

Dec. 18, 1951

R. A. RUSCA ET AL
METHOD AND APPARATUS FOR DRYING SIZED OR
OTHERWISE IMPREGNATED TEXTILE MATERIAL

2,578,744

Filed July 26, 1949

4 Sheets-Sheet 1

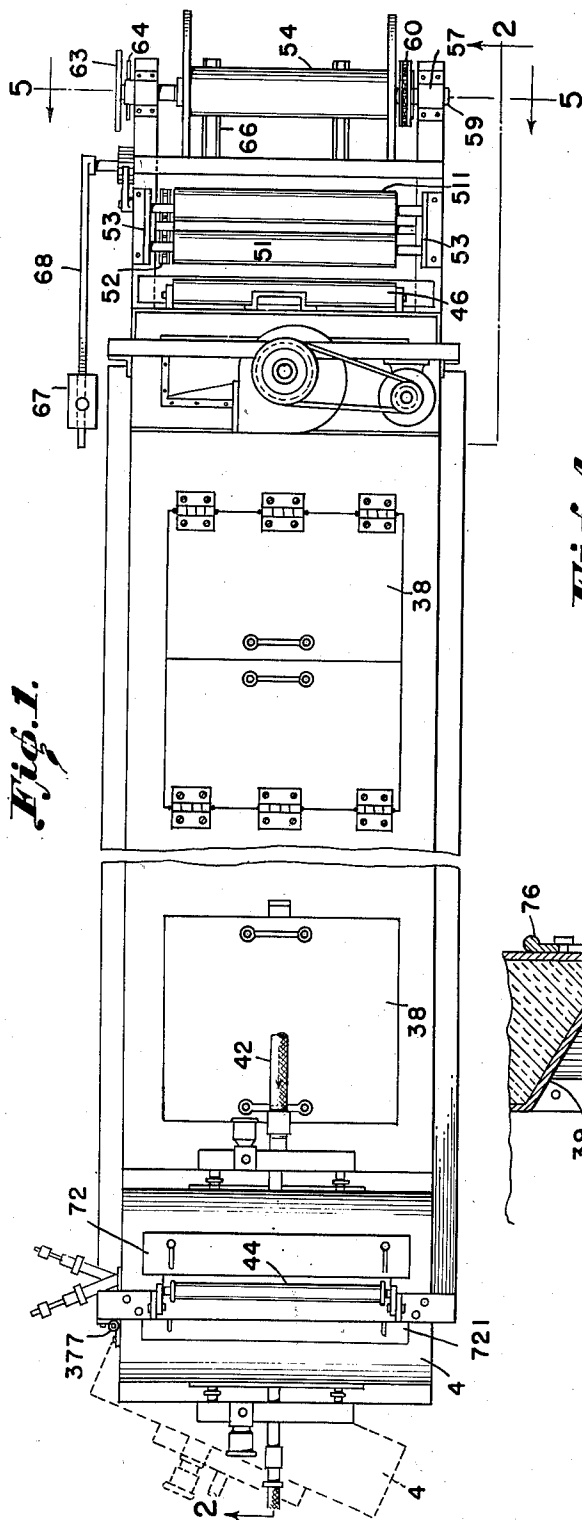


Fig. 4.

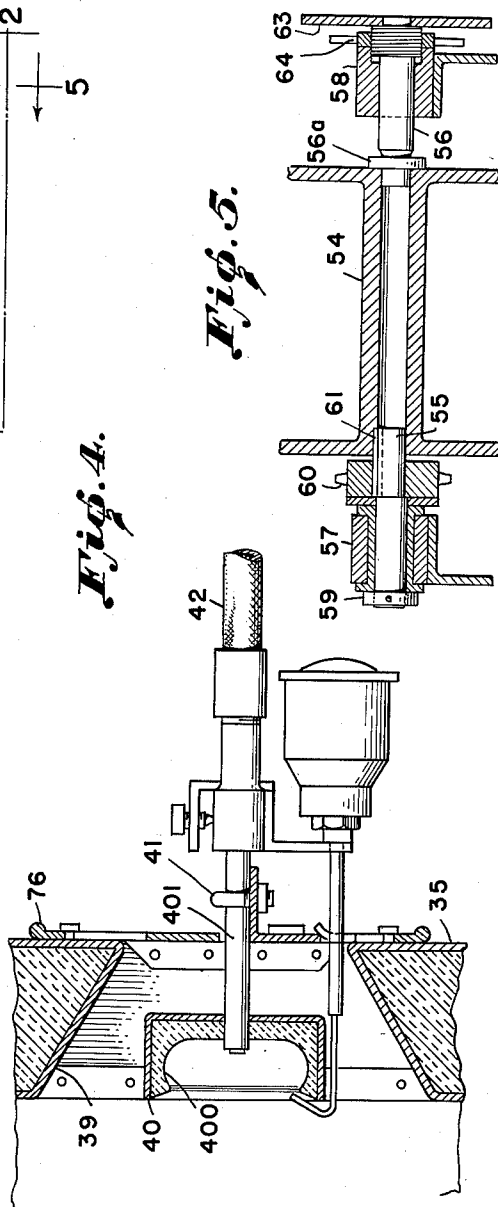


Fig. 5.

