July 21, 1970 D. C. SANDERS, JR 3,521,375

DRYER

Filed May 16, 1968 4 Sheets-Sheet 1

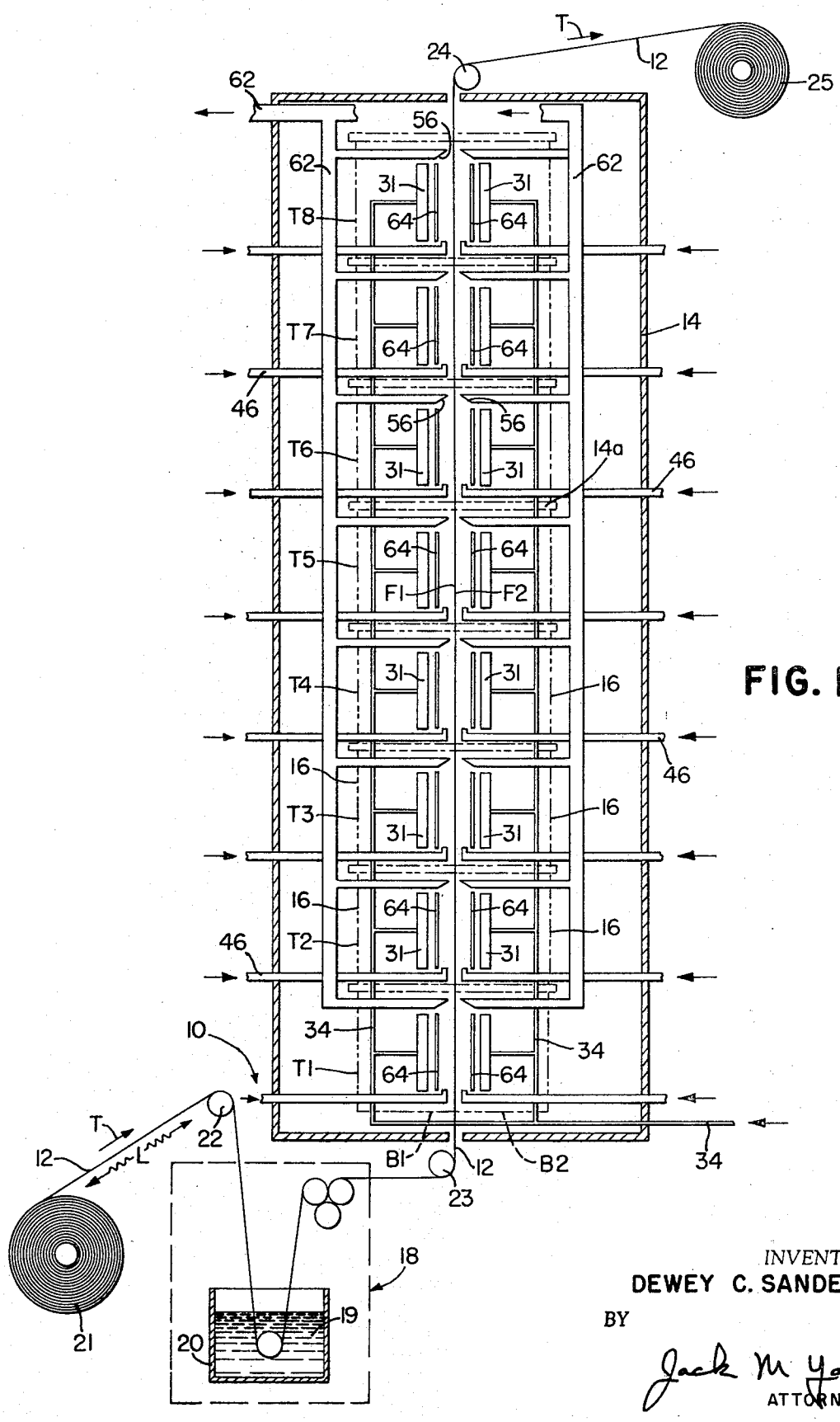


FIG. 1

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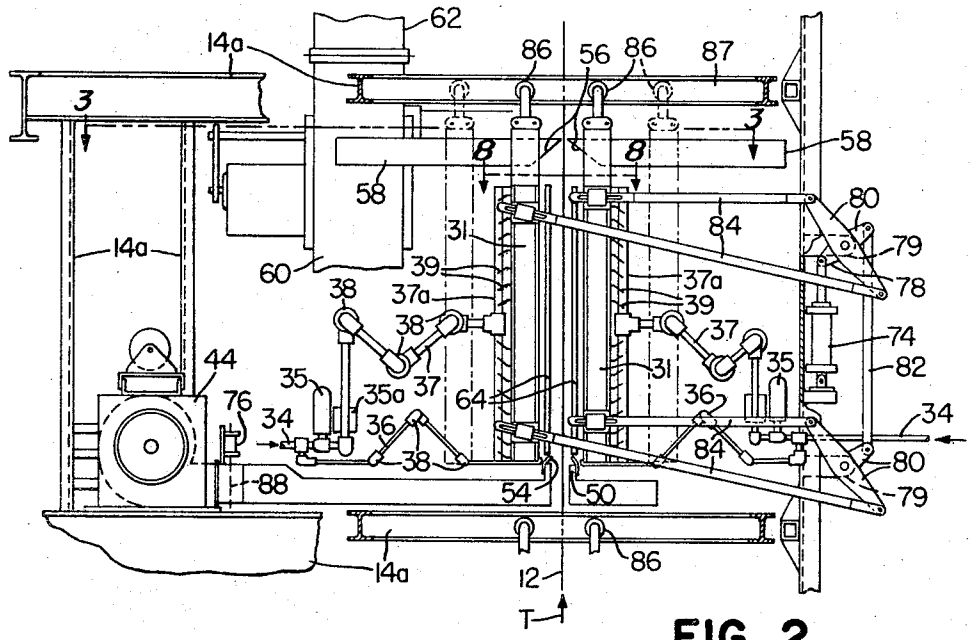


