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APPARATUS FOR DRYING MOVING WEBS

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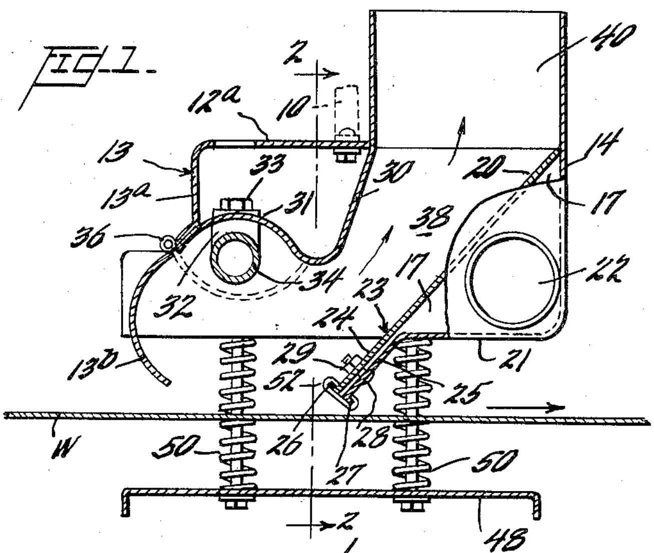

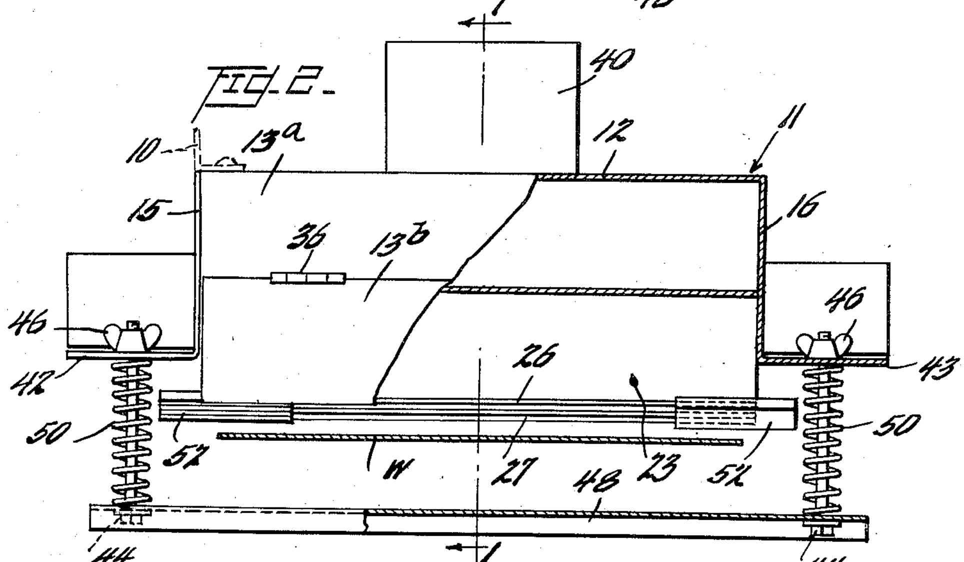

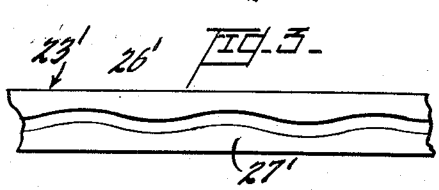

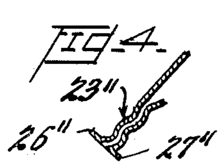

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APPARATUS FOR DRYING MOVING WEBS

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5 Claims. (Cl. 34—68)

This invention relates to drying units for traveling webs and is directed more particularly to an apparatus adapted to remove moisture from traveling webs through the combined action of radiant heating directed against the web and a turbulent stream of high velocity gaseous medium impinged upon the heated webs.

