectively evaporate the volatile substances. In the event the volatiles from the flash-off section are to be vented to the atmosphere, it is desirable to dissipate the volatiles in a safe manner. An air purifying apparatus including the previously described exhaust fan 28 and after burner 30 may be provided for this purpose. The gases are exhausted from the flash-off section at a high rate and passed through the after burner 30 where a plurality of burners 54 each similar in construction to burners 44 in the dynamic-flow section, are located. The fumes are ignited and burned, and harmless vapors are then passed through stack 32 to the atmosphere. A suitable air purifying method and apparatus for treating the volatile substances illustrated in greater detail in my U.S. Pat. No. 3,497,308, issued Feb. 24, 1970, entitled AIR PURIFYING APPARATUS AND METHOD.

The dynamic flow section 16 is a high-efficiency convection heating oven having top walls 33, bottom walls 35, and side walls 37, each of an insulated construction forming a tunnel-like structure open at its ends. The oven includes a central heated oven chamber 34 and a pair of oppositely positioned plenum chambers 36 and 36' located adjacent the top and bottom walls of the chamber respectively.

The plenum chambers 36 extend along the length and width of the heater chamber 34. A plurality of high-volume burner units 38 are arranged to project hot gases into the oven chamber 34 through a plurality of elongated, spaced-apart baffle members 40. Air nozzle assemblies 42 positioned adjacent the baffles are

connected to a source of fluid pressure (not shown) to impart a dynamic Venturi action to the hot gases into the oven chamber 34.

The air nozzle assemblies 42 include a series of openings (not shown) drilled into piping 39 which is connected to the source. The openings or orifices are drilled at predetermined intervals along the pipes 39 along the width of the oven. The orifices are drilled large enough to supply the required effective velocity at the work; in other words, the further the jets are from the work, the larger the orifices must be. In one practical application of the invention, the air is ejected from the orifices at 18,000 ft./min. with a 24 oz. blower as the source. This creates a vacuum that sucks in the heat along the entraining air in the chamber for recirculating and creating a high turbulence that almost eliminates the film coefficient on the material being heated. The entraining ratio is approximately 40 to 1 minimum; i.e., for every cubic foot of air ejected from the orifice there are 40 cubic feet minimum sucked into the stream or entrained, giving the same effect with one cubic foot as normally would exist with 40 CFM flowing at approximately 55 ft./sec. The higher the temperature that the oven is operating, the greater the velocity and it follows, the greater the turbulence.

Each burner assembly 38 includes an elongated manifold 44 supplied with a pressurized combustible mixture of gases, e.g., natural gas and filtered air. The air is directed to the manifold 44 from a filter 46 through suitable conduit means 48 where it is combined with the gas in a mixer 50. A blower assembly 45 is provided to force the air through the filter and through conduit 48 to the mixer 50. The outlet of the mixer is connected to each of the burner manifolds by conduit means 43.

Referring additionally to FIG. 4, each burner assembly 38 includes a plurality of adjacent, cooperating burner units 39, together extending substantially along the width of the oven within the manifold 44. The burner units are preferably of the construction shown in my U.S. Pat. No. 3,232,593, issued Feb. 1, 1966, entitled OVEN. Each burner includes a hollow support housing 41 having an inlet port 43 and an open front covered by a thin porous combustion layer 45 sealed to and held over the open housing front by screen means 47. The combustion layer 45 may be of a metal fiber, a thin porous ceramic felt, or a fine mesh screen. The combustible mixture of gases is forced to pass generally uniformly out of the porous combustion layer to combust at its outer surface. Brackets 49 support peripheral upstanding channel walls 51 forming a hot-gas directing elongated outlet passage 53 discharging into the plenum chambers 36 at opposite sides of the web.

Any number of burner assemblies 38 may be arranged in each dynamic-flow section 16 as required. In the embodiment illustrated in FIG. 1, several dynamic-flow sections 16 are illustrated, each having an upper and a lower burner assembly 38 and 38' respectively, associated therewith. The dynamic-flow sections are arranged in tandem to form the elongated heating chamber.