FIG. 2

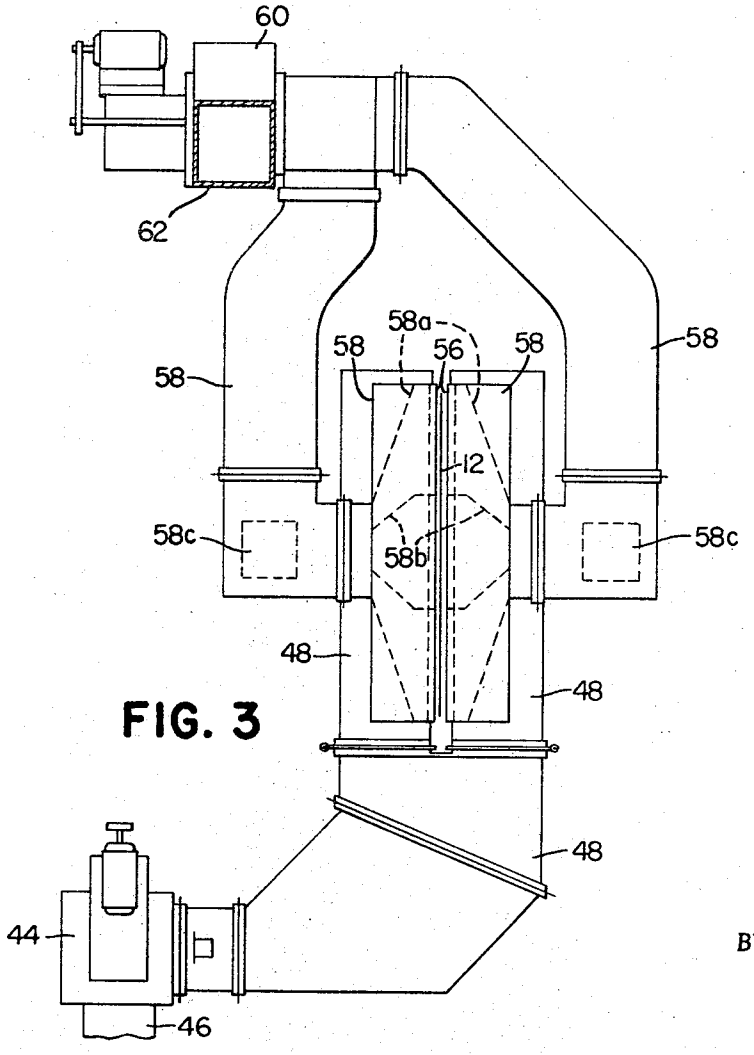


FIG. 3

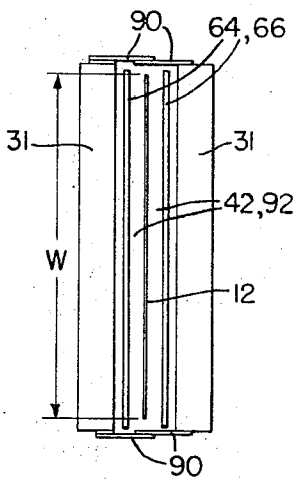


FIG. 8

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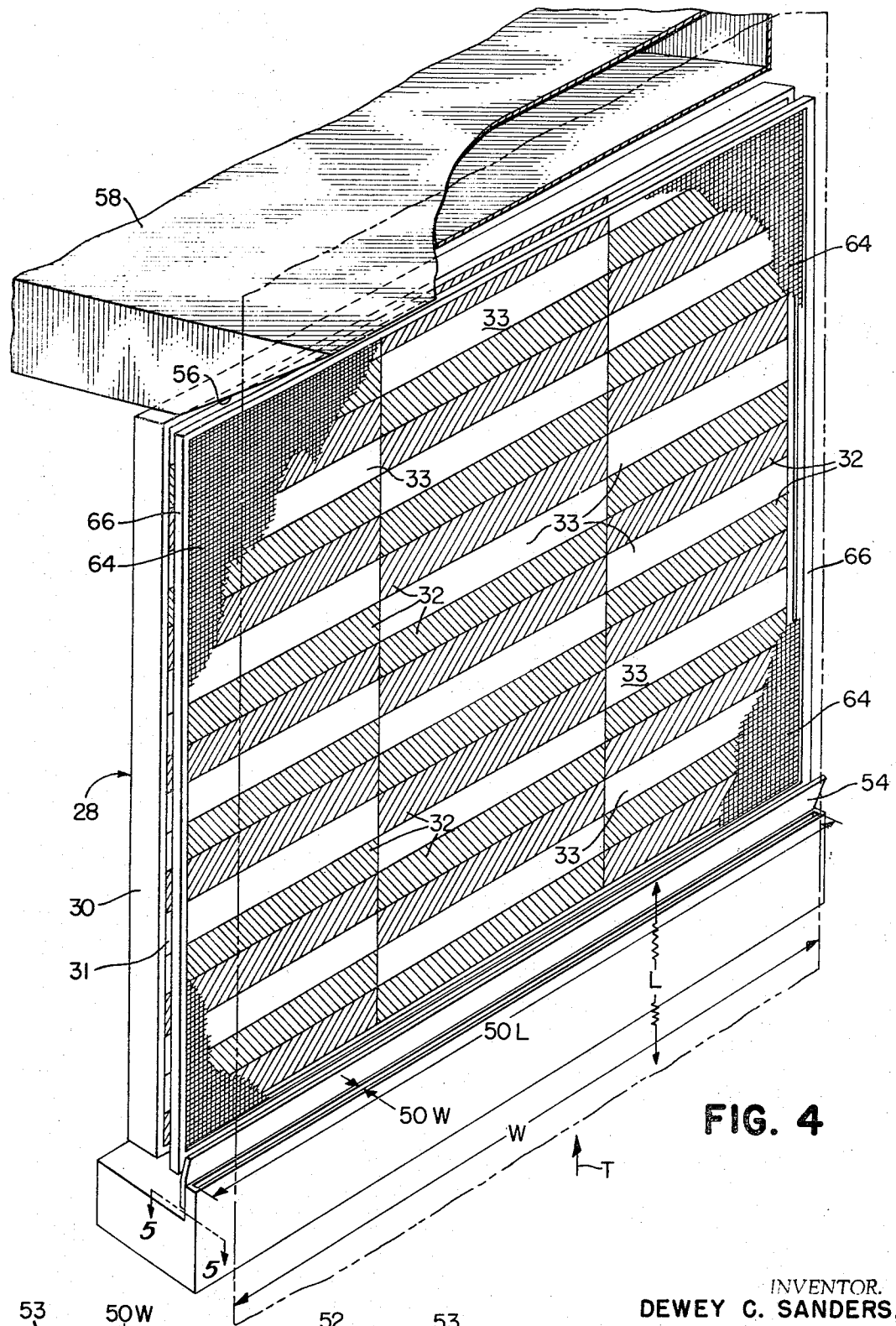


FIG. 4

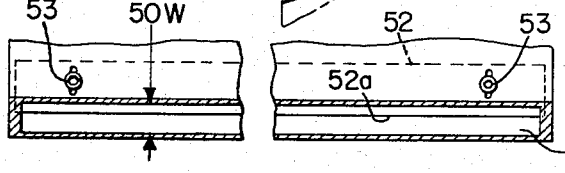


FIG. 5

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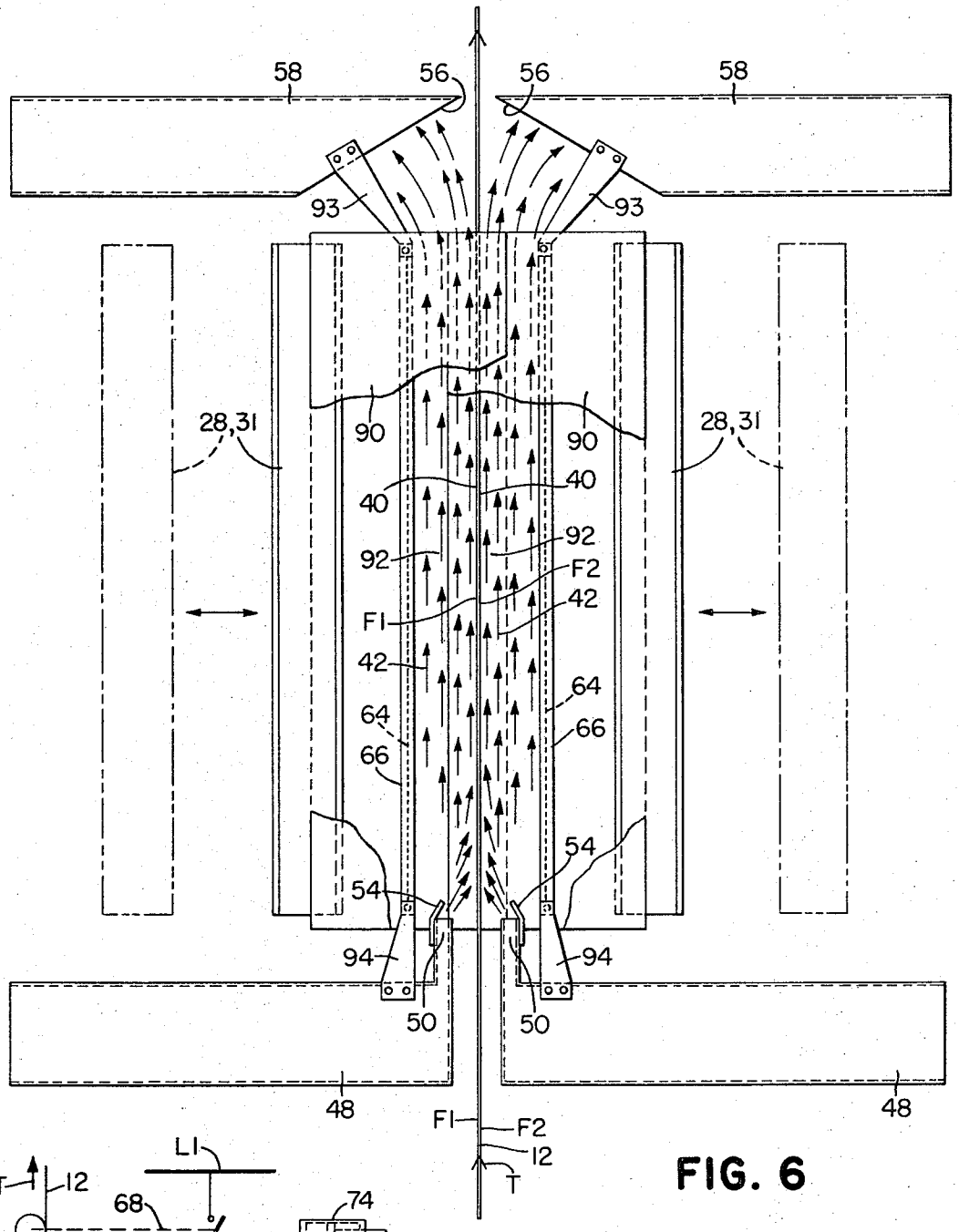