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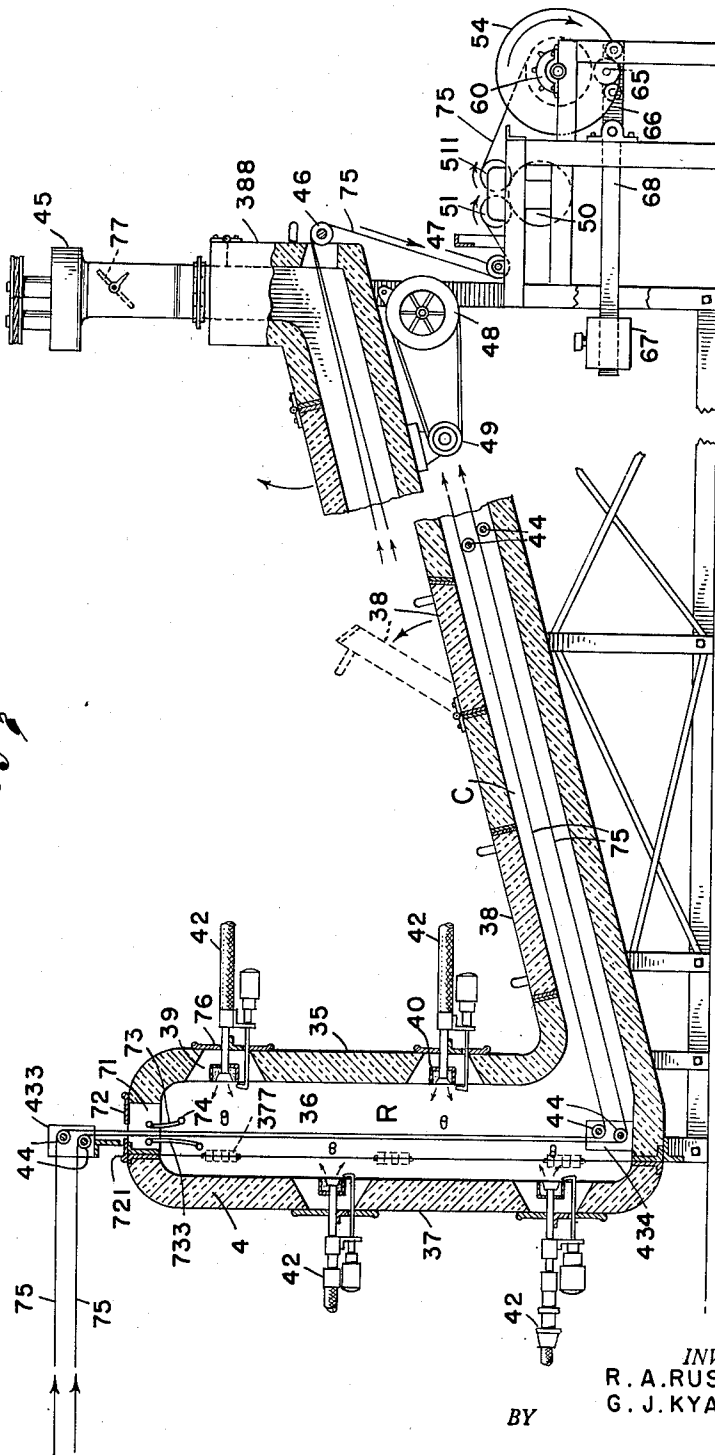
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4 Sheets-Sheet 2

Fig. 2.



