

[54] THROUGH DRYING FOR FIBROUS WEB

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[56] References Cited

UNITED STATES PATENTS

2,889,388 6/1959 Csapo 34/9
3,408,748 11/1968 Dunn, Jr. 34/78 X

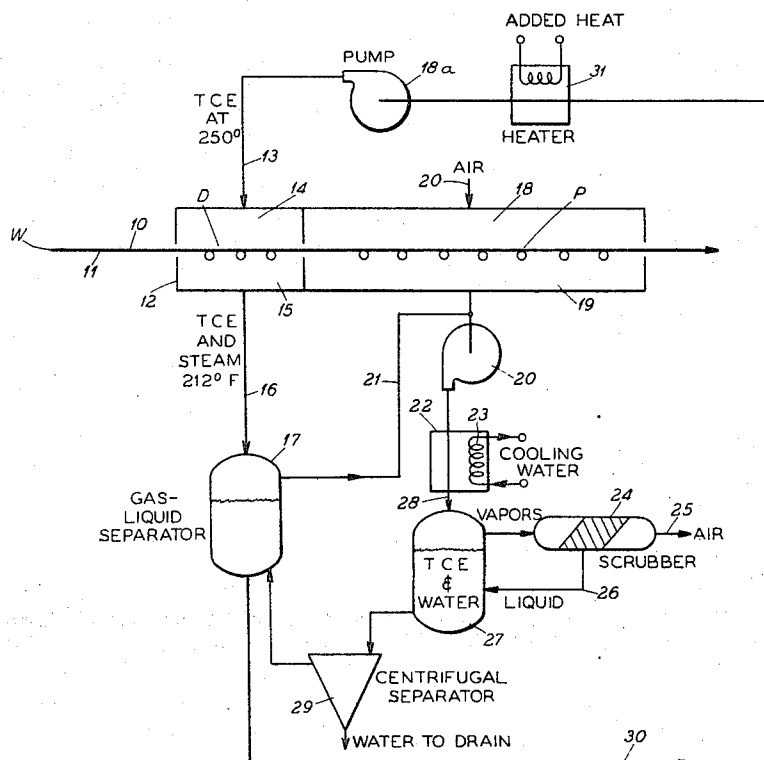
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[57] ABSTRACT

A method and mechanism for the continuous drying of a traveling fibrous web such as a web of paper received from a paper making machine and containing water, including supporting the moving web on a porous screen in a drying zone and directing a flow of heated heat transfer liquid immiscible with the water through the web for evaporating the water and carrying water out with it through the web, separating the immiscible liquid from the water and recycling the immiscible liquid to again pass it through the web in the drying zone for a continuous cycle.