FIG. 6

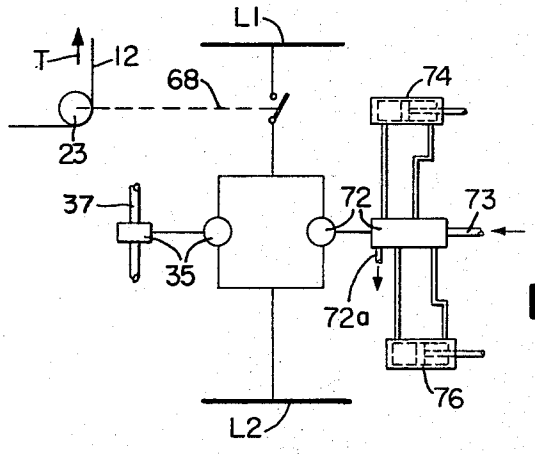


FIG. 7

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United States Patent Office

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3,521,375

DRYER

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Filed May 16, 1968, Ser. No. 729,605
Int. Cl. F26b *13/10;* F27b *9/28*
U.S. Cl. 34—44 7 Claims

ABSTRACT OF THE DISCLOSURE

Drying apparatus for drying fibers in yarn or fabric as a continuous length element, and more particularly a drying apparatus in a machine for impregnating such fiber with a liquid fiber-to-rubber adhesive coating in the manufacture of tires, belting and similar products, wherein the element is rapidly dried at a controlled temperature by flame generated infra-red type heating means while moving a gas stream rapidly over the surface of the element and protecting the heating means by a shielding means from the flowing gas stream against any adverse effect on the infra-red radiation from the heating means.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to dryers, and more particularly to dryers for fibers (whether in yarn, cord, fabric, etc. form), especially such fibers to be used in the manufacture of tires, belting and other rubber products.

The rubber products industry uses various fibers for reinforcement, including rayon, nylon, polyester, fiber glass, etc. and may use now or hereafter other natural and artificial fibers. The term "fiber," unless otherwise modified, is intended to be used in its generic sense to include all of these fibers. This machine is adapted to process by dipping and drying any continuous length element, such as a woven fabric made up of cord formed of fibers, a yarn made up of fibers before being twisted into cord and woven into fabric, etc. Dipping the yarn is usually done where application of the adhesive over the entire surface of the fiber is desired, such as with fiber glass; while other fibers are dipped in the fabric form. Therefore, the terms "continuous length fiber element," "continuous length element," "fiber element" or "element" used herein, unless otherwise modified, are each intended to cover any continuous length yarn, cord or fabric since each is composed of fibers. The term "fabric" unless otherwise modified, is intended to cover any suitable fabric, including square-woven fabric and including so-called "cord fabric" used for tires and having a fairly open and loose weave wherein the cords form the warp and a comparatively small number of fill threads connect the cords solely to facilitate handling.

It is well known that before any such element made of textile material can be incorporated into rubber articles, especially those to be subjected to drastic conditions of flexing or bending, the fibers thereof must be prepared by coating or impregnating with an adhesive that will bond well to both rubber and the fibers. These adhesives are dispersed, dissolved or suspended in a liquid vehicle, generally water, into which the element is dipped and subsequently dried.

Such elements have been dried by blowing hot air through a drying oven in a relatively low temperature. Because of the low drying temperature and the attendant low speed of operation, large capacity drying ovens have been necessary so as to require vast expenditures of capital and large factory areas for operation. It has been recognized that if such elements could be dried more rapidly, but at a controlled temperature to prevent deterioration of the fiber, the speed of drying could be vastly increased, or the size and capacity of the drying apparatus could be considerably reduced.

This invention is an improvement on the invention disclosed in the T. M. Kersker et al. U.S. Pat. No. 3,250,641, granted May 10, 1966, and entitled "Method of Processing Tire Cords, Tire Cord Fabric, And The Like" wherein infra-red radiation is used to speed up the drying and many of the problems in such element processing for rubber goods manufacture are explained in some detail to which reference may be had if desired. The dryer must be of sufficient size to dry the adhesive liquid coating sufficiently so that the coating will not be picked off or ruptured by the support means engaged following the drying step.

This invention is also an improvement on the co-pending U.S. patent application Ser. No. 729,282 entitled "Dryer or Heater" filed May 15, 1968 by Grover W. Rye and Alexander V. Alexeff by the addition of a burner flame shielding means to this type dryer with suitable modification of the gas flow, and the disclosure of that application is incorporated herein by this reference thereto.

The present invention relates to an apparatus for drying such continuous length element in a machine for impregnating such element with a liquid fiber-to-rubber adhesive in a coating in the manufacture of tires, belting and other rubber products, wherein the element is rapidly dried at a controlled temperature by flame-generated infra-red type heating means while moving a gas stream rapidly over the surface of the element and protecting the heating means by a shielding means from the flowing gas against any adverse effect on the infra-red radiation from the heating means.

An object of the present invention is to provide an apparatus for rapidly and uniformly drying a fiber containing element at a controlled temperature so as to manufacture a maximum quality article by minimum sized equipment.

Another object of the present invention is to provide a method of drying fibers at a very high temperature and speed without detriment to the fibers or any coating thereon.

These and other objects of the present invention will become more fully apparent by reference to the appended claims as the following detailed description proceeds in reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. 1 is an elevational schematic vertical view, partially in section, of a machine or apparatus for coating such element and subsequently drying the coating in a drying tower;

FIG. 2 is a side elevational view of two of the drying apparatuses located within the drying tower, having some

parts omitted or cut away, and having opposed heating zones sandwiching therebetween opposite faces of the element;

FIG. 3 is a top plan view, taken generally along the line **3—3** in FIG. 2, and showing only the element and the gas moving means for discharging the gas streams into and through the heating zones and subsequently discharging it from the apparatuses in FIG. 2;

FIG. 4 is a perspective view by the fabric of one of the heating apparatuses in FIG. 2 with some parts omitted or cut away for clarity;

FIG. 5 is a horizontal sectional view, taken generally along the line **5—5** in FIG. 4, through the discharge nozzle and showing its adjustable flow control gate means;

FIG. 6 is an enlarged, schematic, side elevational view with parts omitted or cut away showing the infra-red heating and gas stream action on the element and certain selected parts in FIG. 2;

FIG. 7 is an electrical and fluid flow diagram of the solenoid gas valve controlled main burner gas line to the infra-red burners, a valve controlled flow diagram of the fluid system for the burner panel retracting cylinder and gas flow damper cylinder, and the electrical circiut for controlling the solenoids operating these valves in response to the travel speed of the processed element; and

FIG. 8 is a top plan view taken generally along the line **8—8** in FIG. 2 of the gas stream flow duct, infra-red panels and reflector means surrounding the element.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 of the drawings shows machine **10** for treating continuous length fiber element **12** by applying adhesive thereto and subsequently drying the adhesive with machine **10** including drying tower **14** (taking the form of either a separate tower or one zone of an element processing building) having structural members **14***a* supporting sixteen substantially identical drying apparatuses or dryers **16**, to be described in more detail hereinafter.