Heretofore, moving webs impregnated with water, various solvents and the like have been dried by passage adjacent the surface of a heated plate or cylinder, by exposure to slow moving currents of large volumes of heated air, or both. In each of the arrangements, the heat penetrates the web and the impregnating material from the exterior inwardly so that the impregnated material was subjected to uneven drying with its outer layer receiving the heat prior to and in greater amounts than the inner layers. As a result, the outer layer tends to dry first, developing first into a stagnant film of relatively viscous material, and then, as the drying progresses, into a dry crust or skin. This film or skin materially retards the drying of the sub-surface portions of the impregnating material since the sub-surface part of evaporation material had to be literally forced therethrough. To accomplish thorough drying under these conditions, excessively large amounts of hot air or other form of drying energy are required to maintain satisfactory speed of operation or, if the consumption of energy were to be maintained at a practical level, the speed of operation had greatly reduced. In addition, an incomplete and unsatisfactory bond of the impregnating material to the web frequently occurred due to imperfect drying at the interface of the web and material. Further, where speeds of travel are slow or the rate of energy release high, the chances of the outer film of the material being damaged before uniform drying has been achieved are intensified.

It is therefore an object of this invention to provide an apparatus for drying moving webs in which the formation of a viscous film or hardened skin over the material to be evaporated is prevented by the creation of a condition of turbulence adjacent the surface of the web, accelerated evaporation of the impregnating material being concurrently effected by exposure of the web to the direct action of infra-red radiation.

A further object of the invention is to provide an apparatus for drying moving webs impregnated with a liquid medium in which the web is contacted across its entire width by a high velocity sheet of a gaseous fluid having a component opposed to the direction of travel of the web and simultaneously exposed in the region of such contact to the rays emitted by a radiant heater.

A further object of the invention is to provide an apparatus for drying moving webs which apparatus includes a jet nozzle extending substantially across the entire width of the web with its axis angularly disposed with respect to the plane of the web in a direction opposite to the direction of travel of the web and with its mouth in close proximity to the surface of the web and an infra-red heater disposed adjacent both the surface of the web and the mouth of the nozzle.

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A further object of the invention is to provide an apparatus for drying moving webs by subjecting the web to the conjoint action of direct infra-red radiation and a high velocity jet of a gaseous fluid, which apparatus is exceptionally compact in design, occupying only a minimum of space in the path of the web.

A further object of the invention is to provide a drying apparatus of the type just described which is provided with movable reflecting means for varying and controlling the intensity of the emitted radiation and, in addition, includes an enlarged chamber interposed between a source of a gaseous fluid and the jet nozzle to eliminate fluctuation in the rate of supply of the gaseous fluid and to maintain at a uniform level the velocity of the jet across the entire length of the nozzle.

An additional object of the invention is to provide a dryer of the type described which includes a reflector element located on the side of the web remote from the radiant heating device for directing back to the web unabsorbed and web-emitted radiation.

Other objects and advantages will be apparent from the following detailed description when read in connection with the drawings in which:

Figure 1 is a cross-section of the drying unit of the present invention taken along an axis parallel to the longitudinal axis of the moving web;

Figure 2 is a view taken substantially along line 2—2 of Figure 1 in which a portion of the dryer is shown in full front elevation;

Figure 3 is an enlarged detailed view of an alternate form which the mouth of the nozzle may take, and

Figure 4 is a fragmentary longitudinal section of the nozzle illustrating a further modification.

The scope of the invention is by no means limited to particular materials or substrata to be coated or impregnated or to the particular materials employed for coating or impregnating. Thus, the invention is applicable to virtually any web which is manufactured in substantial lengths, such as paper, laminated board, cellophane, aluminum foil, textile material, either synthetic or natural, and many, many others. In similar fashion, virtually any type of coating material applied in an unlimited variety of solvents may be effectively dried by the invention, provided only that the solvent is capable of evaporation. Of many coating materials, there may be mentioned inks, lacquers, paints, adhesives, plastics and various chemicals. In addition, the invention may be employed to accelerate the drying of webs which, technically, have not been coated, that is, have not had applied thereto an overlying film of a different material, but have merely been immersed in or moistened with a wholly evaporatable liquid, for any one of a number of reasons.

Reference is now made to Figure 1 of the drawings for an illustrative embodiment of the dryer unit constituting the present invention and in this figure the letter W designates a web of material which has been impregnated in any conventional fashion and is to be dried. Web W, of any desired length and width, is moving at a selected rate of speed in the direction indicated by the arrow. Supported above the web by any desired means, such as by suitable brackets or mounting plates **10**, is a casing, generally designated **11**, preferably constructed of heavy gauge sheet metal or the like. The casing is of narrow elongated configuration and includes a top wall **12**, front and back end walls **13** and **14**, respectively (relative to the direction of travel of web W), and right and left side walls **15** and **16**, respectively. The forward portion **12a** of top wall **12** may be omitted but is preferably included since it constitutes a convenient element for attachment to the mounting brackets. Within the casing, preferably adjacent to rear wall **14**, is a pressure equalizing chamber indicated at **17**. This chamber extends across the entire width of casing **11**, i. e. the dimension transverse to the longitudinal axis of web W, and in the embodiment of the invention shown is defined at its front end by a partition wall **20** extending from the rear upper corner of the casing formed by the juncture of end wall **14** and top wall **12** downwardly and forwardly in the direction of front end wall **13**, at its rear end by end wall **14** of casing **11**, at its bottom by a bottom wall **21** extending from the lower termination of end wall **14** forwardly and terminating just short of partition wall **20**, and at its sides by the portions of left and right side walls **15** and **16** included between partition wall **20**, end wall **14**, and bottom wall **21**.