15 Claims, 3 Drawing Figures



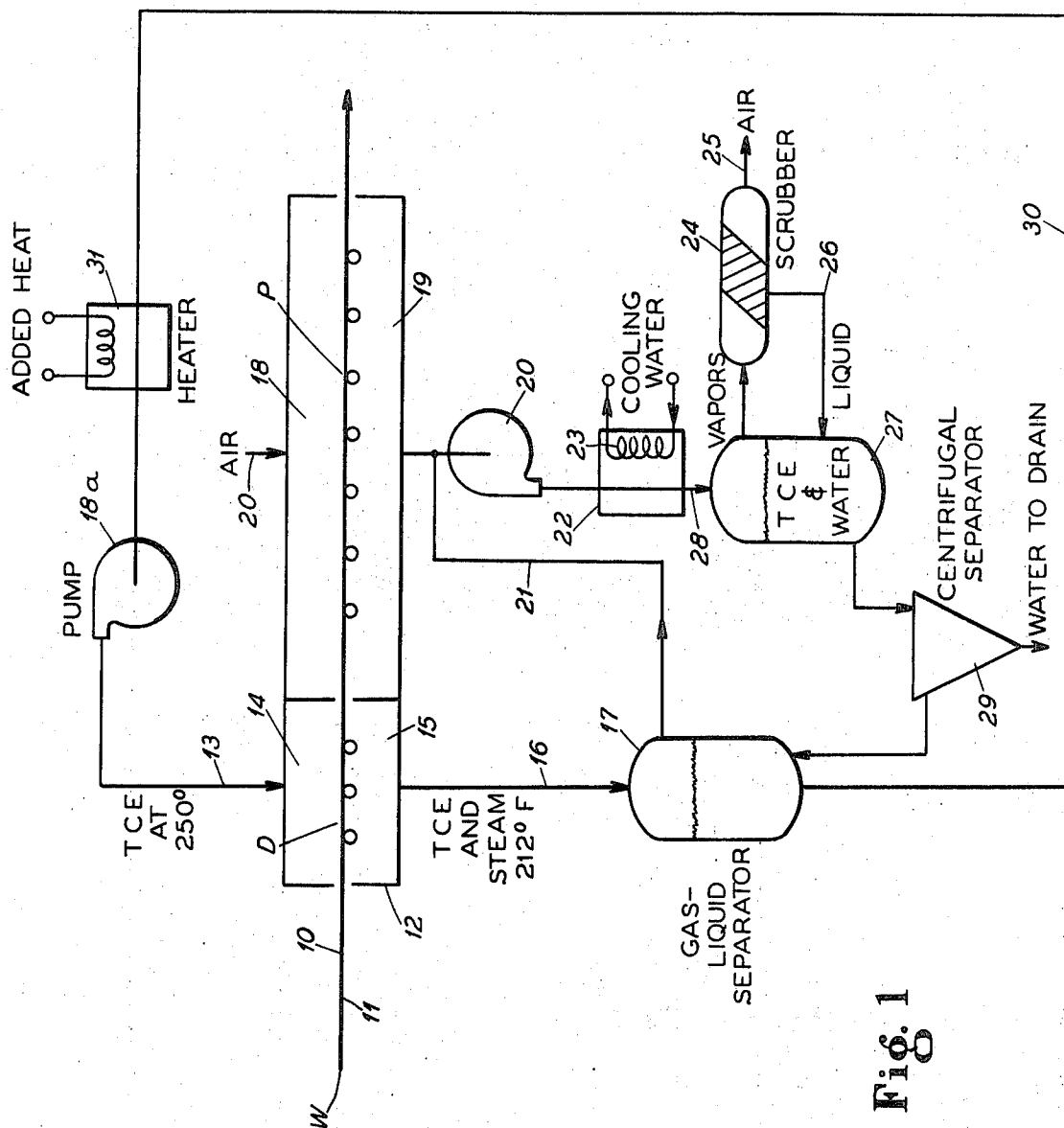
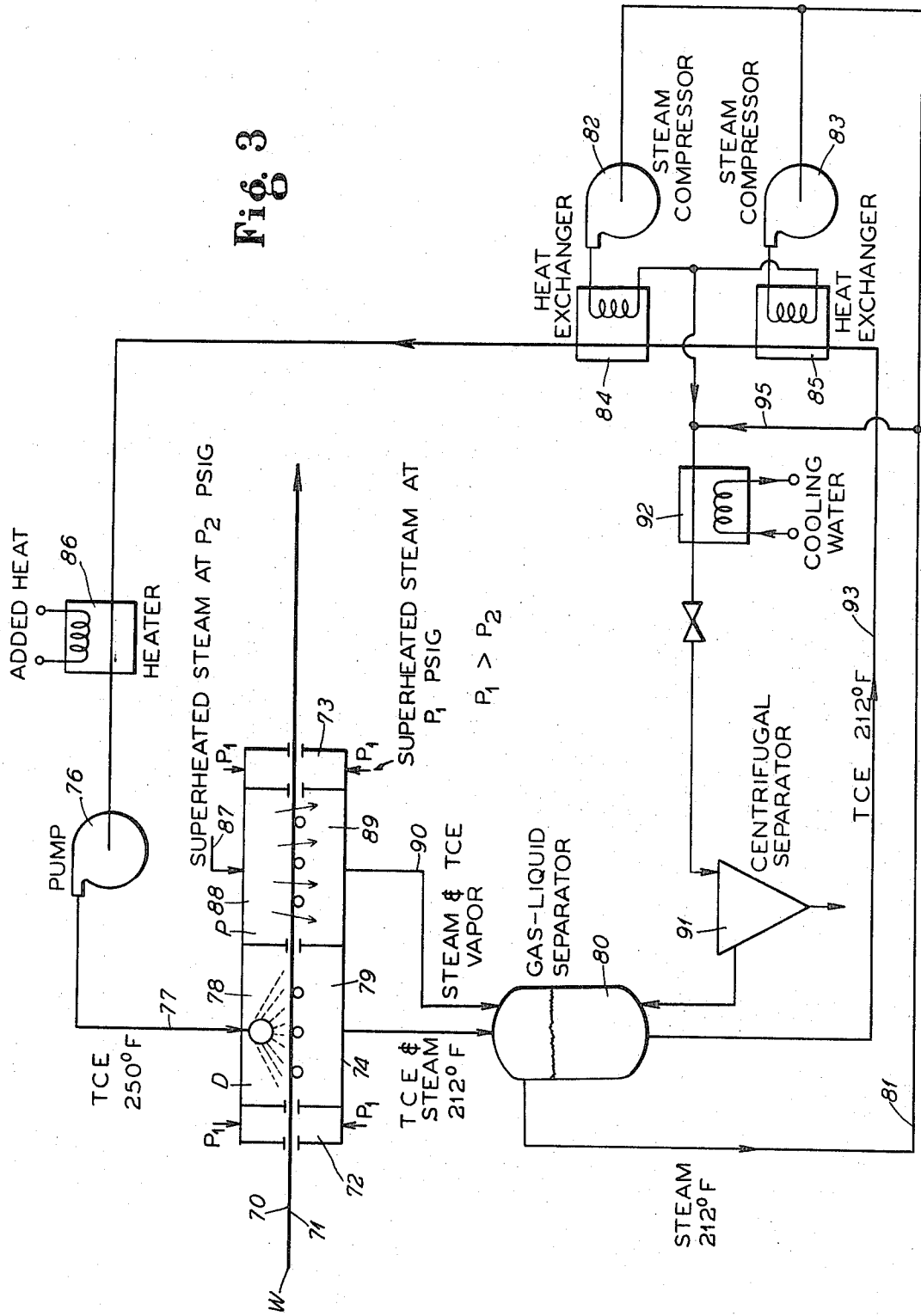