Although machine **10** can be used for treating any suitable fiber element **12** (such as yarn, cord or fabric), a woven fabric will be specifically used hereafter in this description with this fabric having a length dimension L along its direction of movement T by drive rolls **22, 23** and **24**; a width dimension W transverse thereto; and opposite, generally parallel faces **F1** and **F2**.

Since each apparatus **16** is especially adapted for driving moisture out of fibers or fabric, it should be apparent that it has many other uses, such as driving moisture out of woven fabric before calendering in the manufacture of rubber goods.

Machine **10** in FIG. 1 sequentially moves fiber element **12** in travel direction T from feed roll **21** through coating means **18**, through drying tower **14** having sixteen drying apparatuses **16** with each having infra-red heating means **28**, over drive roll or support means **24** with fiber element **12** freely supported between drive rolls **23** and **24** from the bottom or inlet to the heating zones **40** provided by drying tower **14**, and onto wind-up roll **25** or to subsequent heat treating and/or other processing equipment.

Coating means **18** includes tank **20** containing any well-known fiber-to-rubber adhesive **19** dissolved, dispersed, or suspended in a liquid vehicle. Such adhesive is generally based on resorcinol-formaldehyde resins and latex in a aqueous medium.

Suitable drive means is provided for relatively moving element **12** through machine **10** comprising coating means **18** and drying tower **14**. This drive means takes the form herein of suitable tensioning or support rolls **22, 23** and **24** with any one or all driven by a suitable motor driven drive or independent motors to advance element **12**, through machine **10** and to apply suitable tension to element **12**. When fabric element **12** has a width W

of about 60 inches, 2,000–25,000 pounds tension thereon will be the operating range for different fibers, and this tension is used for further processing thereof after the adhesive has been dried and for maintaining the fabric taut and planar against lateral deflection and flapping by gas streams **42** mentioned hereafter.

Element **12** is freely supported in drying tower **14** so that the coating thereon will not be damaged during the drying thereof. There must be sufficient drying capacity in tower **14** to dry the liquid coating sufficiently so that the coating will not be picked off or ruptured by support roll **24**. Hence, it is preferable not to use a drum-type dryer or any other type cylindrical supports in the heating zones **40** because they will tend to pull off the adhesive covering. Also, an air cushion cannot be used to suitably support cord fabric on such drum or roller since the air would quickly penetrate any open weave of the fabric and the 25,000 pounds maximum tension would quickly bring the fabric into contact with the cylindrical surface.

It has been found in practice that drying apparatus **16** in tower **14** manufactures maximum quality element **12** with minimum equipment size.

Machine **10** has a plurality of drying apparatuses **16** therein for drying the fibers in the yarn or fabric in continuous length element **12**. These are arranged in eight tiers **T1–T8**, and in two banks **B1** and **B2** so that each of sixteen apparatuses **16** therein may be identified as to location, as to tier and bank, such as the apparatus in the lower lefthand corner of FIG. 1 being identified as drying apparatus **16** in tier **T1**, bank **B1**. Apparatuses **16** in each bank are arranged in series along the length of the fabric in the tiers while any two horizontal apparatuses **16** in opposite banks **B1** and **B2** and in the same tier are arranged on opposite sides of fabric element **12** as it passes through drying tower **14**. Apparatus **16** in each tier and bank has a width wider than fabric element **12**, as shown in FIGS. 3, 4 and 8, to provide a proper drying action as will be brought out in more detail hereinafter.

DRYING APPARATUS 16

The remainder of this application will be directed toward the specific structure, mode of operation and advantages of each substantially identical drying apparatus **16** considered either alone or in any tier or bank combination. The explanation hereinafter of drying apparatus **16** will emphasize the details in apparatus **16** in tier **T2**, bank **B1** even though all sixteen apparatuses **16** in FIG. 1 are identical in construction except the two apparatuses in each tier have some common operating parts (see FIGS. 2, 3 and 8) and the apparatuses in bank **B1** are substantially mirror images of those in bank **B2**. Then, the structure and mode of operation common to the two horizontally aligned apparatuses **16** in tier **T2** for both banks **B1** and **B2** will be described; later, the eight series arranged and vertically aligned apparatuses **16** in tiers **T1–T8** in bank **B1** will be described.

For reference herein a typical operating example of apparatus **16** will be given now. It has been found that an actual operating drying apparatus **16** operates satisfactorily with approximately the following dimensions and operating characteristics (herein referred to as Table I):

Fabric element **12**:

Width W	60″.
Travel speed in direction T	100 yds. per minute.
Weight	1 lb. per yd. of length.
Water picked up was equal to weight of fabric.	
Tension	2,000–25,000 pounds.

Horizontal distances:

Between reflector plates **90**	75".
Screen **64** to fabric element **12**	4"–6".
Screen **64** to face of burner panel **31**	3"–4".
Face of burner panel **31** to fabric element **12**	7"–10".

Approximate dimensions within frame **30** of burner panel **31** for burners **32** and spacer blocks **33**:

Height	4' 10"
Width	5' 6"
Discharge nozzle **50**:	
Dimensions **50W**	1½"
Dimension **50L**	5' 9"

	With Screen 64	Without Screen 64
Discharged air velocity (Feet per minute)	4,000–5,000	1,000–2,000
Air discharged quantity: Cubic feet per minute ½ output of fan 44)	[1] 3,000	[1] 1,500

[1] Maximum.

Temperatures at downstream side of drying apparatus **16** at exhaust nozzle **56** at top of apparatus **16**

	With Screen 64	Without Screen 64
Fabric, °F	160–180	209
Air, °F	164	180

Each drying apparatus **16** includes heating means **28**, preferably of an infra-red emitting or radiating type, for drying element **12**. Although heating means **28** may use any suitable infra-red source, such as an electric quartz tube heating element, etc., it is preferred to use herein an infra-red heater **32** having a fluid (preferably natural gas) fired flame for generating infra-red radiation because of its economy of operation, rapid cooling, efficient heat transfer, and desirable radiating characteristics. One suitable form of heater **32** is that disclosed in U.S. Pat. No. 2,775,294 granted Dec. 25, 1956 to G. Schwank and entitled "Radiation Burners" wherein a gas-air mixture burns on the outer surface of plate **7** in that patent to heat it to incandescence causing this surface to emit infra-red radiation then striking and heating element **12**. Such burner **32** has a metal screen mounted about ¼ inch from this radiant surface, extending parallel thereto, and being substantially coextensive with this surface serving as a red-radiating screen to increase the burner efficiency and to assist in providing a uniform distribution of infra-red radiatnt energy in the manner well known in the art. Then, combustible gas mixed with air burns so that the outer radiating surface of plate **7** has a visibly radiant temperature of approximately 1300° F.–1600° F. with the radiation intensified by the re-radiating screen.

Heating means **28** includes infra-red heating panel **31** in FIG. 4 having spacer blocks **33** and heaters **32** (shown schematically by diagonal lines in FIG. 4) arranged in a checkerboard-type pattern within its frame **30** to provide a planar, radiating face on panel **31** parallel to and facing element **12** surface F1.