After the web has passed through the flash-off and dynamic-flow sections, it may be subjected to further heat treatment in a high-velocity section 20. The high-velocity section includes a plurality of burners 56 similar to burners 38 and 54 previously described. The burners 56 are arranged to direct heated gases with high velocity toward the upper and lower surfaces of

the web as it passes through the oven chamber 57. Each of the high-velocity burners 56 include a number of individual burner units having an inlet port, and an open front face covered by the thin porous combustion layer held in place by a screen such as that previously described in connection with the dynamic-flow section and illustrated in FIG. 4. The burners are arranged in a manifold 66 extending across the width of the chamber 57. A plurality of manifold burner assemblies 56 are arranged in rows across the chamber, the spacing thereof and the number determined by the particular material being treated. Each high-velocity burner manifold assembly includes a positive pressure chamber 58 similar to the outlet passage 53 illustrated in FIG. 4 and has a restricted outlet 60 which produces a high-volume, high-temperature output of heated gases. The high-velocity output is directed toward the web surfaces. The top, bottom, and side walls of the burner are constructed of an insulating material 59 similar to that construction shown in connection with the dynamic-flow section 16. The insulating material and construction for the high-velocity section must, however, be designed for higher temperatures as the high-velocity sections, in continuous operation, tend to reach temperatures greater than that of the dynamic-flow section.

A combustible mixture of gases and air is formed in mixer 62 and introduced through conduit 64 into the manifold chamber 66 of each burner assembly 56. The volume and temperature output can be regulated by varying the pressure and the gas mixture input to the burner. The high-volume, high-temperature gases developed on the burner surface are injected into the pressure chamber 58. Pressure in the chamber 58 creates a propelling force to expel the gases through the restricted outlet 60 into oven chamber 57. The output flow from the restricted output may be directed in various directions within the oven as illustrated by the arrow shown at outlets 60. In the embodiment illustrated in FIG. 3, the burners 56 located at the inlet end of the high-velocity section are directed upstream with respect to movement of the web 7 thereby injecting a portion of the high-velocity, high-pressure gases toward the dynamic-flow section 16. For a further detailed discussion of a high-velocity burner unit suitable for use in the practice of the present invention, reference may be had to my issued U.S. Pat. No. 3,390,944 issued July 2, 1968 entitled HIGH VELOCITY BURNER ASSEMBLY.

The air curtain or boundary layer removal mechanisms 22 and 24 positioned at the entrance and exit ends of the heat treatment apparatus are connected by suitable piping 27 to a source of air under pressure. As shown in FIGS. 2 and 3, the air curtain mechanisms 22 and 24 each include a pair of pipes 23 and 23' extending across the width of the ends 12 and 14 of the oven. Each of the pipes have a plurality of orifices or nozzles 29 therein to direct a high-velocity stream of air toward the surfaces of the web at an acute angle with respect to the opening as indicated by the arrows in FIG. 3. In some applications, the pressure need only be slightly greater than ambient pressure and the piping means 27 may be connected directly to the same pressure source used to supply the burners.

OPERATION

The stock to be subjected to heat treatment is supported at either end of the heat treatment apparatus in

a conventional manner and is drawn through the oven at a predetermined rate depending upon the treatment desired. After the coating (as, for example, paint) is applied to the web, the surface cannot be touched until the heat treatment is completed. The web stock is painted, coated, or otherwise treated in a conventional manner and enters the heat treatment apparatus at the entrance end (to the left as viewed in FIG. 3). A layer or film of air (sometimes referred to as a boundary layer) follows the surface of the web as it moves. As the web surface enters the flash-off section, air curtain members 22 positioned upstream direct a high-velocity stream of air toward the surface of the web, preferably at an acute angle with respect thereto, creating a turbulence thereon and remove the clinging boundary layer by "peeling" it off, thereby exposing the web surface for subsequent heat treatment. As is well known to those skilled in the art, as the web passes through the flash-off section, the volatile fumes are removed. This, of course, may be accomplished in any number of ways, although to prevent contamination of the environment, I prefer to treat the fumes by passing them into after burner 30 as noted previously. Because the exhaust fan 28 creates a reduced pressure area within the exhaust section, an air flows from areas of higher pressure, i.e., dynamic-flow section 16 and the high-velocity section 20, into the flash-off section. Air jets 52 positioned above and below the web help to remove the solvents by creating a turbulence and flow of the gases which carry off the volatile solvents. The web then passes into the dynamic-flow section.

The hot gases filling the plenum chamber 36 of the dynamic-flow section 16 are driven continuously at a substantial velocity into the oven chamber 34 by the Venturi action resulting from the high-pressure nozzle assemblies 42. The hot gases and propulsion air mix as they flow into the oven chamber, thereby providing a relatively high-temperature dynamic-flow convection heating action on the surfaces of the web in the oven chamber 34.

