United States Patent

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[54] **AIRFOIL NOZZLE**
8 Claims, 4 Drawing Figs.

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[51] Int. Cl. F26b 13/20
[50] Field of Search 34/156, 160; 239/595, 597

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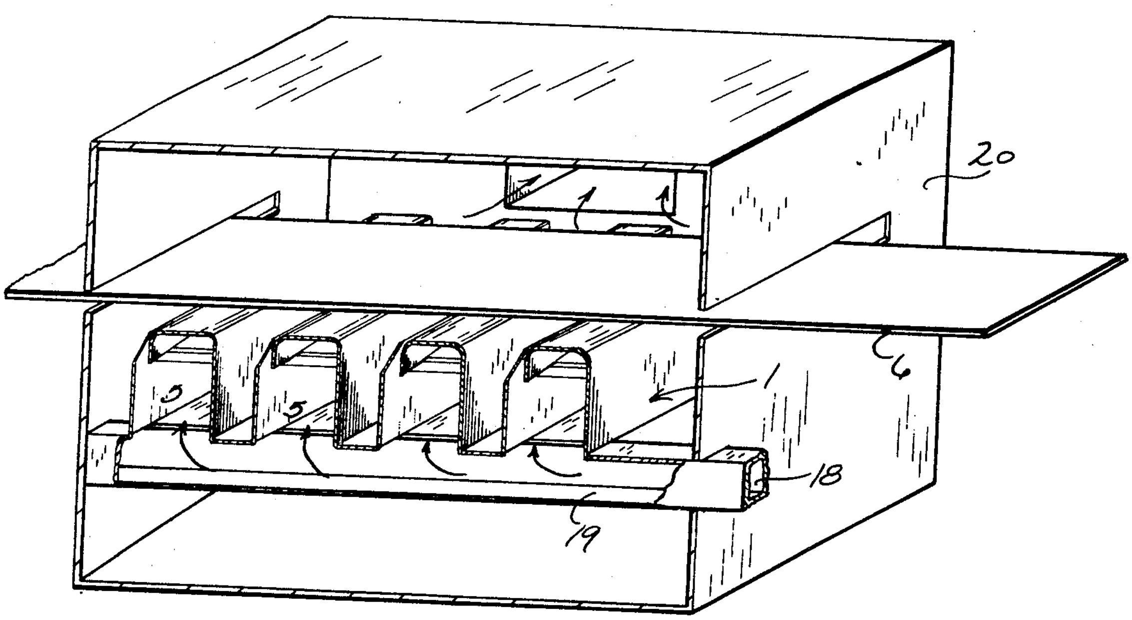
ABSTRACT: For the treatment of surfaces such as a web of material to be cleaned, dried or stabilized without physical contact with the web, an airfoil nozzle is provided from which cleaning, drying or stabilizing gas is discharged tangentially against the web. The nozzle extends across the web to be treated and consists of a foil having a defined radius at the nozzle discharge area and a foil plate which extends along one side of the foil in a direction tangential to the foil to provide a restricted passage between the plate and foil from which the gas is discharged toward the web to be treated. The velocity of the discharged gas is such that the static pressure on the side of the web adjacent the foil is lower than the pressure on the opposite side of the web so that the web is forced by the differential in pressures toward the airfoil and rides on the gas cushion provided by the discharged gas tending to follow the radius of curvature of the foil.



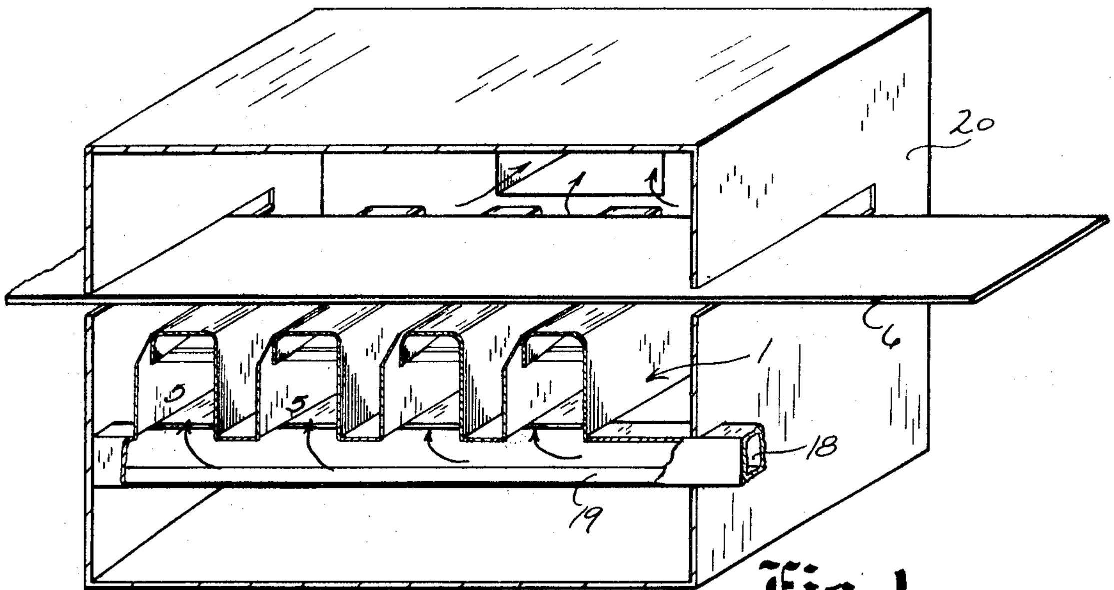
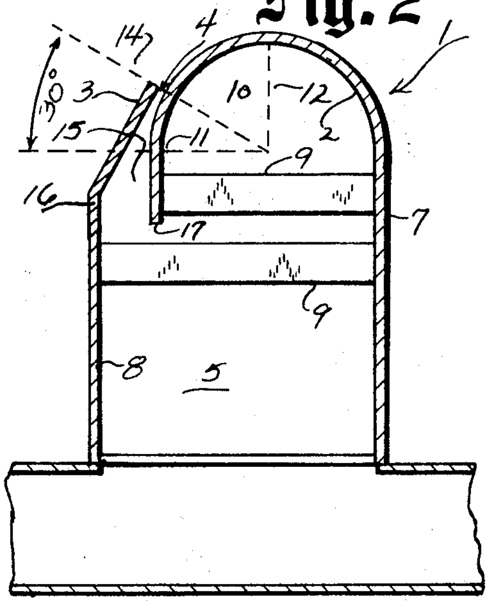


Fig. 1

Fig. 2



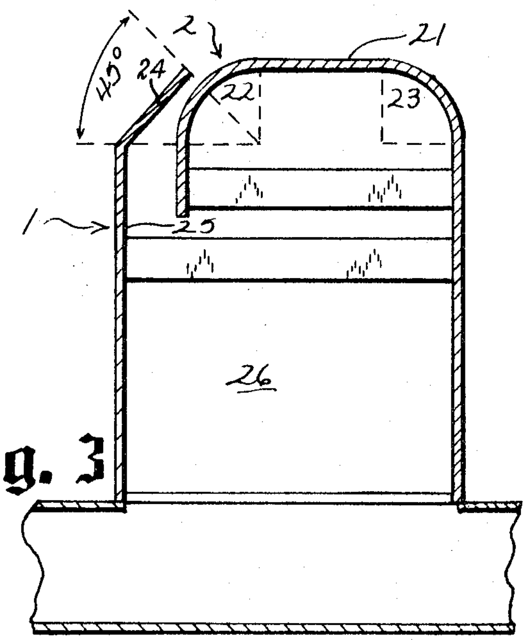


Fig. 3

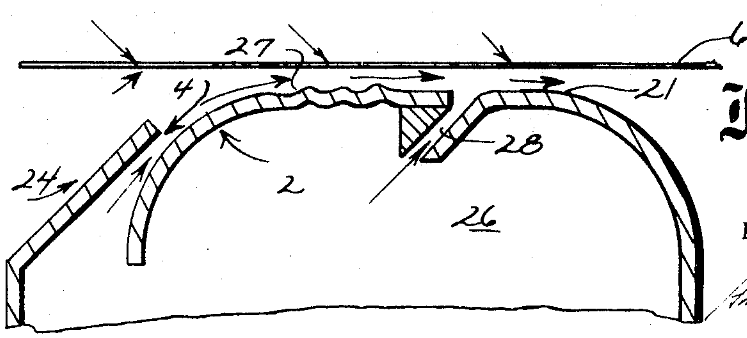


Fig. 4

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AIRFOIL NOZZLE

BACKGROUND OF INVENTION

In the use of the gas discharge apparatus of the prior art for cleaning, drying and stabilizing webs, it has been found difficult to maintain the web in a plane removed from the apparatus since in most installations, the web flutters when engaged by the discharged gas resulting in intermittent contact of the web with the metal parts involved in the gas discharge and consequent deleterious effects on the web or other surface being treated.

The present invention provides apparatus for delivering unlimited quantities of gas (which includes air or heated or cool air or gas) against the surface being treated to effect a stable condition and yet prevents contact of the web or other surface with the gas discharge equipment. Higher pressures and velocities are obtainable with a consequent higher rate of heat transfer, for example, as in the case of drying a web without injury to the web.

SUMMARY OF INVENTION

In general, the invention is directed to an airfoil nozzle which has numerous applications. It can be used as a positioner or stabilizer for webs in letter press, flexography, offset printing, rotogravure work or anywhere a moving web of paper, plastic, textiles, metal, and like surfaces needs to be controlled. It also can be used in cleaning and drying of webs. The term "treated" as used herein refers to engaging a web or surface or wire conveyor with a gas to dry, clean, stabilize or otherwise treat the web to provide the desired end product.

The airfoil nozzle of the invention basically comprises a foil and an associated foil member which normally is a plate, but which could be of a bulbous construction. The foil may take the form of a hollow pipe which extends transversely, either straight or diagonally, of the web or surface to be treated or in the usual application, it can be of a formed member with the surface facing the web to be treated extending on a curvature or in a straight line to provide an extended flat foil surface for a short distance. In both cases, the foil has a defined radius at the area adjacent the foil plate. The foil plate extends at an angle to the foil and terminates along one side of the foil to provide a restricted passage or orifice between the foil and plate through which gas is discharged or pumped from a plenum chamber under pressure at a velocity of not less than 3,300 feet per minute to obtain the turbulence desired in the discharged gas. Turbulence is particularly important in the drying of webs to obtain a high rate of heat and mass transfer. A return chamber is normally provided to pick up and return the discharged gas to the plenum chamber from which the gas is again discharged through the nozzle.

Upon discharge from the orifice the gas tends to follow the radius of curvature of the foil and provides an airfoil gas cushion extending over the entire surface of the foil and air is also inspirated from the surrounding atmosphere and added to the gas cushion. In addition, since gas flowing over a streamlined surface at a high velocity decreases in static pressure, this provides a lower pressure in the gas at the foil side of the web or surface being treated as compared to the opposite side of the web with the result that the web is drawn or forced toward the airfoil and rides on the described air cushion without fluttering into contact with the foil.

In order to obtain maximum efficiency with the nozzle of the invention, the tangential angle of the foil plate with respect to the foil, the radius of the foil, the spacing between the foil plate and foil, the location of the terminal end of the foil plate with respect to the foil are important factors and these will be more fully set forth in the detailed description of the invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view with parts broken away showing a web passing over a plurality of airfoil nozzles assembled under one manner of employing a plurality of nozzles;

FIG. 2 is a section taken through a nozzle of the invention with the foil plate disposed normal to a radius at 30° from the base of the quadrant passing through the nozzle and employing a curved surface on the foil;

FIG. 3 is a section similar to FIG. 2, with the foil plate disposed normal to a radius at 45° from the base of the quadrant passing through the nozzle and illustrating a straight surface on the foil extending from the initial radius of the foil; and

FIG. 4 is a diagrammatic illustration of the flow action of the gas past the airfoil and adjacent the web as it is effected by the high-velocity discharge from the nozzle and in addition illustrates a deformed or roughened foil surface adjacent the orifice discharge of the nozzle and a second nozzle for discharge of gas through the foil surface.

Referring to the drawings, there is illustrated in FIGS. 1 and 2, an airfoil nozzle 1 consisting of a foil 2 and a foil member 3 assembled therewith to provide a slotlike restricted opening or orifice 4 for discharge of gas under pressure from a plenum chamber 5 against a web 6 or surface being treated such as in the cleaning, drying or stabilizing of web 6 as it passes over nozzle 1. FIG. 2 illustrates a single nozzle 1 and FIG. 1 is an example of the assembly of a plurality of nozzles 1.

The nozzles 1 may all face in one direction in some installations as shown in FIG. 1 but the nozzles 1 may also be faced in alternate directions. Each nozzle 1 is of a length to extend across web 6 and slightly beyond the edge of web 6 to insure that the backwash effect of the discharge of gas from the nozzle will occur beyond the edge of the web 6 being treated so that the gas contacts the entire surface of the web.

The foil 2 of nozzle 1, illustrated in FIG. 2, is shown with a radius of curvature of approximately three-quarters of an inch, and is formed of sheet metal into the semicircular configuration shown as an extension of the vertical wall 7 of the plenum chamber 5. The opposite vertical wall 8 of plenum chamber 5 is laterally spaced from wall 7 and terminates in the foil member or plate 3. Braces 9 extend horizontally within foil 2 and internally of walls 7 and 8 of the plenum chamber 5 to support the foil 2 and walls 7 and 8 of the plenum chamber.

As illustrated in FIG. 2, the upper left-hand quadrant 10 of foil 2 is shown as defined by the dotted horizontal radius line 11 and the dotted vertical radius line 12 and these lines for the purpose of this description have been projected beyond the perimeter of the quadrant. Although the radius of curvature of the foil 2, in FIG. 2, is shown as three-quarters of an inch, the radius may vary over a generally wide range. It has been found that if the radius of the foil is too great, the gas discharged from nozzle 1 will separate from the foil 2 at a line too close to the orifice 4 to be effective in the treatment of web 6. On the other hand, if the radius of the foil is too small, there will then be little tendency for the gas discharged from orifice 4 to follow the surface of foil 2. In actual practice, the foil need not, in fact, be a true circle, and for example, could be elliptical.

The foil member 3 may be a separate member or provided as an extension of the wall 8 of plenum chamber 5, as shown in the drawings, and in such event the foil member 3 is bent toward foil 2 to extend in a direction generally tangential to the curved surface of the foil in quadrant 10 of foil 2. Although the drawings illustrate foil member 3 as a plate, it could be of other configuration, such as bulbous, so long as the member presents a surface extending tangential to quadrant 10.

Thus, the free end of foil plate 3 may extend in a vertical plane and terminate at the projected horizontal radius line 11 of quadrant 10 or the foil plate 3 may extend tangentially horizontally and terminate at the projected vertical radius line 12 of quadrant 10, or at any radius line disposed between lines 11 and 12. This provides a wide range of angles at which the foil plate 3 might be located with respect to foil 2 depending on the requirements needed for the web or surface to be treated. However, the best results in operation of the nozzle of the invention have been obtained with the foil plate 3 terminating to provide nozzle orifice 4 disposed at radius angles of 30° to 45° from the base radius line **11** when a radius of three-quarters of an inch is employed in foil **2**. FIG. **2** illustrates foil plate **3** normal to a radius at an angle of 30° from the horizontal radius line **11** as indicated by the angle so designated on the drawing between line **11** and an angle radius line **14**.