The intensity and pattern of radiation desired may be varied. Since the intensity of radiation generally varies inversely as the square of the distance between the objects since one considers a point source of radiation radiating out over the entire interior surface of a surrounding sphere, it would be logical to assume that changing the distance between the radiating face of panel **31** and element surface F1 would be the desirable way of changing the intensity of radiation on surface F1. This is not true here since the radiating face of panel **31** is not a point radiating source but is approximately parallel and coextensive with surface F1 in heating zone **40**. Hence, radiation intensity is not effected by the distance between the radiant face of panel **31** and element surface F1. Even the radiation that might normally escape outward-

ly horizontally in the space between panel **31** and face F1 is held between their parallel faces and reflected back onto fabric element face F1 by reflector plates **90**, which will be described in more detail hereinafter. Therefore, the desirable way to change the intensity and pattern of radiation desired is to change the number of heaters **32** and the number of spacer blocks **33** located within frame **30** of panel **31** and to change their distribution within frame **30**.

Each heater **32** and panel **31** is fed by gas main line **34** in FIGS. 1 and 2. Gas entering drying tower **14** through gas main line **34** travels in FIG. 2 either: (1) through solenoid gas valve **35** to be mixed with air by air mixer **35***a* before going through main burner gas line **37** into vertically extending manifold **37***a* on the back of panel **31** having flexible hoses **39**, one leading from manifold **37***a* to each infra-red burner **32**, or (2) through pilot gas line **36** to the burners on the radiant face of panel **31**. Any suitable conventional igniter and safety features are provided. Each gas line **36** and **37** has pivotal connections **38** therein adapted to permit pivoting of the line components about a horizontal axis during horizontal movement of radiant heating panels **31** between solid and dot-dash line positions in FIGS. 2 and 6, as will be described in more detail hereinafter.

Each infra-red heating panel **31** heats an infra-red heating zone **40** on the outer surface of element **12**, such as on face F1 or F2, and the desired action in each heating zone **40** is to rapidly and uniformly dry fabric element **12** at a controlled temperature. This action is obtained in the present disclosure by rapidly and uniformly evaporating the moisture by the infra-red radiation from panel **31**, and by rapidly and uniformly removing by mass transfer the evaporated liquid molecules and heat from fabric element **12** in this heating zone **40** by drying apparatus **16**. The following paragraphs will explore this mode of operation more carefully and more specifically.

Infra-red radiation from burner **32** is an efficient method of heat transfer to provide the energy necessary to evaporate the water into its vapor form and is much better than many other type high temperature heating sources. Infra-red waves extend over the spectrum in wave length from 0.8 to 300 microns from the near infra-red to the far infra-red range. There is a broad absorption band for water, several microns wide, about at 3.0 microns wave length in the near infra-red region where water is evaporated most quickly and most efficiently. The aforementioned Schwank-type infra-red burner **32** emits strong radiation in this absorption band for water vapor for efficiently and rapidly vaporizing the water or aqueous molecules in the coating. The moisture within the fibers and adhesive coating is heated and evaporated within the time period necessary to dry the adhesive coating on the surface of the fibers while still permitting the moisture to escape therefrom before the outer surface of the adhesive is dried and/or cured sufficiently to form a skin or crust entrapping the remaining moisture.

Any suitable gas may be used, but air is specifically used herein even though the generic term "gas" is used wherever appropriate since any suitable gas may be used. A gas moving means moves gas stream **42** with respect to outer surface F1 of element **12** through heating zone **40** during infra-red heating thereof for scrubbing this surface F1 and removing by mass transfer aqueous vapor molecules so as to rapidly dry element **12** at a controlled temperature. Stream **42** is a rapidly flowing river of gas blowing at surface F1 and traveling along surface F1 being dried by the infra-red. With fabric element **12** saturated with water based chemicals **19**, a fast rate of drying of element **12** to remove the water is highly desirable. Fast drying results in minimum equipment size, improved control of drying conditions, and improved quality of element **12**. The evaporated liquid molecules carried away by stream **42** include, of course, not only water molecules but molecules of any volatile material.

The rate of drying is increased by removal of liquid molecules from surface F1 to allow better penetration of infra-red energy and by the efficient mass transfer of water molecules to the gas by a scrubbing or vacuuming action of surface F1 by flowing stream 42. Flowing stream 42 also removes convectional heat from drying zone 40 and from fabric element 12 so as to provide a rigid control of the temperature of the fabric element so that it will not exceed the safe limit. The gas in stream 42 is cool enough to cool element 12 as it passes across it. This is a peculiar problem to a fabric, such as nylon, some types of which might be damaged if the temperature exceeded 250° F. Not all objects dried require this close temperature control by cooling; for example, ceramics, painted metal parts, etc. preferably pick up as much of heat as possible and cooling is not desired since cooling is a detriment to efficient operation. It should be apparent that velocity of stream 42 will effect the extent of scrubbing action and rate of drying overall quantity of air flowing in stream 42 will effect both rate of drying and heat removal. Preferred condition of the gas in stream 42 is a relatively dry and cool gas, such as air at ambient conditions. The cool gas will have a greater capacity for heat pickup, and the dry gas will pick up the moisture and other evaporated molecules more quickly and is more transparent to infra-red radiation from panel 31. Moisture laden gas interferes with the transmission of infra-red rays (because it absorbs this infra-red radiant energy) and interferes with efficient drying and heat transfer. Therefore, if gas stream 42 is heavily laden with moisture, it may substantially prevent transmission of the infra-red rays from panel 31 to surface F1 and may serve as an insulating layer over surface F1 to prevent removal of heat and water vapor. Hence, recirculation of the gas in stream 42 would not be desirable because it would be hotter than desired so could not pick up more heat and could not cool element 12, and might well be saturated with evaporated molecules, such as water molecules, which would interfere with infra-red transmission and pickup of evaporated water molecules. Hence, gas stream 42 permits infra-red heaters 32 to operate at their most efficient temperature, is located as close as possible to fabric face F1 for fast drying, and still permits accurately controlling the surface temperature of element 12 to prevent damage thereto. Note that the infra-red radiation from heaters 32 strikes heating zone 40 to provide drying at the same time as gas stream 42 scrubs the heating zone. This action provides most rapid drying with minimum size equipment.

The aforesaid gas moving means includes gas discharge means for directing gas stream 42 as a gas layer or gas curtain generally along and over surface F1 in heating zone 40 to provide the aforedescribed scrubbing action. Since air of the condition described in the preceding paragraph is preferred, relatively cool, dry air at ambient conditions is drawn in through inlet duct 46 in FIGS. 1, 2 and 3 (shown schematically in FIG. 1 as two inlet ducts 46 for each tier for simplicity of illustration instead of the single inlet duct 46 in FIGS. 2 and 3) by motor driven, discharge, fresh air or inlet fan 44 in FIG. 3 to be forced through nozzle duct 48 and out nozzles 50 in FIG. 2 to form two gas streams 42. Each gas discharge nozzle 50 is a rectangular outlet having its length 50L in FIGS. 4 and 5 many times greater than its width 50W. Nozzle 50 also has mounted on duct 48 by screws 53 adjustable cutoff plate 52 and has mounted on duct 48 deflector 54 described in more detail hereinafter.

Discharge nozzle 50 is preferably mounted so that length dimension 50L is generally parallel to surface F1 of element 12 in heating zone 40 and width dimension 50W is generally perpendicular to surface F1 with nozzle 50 directing its discharged gas generally along surface F1 in heating zone 40 from the lower edge of this heating zone. It should be apparent that scrubbing action and heat removal will be obtained by having the discharged stream from nozzle 50 directed transversely across, longitudinally with (in co-current flow), or longitudinally against (in contraflow) travel direction T of element 12 Directing stream 42 across travel direction T (across element 12 width W) would not be desirable because stream 42 would not uniformly hit each portion of width W of fabric element 12 so that the fabric would not be uniformly processed across its width. Nozzle 50 may be mounted near one edge of heating zone 40 with its length dimension 50L generally parallel to width dimension W of fabric element 12 with air stream 42 directed in heating zone 40 generally along the length of movement T of element 12 either in the same direction (in co-current flow) or the opposite direction (in contraflow) to the movement T for generally uniformly removing liquid molecules over width W of element 12 to give width W uniform processing. Although stream 42 directed opposite to the direction of travel T (in contraflow) would give an effective scrubbing action, it has been found desirable to mount nozzle 50 at the bottom of heating zone 40, as shown in FIGS. 4 and 6, so that gas stream 42 is directed in direction T of element 12 (in co-current flow) with this direction being upward so that the natural convection will help move gas stream 42 toward gas exhaust vent 56.

