United States Patent

[11] 3,629,952

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[21] Appl. No. **89,744**
[22] Filed **Nov. 16, 1970**
[45] Patented **Dec. 28, 1971**

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Continuation-in-part of application Ser. No. 817,834, Apr. 21, 1969. This application Nov. 16, 1970, Ser. No. 89,744

[54] **AIRFOIL WEB DRYER**
2 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **34/156,** 226/97

[51] **Int. Cl.** **B65h 17/32**

[50] **Field of Search** 226/97, 7; 302/29; 34/156, 160

[56] **References Cited**

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ABSTRACT: An airfoil nozzle is disposed adjacent the moving web to be dried and is constructed with a substantially flat planular guide surface trailing the nozzle, facing the web and substantially parallel thereto.

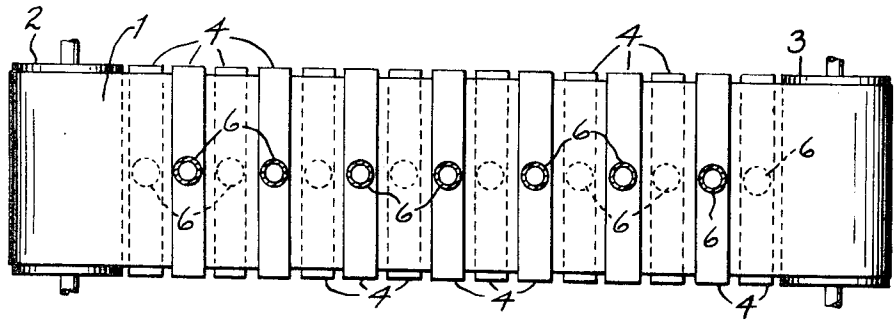


Fig. 1

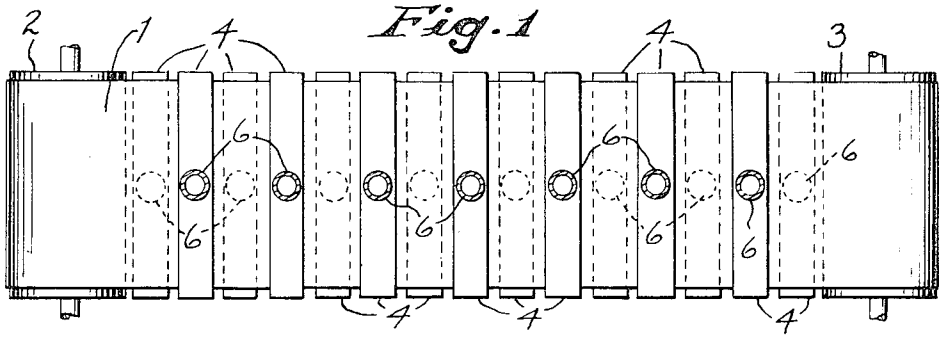


Fig. 2

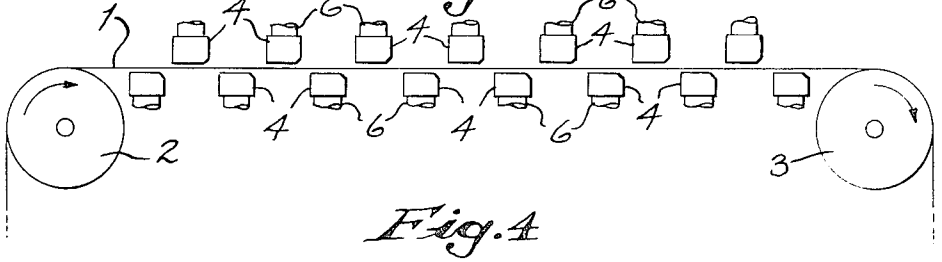


Fig. 4

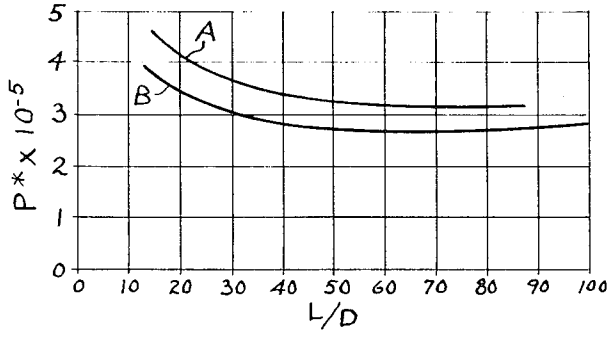
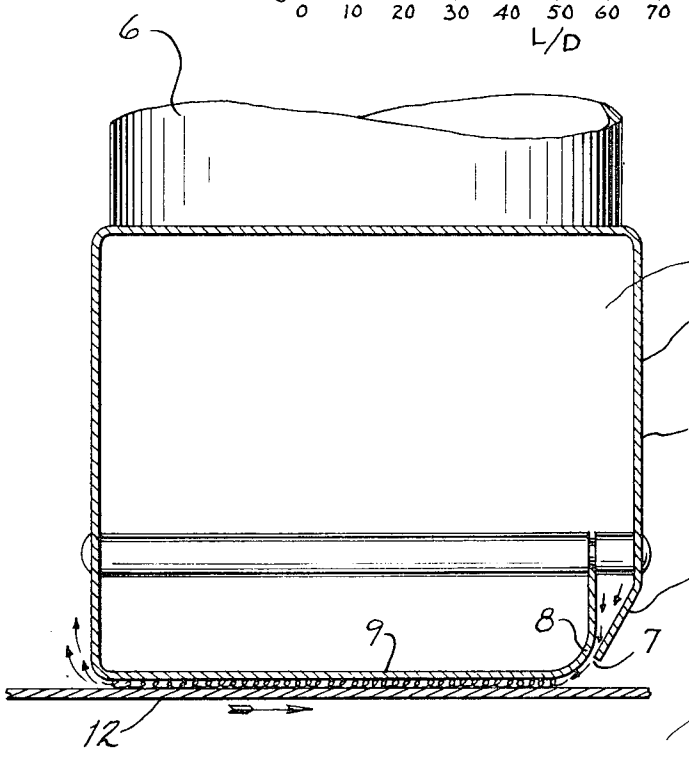


Fig. 3



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AIRFOIL WEB DRYER

CROSS-REFERENCE TO RELATED APPLICATION

This application constitutes a continuation-in-part of U.S. application Ser. No. 817,834, filed Apr. 21, 1969 and which is copending herewith.

BACKGROUND OF THE INVENTION

This invention relates to an airfoil web dryer wherein an airfoil nozzle is employed to direct a flow of air in contact with a moving web to be dried.

The practice in the paper industry and also in the printing industry is to avoid physical contact with the wet paper or with the fresh ink by anything other than the drying air. With a web moving at several thousand feet per minute the drying air impinging thereon must serve to stabilize the web and at the same time provide adequate heat transfer to effect the desired pick up moisture from the web.

It has generally been assumed that laminar flow of air adjacent the web provides the greatest stability for the web and nozzles have generally been designed to provide a laminar flow of air in a direction parallel to the movement of the web.

Airfoil nozzles are particularly adapted to this purpose as illustrated in the copending application Ser. No. 817,834 referred to above.

Also, as recognized in said application there is a need for a turbulent airflow to provide the needed drying, and according to the application, this turbulent flow is obtained in the system there disclosed by the use of air discharge velocities in excess of 3,300 feet per minute and may be enchanced by employing either an interrupted surface or supplemental jet.

No one heretofore has recognized that it is possible by employing a substantially flat extension of the airfoil surface for a distance generally correlated to the nozzle dimensions to obtain an extended turbulent airflow in contact with the web and which greatly increases the heat transfer without increasing the power required.

SUMMARY OF THE INVENTION

The present invention is based upon the recognition that maximum drying efficiencies may be obtained for a given power input to the dryer, by employing a series of airfoil nozzles on one or both sides of the web, each of the nozzles having an extended flat planular surface substantially parallel to the web trailing the nozzle in the direction of web movement, and which surface extends for a distance approximately 60 times the width of the nozzle slot where the nozzle slot width is in excess of about 0.060 inch and the air velocity from the nozzle is substantially greater than 3,300 feet per minute and preferably of the order of 15,000 feet per minute. The Reynolds number should preferably be from about 4,000 to 10,000.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings furnished herewith illustrate the best mode presently contemplated for carrying out the invention as described hereinafter.

In the drawings:

FIG. 1 is a schematic top plan view of a dryer with nozzles above and below the web to be dried;

FIG. 2 is a schematic side elevation of such a dryer;

FIG. 3 is an enlarged section of an airfoil nozzle taken on line 3—3 of FIG. 1 and illustrating the flow of air between it and the web; and

FIG. 4 is a graph illustrating the power requirements for different Reynolds numbers and different L/D ratios.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 to 3 of the drawing, the web 1 is shown as traveling horizontally through a drying zone from a roll 2 to a rewind roll 3 with a plurality of airfoil nozzles 4 disposed above and below the web.

Each of the nozzles 4 comprises a plenum chamber or body 5 extending across the full width of the web 1, with closed ends and a central intake duct 6.

The several nozzles 4 may be arranged in any desired spacing, that shown providing a space between each two adjacent nozzles greater than the width of a nozzle so that by disposing the nozzles alternately above and below the web it is possible to control the web in a series of waves, each extending for the full width of the web and avoid direct interference between the air flows impinging the opposite sides of the web.

The body or plenum chamber 5 of each airfoil nozzle 4 is shown as of substantially rectangular section with a discharge orifice in the form of a slot 7 extending for the full length of the body along one corner thereof.

The slot 7 is formed between an inwardly curved foil edge flange 8 of the face side 9 of body 5 and an inwardly inclined angular foil plate 10 constituting the adjacent edge portion of the corresponding side 11 of the body 5.

The palate 10 is generally tangential to the curved surface of foil flange 8, disregarding the space of slot 7 therebetween.

The face 9 of each body 5 is flat and extends parallel to the general plane of web 1 with a space 12 therebetween generally corresponding to the width of nozzle slot 7.