Fig. 1

Fig. 3



THROUGH DRYING FOR FIBROUS WEB

BACKGROUND OF THE INVENTION

The present invention relates to improvements in methods and mechanism for removing water from a traveling fibrous web. More particularly, the invention relates to a new concept of drying a web in a paper making machine which eliminates present commercial systems and particularly those which embody evaporating water from the web by passing the web over the outer surface of a hot dryer drum.

The concept of the present invention embodies passing a fluid through the web utilizing the fluid in various ways to remove the water from the web. The fluid is utilized in various principles of operation to remove the water including transfer of heat energy to the water and actual physical displacement of the water by the fluid. The fluid in one form may be in the liquid phase, in another form in the gaseous phase and in another form in partial gaseous phase and partial liquid. The fluid may be immiscible with water for ease of separation from the water after it passes through the web to recycle the fluid in a continuous cycled operation.

An object of the invention is to provide a fibrous web drying apparatus and process which avoids disadvantages inherent with structures and methods presently known to the prior art and used commercially.

In a conventional commercial system of steam drums and felts, increasing speeds of paper making machines have created problems of web stability, moisture uniformity, web flutter and web breaks, and additional obstacles have come to the foreground with further speed advances. The present system contemplates complete web stability and control by maintaining the web between traveling porous belts where it is controlled and restrained. As contrasted with the space and cost requirements of a steam dryer drum drying system which can require as many as 100 large dryer drums in an elongate dryer section of a modern high speed paper machine, the present system can utilize a highly efficient heat transfer directly by liquid to the web. This can be compared with gas or air dryers in that liquids have at least 1,000 times the volumetric heat capacity (Btu/ft³F°) that most gases have. The active length of the dryer might be 3 feet, and the recovery unit, as will be described later in connection with a more detailed description, 25 feet in length, or even as small as 4 or 5 feet if superheated steam is used rather than air for recovery.