Nozzle length dimension 50L should be at least as wide as width dimension W of fabric element 12 so that gas stream 42 will uniformly effect each increment of the fabric across its width as it travels in direction T. Dimension 50L should be preferably greater than fabric width W so that the lower velocity components in gas stream 42 emerging from the lengthwise ends of nozzle 50 do not travel across surface F1 and a more uniform velocity layer of gas in stream 42 travels along the length of element 12.

It is desirable to provide a generally uniform quantity of gas flowing over each portion of fabric element width W in heating zone 40 for generally uniformly removing the liquid molecules across this width W and for maintaining a generally uniform temperature across fabric element width W in heating zone 40 since drying and heat removal are directly proportional to the quantity of gas flowing in stream 42 and since the scrubbing action is proportional to the velocity of flowing stream 42. This uniform distribution of gas across width W may be obtained either by carefully designing nozzle 50 and maintaining its width 50W constant while providing certain desirable gas turning vanes and baffles within nozzle duct 48 and closely adjacent nozzle 50 to control the distribution of gas flow to nozzle 50, or by making nozzle 50 adjustable.

Nozzle 50 may be made adjustable by providing in FIG. 5 cutoff plate 52 mounted by screws 53 in elongated parallel slots in the wall of duct 48 to serve as an adjustable flow control gate means with its flow controlling edge 52*a* intercepting the flow through gas discharge nozzle 50. Pivoting plate 52 permits increasing or decreasing the quantity of gas flowing through either end of nozzle 50 so as to obtain uniform quantity of gas flow over element width W. However, since edge 52*a* acts like a sharp edged orifice to laterally disperse stream 42, after it emerges from nozzle 50, to strike the radiating faces of burners 32 to provide disadvantages mentioned in more detail hereinafter, it is preferable to have nozzle 50 discharge a closely held together jet-like stream 42 as a thin layer of gas traveling over face F1 by originally designing nozzle 50 to provide this condition. Suitable gas turning vanes, baffles and tubular extension of nozzle 50 into nozzle duct 48 are desirable to prevent this lateral dispersion.

It is desirable to have gas stream 42 directed toward surface F1 to increase the scrubbing action and heat transfer action. This may be done by so directing nozzle 50 or by adding gas stream deflector 54 mounted on gas discharge nozzle 50 for directing gas stream 42 not only over and along surface F1 but also toward and against

surface F1, as seen by the arrows in FIG. 4, to serve with nozzle **50** as a gas discharge directing means. Directing gas stream **42** toward and causing it to impinge against surface F1 has the advantage of increasing the scrubbing and heat transfer action when stream **42** strikes surface F1 a glancing blow and of protecting it against adversely affecting the flame generated infra-red radiation from flame-type infra-red burners **32**. Water vapor in a boundary layer on surface F1 will also interfere with the transmission of infra-red rays thereto and removal of convection heat therefrom so that striking surface F1 by stream **42** is desirable to break up this boundary layer.

If gas stream **42** strikes the radiating face of burners **32**, it appears to adversely affect the flame generated infra-radiation from this flame-type infra-red burner **32** by either adversely affecting the flame or by excessively cooling the outer infra-red radiating surface on plate **7** in the aforementioned Schwank patent. The flame may be adversely affected by being blown out, sucked off the outer radiating surface of radiating plate **7** in the Schwank patent by the Venturi effect under Bernoulli's Theorem, reduced in size, or at least adversely affected to reduce substantially infra-red radiation output from the radiating plate surface by preventing proper flame combustion.

Although the gas flow characteristics of nozzle **50** will depend upon the geometry of shapes, sizes and relative spacings of the components in drying apparatus **16** and of fabric element **12**, it has been found in the installation in the aforegoing Table I that about 1500 cubic feet per minute of air at a discharge velocity of about 2000 feet per minute is the maximum without adversely disturbing the flame generated infra-red radiation if screen **64** is not used, which screen will be described in more detail hereinafter.

The gas moving means also includes gas exhaust opening **56** having at least (and preferably much greater) flow cross sectional area than the flow cross sectional area of gas discharge nozzle **50** and being similarly oriented with respect to surface F1 of element **12** but located on the downstream side of gas stream **42** from heating zone **40** and discharge nozzle **50**. Preferably, the mouth of exhaust opening **56** is larger in dimension **50**W than discharge nozzle **50** since gas stream **42** to be exhausted has swelled in volume since it has picked up heat and moisture so that a larger volume has to be exhausted through gas exhaust opening **56** by exhaust fan **60** through duct **58** (having duct surfaces **58***a* and suitable turning vanes **58***b*) and outlet duct **62** to the outside of drying tower **14**. Duct **62** is shown schematically in FIG. 1 as two vertical outlet ducts for simplicity of illustration instead of the single outlet duct **62** in FIGS. 2 and 3. Air grills **58***c*, one in each duct **58**, may be adjustably opened to adjust the draw in its associated opening **56** by controlling the admission of makeup air.

The efficiency of heat transfer and moisture vaporization and the high quality of fabric element **12** produced are readily apparent by considering the temperature of the air being exhausted in exhaust opening **56** and the temperature of fabric element **12** at the top end of heating zone **40** in this typical apparatus **16** in tier T2 and bank B1. In the aforegoing Table I, the temperatures of fabric element **12** and of the exhausting air are without screen **64** (mentioned hereafter) respectively 200° F. and 186° F. and with screen **64** respectively 160°–180° F. and 164° F. Hence, there has been a good heat transfer and scrubbing action between air stream **42** and fabric element **12** and most of the infra-red energy supplied has gone into vaporizing water since neither the discharged gas nor fabric element are above the boiling point of water. Since element **12** picks up very little more heat as it travels upwardly in tower **14** in FIG. 1, the temperature of element **12** can still be maintained at about only 180°–200° F. (from Table I) at the top of apparatus **16** in tier T8, if so desired. Also, the fabric temperature of 180°–200° F. is well below the maximum temperature before the aforementioned fibers are damaged by heat. For example, excessive heat when element **12**, if made of certain types of nylon, still contains substantial amounts of water, might cause chemical degradation at temperatures as low as 250° F. so element **12** would not be damaged by drying apparatus **16** but might be damaged by the 600° F. fabric temperature mentioned in the aforementioned Kersker U.S. Pat. No. 3,250,641 not using a high velocity gas stream.

If gas stream **42** is moving at too high of a velocity or if too large of a quantity of gas is flowing in stream **42**, the infra-red radiation from flame-type burner **32** will be adversely affected, as aforedescribed. Reducing and eliminating this adverse effect has been found by insertion of a fine mesh gas deflecting screen **64**, preferably mounted in frame **66** secured by mounting brackets **93** and **94** in FIG. 6 directly to discharge nozzle duct **48** and exhaust opening duct **58**; mounted between infra-red heater panel **31** and fabric element **12** to be dried; extending generally parallel to fabric surface F1 in heating zone **40**; and extending generally parallel to the direction of movement T of fabric element **12**. Various mesh screen has been tried, including 8, 10 and 12 mesh screen. The mesh of the screen and wire thickness control the gas stream velocity—the finer the screen the higher velocity gas stream useable but the less infra-red transmitted. It is best to use just coarse enough screen to handle the gas velocity. Coarse mesh screen has been used to support the fine mesh screen against warping. Stainless steel, Nichrome, and regular steel wire screen have been tried. The problems occurring were warping, oxidation and brittleness under heat. It has been found most satisfactory to use an 8 mesh (0.023 inch wire diameter) ordinary hardware cloth screen of inexpensive cost and to replace the screen when it has been adversely damaged. Broadly speaking, this screen **64** is a burner shielding means intercepting the infra-red rays from the emitting surface of infra-red panel heating surface **31** to element surface F1 in heating zone **40** for preventing adversely affecting the flame generated infra-red radiation, such as by shielding the flame on infra-red heaters **32** from blowout, by gas stream **42** while permitting infra-red rays from heaters **32** or heating means **28** to strike surface F1 in heating zone **40** for drying. Broadly speaking, any suitable baffle means might be used in place of screen **64**.