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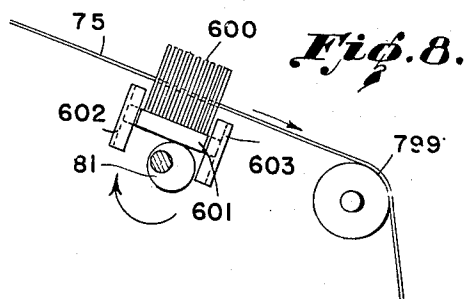
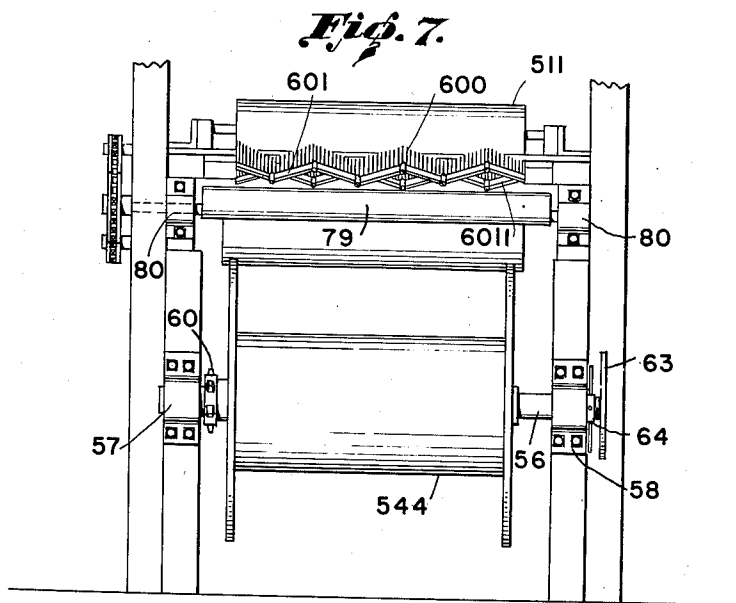
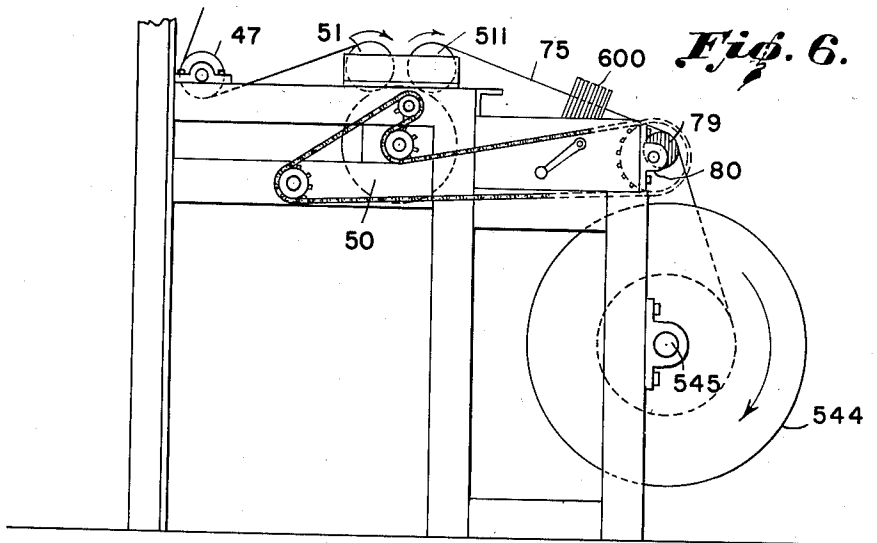
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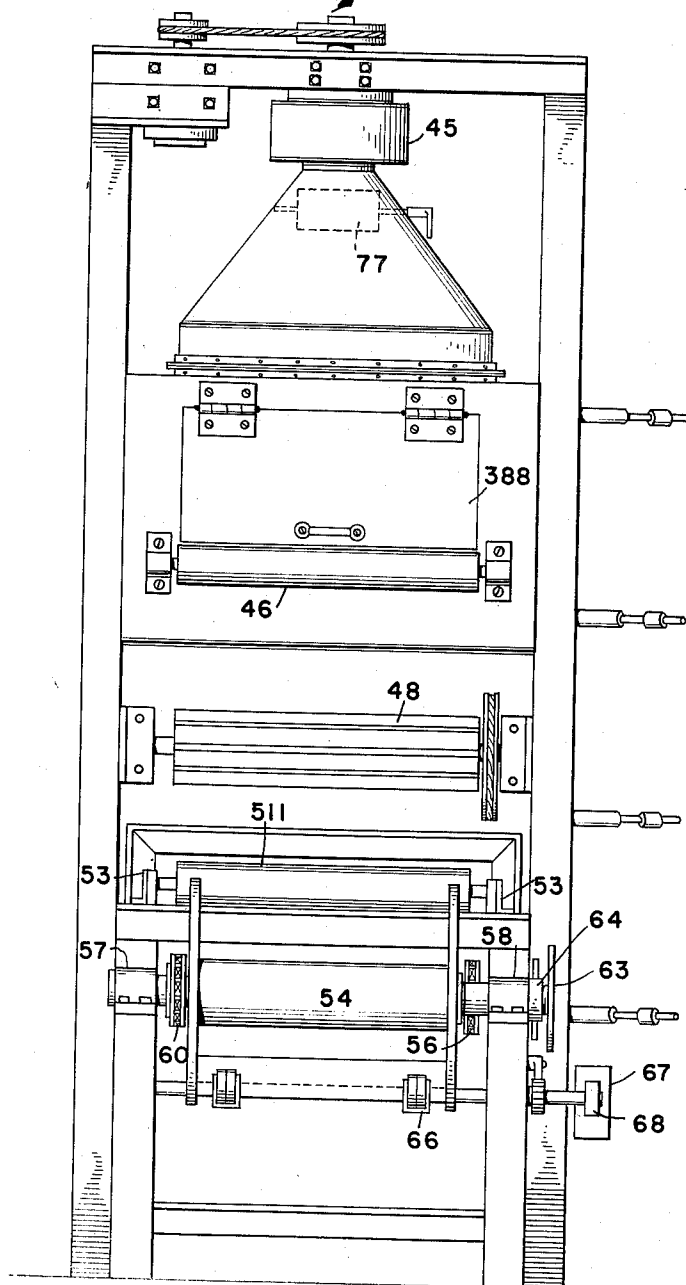
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Fig. 3.



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UNITED STATES PATENT OFFICE

2,578,744

METHOD AND APPARATUS FOR DRYING
SIZED OR OTHERWISE IMPREGNATED
TEXTILE MATERIAL

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7 Claims. (Cl. 34—18)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This application is made under the act of March 3, 1883, as amended by the act of April 30, 1928, and the invention herein described, if patented in any country, may be manufactured and used by or for the Government of the United States of America for governmental purposes throughout the world without the payment to us of any royalty thereon.