There is supplied to pressure equalizing chamber **17** from a source (not shown) a gaseous fluid under pressure, such as hot or cold air, saturated or superheated steam, and the like, via a conduit (not shown) communicating with the chamber through a suitable opening in any of its walls, for example, aperture **22** in end wall **16**. Opening from bottom wall **21** of chamber **17** is one end of a nozzle **23** which is restricted in cross-section and extends across the entire width of the casing. Nozzle **23** is disposed with its axis extending downwardly and forwardly from rear to front, thus making an acute angle with the plane of the web, so that the jet of gaseous fluid issuing from the nozzle will have a component opposite to the direction of travel of the web. The degree of angularity of nozzle **23** may vary from about 5 to 85 degrees and an angle of about 45° has been found to be satisfactory in most instances. As shown, nozzle **23** is constituted by an extension **24** of partition plate **20** on the one end, and by a downwardly and forwardly directed extension **25** of bottom plate **21** on the other end, the openings at the extreme sides of these plates being sealed off by suitable strips of narrow material, formed either integrally with sides **15** and **16** or separately therefrom and secured in place as by welding. At their ends closest to web W, extensions **24** and **25** are bent laterally to form lips or flanges **26** and **27**, respectively, for a purpose to be hereinafter explained.

It is advantageous for the extent of restriction of nozzle **23** to be capable of variation insofar as this restricted cross-section is concerned in order to achieve a limited range of control over the velocity of the jet or sheet of air issuing from the nozzle, independently of changes in the pressure of the fluid supplied to chamber **17**. A simple way in which this may be accomplished is by providing a plurality of apertures at spaced points along the width of walls **24** and **25** and inserting in these apertures bolts **28** carrying at their free ends nuts **29**. By tightening up on nuts **29**, the walls of the nozzle may be brought closer together to narrow the nozzle opening, the inherent rigidity of the walls being sufficient to resist outward bowing under the influence of the pressure of the fluid in chamber **17**. The actual amount of separation between the plates defining the nozzle will largely depend upon the particular circumstances under which the unit is to be used and the amount of turbulence needed for most efficient drying under these circumstances. Ordinarily, a distance between the plates of a small fraction of an inch, say less than ¼ inch, will prove to be most satisfactory.

There is joined to top wall **12** of casing **11**, at about its midpoint between front end wall **13** and rear end wall **14**, a divider plate **30** stretching across the entire width of casing **11** and extending downwardly and forwardly from top wall **12** at a somewhat greater angle than partition wall **20**. At its lower end, divider plate **30** stops substantially short of the extreme lower termination of the end and side walls of casing **11**, joining at this point with the inner edge of a downwardly opening concavo-convex polished metal reflector element **31**, extending across the entire width of casing **11**, and connected at its forward edge to front wall **13**. Partition wall **30** and reflector element **31** may be, and preferably are, formed as an integral unit from a single metal sheet which is bent or stamped in the necessary configuration.

Secured, as by means of bolts **33**, to reflector element **31** substantially in alignment with its principal axis, and depending downwardly therefrom is a plurality of brackets **32** which support an infra-red heating element **34** stretching substantially across the entire width of web W with its longitudinal axis generally parallel to the plane of web W. The heating element may be energized from any desired source of electrical power through the conventional circuitry (not shown). It is to be understood that where in either the specification or claims reference is made to a single heating element, it is not intended to restrict the invention to a single heating element since a plurality of shorter elements arranged end to end would achieve essentially the same result and be equally applicable for the purposes of the invention. The location of the heating element within casing **11** is not limited specifically to that location which is shown but may be changed to meet the needs of a particular situation provided that it is relatively near the web and, further, that the transverse axis of the element perpendicular to the plane of the web is in reasonably close-spaced relationship with the mouth of nozzle **23**.