Gas stream **42** and screen **64** coact to provide numerous advantages. Velocity of stream **42** discharging from nozzle **50** may be as high as 5000 feet per minute with a flow of 3000 cubic feet per minute, and 6000 feet per minute velocities have been used, without adversely affecting infra-red radiation from burners **32** in aforegoing Table I. Also, a portion of the gas layer in gas stream **42** moves across the fabric side of screen **64** while heaters **32** are emitting infra-red heat so as to reduce any infra-red elevated temperature of screen **64** so as to prolong its useful life, to minimize warping and oxidation thereof, and to permit use of the aforementioned inexpensive hardware cloth. The higher velocity gas stream **42** substantially increases the speed of uniform drying while still maintaining a controlled temperature. The fabric quality produced is still better and is produced on smaller sized equipment. Hence, a great superiority is obtained by using screen **42** even though a substantial improvement, as mentioned heretofore, was obtained by using gas stream **42** without screen **64**. Gas stream **42**, traveling between fabric element **12** and screen **64**, at high velocity accelerates the drying while screen **64** diverts this gas from the flame generated radiating surface on burners **32** to allow efficient burner operation. The higher velocity gas removes water vapor more quickly to greatly increase the drying efficiency while still maintaining fabric temperature more uniform across dimension W and at a lower temperature.

Also, this fast drying action makes possible production of cord fabric without a "webbed" condition, wherein the adhesive liquid forms a hardened film across the open mesh of the fabric securing adjacent cords together.

The substantial increase in drying rate and substantial reduction in drying equipment size is shown since drying tower **14** in FIG. 1 and Table I will dry coated element **18** (made of a particular fabric and weave) to the same state of satisfactory dryness while traveling in direction T in:

(1) *Three* tier heights when using screen **64** and 5000 f.p.m. air velocity stream **42** at nozzle **50**.
(2) *Five* tier heights when using 3000 f.p.m. air velocity stream **42** at nozzle **50** and using no screen **64**.
(3) *Eight* tier heights when not using either air stream **42** or screen **64**.

This means that adding air stream **42** gives about a 38% reduction in height of tower **14** and adding screen **64** and faster air stream **42** gives about a 63% reduction in height of tower **14**.

PLURALITY OF DRYING APPARATUSES 16 IN FIG. 2

In any given tier of drying apparatuses **16** in drying tower **14** in FIG. 1, such as tier T2, the two horizontally aligned drying apparatuses **16** straddling opposite faces F1 and F2 of fabric element **12** have certain common structures, modes of operation and advantages as they coact together, as mentioned in more detail in the following paragraphs describing the stopping of element **12** and infra-red shutdown action, reflector side plates **90**, gas flow ducts **92**, elimination of back-up reflector to fabric element **12**, and simultaneous drying and aeration of both sides of fabric element **12**, etc.

When the driving action of drive rolls **22**, **23** and **24** in FIG. 1 on element **12** is shut down so as to stop the relative movement of element **12**, it is important in each of the sixteen drying apparatuses **16** in tower **14** to immediately shut down infra-red radiation from heating means **28** in all apparatuses **16** and to continue the flow of gas stream **42** undiminished, by continued energization of the gas moving means, so as to relatively move gas stream **42** with respect to and over surfaces F1 and F2 of element **12** in all heating zones **40** so as to prevent residual heat from heating means **28** from raising the temperature of and damaging element **12**. This action will be described herein for only one or two drying apparatus **16** since the sixteen in tower **14** are simultaneously controlled in the same manner. Here, inlet fan **44** and exhaust fan **60** in FIGS. 2 and 3 operate continuously so as to run when fabric element **12** is stopped as well as when it is being driven in the direction T during fabric processing and drying. In fact, it is preferred to increase the gas quantity flowing in stream **42** during this infra-red shutdown because fabric element **12** is not moving and cannot escape from heating zone **40**, and infra-red heating means **28** has a great deal of residual heat radiating onto element **12**. Also, increased gas flow now does not adversely affect radiation from gas infra-red burners **32** since they are now shut down. Also, it is desirable either to cover the radiating face of each panel **31** or to retract each panel away from fabric element **12** and screen **64**. The mechanism to be described hereafter provides this action for both drying apparatuses **16** in tier T2 in FIG. 1 (both in banks B1 and B2), and is shown in more detail in FIGS. 2 and 7. In FIG. 7, rotation actuated switch **68** (having its switch contact open during stopping of drive roll **23** and having its switch contact closed when fabric element **12** is being driven in direction T by the drive rolls) opens its switch contact upon stopping of movement of fabric element **12** in direction T in heating zone **40** so as to de-energize each solenoid gas valve **35** controlling main burner gas line **37** to each panel **31** in tier T2 in FIG. 2 and de-energizes solenoid operated four-way valve **72** by breaking their energizing parallel circuits between power lines L1 and L2. De-energizing solenoid operated 4-way valves **72** connects air pressure line **73** to one end of double acting burner panel retracting cylinder **74** and to one end of double acting gas flow damper cylinder **76** and connects its exhaust port **72***a* to the other ends of these cylinders. This action extends the length of cylinder **74** so that its upwardly moving piston rod in FIG. 2 swings arm **78** clockwise on pivot **79** so that bell cranks **80** on parallel pivot shafts **79**, connected by link **82** will cause bell cranks **80** to swing clockwise in FIG. 2 to retract panels **31** away from element **12** from their solid line to their dot dash line positions since the opposite ends of links **82** and **84** and the distal end of arm **78** have pivot connections. The upper end of each panel **31** is supported by at least one pair of trolley rollers **86** travelling in opposite channels of I-beam **87** forming one of the upper structural members **14***a* in each apparatus **16** in drying tower **14**. This action also causes double acting gas flow damper cylinders **76** to move quadrant-type damper **88** in FIG. 2 from a partially open position in gas nozzle duct **48** assumed while fabric element **12** is driven in direction T by the drive rolls during normal drying to a fully open position during infra-red shutdown to increase the gas discharge rate from nozzle **50** to increase gas stream **42** for cooling both screen **64** and surfaces F1 and F2 of element **12** to protect them against residual heat from straddling heating means **28**. When element **12** begins to travel in direction T, switch **68** closes to reverse this action so as to open gas valve **35**, to contract cylinder **72** to advance panels **31** back to their solid line positions, and to move damper **88** back to its partially open position so that each apparatus **16** is now ready for drying again. During this reverse action, four-way valve **72** moves to its opposite position to connect air pressure line **73** and its exhaust port **72***a* respectively to said other and said one ends of said cylinders in the conventional four-way valve operating manner to reverse the action of cylinders **74** and **76**.

Each of the two panels **31** in any given tier, such as tier T2 in FIGS. 1–3, has secured to each of its vertical side surfaces in FIGS. 6 and 8 reflector plate **90**, four in number for each tier, adapted to telescope together over each edge of fabric element **12** in straddling relationship when the burner panels are in their solid line positions in FIG. 2, as shown in FIG. 8. Then, these four reflector plates **90** form two generally parallel reflector means extending along direction T of relative movement of element **12** and straddling the opposite edges of element **12** for heating these edges in heating zones **40** more uniformly by infra-red radiation by reflecting the infra-red radiation back onto these edges of the fabric, since these edges would not otherwise get sufficient radiation since they are close to the edge of panels **31**. Hence, these reflector plates assure uniformity of infra-red radiation over full width W of fabric **12** by capturing the infra-red radiation that would otherwise escape laterally through the gap between panels **31**.