This invention relates to a method and apparatus for subjecting sheets, webs, or strands to a heating operation. It particularly relates to drying textile warps that have been subjected to a sizing operation.

Sized warps are customarily dried by means of a steam-heated cylinder dryer, or by means of a hot-air dryer.

One of the chief objections to steam cylinder dryers is that the warp in many instances is subjected to undue heating and tendering whenever the slasher has to be stopped to tie up broken yarns or to change beams. Steam cylinder dryers also aggravate sticking between adjacent yarns and make necessary the use of lease rods, which tear the stuck yarns apart after they have been dried, leaving them rough and fuzzy. Yarn in this condition is difficult to weave and results in fabric of inferior quality.

Hot-air dryers, on the other hand, are not efficient in transferring heat energy to the warp. To achieve the required degree of dryness, the warp makes several passes through the dryer. This makes threading up more difficult and at the same time adds to the damage done the warp when yarn breakage occurs within the dryer. Also, prior hot-air dryers accomplish their drying by the movement of large volumes of air under positive pressures within the dryer. In many cases, various varieties of jets and baffles are used to secure intimate contact between the warp and the drying medium. This not only increases the initial and operating costs of the dryer, but also adds to its operating problems. Furthermore, lease rods are required with the conventional hot-air dryer.

In the prior art of hot-air drying it is customary to recirculate a major portion of the hot air, and to replace exhausted hot air with fresh air at ambient temperature. Such practice leads to a drying medium relatively rich in oxygen and high in moisture content. It is well known that oxidation and high humidity play important parts in bringing about the deterioration of cellulosic materials, particularly in the presence of high temperatures. In view of this, it is evident that drying by prior means is detrimental to textile

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warps since such dryers, whether they be steam-cylinders, hot-air dryers, or the like, all heat the warp in an oxidizing atmosphere of high humidity and temperature.

Drying of the sized warp is accomplished by us in a dryer of entirely novel character. To prevent adhesion of adjacent warp yarns, the dryer is provided with a plurality of rolls which separate the warp into a multiplicity of sheets, as many as there are section beams supplying the warp, and keep it so separated until the warp emerges from the dryer. Thus, the need for split rods is done away with and the warp is left in better condition for weaving. Heat energy for drying is supplied by gas-fired infra-red ray generators, hereinafter called burners. The infra-red rays are made to impinge on the moving multi-sheet warp as it enters the dryer, and means are provided for regulating the heating of the warp with the infra-red rays. The products of combustion of the gas, hereinafter referred to as hot air, and the warp are then brought into intimate contact in an area of reduced cross-section in another part of the drying chamber. The burners can be regulated so that the products of combustion form a neutral atmosphere which contains little or no free oxygen and, therefore, does not subject the warp to the deleterious effects associated with oxidizing atmospheres. The burners may also be regulated to produce an oxidizing or a reducing atmosphere, if such is desired for polymerizing resins, treating chemically impregnated warps, or the like.

The design of the dryer, with its reduced area in the hot air section, makes economically feasible the use of high air or gas velocities and high air or gas turbulence to enhance drying efficiency. Moreover, the small volume of air or gas being moved allows economic operation at negative or subatmospheric pressures, further increasing drying efficiency through well-known principles of low-pressure or vacuum drying. Intimate contact of the drying air is achieved by these means without the use of baffles, jets or similar expedients which tend to produce undesirable disturbance of the warp and excessive shedding of the size coating.

The apparatus and process are so designed that much higher than ordinary temperatures can be used in the drying operation. Fast drying of sized warps is obtained by our new process and apparatus by operating at temperatures up to 500° F. We have discovered that sized warps can be dried in a continuous operation at temperatures between 300° to 500° F. by passing them

through the hot zone quickly, so that the material is subjected to such temperatures for a period of preferably no more than about 1½ to 2 seconds. The conventional drying of sized warps is at 235° F. The use of the hot exhaust gases at high velocity, such as 1000 to 3000 feet per minute, in the lower temperature drying zone, is also highly conducive to efficient and economical operation.

When yarns, sheets, and the like are to be given a coating of a resin by polymerization thereon, our process and apparatus may be employed at temperatures as high as 800° F., or higher.

Among the objects of this invention is to provide an economical and efficient means for drying sized sheets, webs, or strands, by means of an apparatus permitting increase in speed of travel of the warp through the sizing and drying steps; to provide a method for preventing the adhesion of adjacent warp yarns while drying; to provide for the efficient use of radiant heat energy in combination with hot gases for drying; to provide means of quick access to any part of the warp, particularly to that portion in the radiantly heated space; to provide means for controlling the intensity of the radiant energy falling on the warp; to provide means for controlling the oxygen content of the heat transfer medium to prevent degradation of a textile warp by oxidation when said warp is dried in this medium; to provide means for rapidly cooling the drying chamber in the event of warp stoppage during its passage therethrough; to provide means for facilitating the doffing of full beams at the head end; and to provide means to minimize wear on the comb.