The optimum ratio of the total trailing length of the flat face 9 in the direction opposite to web movement, to the slot width, to obtain favorable drying of the web with a minimum of power and with air velocities of the order of 15,000 feet per minute is generally approximately 60.

The practical width of slot 7 which also corresponds generally to the space 12 should be within the range of 0.04 inch to 0.125 inch.

The practical horsepower required to provide the necessary flow of air generally ranges from about 0.3 to 0.8 horsepower per square foot of the web in the drying zone.

In general within practical limits the higher the temperature of the air from the nozzle the lower the horsepower required for a given velocity of airflow in contact with the web but the higher the horsepower required for a given drying effect.

Also in general in the operating range of the system the greater the length of the flat face 9 in the direction of web movement for a given slot width the less horsepower required for a given drying action.

The air discharging through the nozzle slot 7 flows in a laminar flow along and following the curved surface of foil edge flange 8 until it reaches the flat face 9 of the plenum chamber 5.

The air continues in the turbulent flow between and in contact with the face 9 and web 1 in a direction opposed to the direction of web movement through the drying zone.

After the air reaches the edge of face 9 opposite the curved foil flange 8 it flows away from web 1 losing its pressure and is exhausted from the dryer by any suitable means, not shown.

The turbulent flow of air in contact with the web 1 and the face 9 effects a heat transfer to the web resulting in evaporation of moisture from the web at a rapid rate.

In general, the power required for a given heat transfer or drying effect will depend upon the Reynolds number indicating turbulence and the L/D ratio where L is the length of face 9 in the direction of web movement and D is the distance between face 9 and the web 1. Formulas for these may be derived according to the teaching in the college instruction book entitled "Transport Phenomena" by R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot, and published in 1960 by John Wiley & Sons, Inc. of New York.

Referring to FIG. 4 of the drawings, the graph plots the L/D ratio as the abscissa and the mass flow rate or power requirement as the ordinate for two Reynolds number curves A and B, giving the range considered most practical for employment of the invention. Curve A is for a Reynolds number of 10,000 and curve B is for a Reynolds number of 5,000.

The power number expressed as $10^{-5} \times P^*$ is a convenient measure of power requirement which is derived from an energy balance as taught in Chapter 13 of the above book, and

from a power function expressed in terms of the air velocity and density, the dimensions of the nozzle and web, and a constant heat coefficient. In this number:

$$P^* = \frac{(L/D)^2}{[1-e-\phi]^3}$$

In the above equation:

L = length of foil surface **9** in direction of web movement,

D = width of nozzle slot **7**, and

$[1-e^{-\phi}]^3$ is a logarithmic function in which Φ represents the units of heat transfer per nozzle and e is a logarithmic base.

From the curves it can be determined that the most favorable conditions for low power consumption is with an L/D ratio between about 40 and 100 with a Reynolds number generally below 10,000. For a 4,000 Reynolds number the lowest power is needed with an L/D ratio of about 65.

It is well to keep below 3.00 as a power number since efficiency drops rapidly with increasing power consumption. Stated in horsepower consumed per square foot of web in the dryer it is considered good practice to stay within 0.3 to 0.8 horsepower per square foot.

In the airfoil nozzle illustrated, there will be a loss in velocity of air immediately after leaving the slot **7** amounting to about 1,000 feet per minute for each one-sixteenth inch of travel along the curved foil until the air reaches the space **12** between the web and the flat surface **9** where it becomes turbulent and continues to the opposite side of the body **5**.

The turbulent air impacts the web **1** and gives up heat in picking up moisture from the web. In this process the air cools and loses some velocity as it moves toward discharge from space **12**.

The optimum air velocity at the nozzle slot **7** is generally in excess of 14,000 feet per minute although if other conditions are favorable an air velocity as low as 3,300 feet per minute has been satisfactory.

The exact slot width is largely a matter of practicality considering the L/D ratio needed and the air velocities available.

In constructing a dryer, certain factors are determined early, such as the speed of the web, the approximate amount of moisture to be removed from it, the general space requirements of the dryer, the available horsepower, air velocities available and the facility for heating the air to a desired operating temperature.

Given the above approximate initial determinations, it is possible to determine by suitable formula the approximate numbers and size of air nozzles needed, the Reynolds number most favorable, the distance L for face **9** and the width D of the slot.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention

We claim:

1. An airfoil web dryer comprising one or more airfoil nozzles disposed on at least one side of a moving web with the nozzle slot disposed to discharge the air at an air velocity in excess of 3,300 feet per minute, with a Reynolds' number of from about 4,000 to 8,000 and said nozzle having a substantially flat face generally parallel to the web to provide turbulent flow of the air between the face and the web, and an L/D ratio within the range of about 40 to 90 where L is the dimension of the flat face in the direction of air flow and D is the width of the nozzle slot.

2. The construction of claim **1** wherein the L/D ratio is approximately 60 and the air velocity is approximately 14,000 feet per minute as it enters the space between said face and the web, with a Reynolds' number of approximately from 5,000 to 7,000.

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