Flow ducts or flow channels **92** are formed, one duct on each side of fabric element **12**, for conveying the gas in each gas stream **42** as an air curtain from its discharge nozzle **50** to its exhaust opening **56**. Each gas flow duct **92** extends along the length of element **12**, has element **12** surface F1 and F2 as one wall thereof, and is mounted to receive gas stream **42** from discharge nozzle **50** for keeping gas stream **42** flowing over and close to this element surface and for discharging the gas stream **42** into discharge opening **56** for exhausting from drying tower **14**.

Each vertically extending flow channel or duct **92** for gas stream **42** is formed by surface face F1 or F2 of element **12**, reflector plates **90** and the element **12** side face of screen **64** with these two ducts **92** each being rectangular in cross section, generally parallel, and straddling

element surfaces F1 and F2. Although each screen 64 may be secured to its associated burner panel 31, each screen 64 is preferably secured in FIG. 6 at its upper and lower ends respecitvely by mounting brackets 93 and 94 (one at each corner) to ducts 58 and 48 so that screens 64 will be fixed against lateral movement relative to gas discharge nozzles 50 and element surfaces F1 and F2 in heating zone 40, and therefore will not move with panels 31 as they are retracted to the dot dash line positions in FIGS. 2 and 6 during infra-red shutdown. Hence, there is constant geometry between screens 64 and element 12 for controlling the thickness of gas streams 42 straddling element 12, which geometry will not change even though panels 31 are movable between these solid and dot dash line positions. Movement of reflector plates 90 with retractable burner panels 31 between the solid and dot dash line positions in FIGS. 2 and 6 does not matter because they will return to their telescoped relationship to form the sides of flow ducts 92 each time burner panels 31 are moved to their advanced and solid line position in FIG. 2.

Each duct 92 plays an important part during travel of its stream 42 from discharge nozzle 50 to exhaust vent 56. Duct 92 guides, holds laterally compact and prevents lateral dispersion stream 42 to maintain the flow action of stream 42 in direction T along element 12 and toward exhaust vent 56 while keeping stream in close contact with element face F1 or F2.

Although two ducts 92 and four reflector plates 90 have now been described for two apparatuses 16 in FIGS. 2, 3 and 8 for convenience, it should be apparent that a single duct 92 straddled by only two reflector plates 90 give the same advantages for a single apparatus 16.

There are other advantages in having two drying apparatuses 16 facing each other at each tier, such as tier T2 in FIG. 1, with one apparatus 16 in each bank B1 and B2. Then, these two heating apparatuses 16 are mounted with their two heating zones 40 having sandwiched therebetween the generally coinciding opposite faces F1 and F2 of element 12 so that each dries one of the opposite generally coinciding parallel faces of element 12. This structural arrangement and coaction has a higher drying heat; simultaneously dries both sides of fabric element 12; more rapidly dries fabric element 12; and requires no reflector behind element 12, such as would be necessary if only one drying apparatus were used. Such reflector frequently has a short useful wear life since it gets tarnished and tends to melt under the hot infra-red radiation heat.

The eight drying apparatuses 16 in bank B1 in FIG. 1 in tires T1–T8 arranged in series along direction T of travel of element 12 have certain advantages. Each of these apparatuses 16 has its own gas discharge nozzle 50 and gas exhaust opening 56 for generally uniformly processing width W of element 12 in series arranged heating zones 40 as element 12 moves upwardly in FIG. 1 past these eight series arranged drying apparatuses 16 in bank B1. Each of these eight drying apparatuses has its own vertically traveling gas stream 42 formed from relatively fresh, dry, cool air at ambient conditions sucked in from outside drying tower 14 for its discharge nozzle 50 and has water molecule saturated, or at least heavily laden, air (substantially raised in temperature) exhausted through exhaust opening 56 and outlet duct 62 at the top of drying tower 14 so as to not interfere with the flow of fresh, dry air into tower 14 for discharge nozzles 50. Having eight separate gas streams 42 is a substantial advantage over having a single gas stream 42 passing from the bottom to the top of drying tower 14. This single gas stream would (after it traveled more than one tier in height) be too heavily laden with water molecules to provide an effective scrubbing action, be too heated up to provide an effective temperature control by cooling element 12, be too heavily concentrated with water molecules so as to prevent effective infra-red transmission from heaters 32 to element 12, have lost its upward velocity so it would no longer scrub off the water molecules or remove the convection heat, not be able to be kept confined to surface F1 or F2 of fabric element 12 because it would lose its upward velocity, and not be able to be confined to a compact stream but would spread laterally and thus be totally useless. The advantage of dividing a single gas stream into eight separate series arranged gas streams 42 becomes more apparent when one realizes that the free vertical travel of each gas stream 42 at each tier in FIG. 1 is about eight feet vertically in the typical installation in Table I while a single stream would have to travel about 100 feet traveling the vertical heights of drying tower 14. Also, it is possible by using the sixteen separate drying apparatus 16 in drying tower 14, arranged in horizontally opposed pairs and in eight series arranged pairs, separately to control the infra-red heating action and flow of gas stream 42 in each component apparatus 16 to match the existing and desired conditions of temperature and moisture removal from element 12 as it is progressively dried as it moves vertically through drying tower 14. This would not be possible if a single gas stream were used for the whole height of tower 14. Also, it has been found during operation of drying tower 14 that the temperature of element 12 and the temperature of the discharged air at the top of each tier T1–T8 can be controlled to be approximately the same even though element 12 moves upwardly in tower 14 and becomes progressively drier.

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 with 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 U.S. Letters Patent is:

1. An apparatus for drying yarn or fabric fibers in a continuous length element, comprising:
   - a heater with a flame for generating infra-red radiation, disposed in a heating zone;
   - means for moving the continuous element past the heater;
   - means for moving a stream of gas adjacent the heater in parallel and contacting relation with the continuous element;
   - means separate from the heater and interposed between the heater and element during normal operation of the heater to dry the fibers, for shielding the flame of the heater against the gas stream without disrupting the infra-red radiation against the element.

2. The apparatus as set forth in claim 1, wherein the flame shielding means includes a wire screen.

3. The apparatus as set forth in claim 2, which includes means for holding the wire screen in parallel relation to the moving element to form an air passageway for the gas stream.

4. The apparatus as set forth in claim 3, wherein the screen size is between 8–12 mesh.

5. An apparatus, as set forth in claim 1, with
   - generally parallel reflector means extending along the direction of relative movement and straddling the edges of said element for heating the edges of said element in said heating zone more uniformly by the infra-red radiation and for providing a flow channel for said gas layer in said heating zone straddled on opposite sides by said element and by said shielding means.

6. A combination, comprising
   - two of the apparatuses, as set forth in claim 5, mounted with heating zones having sandwiched therebetween generally coinciding opposite element faces so that each dries one of the opposite generally coinciding faces of the element with said gas flow chan-

nels being generally parallel and straddling said element.

7. A combination, as set forth in claim 6, with each of said apparatuses including

said burner shielding means being a screen extending generally parallel to the direction of element relative movement, extending generally parallel to the associated face of said element in said heating zone, and being fixed against lateral movement relative to said last mentioned face in said heating zone,

said gas moving means having a portion of its gas layer moving across said screen during energization of said heating means for reducing any infra-red elevated temperature of said screen, and

heating cutoff means for moving said infra-red heating means relative to said screen and element during infra-red heating shutdown and stopping of relative movement of said element with the relative positions

of said screen, element in said heating zone, and gas discharge means being maintained,

said gas moving means being energized for relatively moving the gas layer with respect to said last mentioned face of said element in said heating zone during infra-red shutdown of said heating means and shutdown of said drive means for preventing residual heat from said heating means from damaging said screen and said element not now relatively moving.

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JOHN J. CAMBY, Primary Examiner

U.S. Cl. X.R.

34—155; 263—3

PO-1050
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,521,375 Dated 7/21/70

Inventor(s) D. C. Sanders, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, lines 27-28 should read $\frac{200}{186}$

instead of $\frac{209}{180}$

SIGNED
SEALED
OCT 20 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents