Oct. 1, 1968 H. L. SMITH, JR 3,403,454

HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Original Filed March 24, 1966 7 Sheets-Sheet 1

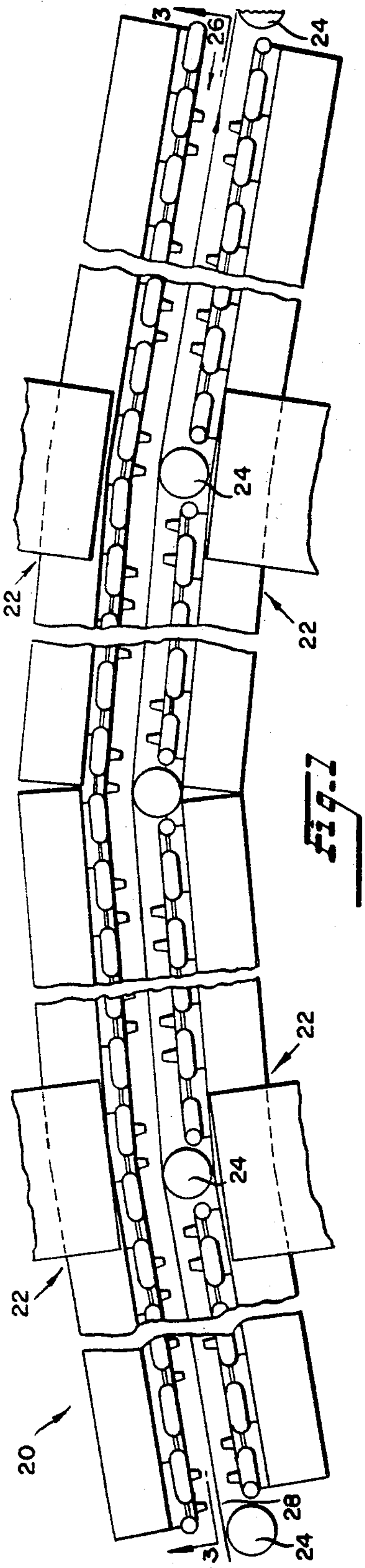

FIG. 1

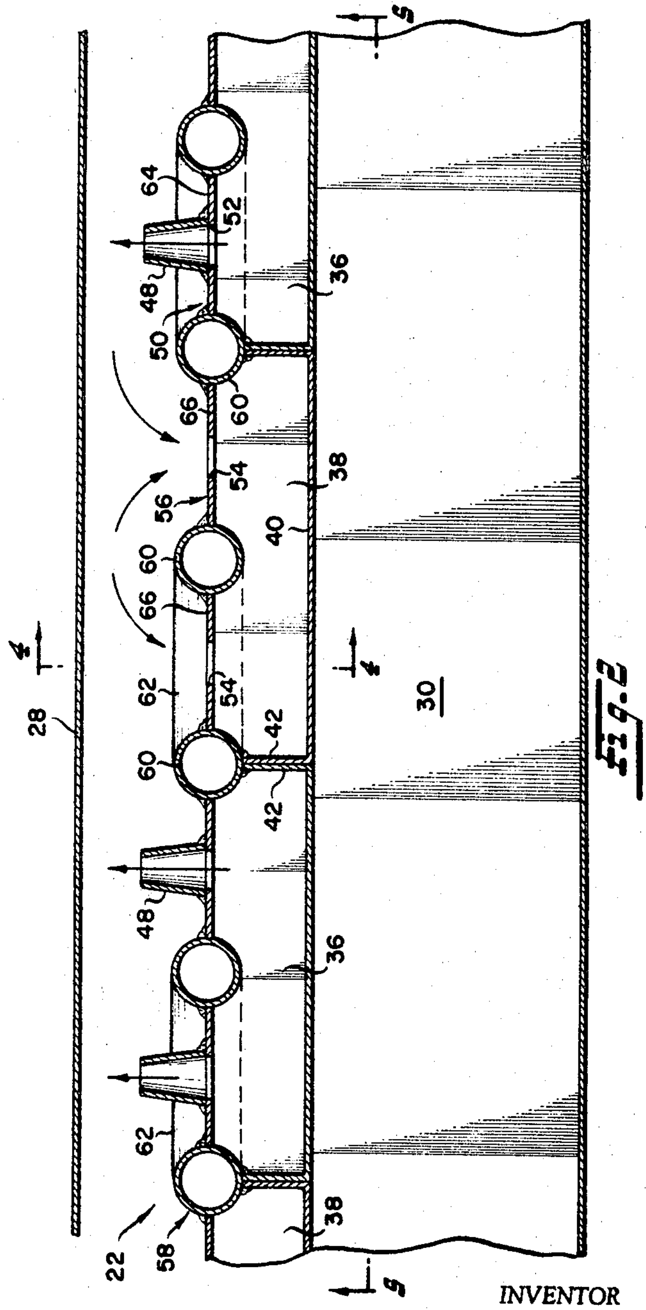

FIG. 2

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HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Original Filed March 24, 1966 7 Sheets-Sheet 2