One embodiment of the invention is illustrated in the accompanying drawings in which:

Figure 1 is a plan view of the assembled dryer;

Figure 2 is a vertical section of the dryer on the line 2—2 of Figure 1 with a section removed to save drawing space;

Figure 3 is a vertical end view;

Figure 4 is a detail of the radiant heater or burner;

Figure 5 is a detail section of a doffing beam on line 5—5 of Figure 1;

Figure 6 is a side view of a modified form of comb, roller, and doffing beam;

Figure 7 is an end view of Figure 6;

Figure 8 illustrates means to raise and lower the comb.

The dryer 35 is an elongated double-walled structure forming a U-shaped chamber 36. Chamber 36 comprises two sections or zones designated in the drawings by the letters R and C. Zone R, the taller vertical portion of chamber 36 comprises that part of the dryer space wherein the warp 75 is subjected to the action of radiant heat energy. Zone C, which includes the transverse inclined part, and the shorter vertical part is that wherein drying is done with hot air or other gas. To provide access into zone R, the front wall 37 is hinged at 377 (Figure 1) and may be swung outwardly to expose the interior. Access to zone C is through a number of small double-walled doors 38 located in the upper wall of the chamber. The space between the double walls of the dryer and the doors is packed with insulating material 4 to confine the heat to the interior of said dryer.

The front and rear walls of zone R are pierced with a plurality of funnel-shaped rectangular openings 39, into which gas-fired intra-red ray generators 40 project. The generators, of the type wherein a ceramic member 400 is heated

to incandescence in a gas flame, are mounted in such manner that the distance between the burner face and warp is made adjustable. Any suitable means, manual or automatic, may be employed to achieve said burner-warp distance adjustment. In the embodiment described, burner pipes 401 are held in place by U-bolts 41 which may be loosened to permit sliding the burners toward or away from the warp. Gas supply lines 42 of flexible metal hose provide the flexibility necessary when making adjustments in said distance as well as that needed when opening and closing hinged wall 37.

An opening 71 in the upper end of zone R is provided for the purpose of admitting outside air, if so desired, to supplement the hot air furnished by the burners. Two sliding sheet-metal cover plates 72 and 721 regulate the air intake through said opening 71. Two curved sheet-metal baffles 73 and 733, hanging from studs 74, divert the incoming air stream away from warp 75 and toward burners 40 for prewarming. Both baffles 73 and 733 are readily removed for threading up or maintenance of the warp. Additional sheet metal sliding cover plates 76 mounted on the vertical walls of zone R just back of burners 40 serve to regulate the amount of air entering the dryer through openings 39. With cover plates 72 and 76 set to exclude outside air the drying atmosphere within chamber 36 may be adjusted to any desired composition, oxidizing, neutral, or reducing, by regulating the air-gas ratio in the mixture fed to burners 40.

Atop dryer 35 above the upper end of zone R and also within the dryer at the lower end of said zone are sets of brackets 433 and 434. Each set of brackets supports a plurality of flanged conveyor rolls 44, hereinafter called lease rolls, in staggered relationship to each other as shown. The number of lease rolls supported by each set of brackets is equal to the number of section beams supplying the warp. Still another set of lease rolls 44 are to be found in the middle of zone C. Although lease rolls 44 are preferred, it is not necessary that rolls be used; they may be replaced by highly polished metal split rods. At its colder end chamber 36 makes an upward turn and connects with the inlet of an exhaust blower 45. Interposed between the inlet of said exhaust blower and the termination of zone C is an air flow control valve 77. Regulation of valve 77 determines the rate of flow of air within chamber 36.

Although the drawing shows manual means for opening hinged wall 37, doors 38, and valve 77, it is to be understood that the invention is not so limited. A preferred arrangement is to have hinged wall 37, doors 38, valve 77, and burner gas supply source all interlocked, mechanically or electrically or both, with the warp advancing means so as to provide means for rapidly cooling chamber 36 in the event of warp stoppage. Thus, when forward movement of the warp ceases burners 40 are extinguished and hinged wall 37, doors 38, and valve 77 are all opened simultaneously allowing the hot air within the dryer to be replaced almost immediately with air at room temperature.

An auxiliary door 388 in the above mentioned upright section of zone C gives access to the warp at the "cold" end and facilitates threading up. A pair of idling conveyor rolls 46 and 47 guide the warp past a paddle-fan 48 driven by motor 49.

Warp 75 is advanced through the dryer by

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means of three rolls 51, 511, and 50. Roll 50, called the delivery roll, is a cloth-covered metal roll about nine inches in diameter and is driven through sprocket 52 (Figure 1) by means not shown. The pair of rolls 51 and 511 are floatingly supported between guides 53, which restrict the rolls to movement in the vertical direction only. When threaded up as shown, the warp almost completely encircles the periphery of the delivery roll, and on applying tension considerable traction develops between delivery roll 50 and warp 75.

The takeup beam 54 is supported between two stub shafts 55 and 56, held in bearings 57 and 58 respectively. A stub shaft 55, prevented from lateral movement by set-collar 59 and sprocket 60, is driven by said sprocket 60 and rotates within bearing 57. Means for driving sprocket 60 are not shown. Stub shaft 55 protrudes a short distance from the end of the hub of sprocket 60. A key 61 keys sprocket 60 to shaft 55 and extends to the end of the protruding shaft. The protruding ends of shaft 55 and key 61 insert into one end of beam 54. The other end of beam 54 is supported by stub shaft 56 which inserts therein. A rotatably mounted sleeve 56a, held to shaft 56 by a retaining screw not shown separates shaft 56 from beam 54 and allows the shaft to be held stationary while the beam rotates. The opposite end of shaft 56 is threaded part way and has a round metal plate 63 attached thereto forming a handwheel for turning said shaft 56. Bearing 58 is internally threaded part way at one end of its bore to receive the threaded portion of shaft 56. A locknut 64 locks any adjustment of shaft 56.

An expansion comb, not shown, is mounted in the path of the warp between rolls 47 and 51, and serves to guide the warp yarns in parallel alignment and distribute them uniformly across the width of takeup beam 54.

A press roll 65, cradled in a pivotally mounted support 66 and loaded by a weight 67 through lever 68, compacts the warp as it is being wound on the takeup beam 54.

The delivery roll 50, and the takeup beam 54 may be driven by any suitable means. It is necessary only that the warp be advanced through the size box and dryer under a minimum of tension, and that the warp be wound onto the takeup beam under constant tension.

In operation, the size impregnated warp leaves a size box, for instance, the size box shown in Rusca Patent 2,564,725 issued August 21, 1951, and the warp then passes to an overhead flanged conveyor roll, not shown, which keeps the warp clear of hinged front wall 37 of dryer 35. From said overhead conveyor roll warp 75 separates into a plurality of sheets each going over a separate lease roll 44 of the group mounted above the radiantly heated dryer space, and then under a similar group in the bottom of said dryer space. Said lease rolls are so disposed in their respective mountings as to suspend the warp in the center of the radiantly heated space in the form of a multilayer sheet, each layer being slightly separated from its counterpart. Spacings of from $\frac{3}{8}$ to $\frac{1}{4}$ inch between layers have been found satisfactory.

Although the drawing shows warp 75 separated into two sheets, it is to be understood that the invention is not so limited. More or less than two section beams may be used, and the dryer may be equipped with a corresponding number of lease rolls in each group. Also the number

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of burners need not be limited to four. However, it is preferred that an even number be used, and that these be distributed in equal number on each side of the warp to insure uniform drying. Furthermore, the staggered relationship between burners on opposite sides of the warp is a preferred arrangement and not an essential one. The burners may be placed directly opposite each other.

From the lowermost group of lease rolls 44, warp 75 passes over a similar set in the middle of zone C, and out of the dryer over conveyor roll 46, on which the various sheets are reunited to form a single sheet. The reunited warp then goes around and under conveyor roll 47, through an expansion comb not shown, over and around floating roll 51, around delivery roll 50, over floating roll 511 and finally, onto takeup beam 54.

Thus on leaving the size box, warp 75 is divided into a plurality of sheets which enter the dryer at the upper end of zone R. These sheets, confined to the center of the zone in close proximity to each other, are heated by the combined action of extremely hot air and intense infra-red radiation. This action, coupled with the well-known penetrating power of the radiant energy, quickly raises the temperature of the warp to the boiling point of the size solution and the volatile ingredients begin to boil off into the surrounding hot air. Since the said surrounding hot air is made up of the combustion products of the gas-air mixture fed to the burners, the warp is, therefore, heated in a neutral or non-oxidizing atmosphere which has a very low relative humidity and remains so because it is constantly being replaced with fresh combustion products. Thus at no time is the warp subjected to the deteriorative effects of oxidation and relative humidity in the presence of high temperatures.

Complete control over the intensity and penetrability of the infra-red radiation and also over the hot air velocity makes the dryer particularly adaptable to the drying of surface coatings. When desired, heating may be done so rapidly that surface coatings are completely dried, or, in the case of resins and the like, completely cured without materially disturbing the underlying base material. Control over the intensity and penetrability of the infra-red radiation is had through regulation of the incandescent burner surface temperature which determines the wavelength, and hence the penetrability, of the emitted radiation.

At the bottom of zone R the individual sheets of the multi-layered warp are spread farther apart as they leave the group of lease rolls to enter zone C. They remain so separated up to the lease roll group in the middle of the zone and thereafter gradually come together to be reunited just outside the dryer on roll 46. Within said zone C the warp sheets are brought into intimate contact with hot air which is being drawn through from zone R by exhaust blower 45. The remaining volatiles removed, the completely dried warp 75 emerges from the dryer. The warp then moves past the conventional paddle-fan 48 where it is cooled, and on through the expansion comb to be guided as it is being wound on takeup beam 54.

The interior walls of zone C fit rather closely to warp 75 thereby reducing the cross-sectional area to the extent that high air velocities are obtained without the need for large and expen-

sive exhaust blower systems. Walls within 1½" to 2" of the warp have been used without experiencing any ill effects from side-wall radiation. A 12" diameter x 1750 R. P. M. exhaust blower has been found to produce the air velocities desired in zone C.

Presented herewith are two sets of data which show typical conditions under which textile warps have been satisfactorily sized and dried. These data are given merely to illustrate the possibilities of the invention, and not to limit its scope.

Table

	Case I	Case II
Number of yarns per inch of warp width.....	50	50
Yarn count (size of yarn).....	48	13.5s
Distance from burners to warp.....inches.....	8	8
Temperature in zone R.....° F.....	450	450
Temperature in "hot" end of zone C.....° F.....	375	410
Temperature in "cold" end of zone C.....° F.....	220	248
Speed of travel of warp (yards per minute).....	20	40

Additional data obtained on drying a water saturated warp showed that the water was removed at the rate of 225 pounds per hour when the heat input rate was 328,000 B. t. u.'s per hour. These data give an overall efficiency of 80.8% as revealed in the following calculation.

Saturation of warp 100% (based on dry warp weight). Warp dried to 10% moisture content (dry wt. basis). Thus, for each pound of water removed

$$\frac{1}{.9}$$

or 1.11 lbs. of warp and 1.11 lbs of water had to be raised from room temperature (80° F.) to the boiling point of water (212° F.).

$$H = M_c S_c \Delta T + M_w S_w \Delta T + M_e L \quad (1)$$

$$E = \frac{H \times \text{rate of water removal} \times 100}{\text{Rate of heat input}} \quad (2)$$

where

H=total heat required per pound of water removed

M_c=mass of warp heated per pound of water removed

M_w=mass of water heated per pound of water removed

S_c=specific heat of warp=.42

S_w=specific heat of water=1.0

L=amount of heat required to evaporate one pound of water at the boiling point

ΔT=change in temperature (from room temperature to the boiling point)

E=efficiency

From Equation 1

$$H = 1.11 \times .42(212-80) + 1.11 \times 1.0 \times (212-80) + 1 \times 970 = 1,178 \text{ B. t. u./lb.}$$

From Equation 2

$$E = \frac{1,178 \times 225 \times 100}{328,000} = 80.8\%$$

To change takeup beam 54, locknut 64 is first loosened. Shaft 56 is then unscrewed completely from bearing 58 and retracted into said bearing, thus freeing one end of beam 54. Beam 54 may then be slipped off of shaft 55. A new beam is put on by reversing the above operation. Shaft 56 is screwed into bearing 58 only so far as is necessary to hold beam 54 firmly but not rigidly in place. Locknut 64 is then tightened to hold said adjustment of shaft position.

Figures 6 and 7 illustrate a modification. Expansion comb 600 is of conventional design. The teeth or dents 601 are mounted upon lazy tongs 601 in a manner well known to the art. Comb 600 is placed between roll 511 and takeup beam 544, which rotates upon shaft 545. A novel means 70 is provided to minimize wear on the comb.

Eccentric roll 70, rotatably supported by pillow blocks 80, is driven by any suitable means which may be external or, as shown in the preferred embodiment by means of a chain and sprocket drive which derives its motive power from the shaft of delivery roll 50. The direction of rotation of roll 70 is immaterial, but it is preferred that said rotation be such that the surface of the roll in contact with warp 75 moves in the same direction as the warp.

Eccentric roll 70 has an eccentricity of ½", is approximately 1½" in diameter and turns at the relatively slow rate of 6-8 R. P. M. Such being the case, there is a slippage or sliding action between the roll surface and warp 75. Therefore, to prevent damage to the warp yarns and to minimize the power required, it is desirable that the roll be highly polished.

Eccentric roll 70 has a two-fold function. Firstly, it keeps warp 75 in proper alignment with expansion comb 600 at all times. Secondly, its more important purpose is, by its eccentric movement, to cause the warp to traverse an extended area in the dents of comb 600. Thus, since the warp moves a distance of approximately one inch up and down in the comb dents, wear on the comb is reduced and the life of the comb is increased at least ten-fold. This traversing movement also minimizes the accumulation of fuzz and dirt which tend to block the comb dents, thereby causing breakage of the warp yarns.

The above preferred means for minimizing wear on the comb and accumulation of fuzz and dirt is not the only method. Like results may be achieved by reciprocating expansion comb 600 by various means. For example, comb 600 may be caused to move up and down through the action of eccentric cams bearing on the supports for said comb, said supports being slidably mounted between upright guides. It is understood, of course, that if such method be used roll 70 need no longer be driven or be eccentric; it would be a plain idling roll used solely to guide the warp.

Figure 8 illustrates the use of cams to reciprocate the comb. The ends of comb frame 601 are slidably engaged in guides 602 and 603. A cam 81 at each end raises and lowers the frame 601.

Having thus described our invention, we claim:

1. A heater for continuous strands comprising a housing having an inlet and an outlet for the strands, a second housing having an inlet communicating with the outlet of the first housing, and having an outlet, a number of gas-fired infra-red generators mounted in the first housing, means for feeding combustible gas and oxidizing gas to the infra-red generators, and suction means for drawing the products of combustion from the first housing through the second housing, the second housing comprising a baffle-free lower temperature heating zone, the cross-sectional area of the second housing being less than that of the first whereby the velocity of the gases is greater in the second housing than in the first, means for supporting and feeding the strands within the housings and for removing the strands from the outlet of the second housing, the means for feeding and supporting the strands comprising

a number of groups of rollers, the rollers of a group feeding the strands within the second housing being mounted farther apart from each other than the rollers of the first housing, whereby the strands are farther apart in the second housing than in the first, to facilitate heating.

2. A heater for continuous strands comprising a housing having an inlet and an outlet for the strands, a second housing having an inlet communicating with the outlet of the first housing, and having an outlet, a number of gas-fired infra-red generators mounted in the first housing, means for feeding combustible gas and oxidizing gas to the infra-red generators, and suction means for drawing the products of combustion from the first housing through the second housing, the second housing comprising a baffle-free lower temperature heating zone, the cross-sectional area of the second housing being less than that of the first whereby the velocity of the gases is greater in the second housing than in the first, means for supporting and feeding the strands within the housings and for removing the strands as sheets from the outlet of the second housing, the means for feeding and supporting the strands within the second housing including means to separate the strand sheets wider apart in the second housing than in the first.

3. A continuous single pass process of drying a material such as coated or impregnated continuous textile warps, sheets, or webs comprising continuously passing a number of closely spaced continuous strands of said textile material through a radiant heating zone in which they are exposed to the rays from a gas-fired infra-red generator, controlling the ratio of combustible gas to oxidizing gas supplied to said generator and to said radiant heating zone to obtain a neutral, or oxidizing, or reducing atmosphere, at will, continuously drawing the exit hot products of combustion from said radiant heating zone into and through a lower temperature heating zone, continuously passing said strands from said radiant heating zone into the low temperature heating zone, throughout which zone the strands move parallel to and in the same direction as, and in contact with the said exit products of combustion, the speed of drying in the lower temperature zone being raised by decreasing the cross-sectional area of this zone with respect to the radiant heating zone to increase the velocity of the products of combustion passing through the lower temperature zone, and by spreading the strands farther apart in the inlet region of the lower temperature zone than in the radiant heating zone, and thereafter venting substantially all of the gases from the system without recycling, the lower temperature zone being under negative pressure produced by said drawing of the combustion gases therethrough.

4. The process of claim 3 in which the material is sized material which is subjected to temperatures in the range of 300° to 500° F. for a period of 1½ to 2 seconds in the infra-red radiant heating zone, the temperature dropping to about 220° to 250° F. at the exit of the lower temperature heating zone, the velocity of the gases in the latter zone being from 1000 to 3000 feet per minute, the supply of oxidizing gas being controlled to produce a non-oxidizing atmosphere in both heating zones.

5. A continuous single pass process of drying a sized textile material comprising continuously passing a plurality of continuous strands of said textile material through a radiant heating zone

in which they are exposed to the rays from a gas-fired, infra-red generator, controlling the ratio of combustible gas to oxidizing gas supplied to said generator and to said radiant heating zone to obtain a non-oxidizing atmosphere, continuously drawing substantially all of the exit hot products of combustion from said radiant heating zone through a lower temperature convection-heating zone in which the strands are dried primarily by contact with the said hot gases, there being no other heat source in the zone, continuously passing said strands from said radiant heating zone into the lower temperature zone, substantially throughout which zone the material moves parallel to and in the same direction as, and in contact with, said exit products of combustion, the speed of drying in the lower temperature zone being raised by decreasing the cross-sectional area of this zone, with respect to the radiant heating zone to increase the velocity of the exit products of combustion passing therethrough, and by spreading the strands farther apart in the inlet region of the lower temperature zone than in the radiant heating zone, and thereafter venting substantially all of the gases from the system without recycling, the lower temperature drying zone being under negative pressure produced by said drawing of the combustion gases therethrough, the gases in the lower temperature zone traveling at least about 1000 feet per minute, whereby the material is not subjected to the deteriorative effects of subjection to oxidizing gas and to gas of relatively high humidity.

6. A process of continuously drying a coated or impregnated textile warp which comprises: passing said warp divided into a plurality of separate but adjacent sheets through a radiant heating zone in which it is exposed to the rays generated by gas-fired infra-red generators, and to an atmosphere controllable to be reducing, neutral or oxidizing; then subjecting said warp to a single pass through a chamber in which the sheets, as they pass therethrough, are separated until they are distributed uniformly over the cross-sectional area of the chamber and are uniformly contacted by the combustion products from the generators, said combustion products being drawn through the chamber at a substantially uniform speed greater than their speed in the heating zone and being continuously replaced by fresh combustion products that are free of moisture accumulated from preceding portions of material.

7. A heater for continuous strands, comprising: a housing having an opening for the entrance of the strands, a plurality of openings in which are mounted gas-fired infra-red generators and means through which the entrance of combustible gases and air can be controlled, and an opening for the exit of the strands into a second housing; a connecting second housing which is free of baffles, has a smaller cross-sectional area than the first housing and has an outlet for the strands; means for drawing the combustion products from the generators through and out of the housings so that they are continually replaced by fresh combustion products free of moisture accumulated from preceding portions of material; and means for propelling and supporting the strands in a single pass through each of the housings, said means being rollers positioned so that the strands as they pass through the first housing are separated but are closely adjacent and as they pass through

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the second housing are substantially uniformly distributed over the cross-sectional area of the housing.

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