As can be seen in Figure 1, front wall **13** actually comprises two articulated sections; an upper section **13*a*** which is integrally joined to top wall **12** and a lower section **13*b*** connected at its upper edge to the lower edge of section **13*a*** by means of one or more hinges **36**. Lower section **13*b*** is preferably made of polished metal in concavo-convex configuration and functions in a dual capacity. When this lower section is in its downwardly directed position, extending more or less perpendicularly to plane of web W (as shown in the solid lines) it serves as an auxiliary reflector for the infra-red heating element 34, limiting the effects of the radiation from the heating element to the area of web W in the immediate vicinity of nozzle 23 and, in addition, acts as a barrier against excessive escape from the casing of the gaseous fluid issuing from nozzle **23**. It will be realized that in many instances the liquid needed to be evaporated will be a solvent that is unpleasant or even toxic to human beings; consequently, the provision of means for preventing undue permeation of the solvent saturated gaseous fluid into the atmosphere surrounding the dryer is advantageous from the standpoint of the operator's health and safety. While, in most cases, heating element **34** will be of a type in which the intensity of its radiation can be regulated by a suitable control instrument included in its circuitry, in other cases, it may be desirable to be able to control the intensity of the radiation emitted by this device without changing the settings of the electric regulating devices; lower section **13*b*** is also adapted for this purpose. By moving the lower section within the limits defined by its extreme downward position, shown in solid lines and its extreme upward position, shown in dotted lines, the intensity of the radiation to which web W is subjected may be varied from a maximum to virtually zero. Any suitable means may be employed to hold lower section **13*b*** in any position at and between these limits; for example, hinge **36** may be of a type having an inherent frictional resistance sufficient to support the weight of the section.

The intermediate region of casing **11** bounded by the upwardly diverging inner surfaces of divider plate **30** and partition wall **20** constitutes an exhaust manifold or passageway **38** extending the full width of the casing through which the gaseous fluid, which has impinged upon web W under the action of nozzle **33**, may be withdrawn from the casing. At its upper end exhaust manifold **38** connects with an exhaust outlet **40** which is in communication through any suitable conduit with a source of suction or vacuum (not shown). As illustrated in Figure 1, the partition 30 is of such length that it does not extend into the space between the heating element 34 and the wall 24 of nozzle 23 so that this wall is exposed to a substantial amount of radiation from the heating element and will itself be heated. Since the walls 24 and 25 of nozzle 23 are closely spaced together the thin stream of air flowing therebetween will be heated by the hot wall 24 and will be a more effective drying medium.

Where a woven textile material or the like is undergoing drying, a certain amount of radiation emitted from the heating element 34 will pass through the interstices of the web. Also, as the temperature of the web is elevated, the web itself emits radiation. To prevent loss of this unabsorbed and/or secondarily emitted radiation, a planar reflecting element is provided on the side of the web remote from the heating element. In the form of the invention that has been selected for illustration, the side walls 15 and 16 of casing 11 are extended laterally in the form of flanges 42 and 43 and are formed with apertures for penetration by bolts 44 held in place by means of wing nuts 46. The bolts are long enough to project below the plane of web W and by their heads support a polished metal reflecting plate 48, which corresponds in transverse dimension to the full width of casing 11, including flanges 42 and 43, and in longitudinal dimension to the length of casing 11 between end walls 13 and 14. Each of the bolts 44 is embraced by a compression spring 50 bearing at its upper end against the lower surface of flanges 42 and 43 and at its lower end against the upper surface of reflector plate 48 to thereby hold the plate in place. Because of plate 48, virtually all of the energy that is supplied to the dryer for conversion into radiation is effectively utilized for active drying, only a negligible amount being lost to the surroundings.

Units of the type contemplated by the present invention may be constructed in any desired width commensurate with the width of the fabric to be dried. Preferably, however, the unit should not be limited for use with only one particular width of web but should be adapted to accommodate widths varying within a reasonable range. Accordingly, there is fitted over each of the end portions of nozzle 23 a sliding closure 52. Closure 52 may take the form of a channel generally C-shaped in a cross-section, which slidably embraces the flanges 26 and 27 at the lower end of the nozzle. By adjusting closures 52, laterally, the unobstructed width of the mouth of nozzle 23 may be varied in accordance with the width of the particular web to be dried.