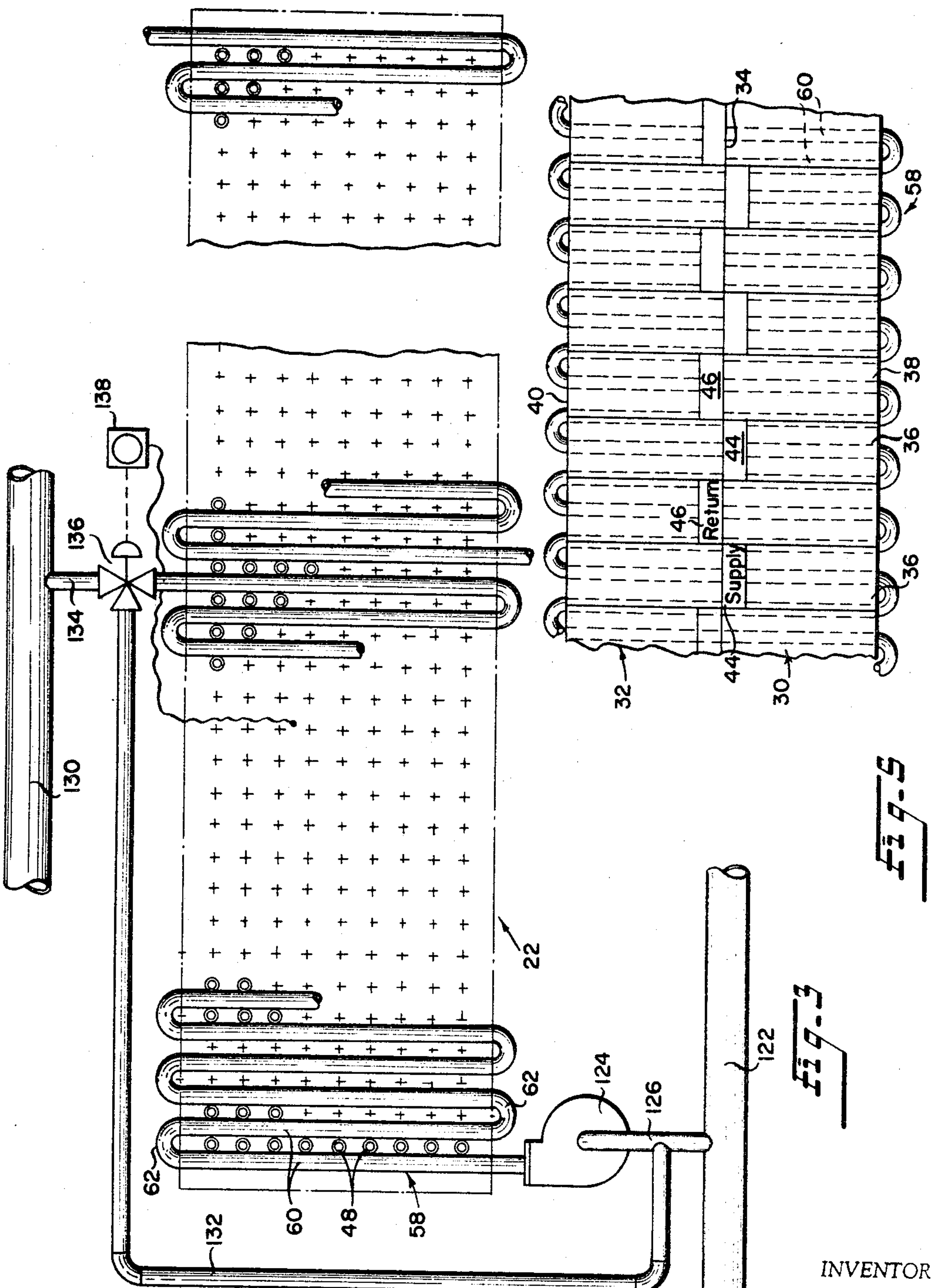

FIG-5

FIG-3

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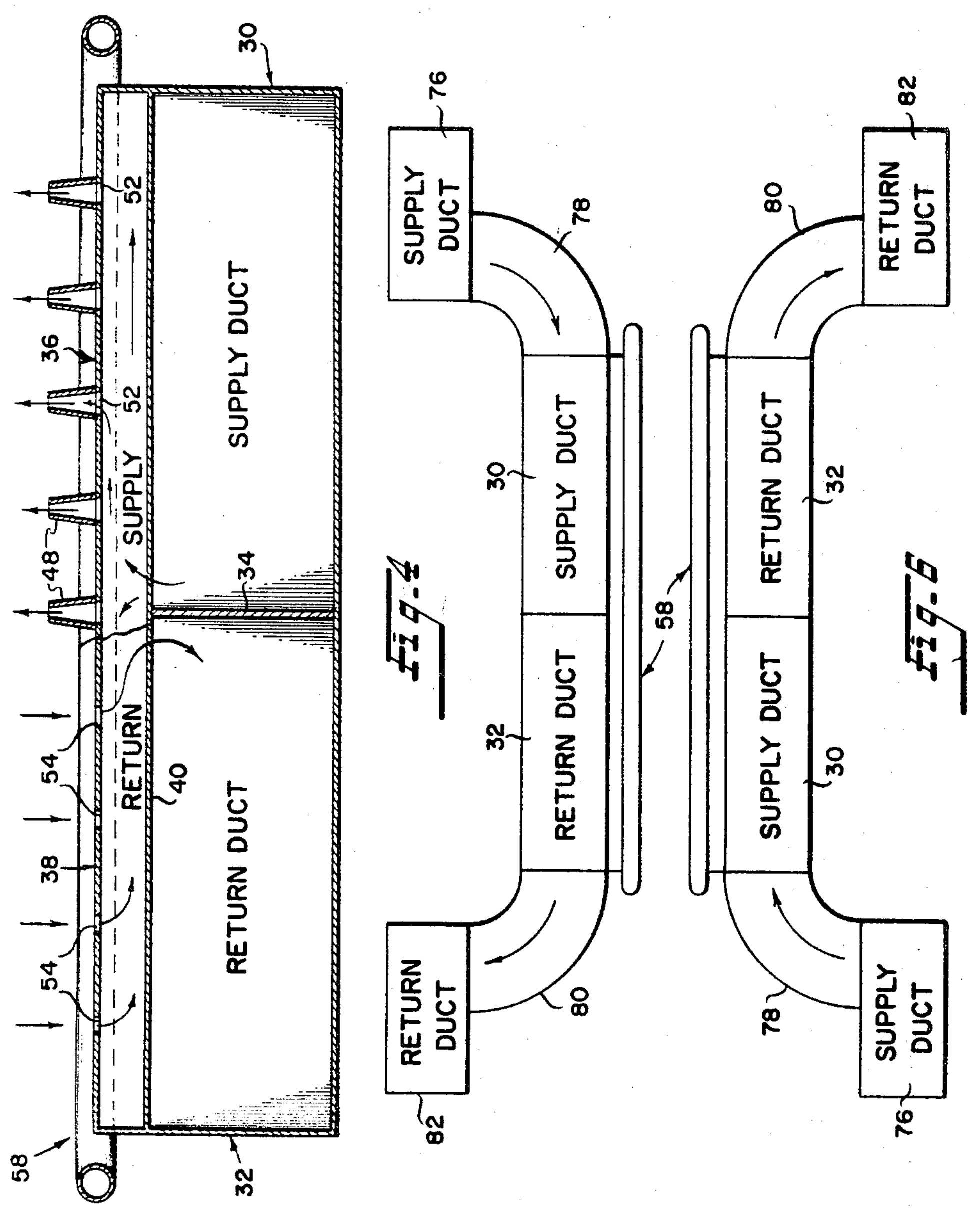
HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Original Filed March 24, 1966 7 Sheets-Sheet 3



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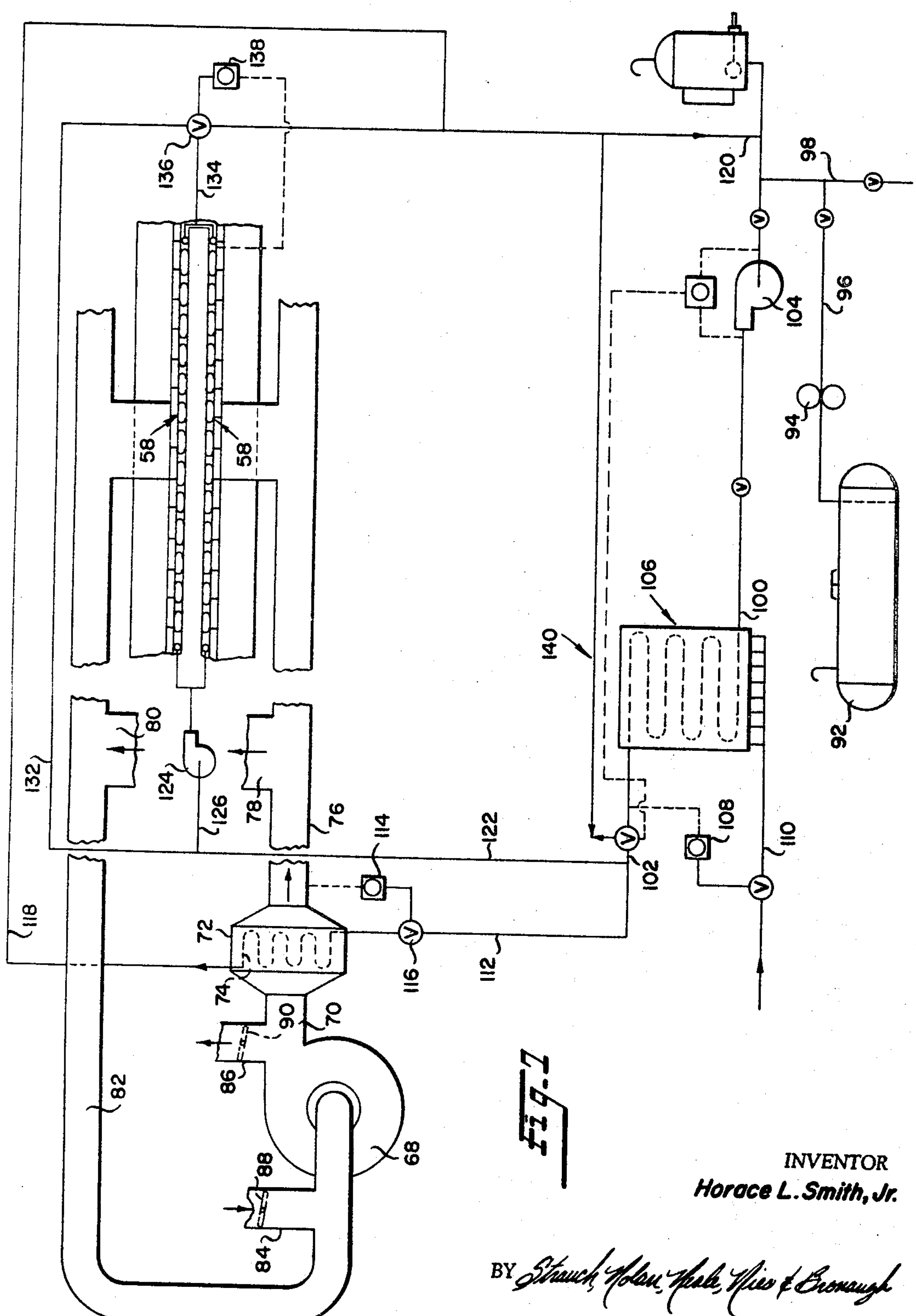

FIG. 1

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HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Original Filed March 24, 1966 7 Sheets-Sheet 5

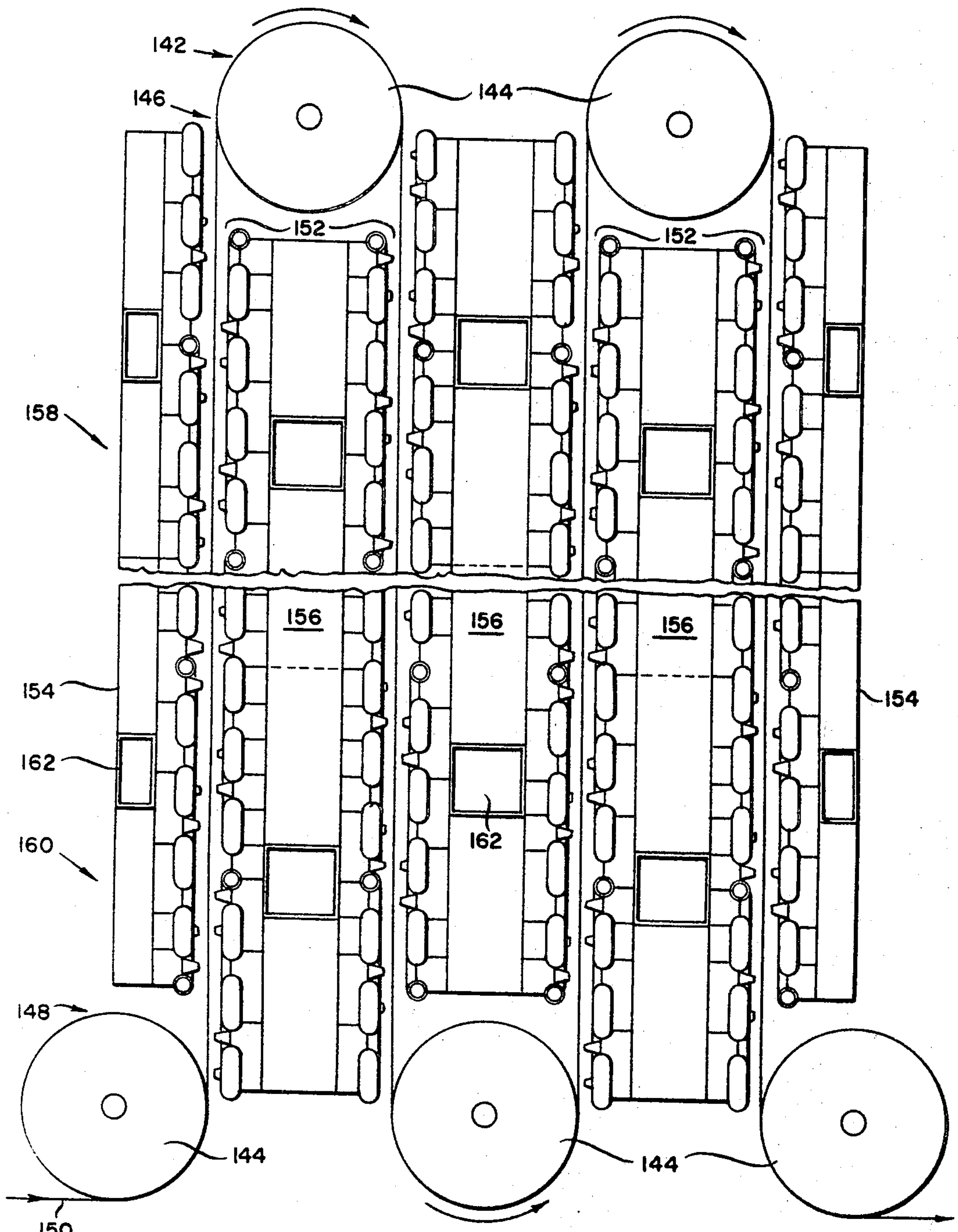

Fig. 8

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HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

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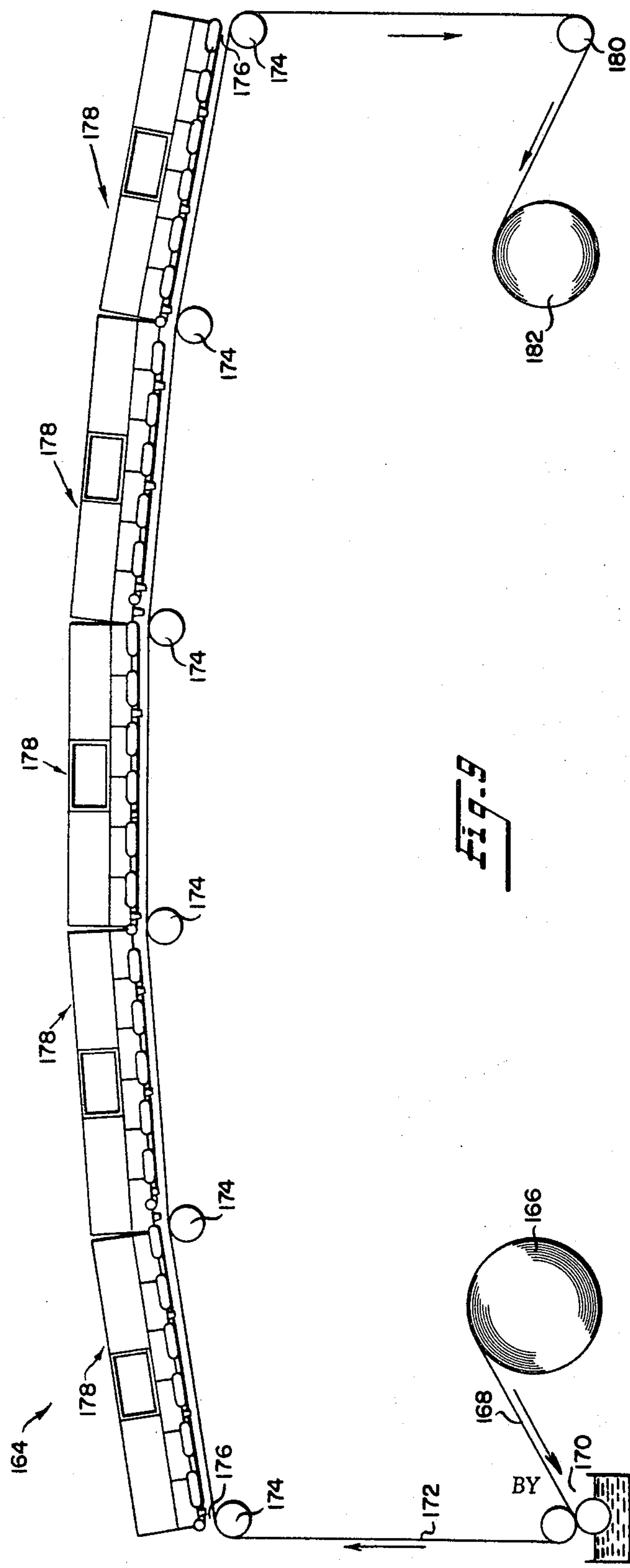

FIG. 9

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HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Original Filed March 24, 1966 7 Sheets-Sheet 7

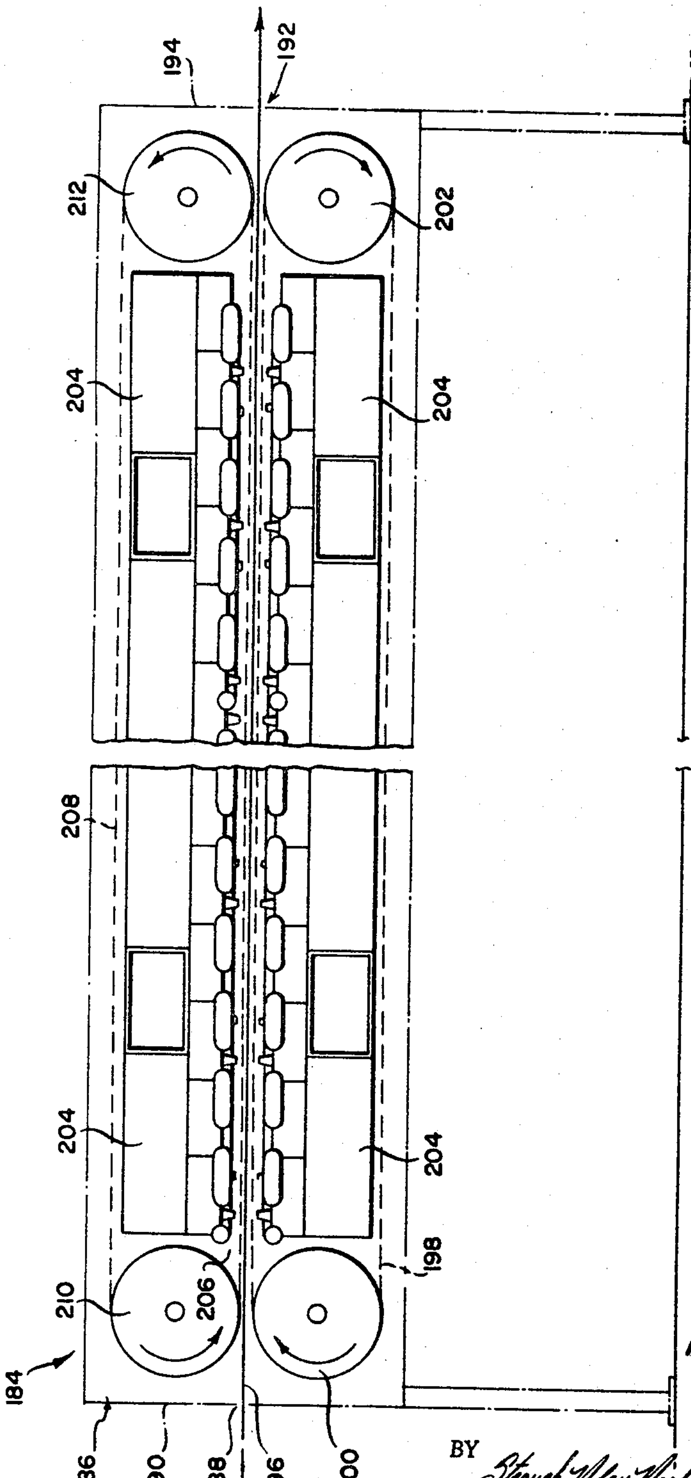

FIG. 10

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United States Patent Office

3,403,454

Patented Oct. 1, 1968

3,403,454

HEAT TREATING APPARATUS FOR WEB AND SHEET MATERIAL

Horace L. Smith, Jr., Richmond, Va., assignor to White Consolidated Industries, Inc., a corporation of Delaware

Continuation of application Ser. No. 537,132, Mar. 24, 1966. This application Apr. 5, 1967, Ser. No. 623,783
29 Claims. (Cl. 34—68)

ABSTRACT OF THE DISCLOSURE

Fluid supply and radiant heating systems for drying and similar apparatus including main supply and return ducts, branch ducts extending transversely across the main ducts, and an arrangement for directing fluid from the branch supply ducts into contact with the material being treated and for exhausting the fluid and evolved volatiles into the branch exhaust ducts. For applications requiring the application of heat to the product, radiant heaters may be incorporated in the foregoing structure and a single system may be used to heat the treating fluid and the radiant heaters. Apparatus employing fluid supply and radiant heating systems in accord with the foregoing.

Relation to other applications

This application is a continuation of application No. 537,132 filed Mar. 24, 1966, and now abandoned.

In one aspect this invention relates to novel improved fluid supply and radiant heating systems for various types of drying and similar apparatus and, more specifically, to novel improved drying and other apparatus having fluid supply systems as disclosed herein and to the combination of radiant heaters with such systems.

The use of air and other fluids to evolve and/or scour away evolved volatiles in drying and similar apparatus is a well-known technique as discussed in U.S. Patent No. 3,199,213 issued Aug. 10, 1965, to F. H. Milligan et al., for Method of Changing the Moisture Content of Wood, for example. Previously known systems have, however, had a number of significant disadvantages. Among these is an inability to supply the fluid in a manner effective to control the moisture content across the web or sheet of material being dried, which results in a lack of uniformity in the processed product.

A further drawback of many previously known dryers is that fluid is delivered so that it flows parallel to the material being treated at a relative low temperature and velocity. As discussed in the Milligan patent just mentioned, such dryers are inefficient and uneconomical in addition to being incapable of providing good control over the treatment of the material.

Another disadvantage of many heretofore known dryers and similar devices is that there is a lack of uniformity in the velocity with which the spent fluid and its burden of evolved volatiles is exhausted from the vicinity of the sheet or web being treated and/or the lack of a capability for exhausting the fluid in the immediate area in which it impinges on the sheet or web. This also results in a nonuniform final product.

A further disadvantage of numerous prior systems is that they are not, as a practical matter, susceptible of being employed in conjunction with radiant heaters. This is a serious deficit since, as pointed out in my copending application No. 254,674 filed Jan. 29, 1963, for Heat Treating Method and Apparatus (which is now abandoned), for example, the combined use of radiant heating and a scouring gas materially increases the efficiency with which many products may be dried or similarly processed.

Another drawback of many previously known systems is that they are only usable in one type of dryer such as a festoon dryer or a tunnel dryer, for example. This makes the design and manufacture of fluid supply and return systems relatively expensive as they must be produced on virtually a custom-made basis.

Yet another disadvantage of heretofore known dryers and similar devices is in the amount of ductwork required. A related drawback is that such devices often require an excessive amount of space to accommodate the ductwork and other components of the fluid supply and return system.

One important and primary object of the present invention resides in the provision of novel improved dryers and similar devices which are free of the above-discussed drawbacks of similarly known devices of this type.

A related important and primary object of this invention is the provision of novel improved fluid supply and return system for dryers and like devices which eliminate the foregoing disadvantages of such devices.

The novel fluid and supply return systems of the present invention, by which the foregoing and other important objects of this invention are attained, include main supply and return ducts arranged in side-by-side fashion. A number of branch supply and return ducts extend transversely across the two main ducts, supply ducts being alternated with return ducts.

Nozzles or other flow directing members are located at spaced intervals along the branch supply ducts to direct the treating fluid from the ducts at high velocity (and preferably at high temperature) into contact with the material being treated. The high velocity fluid evaporates volatiles in the material and scours the evolved volatiles away from the surface of the material to prevent the formation of a stagnant boundary layer which would materially reduce the evolution of the volatiles. Moreover, the rapid evaporation of the volatiles produces an evaporative cooling effect, which cools and prevents heat damage to the surfaces of the material being treated.

Inlets located in the branch exhaust ducts in a similarly spaced arrangement facilitate the removal of the treating fluid and its burden of evolved volatiles from the dryer or other device. The exhaust arrangement also ensures that the volatiles and treating fluid are exhausted from the vicinity of the web at uniform velocity, contributing further to the uniformity of treatment.

In processes involving the application of heat to the product, tubular type radiant heaters are incorporated in the fluid supply and return systems. The legs of the radiant heaters form part of the branch duct walls, and the fluid supply nozzles and exhaust inlets are fixed to or formed in branch duct wall members fixed between the heater legs. This arrangement is highly efficient and compact and yet is relatively inexpensive to produce.

Multiple pass apparatus branch ducts (and radiant heaters) may be located on both sides of the main supply and return ducts. Thus arranged, a single unit is capable of heating products in both of the passes between which it is located and/or of scouring evolved volatiles therefrom, which materially reduces the cost of many forms of drying apparatus.

The present invention also includes a system for heating both the treating fluid and the radiant heaters by use of a single liquid heating unit connected to the radiant heaters and a heat exchanger over which the treated fluid is adapted to pass. Provision is made for independently regulating the flow of the heat transfer liquid through the radiant heaters and the heat exchanger so that the radiant heaters and the treating fluid can be maintained at different temperatures. An arrangement is also preferably provided for recirculating treating fluid from the dryer or other treating apparatus to the heat exchanger to minimize the loss of the sensible heat in the treating fluid. Vent and make-up ducts may also be provided to vary the proportion of recirculated fluid and thereby control its content of evolved volatiles.

One important advantage of the novel fluid supply and return system just described is that it may be incorporated in a variety of different types of dryers and similar devices without modification. Among these are various single pass dryers, tunnel dryers, festoon dryers and other types of multiple pass dryers, and various forms of coating apparatus.

A further important advantage of this system is that it requires much less space than is commonly required by previously known supply and return systems. In part this is due to the partial or total elimination of external ducts along the dryer or other treating device for supplying the treating fluid and to the compactness of the system. Also, as discussed above, a single unit can be employed to supply treating fluid to two passes on opposite sides of the unit, resulting in a significant reduction in ductwork and the space required for it.

A significant reduction in size can also be effected in dryers and similar devices by constructing them in accord with the principles of this invention because the supply and return units can be arranged to provide a substantially continuous array of branch supply and return ducts over a given area. This provides substantially more capacity per given area than the conventional dryer which employs transversely extending supply and exhaust plenums located at opposite sides of a radiant heater to supply and carry away the treating fluid.

Another important advantage of dryers and similar devices constructed in accord with the present invention is that they are capable of producing a more uniform and higher quality product. This is because the fluid supplied can be uniformly distributed across the product being treated; or the distribution can be selectively regulated to eliminate the wet streaks which occur in paper drying and similar processes. Uniformity is also enhanced in the present invention by the continuous removal of the spent drying fluid and its burden of evolved volatiles at a uniform velocity and closely adjacent its point of impingement on the web. Still further uniformity may be provided by tapering the branch ducts to provide uniform distribution of the treating fluid to the supply nozzles and a uniform flow of the spent fluid into the branch return ducts.

Yet another important advantage of this invention is that it provides a highly efficient combination of radiant heating and high velocity scouring fluid. This results in significant increases in processing rates in many applications of the present invention such as paper drying, the drying and curing of coatings, and others.

From the foregoing, it will be apparent that other important objects of the present invention reside in the provision of novel, improved fluid supply and return units for drying apparatus and the like, which:

(1) Can be incorporated in a wide variety of dryers and similar devices.

(2) Require significantly less space than fluid supply and return systems heretofore known.

(3) Provide a highly efficient combination of radiant heating and high velocity scouring fluid which may also be at a high temperature, thereby materially increasing the rate at which volatile constituents can be evolved from the product being treated.

(4) Are capable of producing an evaporative cooling effect which prevents overheating of the material being treated.

(5) Are capable of providing a uniform or other controlled distribution of treating fluid across the span of the material being treated and uniform exhausting of the spent treating fluid and its burden of evolved volatiles from adjacent the vicinity of the web.

(6) Incorporate radiant heaters as integral components.

(7) Are capable of simultaneously supplying radiant heat and treating fluid to products on opposite sides of the unit.

Still other important objects of the present invention include the provision of novel, improved dryers and the like which include fluid supply and return systems and fluid supply-return and radiant heating systems constructed in accord with the present invention and which:

(1) Require substantially less space than previously known devices of like capacity.

(2) In conjunction with the preceding object, require significantly less ductwork than the previously known devices.

(3) In conjunction with the two preceding objects, have alternating branch supply and return ducts which virtually continuously span the pass or passes for the material being treated.

(4) Are more efficient and therefore capable of operating at higher rates than heretofore known units of like capacity.

(5) Are capable of producing a more uniform product of higher quality than previously known units.

(6) Include radiant heaters and a fluid heater and a single liquid heating unit for supplying a heated transfer medium to both the radiant heaters and the fluid heater.

(7) Include an arrangement for recirculating spent treating fluid to retain its sensible heat and vent and make-up systems for controlling the proportion of recirculated fluid and, therefore, its volatiles content.

Other objects, additional advantages, and further important features of the present invention will become more fully apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a diagrammatic section through a novel, improved dryer constructed in accord with the principles of the present invention;

FIGURE 2 is a section through a novel, improved fluid supply-return and radiant heating unit constructed in accord with the principles of the present invention;

FIGURE 3 is a section through the dryer of FIGURE 1, taken substantially along line 3—3 of the latter figure;

FIGURE 4 is a section through the unit of FIGURE 2, taken substantially along line 4—4 of the latter figure;

FIGURE 5 is a section through the unit of FIGURE 2, taken substantially along line 5—5 of the latter figure and showing the ports providing communication between main supply and return ducts and brach supply and return ducts incorporated in the latter;

FIGURE 6 is a diagrammatic illustration of the main system duct work which may be employed in delivering the fluid to and exhausting spent fluid from the main supply and return ducts of the fluid supply-return and radiant heating units;

FIGURE 7 is a diagrammatic view of a system for heating the treating fluid and the radiant heaters and for circulating the treating fluid through the supply-return and radiant heating units;

FIGURE 8 is a partly diagrammatic section through a multiple pass dryer, illustrating the arrangement and type of fluid supply-return and radiant heating units employed in apparatus of this type;

FIGURE 9 is diagrammatic view, partly sectioned, of coating apparatus equipped with fluid supply-return and radiant heating units constructed in accord with the principles of the present invention; and

FIGURE 10 is a diagrammatic sectional view through a novel, improved tunnel dryer equipped with fluid supply-return and radiant heating units constructed in accord with the principles of the present invention.

Referring now to the drawing, FIGURE 1 depicts a novel, improved single pass dryer **20** which features fluid supply-return and radiant heating units **22** constructed in accord with the principles of the present invention for dryig the product to be treated. Dryer **20** also includes a series of parallel, spaced apart, rotatably mounted rolls **24** establishing a path **26** for the product or material being dried, which is in the form of a web **28**. As shown in FIGURE 1, units **22** are located on both sides of path **26** to dry web **28** by simulataneously applying radiant heat to both sides of the web to evolve volatiles from it. Units **22** also direct air or other treating fluid at high velocity into contact with the sides of the web to assist in evolving the volatiles and to scour away evolved volatiles from adjacent its surfaces. The high velocity fluid prevents retardation of the drying process by eliminating the formation of a stagnant layer adjacent the web and, in addition, causes evaporative cooling adjacent the surfaces of the material being treated and thereby prevents it from being overheated. It is preferred that the treating fluid also be heated, preferably to a temperature typically on the order of 300 to 650° F. since, as explained in the Milligan patent mentioned above, hot, high velocity air is a highly effective drying agent; and the same is true for other treating fluids.

Referring now to FIGURES 2–4, each of the novel fluid supply-return and radiant heating units **22** incorporated in dryer **20** includes a main duct pair consisting of elongated main supply and return ducts **30** and **32** separated by a common dividing wall **34**. The main ducts **30** and **32** extend lengthwise of dryer **20** with two main duct pairs above and two below the path **26** of the product being dried. The two main duct pairs above path **26** are arranged in end-to-end relationship as are the main duct pairs below path **26**. Thus, dryer **20** employs four fluid supply-return and radiant heating units, two of these being arranged in end-to-end relationship above path **26** and two similarly arranged below the path.

Referring now specifically to FIGURE 2 and 4, each of the units **22** includes a number of branch supply and return ducts **36** and **38** extending transversely across the associated main supply and return ducts **30** and **32**. As shown in FIGURE 4, the main and branch ducts are integral, the common top wall **40** of the main ducts forming the bottom walls for the branch ducts and the side walls of the main ducts forming the end walls for the branch ducts. Branch supply ducts are alternated with branch return ducts (see FIGURES 4 and 5); and the branch return ducts are arranged with their side walls **42** in abutting relationship (see FIGURE 2).

Branch supply ducts **36** communicate with main supply ducts **30** through apertures **44** (see FIGURE 5) in the common wall **40** between the main and branch ducts adjacent the wall **34** separating the main supply and return ducts. Branch return ducts **38** similarly communicate with main return duct **32** through apertures **46** in common wall **40** on the side of common partition **34** opposite apertures **44**.

Air or other treating fluid is accelerated and directed normally at high velocity (typically on the order of 2,000–15,000 feet per minute) against web **28** by nozzles **48** fixed to the top wall **50** of each branch supply duct **36**. The nozzle inlets communicate with the interior of the duct through apertures **52** in its top wall **50**. As shown in FIGURE 3, nozzles **48** are disposed in spaced apart relationship the length of each of the branch supply ducts **36**. The treating fluid exiting from nozzles **48** contacts the surfaces of web **28** at high velocity, scouring away from the surfaces volatiles evolved from the web. The spent fluid, together with its burden of evolved volatiles, flows into branch return ducts **38** through inlet apertures **54** (see FIGURE 4) formed in the top walls **56** of the branch return ducts.

It will be apparent, from the foregoing, that a uniform distribution of the treating fluid across the span of web **28** can be provided by uniformly spacing nozzles **48** the length of branch supply ducts **36**. Similarly, where desired, controlled nonuniform distribution of the treating fluid can be provided by appropriate spacing of the nozzles. For further control over the distribution of the treating fluid against web **28**, dampers or other flow control members (not shown) may be located at the inlet ends of nozzles **48**.

Another important feature of the arrangement just described is that the inlets **54** to branch return duct **38** are distributed uniformly the length of the branch duct and are adjacent supply nozzles **48**. This insures that the spent treating fluid, together with its burden of evolved volatiles, flows with uniform velocity into the return ducts over the entire length thereof and that the spent fluid flows into these ducts at points closely adjacent those at which it impinges upon the web being treated. This provides uniform exit velocities for the spent fluid, which further insures uniform treatment of the web being dried. For other than uniform distributions of the treating fluid, the exhaust openings can of course be spaced at varied intervals like nozzles **48**.

As discussed above, it is important that the treating fluid be directed at high velocity against the material being treated as low velocity fluid is not effective to scour away evolved volatiles or to cause evaporative cooling of the material. Typically, the impingement velocity will be on the order of 2,000–15,000 feet per minute as mentioned above. Even higher velocities may be beneficially employed, however, to increase the scouring and evaporative cooling effect. The only significant limitations on this velocity are the ability of the material being treated to withstand the impact of the fluid and the expense of providing equipment capable of delivering fluid at extremely high velocities.

As discussed above, volatiles may be evolved from the web **28** being treated merely by supplying air or other treating fluid at high velocity and high temperatures through nozzles **48**. However, in the preferred embodiment of the present invention, volatiles are evolved much more rapidly, thereby materially increasing the efficiency of units **22**, by incorporating in them one or more tubular type radiant heaters **58**. Each heater consists of a plurality of parallel, spaced apart, straight legs **60** (see FIGURES 3 and 5) having coplanar centerlines and extending in the same direction as branch ducts **36** and **38**. The legs **60** are connected by end bends **62** alternately located at opposite ends of the heater.

As is best shown in FIGURE 2, legs **60** of the radiant heater partially define the top walls **50** and **56** of branch supply and return ducts **36** and **38**, respectively; and alternate legs **60** also partially define the side walls of the branch ducts, being welded to branch duct wall members **42** of the latter. The configurations of the branch duct top walls **50** and **56** are completed by wall members **64** and **66**, respectively, which are welded or otherwise fixed between adjacent radiator legs **60**. As shown in FIGURE 2, fluid supply nozzles **48** are fixed to branch duct wall members **64**; and the inlet apertures to branch return ducts **38** are formed in wall members **66** so that, as shown in FIGURE 3, the rows of nozzles **48** and exhaust apertures **54** are disposed between adjacent legs **60** of the radiant heater.

In the particular embodiment of the invention illustrated in FIGURES 2–4, there are two rows of supply nozzles **48** associated with each branch supply duct **36** and two rows of inlet apertures to branch return duct **38** associated with each of the branch return ducts. The number of rows may of course be varied as desired; but it is preferred that a single or double row of apertures be used since this insures a row of inlet apertures adjacent each row of nozzles. As discussed above, this adjacent relationship is important in obtaining uniform exit velocities for the treating fluid by removing it from adjacent the surface of the material being treated as near as possible to the area at which the fluid impinges upon the web being treated.

Referring next to FIGURES 6 and 7, the treating fluid is supplied to the main supply duct **30** in each unit **22** by a blower **68** connected through a duct **70** to a fluid heater

72. As it flows through the fluid heater, the treating fluid is heated as it flows over a heat exchanger **74**. From fluid heater **72**, the heated treating fluid flows through a main system supply duct **76** and branch system supply ducts **78** into the main suply ducts **30** of units **22** (see also FIGURE 6), the branch system ducts being connected to the main unit ducts at about the midpoint of the latter. Similarly, the spent treating fluid and its burden of evolved volatiles flows from branch return ducts **38** of the various units **22** through ports **46** into the associated main unit return ducts **32**. From these ducts, the spent fluid and its burden flows through branch system return ducts **80** into main system return ducts **82**.

As discussed previously, in the present invention, main system return ducts **82** are preferably connected to the inlet of circulating blower **68** so that the spent treating fluid may be recirculated through the system, thereby eliminating the loss of sensible heat which would result if the spent fluid were discharged from the system.

In many applications of the present invention, such as in the drying of paper, for example, the percentage of moisture or other volatiles in the treating fluid must be closely controlled to produce the desired characteristics in the treated product. To permit such control, main system return duct **82** is provided with a make-up duct **84**; and a vent duct **86** is located in the duct **70** between blower **68** and fluid heater **72**. Valves **88** and **90** control the flow through make-up and vent ducts **84** and **86**, respectively. By properly adjusting valves **88** and **90**, the proper proportion of spent recirculated fluid can be discharged from the system and replaced with treating fluid having a lower content of volatiles to maintain the volatile content at the desired level. Valves **88** and **90** may be adjusted manually or, if desired, may be automatically controlled by a control system of the type disclosed in my U.S. Patent No. 3,208,158 issued Sept. 28, 1965, for Dryers.

Referring now to FIGURE 7, the heat exchanger **74** in fluid heating unit **72** and radiant heaters **58** are of the type through which a heated fluid heat transfer medium is circulated to elevate them to the desired temperature. The preferred heat transfer mediums are high boiling point organic liquids and eutectic mixtures of inorganic salts, which can be circulated at extremely high temperature in liquid form. Suitable media of this type are discussed in detail in my copending application Ser. No. 323,848 filed Nov. 14, 1963 for Heat Exchangers, which is hereby incorporated by reference in this application.

The advantage of employing liquid heat transfer media is that the problems appurtenant to the high pressures associated with high temperature steam are eliminated and yet the radiant heaters and the treating fluid may be heated to temperatures of several hundred degrees Fahrenheit.

The system illustrated in FIGURE 7 for heating and circulating the liquid heat transfer medium includes a storage tank **92** from which the liquid can be pumped by a transfer pump **94** through a conduit **96** to a drain **98** or to the main circulation system, which includes main return and supply conduits **100** and **102** and is a closed loop through which the liquid is circulated by a main circulation pump **104**.

From main return conduit **100** the heat transfer liquid flows into a liquid heating unit **106** where it is heated to the desired temperature. This unit may be of any desired construction and includes a temperature responsive controller **108** which so regulates the flow of fuel to the heating unit through conduit **110** as to maintain the temperature of the heated liquid flowing into main supply conduit **102** constant.

From main supply conduit **102**, part of the heated liquid flows through branch supply conduit **112** to the heat exchanger **74** in fluid heater **72**. The volume of flow through conduit **112** is controlled by temperature responsive controller **114**, which is connected to a valve **116** in conduit **112** and has a sensor (not shown) in the main system fluid supply duct **76**. Controller **114** regulates valve **116** so as to maintain the temperature of the treating fluid flowing into main system supply duct **76** constant. From fluid heating unit **72**, the heat transfer liquid flows through branch return conduits **118** and **120** back into main return conduit **100**.

Referring now to FIGURES 3 and 7, part of the heated heat transfer liquid flowing through main supply conduit **102** is diverted through branch supply conduit **122** to the radiator or radiators **58** of the dryer in which they are incorporated. From supply conduit **122**, the heated liquid is pumped through the radiator or radiators **58** in each zone of the dryer by an independent zone pump **124** (only one of which is shown) with its outlet connected to the radiator or radiators and its inlet connected to conduit **122** by a branch supply conduit **126**.

As shown in FIGURE 3, each radiator **58** is connected, at its outlet end, to a branch return conduit **130** to recirculate the liquid to the heating unit. Each branch circulation system also includes a branch bypass conduit **132** connected between its branch inlet conduit **126** and a branch return conduit **134** connected between radiator **58** and return conduit **130**. Flow through bypass conduit **132** is regulated by a three-way valve **136** which, in turn, is adjusted by a temperature responsive controller **138** with its temperature responsive probe located on the side of radiator **58** facing the product to be treated.

As long as radiator **58** remains at the desired temperature, pump **124** circulates the heat transfer liquid through the closed branch loop consisting of conduit **126**, radiator **58**, and bypass conduit **132**. When the temperature of the radiator starts to drop, controller **138** adjusts valve **136** to divert less liquid through bypass conduit **132** and more into return conduit **130**. This permits fresh, hotter liquid to flow from conduit **122** into the branch system to bring radiator **58** back to the desired temperature.

One of the important features of the fluid circulation system just described is that the temperature of the heat exchanger **74** in fluid heating unit **72** and the temperatures of radiators **58** can be independently regulated. This permits the temperatures of these components to be so adjusted that the radiant energy supplied by the radiators will be at the most effective wave length range and the treating fluid will be at the optimum temperature.

Where more than one radiator **58** is employed in each zone, each radiator can be connected in parallel between supply and return conduits **122** and **130** in the manner just described as shown in FIGURE 3. This is an important practical feature of the present invention inasmuch as it permits independent control of the radiator temperatures in succeeding zones of the dryer in which they are incorporated, adding to the flexibility of the dryer.

Inasmuch as the details of the fluid heating and circulating system just described such as the bypass system **140** provided to maintain constant flow through heating unit **106** are not by themselves part of the present invention, it is not considered necessary to describe them further herein. Systems of the type just described are discussed in more detail in my U.S. Patent No. 3,236,292 issued Feb. 22, 1966, for Dryers, which is hereby incorporated by reference herein.

The novel fluid supply-return and radiant heating units discussed above may be employed in various types of multiple pass driers as well as the single pass type described above. One type of multiple pass dryer in which such units may be incorporated is the festoon or multiple run vertical dryer **142** of FIGURE 8.

Dryer **142** includes a plurality of rotatably supported rolls **144** arranged in upper and lower rows **146** and **148**. The rolls in upper row **146** are directly above the spaces between the rolls in lower row **148** to direct the web **150** of product to be treated through the dryer in a plurality of parallel, spaced apart passes **152** extending between the two rows of rolls. As the web of product **150** moves through dryer **142**, it is dried and evolved volatiles are carried away from it by fluid supply-return and radiant heating units **154** and **156** oriented adjacent and parallel to passes **152** so that the centerlines of the radiant heater legs lie in planes parallel to the passes and the fluid supply nozzles are at equal distances from the passes. Units **154**, which are located outside the outermost pass **152**, may be identical to the units **22** described above. These units are oriented with their nozzles and radiant heaters facing the pass **152** adjacent which they are located.

The fluid supply-return and radiant heating units **156** are each located between a pair of adjacent passes **152** and, like units **154**, extend generally from one row of roll **144** to the other. Units **156** are identical to those described previously except that there are branch ducts and radiant heaters on both sides of the main duct pairs in these units, the arrangement of these components on both sides of the main duct pairs being identical. This modification adapts each unit **156** for simultaneously heating and scouring volatiles from portions of web **150** in two passes on opposite sides of the unit. Thus, the combination of units **154** and **156** insures that, in each of the passes **152**, both sides of web **150** are simultaneously radiantly heated and contacted by high velocity fluid to assist in evolving volatiles and to scour away those volatiles which have evolved while preventing overheating of the web.

As shown in FIGURE 8, between or adjacent each of the passes **152**, there are two fluid supply-return and radiant heating units **154** or **156** connected in end-to-end relationship. This arrangement divides dryer **142** into an upper zone **158** and a lower zone **160**. If desired, temperatures and other parameters may be varied in each of these zones for a particular application of dryer **142**. Control of the radiant heater temperature is readily accomplished by the control arrangement illustrated in FIGURES 3 and 7. Similarly, the temperature, velocity, etc. of the treating fluid can readily be controlled by installing flow control dampers, which may be temperature responsive, in the branch system supply ducts **162** through which the treating fluid is supplied to units **154** and **156**.

As mentioned previously and as shown in FIGURE 8, dryer **142** is of the vertical run type. However, it will be readily apparent to those skilled in the arts to which this invention relates that the arrangement of fluid supply-return and radiant heating units illustrated in FIGURE 8 is equally adaptable to a multiple run drier of the horizontal type.

FIGURE 9 illustrates the application of the principles of the present invention to coating apparatus identified generally by reference character **164**. This apparatus includes an unwind stand **166** from which the web **168** to be coated is fed through the coating apparatus. From stand **166**, the web passes through a conventional coating station **170** where the desired coating material is applied to one side **172** of the web. From the coating station, the web passes over a series of rotatably supported rolls **174**, which define a path **176** for the web and are preferably arranged to periodically change the direction of web and thereby prevent high speed flutter in the manner discussed in my U.S. Patent No. 3,228,114 issued Jan. 11, 1966, for Multiple Run Drier. As shown in FIGURE 9, only the uncoated side of the web contacts rolls **174**.

As the coated web moves through pass **176**, the coating is cured or dried by radiant energy and high velocity heated air or other fluid emanating from fluid supply-return and radiant heating units **178**, which may be identical to the corresponding units **22** and **154** described above. From the last path defining roll **174**, the finished web **168** is led over a direction changing roll **180** to a rewind stand **182**.

Coating apparatus **164** may be supplied with a heat transfer liquid for the radiant heaters in units **178** and a heating unit for the treating fluid in the same manner as the dryer **20** illustrated in FIGURE 1 and the festoon dryer **142** illustrated in FIGURE 8.

FIGURE 10 illustrates the application of the principles

of the present invention to a dryer **184** of the tunnel type. Tunnel dryers are commonly employed for drying wallboard, veneers, and similar relatively thick products.

As shown in FIGURE 10, a tunnel dryer typically includes a casing **186** with a product inlet **188** in one end wall **190** and an outlet **192** in the opposite end wall **194** for the product **196** being treated. As the web or sheet of product **196** moves through casing **186**, it is supported by an endless belt **198** trained around rotatably supported rolls **200** and **202** at opposite ends of the casing.

During its passage through the casing, the product **196** is dried by radiant heat and high velocity air or other fluid from fluid supply-return and radiant heating units **204**, which may be identical to those described previously. As shown in FIGURE 10, units **204** are located closely adjacent and both above and below the path **206** of the material through the dryer so that it is simultaneously heated from both sides. As is also shown in FIGURE 10, units **204** extend substantially the entire distance between the rolls and **202** at opposite ends of the casing **186**; and two (or even more) units are arranged in end-to-end relationship to span this distance. As discussed in conjunction with the embodiment of the present invention illustrated in FIGURE 8, this divides the dryer into zones in which different temperature and other conditions may be maintained.

Because of their uncommon thickness, products of the type dried in tunnel dryers are subject to curling, cockling and other forms of warpage. To prevent this, the product **196** being dried may be maintained flat as it moves through casing **186** by a second, upper endless belt **208** trained around rolls **210** and **212** at opposite ends of the casing above rolls **200** and **202**. For products which are not subject to such warpage the upper belt may, of course, be omitted.

As shown in FIGURE 10, belts **198** and **208** pass between units **204** and the product **196** being dried. These belts are therefore preferably of an open mesh construction so that the radiant energy and the treating fluid can penetrate to the product through the belt and so the fluid and its burden of evolved volatiles can pass back through the belt into the fluid return ducts of units **204**.

The details of the tunnel dryer are not, by themselves, part of the present invention; and it is therefore not considered necessary to discuss them further herein. Tunnel dryers of the type illustrated in FIGURE 10 are disclosed in detail in my copending application No. 530,146 filed Feb. 25, 1966, for Apparatus, which is hereby incorporated by reference.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. Multiple run treating apparatus for continuous webs, comprising:

(a) a plurality of rotatably supported rolls in two parallel, spaced apart rows defining a plurality of parallel, spaced apart passes extending from one to the other of said rows for a web trained alternately over succeeding rolls in alternate ones of said rows; and

(b) a ventilating system for effecting a flow of fluid into contact with the surfaces of said web as it moves through each of said passes, said ventilating system including:

(c) a plurality of main duct pairs each including a main supply duct and a main return duct arranged in side-by-side relationship, there being duct pairs between adjacent passes and adjacent the outer sides of the outermost passes;

(d) branch supply and return ducts extending across and communicating with the main supply and return duct in each main duct pair;

(e) fluid supply means at spaced intervals along each said branch supply duct and communicating therewith for directing fluid from the associated branch supply duct toward the pass thereadjacent; and

(f) at least one fluid inlet to each branch return duct for fluid from the pass thereadjacent;

(g) there being branch supply and return ducts on both sides of the main duct pairs between passes and on the sides of the outer main duct pairs facing the outermost passes, whereby fluid is supplied to and removed from both sides of each pass.

2. The apparatus of claim **1**, together with a tubular radiant heater on each side of the main duct pairs between passes and on the sides of the outer main duct pairs facing the outermost passes for heating the web moving through said passes from both sides thereof.

3. The apparatus of claim **1**, wherein there are plural main duct pairs between adjacent passes and adjacent the other sides of the outermost passes and independent fluid supply and return means for each of said main duct pairs, thereby dividing the passes between said rows of rolls into a plurality of zones.

4. Coating apparatus for web material, comprising:

(a) means for applying a coating material to one side of the web to be coated; and

(b) means for curing said coating including:

(c) a plurality of parallel, spaced apart rolls establishing a pass for the coated material and adapted to support the uncoated side of said material, and

(d) a radiant heating and ventilating system on the opposite side of the pass from said rolls including:

(e) a tubular radiant heater closely adjacent and generally parallel to the pass for the coated material;

(f) branch supply and return ducts extending transversely of said pass on the opposite side of the radiant heater therefrom;

(g) fluid supply means at spaced intervals along said branch supply ducts for directing fluid from said branch supply ducts into contact with the coated side of said material;

(h) at least one fluid inlet to each of the branch return ducts; and

(i) means including main supply and return ducts on the side of the branch ducts opposite the radiant heater for supplying fluid to and evacuating it from the branch supply and return ducts, respectively.

5. A radiant heating and fluid supply system, comprising:

(a) a tubular radiant heater having a plurality of elongated, spaced apart legs;

(b) a plurality of branch supply and return ducts disposed in side-by-side relationship;

(c) means for supplying fluid to said branch supply ducts including a main supply duct, said branch supply and return ducts extending across the main supply duct at intervals therealong and communicating therewith;

(d) the side walls of the branch supply and return ducts being fixed to legs of said radiant heater and the walls of said ducts opposite the main supply duct comprising said heater legs and wall members fixed to and between said heater legs;

(e) fluid discharge means at spaced intervals along said branch supply ducts and communicating therewith for discharging fluid from each said branch supply duct to the area thereadjacent; and

(f) at least one inlet to each of said branch return ducts.

6. The radiant heating and fluid supply system of claim **5**, wherein:

(a) at least one of the wall members forming the said opposite wall of each of the plural supply ducts has a row of spaced apart apertures therein; and

(b) said fluid discharge means comprise nozzles fixed to said supply ducts and communicating with the interiors thereof through the apertures in said wall members.

7. The radiant heating and fluid supply system of claim **6**, wherein:

(a) the said opposite walls of said supply ducts include plural wall members; and

(b) there is a row of said nozzles fixed to each of said wall members.

8. The radiant heating and fluid supply system of claim **6**, wherein the fluid inlets to the return ducts are apertures in the wall members forming the said opposite sides of said return ducts.

9. Apparatus for treating web and sheet material and the like, comprising:

(a) a fluid supply system which includes:

(b) at least three main duct pairs, each of which comprises a main supply duct and a cooperating main return duct, the ducts in each pair being arranged in side-by-side relation and the main duct pairs being disposed in parallel spaced apart relationship to provide at least two passes through the apparatus for the material to be treated;

(c) branch supply and return ducts extending transversely of and across said passes between said main ducts and the passes thereadjacent and communicating with the main supply and return ducts, there being a first series of branch supply and return ducts on one side of each inner main duct pair and a second series of branch supply and return ducts on the opposite side of each said inner main duct pair and a single series of branch supply and return ducts associated with each of the outer main duct pairs, said single series of branch ducts being on the side of the outer duct pair facing the adjacent inner duct pair, whereby the branch ducts define and are located on both sides of each of the passes through said apparatus;

(d) fluid discharge means at spaced intervals along the branch supply ducts for effecting flows of fluid from said branch supply ducts toward the passes for the material to be treated;

(e) inlets to said branch return ducts facing the passes for the material to be treated; and

(f) means for guiding the material to be treated through said apparatus by way of the passes between said branch ducts.

10. A radiant heating and fluid supply system, comprising:

(a) a tubular radiant heater having a plurality of spaced apart legs, the centerlines of the radiant heater legs being parallel and lying in the same plane and said legs being connected into a single fluid channel by end bends joining adjacent legs and alternately located at opposite ends of said legs;

(b) a plurality of branch supply and return ducts all lying substantially to one side of said heater, said branch supply and return ducts all being disposed in side-by-side relationship and branch return ducts being alternated with branch supply ducts;

(c) fluid discharge means at spaced intervals along said branch supply ducts and communicating therewith for discharging fluid from said branch supply ducts to the areas thereadjacent;

(d) at least one fluid inlet to each of the branch return ducts; and

(e) main supply and return ducts extending transversely of said branch supply and return ducts on the side thereof opposite said heater.