Another prior art system which has attempted to solve the problems of rapid drying at high speeds uses high velocity air impingement, and through drying has been attempted. Because of the relatively low efficiency in the heat transfer properties of gas, these arrangements do not substantially shorten the required length of the drying system and offer additional problems. Further, because of the relatively low heat content of gas, the large volumes make efficient utilization of the residual heat in the hot gas a problem. In the instant invention with the requirement of substantially lower volumes, recycling is possible to utilize residual heat and thereby attain substantial increase in efficiencies. In radiant drying and in hot air drying, restraint of the web is a problem, and because of the desire to increase the speed of drying, fire hazards are a problem requiring safety precautions and presenting dangers in

the equipment used. Microwave and dielectric drying have been attempted using high frequency electric power, but the use has been restricted to auxiliary and special applications, and these systems have been incapable of competently operating on high speed commercial machines. The problems of web handling and use of dryer felts with conventional steam dryer drum systems have presented problems and increased space requirements and costs.

An object of the present invention is to provide a drying system which substantially reduces the amount of space and equipment required in conventional art systems.

A further object of the invention is to provide a drying structure and method for drying a web in a paper making machine which has increased effectiveness and efficiency and which is particularly suitable for drying tissue.

Other objects, advantages and features will become more apparent, as will equivalent structures which are intended to be covered hereby, in the teaching of the principles of the invention in connection with the disclosure of the preferred embodiments thereof in the specification, claims and drawings, in which:

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a mechanism utilizing the method and operating in accordance with the principles of the present invention;

FIG. 2 is another schematic showing of a further form of the invention; and

FIG. 3 is a schematic showing of a further form of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a through liquid dryer wherein a liquid is passed through the web with a through air recovery of the liquid.

The second arrangement is illustrated in FIG. 2 and differs from the first in that a major part of the latent heat of evaporation of the water is recovered and returned to the system.

FIG. 3 is an arrangement utilizing a through liquid dryer with a steam evaporative liquid recovery system.

In accordance with the method of the invention, the traveling paper web is sandwiched between two porous screens or fabrics or is supported on a single screen, and a fluid is passed through the web to remove the water transferring heat energy through the water to vaporize it and/or by physical displacement of the water from the web by the fluid. The term fluid as used herein will refer to material either in the gaseous or liquid phase or both. While various fluids may be used, a preferred arrangement uses a fluid immiscible with water and with air so that it can readily be separated from the water such as by centrifuging and readily be separated from the air such as by condensation.

By use of a fluid in the liquid form, the volumetric heat capability is substantially greater than with gas heating systems heretofore used. Most liquids have at least 1,000 times the volumetric heat capacity of gases, as above mentioned. Even though most liquids have a higher viscosity than air, for the same through flow area through the web, the same through flow pumping work and the same liquid supply temperature, much more

heat (of the order of 100 times) can be transferred to the web with a liquid than with a gas.

Alternatively, as in the specific systems described in the figures of the drawings, the liquid supply temperature can be very much lower than that of through gas drying while still allowing the length of the process time required to evaporate water from the web to be greatly reduced.

A liquid is preferably chosen that is immiscible in water so that low energy methods of separation and recovery can be utilized following the water removal process. Settling basins and centrifuges are two such methods that are contemplated, with the latter being much faster in achieving the separation of water and immiscible liquid. The boiling point of the liquid used should be greater than that of water in order to achieve an effective heat transfer to evaporate the water from the web. While several liquids can be found to meet these and other requirements, such as little or no interaction with the fibers of the web, safety, etc., tetrachloroethylene (TCE) is one such liquid and will be used as an example of a suitable immiscible liquid in the following description.