After passing through the dynamic-flow section, the stock may be subjected to further heat treatment in the high-velocity section 20 which provides a more localized application of heated gases. Generally, the high-velocity section provides a heat treatment at a considerably elevated temperature to cure and set the finishing material. The heated gases are directed with high-velocity from the restricted outlet 60 toward the web surface in the oven chamber 57.

As the web continues its movement out of the high-velocity section, the hot gases create another boundary layer that clings to and follows the web stock. If the web is drawn out of the oven with the hot gas boundary layer remaining thereon, the web will tend to stay hot, with the heat tending to overcure the finished material. It is therefore desirable to provide a second air curtain or boundary layer removal means 24 at the outlet end of the heat treatment apparatus. Jets of air are directed from the air curtain mechanism 24 toward the surface of the web, preferably at an acute angle, break up or strip the boundary layer of heated gases following the web to expose the surfaces of the web to the ambient atmosphere to allow rapid cooling thereof. Also, the curtain closes off the outlet end of the tunnel, and, by being directed with its acute angle toward the outlet end (see FIG. 1), largely keeps the hot gases inside the oven. As will be obvious to those skilled in the art, a

final exhaust section may be positioned adjacent the outlet end of the high-velocity section to carry off heated gases.

The catenary or sag of the web in the oven between its supports at the ends thereof determines the length of the web which can be heat treated. This in turn determines the speed at which the coating can be applied and heat treatment can be accomplished. In prior art systems, the basic factor involved with all heating operations and which greatly influences the retention time in the oven is the heat transfer rate. This in turn is dependent upon oven temperature, the effectiveness of hot gas contact, heat exchange with the article surfaces, radiant heat intensity, and the rate of vapor removal away from the article surfaces. As will become apparent to those skilled in the art, from the foregoing detailed description, the present invention drastically reduces the necessary retention time over the conventional equipment by reducing the time necessary to treat the web. By the present invention, the surfaces can be heat treated in less than one-third of the time necessary for conventional equipment; therefore, production can be increased approximately three times over that of the prior art systems, resulting in greatly reduced costs.

While a preferred embodiment of this invention has been illustrated and described, it will be recognized that other embodiments and modifications of this invention incorporating the teachings hereof may be readily made in light of this disclosure. All modifications embodying the principles of this invention are to be considered as included in the appended claims unless these claims by their language expressly state otherwise.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

1. Apparatus for high-speed heat treatment of a coating on a continuous web comprising:
a first heating chamber;
a second heating chamber positioned downstream of said first heating chamber, each of said heating chambers having side, bottom, and top walls forming an elongated tunnel having an inlet end and an exit end for the web;
exhaust means positioned adjacent said first heating chamber at the inlet end thereof for removing volatile fumes from the coating on the web;
first hot gas burner means positioned in said first heating chamber adjacent said walls for generating a continuous flow of heated gases about the upper and lower surfaces of the web, said hot gas burner means including a plurality of individual burner assemblies, each formed of a housing having a gas inlet means connected thereto and having means thereon forming a combustion surface;
second hot gas burner means positioned in said second chamber adjacent said walls for directing a high velocity jet of heated gases toward the upper and lower surfaces of the web, said second hot gas burner means including a plurality of individual burner assemblies each having enclosure means forming a hot-gas pressure chamber, a restricted orifice outlet from said pressure chamber to allow hot gaseous flow from said pressure chamber into said second heating chamber while retaining a positive pressure in said pressure chamber, a combus-

tion burner having a burner surface in said enclosure means and gas inlet means connected thereto, said hot gas pressure pressure chamber and said restricted nozzle outlet causing a high velocity flow of hot combustion gases in a jet stream from said outlet toward the surface of the web;
manifold means connected to said inlet means of each of said first and said second hot gas burner means to supply a combustible mixture thereto; and

air curtain means positioned at one of said inlet and exit ends to remove the gaseous boundary layer on said web passing through said chamber.

2. The heat-treatment apparatus as defined in claim 1 wherein said exhaust means includes a blower, said blower having an inlet and an outlet to remove the volatile fumes from said exhaust means, said outlet connected to a stack conduit means having a discharge opening therein; burner means in said stack conduit having combustible gas mixture inlet means thereto and having a hot-gas discharge surface area oriented toward said discharge end of said stack to create a hot-gas flow zone therein for continuous ignition and combustion of said volatile fumes before passage out of said stack.