The object of impinging a thin sheet of gaseous fluid moving at a high velocity against web W at an angle opposed to its direction of movement is to create a condition of extreme turbulence over a portion of the surface of the web, and the degree of turbulence is principally controlled by the pressure at which air is supplied to the nozzle from equalizing chamber 17 and at the cross-sectional area of the nozzle which may be selected in accordance with well known principles of fluid flow. In addition, the mouth of the nozzle itself may be given any desired configuration which would contribute to the creation of this condition of turbulence. For example, as illustrated in Figure 3, the mouth of the nozzle 23′ bordered by flanges 26′ and 27′ may be of a wavy or sinuous configuration, rather than the rectilinear configuration shown in Figures 1 and 2. Also, the configuration of the nozzle when viewed in cross-section may be selected with a view to enhance the turbulence of the gaseous medium flowing therethrough, the modification depicted in Figure 4 being one of the many possibilities, wherein the nozzle 23″ is of sinuous shape from its egress opening at the bottom of equalizing chamber to its mouth bordered by flanges 26″ and 27″.

It is known that useful non-visible radiation is of a wave length falling within the range of about 0.8 to 10 microns and that the energy of the radiation emitted by any source will be distributed over this range in accordance with a curve rising from the visible range to the peak and then falling off as the higher wave lengths are approached. The wave length of peak emissivity, i. e. point of maximum energy on the curve, for any given body is determined by the temperature and will be fixed at any specified temperature. For example, for the perfect radiator, a black body, peak emissivity at about 1175° C. will be about 2 microns, at 700° C., approximately 3 microns; and at 200° C., about 6.2 microns. This knowledge becomes of consequence to the practice of the present invention when it is realized that different subtrata i. e., material that is coated, and different coating materials, i. e., materials to be at least partially evaporated, all have differing absorption rates for radiant energy of different wave lengths with maximum absorptivity occurring at one or more particular wave lengths. Having determined the wave length at which maximum absorptivity or, at least, optimum absorbtivity, exists for both the substratum and the coating material, more efficient drying can be effected by selecting the temperature of the radiating body, assuming the nature of the surface to be unchanging at that value where peak emissivity of the radiating body corresponds to peak absorptivity of the material to be dried and the coating material. It is contemplated by the present invention, therefore, that the nature of the surface of the radiating body and a temperature at which it is maintained will be chosen with a view to the emission of radiation of a wave length that will be best absorbed by both the material to be dried and the material to be evaporated wherein the range is of about 1.4 to 9.5 microns.

It will be appreciated that the existence of a turbulent condition at the surface of the web adds materially to the efficacy of the drying action. As has already been mentioned, this is accomplished, in part, by preventing the formation of a viscous film or hardened skin over the surface of the material to be evaporated which tends to retard the rate of diffusion of the sub-surface portions of this material. Furthermore, a turbulent condition maintains the coating of liquid medium in a constant state of agitation which causes the medium to be broken up into minute droplets and dispersed throughout the gaseous fluid, thereby increasing tremendously the area of contact between the gaseous fluid and the medium. As the rate at which a liquid is absorbed by a fluid is largely governed by area of contact between the two, a substantial increase in the contact area is of vital significance to an understanding of the result achieved by the invention. A more complete comprehension of the details of the invention may be derived from the following illustrative example:

The material to be dried is a paper web that is printed in three colors by means of a flexographic printing machine, the initial color being a heavily pigmented underprint. It is first determined that the solvents, lacquers, colors, and paper had a good absorptivity for radiant energy in wave lengths over three microns. From this information, it is concluded that the temperature of the heating element should be about 960° F., giving peak emissivity at about 3.7 microns. The element itself is ceramic with an output of 300 watts per ten inches of length. The gaseous fluid used is air, supplied to the equalizing chamber at a pressure of 30 inches of water (gauge), and yielding an approximate rate of flow of 150 feet per second with a nozzle gap of $^{20}/_{1000}$ (.020) inch. The axis of the nozzle is inclined at an angle of 45° to the plane of the web; the mouth of the nozzle is spaced .12 inch from the surface of the web. The fume-saturated air is exhausted from the dryer under a vacuum of 1¼ inches of water (gauge). With this arrangement, the drying capacity of the machine is about 700 ft. of web per min., representing an increase of about 40% over the previous practical maximum for this particular operation.

Using the same installation for removing water from surface-coated paper, 3–10 pounds of water can be removed per hour per 1000 watts of power of the heater.

As is readily evidenced by the drawings, the entire unit is exceedingly compact, largely because of the efficient arrangement of the various elements. In fact, with the possible exception of installations of extremely high capacity, an unobstructed stretch of 10 inches in the path of the web is all that is required to accommodate an entire unit. For this reason, the dryer of the present invention is peculiarly well adapted for use with complex machines, performing a number of successive operations on the web, where space is at a premium. In addition, the unit is equally suited for application to existing machines and can usually be fitted between one or more stations of such machines without alteration thereof.

By virtue of the unique combination of direct radiant heating and agitation at the surface of the material to be dried induced by the high velocity sheet of fluid impinged thereon and, in addition, the particular arrangement of the components of the dryer within a limited space, the efficiency of the invention is virtually unsurpassed in its field, maximum utilization for drying purposes of both the electrical and mechanical energy supplied to the unit being an important characteristic. Thus, the unit is equally capable of maximum capacity of optimum power consumption or optimum capacity at minimum power consumption.

Those skilled in the art will appreciate that the details of the design and construction of the embodiments described and illustrated are not essential to the invention and are included principally for the purpose of disclosing a complete operative unit, variations and modifications of such details to meet the needs of particular situations will be obvious and are considered with the purview of the invention except where excluded from the scope of the appended claims.

Having thus described the invention what is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for drying a moving web impregnated with an evaporatable liquid comprising a casing, having a top wall, end walls, and side walls, arranged adjacent a straight stretch in the path of said web, a partition wall in said casing extending from adjacent the corner of said top wall and the wall at the end of the casing toward the direction of travel of said web at an angle toward the opposite side wall and terminating closely adjacent the surface of the web, a partial bottom wall for said casing extending from said first-mentioned side wall to just short of said partition wall to define a pressure equalizing chamber with said partition wall, said side wall and the portion of the two adjacent side walls included therebetween, said floor wall being extended downwardly in closely spaced relationship with the portion of the partition wall adjacent the web to constitute a nozzle with said portion of the partition wall, a radiant heater mounted in said casing between said partition wall and said opposite side wall, a reflector disposed on the side of the heater remote from said web, said reflector being extended from its inner end upwardly to said top wall and constituting with the partition wall and the included portions of said side walls an exhaust manifold from said casing, means for supplying a gaseous fluid under pressure to said equalizing chamber, and means communicating

with said exhaust manifold for removing said fluid therethrough.

2. The apparatus as in claim 1 wherein said opposite side wall is articulated, the section adjacent said web being pivotable in the direction of said heater to vary the intensity of the radiation emitted from the heater.

3. The apparatus as in claim 1 including a reflector plate supported in spaced relationship from said casing on the side of the web opposite to said casing.

4. Apparatus for drying a moving web impregnated with an evaporatable liquid comprising a relatively narrow elongated casing extending across said web adjacent one surface thereof, a pressure equalizing chamber at the end of said casing in the direction of travel of said web, a nozzle communicating with said chamber and extending across the web, being directed downwardly and away from said end of the casing and terminating in close proximity to the web, said nozzle being defined by uniformly closely spaced, substantially parallel walls extending a substantial distance in the direction of flow therethrough, means for supplying gaseous fluid under pressure to said chamber, an infra-red heating element housed within said casing adjacent the web and one of said walls, the space between said element and said one wall being unobstructed whereby to heat said wall, at least one reflector plate for said element for directing radiation therefrom against the web in the vicinity of the nozzle, and an exhaust passageway intermediate said element and said chamber for withdrawing said fluid from said casing.

5. An apparatus for drying a moving web impregnated with an evaporatable fluid comprising a substantially flat nozzle extending across the whole of the width of said web and directed at an acute angle towards the web with the direction of angularity being opposed to the direction of travel of the web, said nozzle being defined by uniformly closely spaced, substantially parallel walls having a length, as measured in the direction of flow through said nozzle, substantially in excess of the spacing therebetween and terminating closely adjacent the web, a source of gaseous fluid communicating with said nozzle, and an elongated generally cylindrical source of radiant energy disposed on one side of the web with its axis extending in spaced parallel relationship to the plane of the web and generally at right angles to the longitudinal axis of the web, a plane perpendicular to the plane of the web through the axis of the said source being spaced oppositely to the direction of travel of the web from the mouth of the nozzle, said source also being spaced above the upper termination of the walls defining the nozzle, the space between the cylindrical source and the adjacent wall being unobstructed whereby said wall is heated by said source.

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