A flow diagram of application of one form of the method is shown in FIG. 1. Hot TCE (approximately 250°F) is supplied to a through liquid dryer which can be any suitable unit for providing support for the web, and accommodating distribution of hot liquid to a specific drying area of one surface of the paper web. The support must also accommodate a small pressure differential between the supply side of the web and the opposite side, and a recovery area is provided on the opposite side of the web.

The web W is carried between a pair of traveling porous wires or fabrics 10 and 11 which pass through a drying zone D and thereafter carry the web onto a purging zone P. These zones are defined within a housing 12, and hot fluid such as TCE is supplied by pump 18 through a line 13 to a pressure area 14 above the web. The TCE passes through the supported web to be collected in a recovery area 15. The hot TCE will transfer its heat to the web to evaporate the water, and the TCE and steam will pass out of the recovery area 15 into a line 16 down to a gas-liquid separator 17.

The web travels from the drying zone D onto the purging zone P with as much as 70 percent to 80 percent TCE in the web. The hot TCE in the web is very volatile and is readily removed by passing air through the web leaving a dry web coming out of the purging zone. Air is directed into the purging zone through a pressure air inlet 20 into a chamber 18 above the web and the TCE passes out with the air into the lower recovery chamber 19 to be withdrawn by a vacuum pump 20. The intake of the vacuum pump is also connected to the separator 17 to receive gaseous TCE and steam.

The TCE and water vapors from the pump are directed to a condenser 22 having a cooling water coil 23, and the TCE vapor is condensed to the liquid phase in this condenser 22. The recovery of liquid TCE is controlled by the cooling temperature in the condenser. It may be desirable to subject the remaining gaseous mixture to additional recovery steps before returning the air and water vapor to the atmosphere. An example of this is illustrated by a scrubber 24. The scrubber may consist of a centrifuging mechanism or chemical recovery with activated carbon. Air is discharged from the scrubber as shown at 25, and the liq-

uid TCE is returned through a line 26 to a TCE and water container 27, which also receives liquid TCE and water from the condenser 22 through a line 28.

The TCE and water from the container 27 are fed down to a centrifugal separator 29 wherein water is separated to flow down to a drain and liquid TCE is directed up to a separator 17. Separated TCE from the separator 17 is directed back to the drying zone D through a line 30. The liquid separated TCE is first directed through a heater 31 to bring it to substantially 250°F before it is pumped back through the drying zone D in a continuous recycling operation.

The condensed mixture of TCE and water which is sent to the centrifuge, is typically 50 percent water and 50 percent TCE. With effective separation, the water passed to the drain should contain less than ½ percent TCE. The TCE returned to the first separating container 17 may contain a higher percentage of water, but this water can be recycled through the condenser-centrifugal separator system above described.

Another arrangement of the through liquid process is illustrated in FIG. 2. In this arrangement all air is kept out of the through drying chamber by suitable steam seals 40 and 41. These steam seals are small chambers at the ends of the drying zone supplied with pressurized steam shown at P₁ and provided with seals which are in close running relation to upper and lower wires 43 and 44 carrying a web W therebetween. By excluding air, the effluent from the through drying system now consists entirely of TCE and water in liquid and vaporous phases. This mixture is delivered to a first separator or recovery tank 45 as illustrated. The water and TCE vapors are pumped from this recovery tank to a higher pressure and temperature and sent to a heat exchanger as illustrated by the steam compressor pumps 46 and 47 and the heat exchangers 48 and 49. As much as 70 percent of the heat energy used to evaporate the water from the web can be recovered and transferred to the TCE liquid being returned to the through dryer.

As further illustrated in FIG. 2, a pump 50 delivers hot TCE to a pressure chamber 51 above the web, and the TCE flows through the web evaporating the moisture therefrom whereupon they flow into a recovery chamber 52 beneath the web. This combination of TCE and steam at 212°F passes down into the separator 45. Liquid TCE at 212°F recycles back to the system through line 53 through the heat exchangers 49 and 48 receiving heat therefrom, as illustrated. The steam which is directed through the heat exchangers 48 and 49 passes into a chamber 61 cooled by cooling water to flow into a TCE and water container 59. This TCE and water flow down to the centrifugal separator 62 where the water passes to drain, and the separated liquid TCE passes back up to the separator 45. The secondary separator 59 is supplied with air and TCE vapor from the purging chamber. Air is directed through the web, being delivered to a pressure chamber 55 above the web by an air supply 54. The air passes through the web into a collection chamber 56 and is withdrawn by a vacuum pump 57 which delivers the mixture down through a condenser 58. Uncondensed TCE vapor will flow into a scrubber 60 from which air will be discharged, and the liquid TCE will flow into the secondary separator 59.

The recycled liquid TCE flowing through line 53 will flow up to a heater 63 before being directed back through the drying zone D.

In the arrangement shown in FIG. 3, all air is kept separated from the TCE at all parts of the process simplifying the recovery of the TCE in that TCE and water vapors may be completely condensed at a higher temperature when no air is in the mixture. Superheated steam instead of air is used to remove the TCE from the paper web. This higher condensing temperature also makes it more feasible and economically advantageous to extract the latent heat of evaporation from the vaporous water and TCE removed from the paper web.

In the structure of FIG. 3, hot TCE at 250°F is directed to the drying zone D through a line 77 from a pump 76 into a pressure chamber 78 above the wires 70 and 71 supporting the web W. The ends of the housing 74 contain a drying zone D and a purging zone P and have end seals 72 and 73.

The TCE and evaporated water pass into a recovery zone 79 and flow down into a gas-liquid separator 80.

The steam will pass out of the top of the separator through a line 81 to heat exchangers where it is pumped by pumps 82 and 83 with the heat exchangers being shown at 84 and 85. These heat exchangers contribute heat to the TCE flowing through the line 93 back to the recycling system. The preheated TCE passes up to a heater 86 back to the pump 76.

In the purging zone P superheated steam is directed through a line 87 into a pressure chamber 88 above the web. The steam passes through the web carrying the TCE with it into a recovery chamber 89 where the steam and TCE vapor flow through line 90 down to the separator 80. Additional TCE is fed to the separator 80 from centrifugal separator 91 which receives a mixture of water and TCE from the condenser 92 which in turn is supplied from the heat exchangers 84 and 85 and a by-pass line 95 leading from the steam line 81.

There are two chief advantages of the through liquid drying system. First, in through liquid drying, air can more or less be excluded from the system and the temperature of the evaporation heat source (e.g., the TCE) may be quite low. As a result, heat recovery becomes very feasible. With heated cylinder or through air drying, recovery of the latent heat of evaporation is difficult and not economically attractive. Secondly, the machine length can be substantially shortened in the direction of web travel with a consequent reduction in capital cost of equipment and building. For example, the active length of the dryer might be 3 feet and the recovery unit 25 feet, as above stated, when air is used for recovery in the purging chamber, or even as small as 4 or 5 feet when superheated steam is used. The entire drying and TCE removal processes may be accomplished on suitably designed cylinders if desired. The presence of immiscible liquid TCE may have some influence on the strength of paper. TCE has been found to reduce tensile strength by 10 percent to 30 percent below that of an all water dried sheet. In certain cases where this is an important factor, other liquids may be employed such as Freon 13 which does not affect the strength property of the paper. If no water is removed from the paper web by mechanical pressing, then the bulk or caliper of the web may be as much as twice that of a conventionally pressed web. This may be desirable on certain grades of paper. Through liquid drying is particularly attractive for such grades because, without the use of web pressing, enormous quantities of water must be evaporated from the paper web. This is encountered in the making of tissues. Paper dried with

TCE may have from 5 percent to 20 percent greater bulk than paper allowed to dry in air without pressing. The greatly increased drying rate with TCE has not been found to produce any deleterious effects. The very rapid conversion of water in the paper to steam without accompanying increase in volume tends to expand the structure and give greater bulk which is highly desirable from a functional standpoint and from the standpoint of a merchandiseable product acceptable by the public.

It will be understood that the drying method described is not limited to any particular web or material, but has been described in the environment of the making of paper. It is particularly well suited to the manufacture and drying of tissue grade paper. Increased bulk is particularly desired on tissue grades and some loss in tensile strength is permissible. In addition, the high speed capability of drying and the low capital cost of equipment required, make this a highly desirable process and mechanism for such paper grades.

We claim as our invention:

1. A mechanism for the continuous drying of a traveling fibrous web comprising,
 - means supporting a moving web passing through a drying zone, means directing a flow of hot transfer fluid in a liquid phase through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid, and heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water.
2. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 1 wherein said heat transfer fluid is in part in the gaseous phase and in part in the liquid phase upon entering the web.
3. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 2 and including first separating means receiving the fluid and water from the web and separating the liquid phase of the fluid for recycling through the drying zone of the web, and a second separator including condensing means for condensing the evaporated water in the liquid phase of the fluid with a separator for separating the water and liquid phase of the fluid for recycling through the drying zone of the web.
4. A mechanism for the continuous drying of a traveling fibrous web comprising,
 - means supporting a moving web passing through a drying zone, means directing a flow of hot heat transfer fluid through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid.
 - said fluid being at least in part in the gaseous phase, and heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water,
 - said heating and said flow directing means related so that the gas is condensed to the full liquid phase in passing through the web to yield its heat of vaporization through the water.
5. A mechanism for the continuous drying of a traveling fibrous web comprising,
 - means supporting a moving web passing through a drying zone, and

means directing a flow of a liquid immiscible with water through the web carrying a portion of the water from the web.

6. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 5 and including means for separating said liquid from the water after it is passed out of the web.

7. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 6 including means for recycling said separated immiscible liquid through the traveling web in said drying zone in a continuous recycled operation.

8. A mechanism for the continuous drying of a traveling fibrous web comprising,
means supporting a moving web passing through a drying zone, means directing a flow of hot transfer fluid through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid,

heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water,
and means for separating said fluid from the evaporated water after it is passed through the web.

9. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 8 including means for recycling the separated fluid back through the web in a continuous recycled operation.

10. A mechanism for the continuous drying of a traveling fibrous web comprising,
means supporting a moving web passing through a drying zone, means directing a flow of hot transfer fluid in the form of tetrachloroethylene through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid,
and heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water.

11. A mechanism for the continuous drying of a traveling fibrous web comprising,
means supporting a moving web passing through a drying zone, means directing a flow of hot transfer fluid in the form of Freon through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid,

and heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water.

12. A mechanism for the continuous drying of a traveling fibrous web comprising,
means supporting a moving web passing through a drying zone, means directing a flow of hot transfer fluid through the web for evaporating the water in the web with the evaporating water passing out of the web with said fluid,

heating means for heating said fluid prior to passing through the web to a temperature in excess of the vaporization temperature of the water,

and means defining a purging zone position subsequent to said fluid directing means with means for directing a flow of gas through the web in said purging zone to remove fluid therefrom remaining in the web.

13. A mechanism for the continuous drying of a traveling fibrous web constructed in accordance with claim 12 wherein superheated steam is directed through the web in said purging zone.

14. The method of continuously drying a traveling fibrous web comprising the steps of supporting a moving web passing through a drying zone,

directing a flow of heat transfer fluid through the web in said drying zone wherein said fluid is at least in part in the gaseous phase upon entering the web with the evaporating water passing out of the web with said fluid,

and heating the fluid prior to passing through the web to a temperature in excess of the evaporation temperature of the water,

said fluid being of a temperature and being passed through the web at a speed so that gas is condensed to the liquid phase in passing through the web giving up its heat of vaporization to evaporate the water.

15. The method of continuously drying a traveling fibrous web comprising the steps of supporting a moving web passing through a drying zone,

directing a flow of liquid immiscible with water through the web forcing water from the web in said drying zone, and separating the immiscible fluid from the water after it has passed from the web.

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