3. The heat-treatment apparatus as defined in claim 1 wherein said air-curtain means is positioned at the inlet end of said first heating chamber and at the exit end of said second heating chamber to remove the boundary layer of ambient air at the entrance end of said heat treatment apparatus and to remove the boundary layer of heated air at the exit end thereof.

4. The heat-treatment apparatus as defined in claim 3 wherein said exhaust means includes a blower, said blower having an inlet and an outlet to remove the volatile fumes from said exhaust means, said outlet connected to a stack conduit means having a discharge opening therein; burner means in said stack conduit having combustible gas mixture inlet means thereto and having a hot-gas discharge surface area oriented toward said discharge end of said stack to create a hot-gas flow zone therein for continuous ignition and combustion of said volatile fumes before passage out of said stack.

5. The apparatus as defined in claim 3 wherein said air-curtain means is positioned at an acute angle with respect to said web and said inlet and exit ends to direct a high-velocity stream of air toward said web to peel the boundary layer from said web.

6. The apparatus as defined in claim 5 wherein said air-curtain means is positioned adjacent an upper and lower portion of said ends, said high-velocity stream of air is directed toward the upper and lower surfaces of said web at an angle with respect thereto to peel the boundary layer therefrom and to close said ends to retain the heated gases in said first and second.

7. The heat-treatment apparatus as defined in claim 5 wherein said exhaust means further includes a plurality of air nozzles arranged above and below said web to direct a continuous jet of pressurized air about said web to accelerate the removal of volatile fumes therefrom.

8. The heat-treatment apparatus as defined in claim 1 wherein said first heating chamber includes a plurality of elongated spaced baffle elements arranged between said hot-gas burners and said web above and below said web; pressurized air manifold means adjacent said baffle members to eject pressurized air into

said first heating chamber to thereby cause a dynamic flow of heated gases in said first chamber about said web.

9. Apparatus for high-speed heat treatment of continuously moving coated web stock comprising:

a first heating chamber;

a second heating chamber;

an exhaust chamber positioned adjacent said first heating chamber, each of said chambers having side, bottom and top walls forming an elongated tunnel having an inlet end and an exit end for said web stock;

hot-gas burner means positioned in each of said chambers adjacent said top and said bottom walls for directing a continuous flow of heated gases about the upper and lower surfaces of said web;

each of said hot-gas burner means including a plurality of individual burner assemblies, each formed of a housing having a gas inlet means connected thereto, an open side covered by a thin porous combustion layer forming a combustion surface; manifold means connecting each of said individual burner assemblies to a combustible mixture of gases; and

air-curtain means positioned at said inlet end and said outlet end of said heating chambers to remove the boundary layer from said web passing through said chambers and to close said ends.

10. The apparatus as defined in claim 9 wherein said first heating chamber includes dynamic-flow means cooperating with said burner means to provide a dynamic flow of heated gases about said web and wherein said burners in said second chamber are adapted to direct

a high-velocity jet of heated gases toward said surfaces.

11. The heat-treatment apparatus as defined in claim 9 wherein said exhaust means includes a blower, said blower having an inlet and an outlet to remove the volatile fumes from said exhaust means; stack conduit means having a discharge opening therein, said blower means connected to said stack conduit means; burner means in said stack conduit having a hot-gas discharge surface thereon oriented toward said discharge to create a hot-gas flow zone therein for continuous ignition and combustion of said volatile fumes before passage out of said stack.

12. The heat-treatment apparatus as defined in claim 11 wherein said exhaust means further includes a plurality of air nozzles arranged above and below said web to direct a continuous jet of pressurized air about the surface of the web to accelerate the removal of volatile fumes therefrom.

13. The apparatus as defined in claim 9 wherein said air-curtain means is positioned at an acute angle with respect to the web and said inlet and outlet ends to direct a high-velocity stream of air toward the web to peel the boundary layer from the web.

14. The apparatus as defined in claim 13 wherein said air-curtain means is positioned adjacent an upper and lower portion of said ends, said high-velocity stream of air is directed toward the upper and lower surfaces of the web at an angle with respect thereto to peel the boundary layer therefrom and to close said ends to retain the heated gases in said first and said second heating chambers.

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