11. Heat treating apparatus for web and sheet material and the like, comprising:
(a) means establishing a path for the material to be treated; and
(b) at least one radiant heating and fluid supply system located adjacent said path and comprising:
(c) a tubular radiant heater having a plurality of spaced apart fluid conducting legs;
(d) a plurality of branch supply and return ducts all lying substantially to one side of said radiant heater, said branch supply and return ducts being arranged in side-by-side relationship and said branch supply ducts being alternated with said branch return ducts;
(e) said supply and return ducts all having wall members opposed to the path of the material to be treated and the exposed surfaces of said wall members all lying in a common plane more remote from said path than the portions of said radiant heater fluid conducting legs, whereby said legs are exposed to thereby emit radiant energy directly to the material to be treated;
(f) fluid discharge means at spaced intervals along said supply ducts, each said fluid discharge means being oriented to effect a flow of fluid from the associated supply duct toward the path of the material to be treated;
(g) at least one inlet to each of said return ducts, each said inlet facing the path of material to be treated and said inlets being spaced away from said path; and
(h) means for supplying fluid to the supply ducts.

12. The apparatus of claim 11, wherein there are radiant heating and fluid supply units on both sides of the path of the material being treated for simultaneously treating both sides of said material.

13. The apparatus of claim 11, wherein the centerlines of the radiant heater legs lie in at least one plane, each said plane being parallel to the path of the product through the treating apparatus, whereby there is a substantially uniform distribution of radiant energy from said heater to the product being treated.

14. The heat treating apparatus of claim 11, together with:
(a) main supply and return ducts extending along and adjacent the path of the material to be treated and on the opposite sides of the branch ducts therefrom; and
(b) means providing fluid communication between the main supply duct and the branch supply ducts and between the branch return ducts and the main return duct.

15. The heat treating apparatus of claim 11, wherein the branch ducts are arranged in abutting relationship.

16. The heat treating apparatus of claim 14, wherein each said fluid discharge means comprises an aperture extending through the sides of the branch supply ducts opposite said main ducts.

17. The heat treating apparatus of claim 14, wherein there are a plurality of independent fluid inlets to each of said branch return ducts, said inlets being in and spaced along the sides of said branch ducts opposite the main ducts.

18. The heat treating apparatus of claim 14:
(a) wherein the main supply and return ducts are arranged in side-by-side relationship; and
(b) there are plural pairs of main ducts, each including a main supply duct and a main return duct cooperating therewith.

19. The heat treating apparatus of claim 18, wherein the main duct pairs are disposed in parallel spaced apart relationship to provide at least one pass through the apparatus for the material to be treated.

20. The heat treating apparatus of claim 18, wherein the main duct pairs are arranged in end-to-end relationship.

21. The heat treating apparatus of claim 18, together with:
(a) means for supplying fluid to said main supply ducts including a main system supply duct and a branch system supply duct connected between the main system supply duct and each of the aforesaid main supply ducts; and
(b) a main system return duct and branch system return ducts connected from each of the aforesaid main return ducts to the main system return duct.

22. The heat treating apparatus of claim 18, together with:
(a) fluid circulating means having an inlet and an outlet;
(b) first duct means connecting said outlet to said main supply duct; and
(c) second duct means connecting said main return duct to the inlet of the fluid circulating means for returning fluid thereto.

23. The heat treating apparatus of claim 22, together with:
(a) a fluid vent duct connected to said second duct means;
(b) a fluid make-up duct connected to said first duct means; and
(c) selectively adjustable valves in said vent and make-up ducts for adjusting the amount of fluid respectively discharged and admitted through the vent and make-up ducts, respectively.

24. The heat treating apparatus of claim 22, together with a fluid heater interposed in said first duct means for heating the fluid flowing to said main supply duct.

25. Heat treating apparatus for web and sheet material and the like, comprising:
(a) means establishing a path for the material to be treated, said path establishing means providing at least two path segments extending in different directions; and
(b) at least one radiant heating and fluid supply system located adjacent said path and comprising:
(c) a tubular radiant heater having a plurality of spaced apart fluid conducting legs associated with each of said segments, the centerlines of the legs of each said radiant heater lying in at least one plane which is parallel to the path of the product through the segment with which the radiant heater is associated;
(d) a plurality of supply and return ducts all lying substantially to one side of each said radiant heater, said branch supply and return ducts being arranged in side-by-side relationship and branch supply ducts being alternated with branch return ducts;
(e) fluid discharge means at spaced intervals along said supply ducts, each said fluid discharge means being oriented to effect a flow of fluid from the associated supply duct toward the path of the material to be treated;
(f) at least one inlet to each of said return ducts, each said inlet facing the path of material to be treated and said inlets being spaced away from said path; and
(g) means for supplying fluid to the supply ducts.

26. Treating apparatus for web and sheet type material, comprising:
(a) an elongated casing having inlet and outlet openings at the opposite ends thereof for the material to be treated;
(b) means for supporting said material as it moves through said casing comprising rolls at the opposite ends of said casing adjacent said openings and an endless, flexible, open mesh belt trained around said rolls to provide material supporting and return legs; and
(c) a ventilating system for effecting a flow of fluid into contact with said material as it moves through said casing, including:
(d) co-operating main supply and return ducts extend-

ing lengthwise of said casing and located between the legs of said belt;

(e) branch supply and return ducts between said main ducts and the material supporting leg of said belt, said branch ducts extending transversely in the casing across the main ducts and communicating therewith, the sides of the branch ducts opposite the main ducts being adjacent and parallel to the path of the material through said casing;

(f) fluid supply means at spaced intervals along each of said branch supply ducts for directing fluid from the associated duct through the openings in said belt toward the material being treated; and

(g) at least one fluid inlet to each branch return duct.

27. Treating apparatus for web and sheet type material, comprising:

(a) an elongated casing having inlet and outlet openings at the opposite ends thereof for the material to be treated;

(b) means including a first set of rolls and a first belt of open mesh construction trained therearound to provide a material bearing leg for supporting said material as it moves through said casing; and

(c) a ventilating system for effecting a flow of fluid into contact with said material as it moves through said casing, including:

(d) co-operating main supply and return ducts extending lengthwise of said casing;

(e) branch supply and return ducts between said main ducts and the path of the material through the casing, said branch ducts extending transversely in the casing across the main ducts and communicating therewith, the sides of the branch ducts opposite the main ducts being adjacent and parallel to the path of the material through said casing;

(f) fluid supply means at spaced intervals along each of said branch supply ducts for directing fluid from the associated duct toward the material being treated;

(g) at least one fluid inlet to each branch return duct;

(h) means for preventing wrinkling, cockling, and other distortions of the material being treated as it moves through said casing including a second set of rolls adjacent the first set of rolls and a second endless belt of open mesh construction trained around the second set of rolls for pressing said material against the material bearing leg of the first belt; and

(i) a second ventilating system as aforesaid between the legs of the second belt for effecting a flow of fluid into contact with the side of the material opposite that facing the first ventilating system.

28. Treating apparatus for web and sheet type material, comprising:

(a) an elongated casing having inlet and outlet openings at the opposite ends thereof for the material to be treated;

(b) an endless belt having a leg for supporting said material as it moves through said casing; and

(c) a ventilating system for effecting a flow of fluid into contact with said material as it moves through said casing, including:

(d) co-operating main supply and return ducts extending lengthwise of said casing;

(e) branch supply and return ducts between said main ducts and the path of the material through the casing, said branch ducts extending transversely in the casing across the main ducts and communicating therewith, the sides of the branch ducts opposite the main ducts being adjacent and parallel to the path of the material through said casing;

(f) fluid supply means at spaced intervals along each of said branch supply ducts for directing fluid from the associated duct toward the material being treated;

(g) at least one fluid inlet to each branch return duct; and

(h) radiant heater means between the main duct pairs and the material supporting leg of the endless belt for supplying radiant energy through openings in said belt to said material.

29. Heat treating apparatus for web and sheet material and the like, comprising:

(a) means establishing a path for the material to be treated;

(b) at least one radiant heating and fluid supply system located adjacent said path and comprising:

(c) a radiant heater means;

(d) fluid supply and return ducts extending across said path at intervals therealong;

(e) fluid supply means at spaced intervals along each said supply duct for directing fluid from the associated duct toward the path of the material to be treated;

(f) at least one inlet to each of said return ducts, each said inlet facing the path of material to be treated; and

(g) means including a fluid heating unit having a heater therein for supplying heated fluid to said supply ducts; and

(h) means including a single heating unit for effecting a flow of a heated heat transfer medium through said radiant heater means and the heater of said fluid heating unit, said last-named means including first and second temperature responsive means for independently controlling the flow of the heat transfer medium through said radiant heater means and the heater of said fluid heating unit, respectively, and thereby independently regulating the temperature of said radiant heater means and the heater of the fluid heating unit.

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