The foil plate **3** is also located generally on a tangent relative to foil **2** to provide the slot-like orifice **4** between the foil **2** and plate **3** through which gas is discharged from plenum chamber **5** against web **6**. The width of the orifice **4** may be varied, but it must be of at least a width so that the gas can be discharged through orifice **4** at a velocity not less than 3,300 feet per minute. To obtain best results the discharge of gas from the orifice should ordinarily be in a thin film and at a high velocity. Nozzles having orifices varying from 0.020 to 0.25 inches in width have been successfully operated, but it is believed that orifices having a width greater than 0.25 inches could in some installations be successfully employed. If the width of the orifice is too small, the orifice may clog with foreign materials, and if the width of the orifice is too great, too much power may be required to flow the gas through the orifice at the velocity desired and thereby make the use of the nozzle uneconomical. When the gas is discharged through orifice **4**, it tends to follow the radius of curvature of foil **2**, but it has been found that it fails to provide the desired turbulence in the discharge jet with velocities less than 3,300 feet per minute. The upper limit of velocity is not a limiting factor other than the horsepower which might be available to pump the gas to chamber **5**. In the case of the use of the nozzle of the invention in web dryers, the higher the velocity, the greater the drying rate.

The gas flowing through orifice **4** from plenum chamber **5** passes to orifice through the tapered passage **15** provided at the discharge side of plenum chamber **5** by foil **2** and the tangential extent of plate **3**. It has been found that to effect the desired taper of the passage **15**, the bend **16** at the juncture between foil plate **3** and plenum chamber wall **8** should be not less than about three-eights inch removed from the terminating end portion **17** of foil **2**. The bend **16** also acts to reinforce foil plate. **2**.

The plenum and collecting chambers with which the nozzle **1** is employed may be of various constructions and are of no importance with respect to the invention except that plenum chamber **5** should be of a size so that there will be no drop in pressure when gas is being discharged through orifice **4**.

In FIG. **1** illustrating a plurality of nozzles **1**, there is also shown a plurality of plenum chambers **5** to which gas is supplied under pressure through pipe **18** from a source, not shown, by means of the common header **19**. After the gas is discharged against web **6**, it flows into a collecting chamber **20** from where it returns, not shown, to the source for recirculation to header **19** through pipe **18**.

As previously noted, the gas discharged toward web **6**, which is illustrated in FIG. **1** as a coated web of paper to be dried, which is passing over the plurality of nozzles **1** there shown, tends to follow the curvature of foil **2**. At the same time since the gas discharged from orifice **4** is at a high velocity as it passes over the streamlined surface of foil **2**, the static pressure of the gas decreases. Consequently, the static pressure of the gas on the foil side of web **6** with the described decrease in static pressure is at a lower pressure than the gas on the opposite side of web **6** and to the rear of the nozzle **1**. The flow pattern of the gas (air) as a result of the decrease in static pressure on the foil side of the web as described and the tendency of the discharged gas as well as the gas or air induced into the area from the rear of the nozzle **1** to follow the curvature curvature of the foil **2**, there shown as of somewhat different construction, is illustrated by the arrows in FIG. **4**. Thus, the arrows show the gas (air) on the opposite side of the web from the foil and to the rear of the nozzle as flowing to the lower static pressure area on the foil side of the web. This flow of gas forces the web **6** toward foil **2**, but the web remains out of contact with foil **2** as it rides on the cushion of air tending to follow the curvature of the foil. The result is that the web **6** remains in a stabilized condition as it passes over nozzle **1** and flutter is substantially eliminated. Consequently, the web never makes contact with foil **2**.

Besides the requirement of discharging the gas at a velocity not less than 3,300 feet per minute, there is a definite relationship between the width of orifice **4** and the distance at which web **6** is maintained from foil **2** since the width of orifice **4** governs the distance between the web **6** and foil **2**. Thus the distance between web **6** and foil **2** will be approximately the same as the width of orifice **4**.

It has also been found that the web **6** can be additionally stabilized by extending the surface of the foil beyond quadrant **10** in either a straight or curved plane.

Thus, referring to FIGS. **3** and **4**, there is shown an airfoil nozzle **1** in which the foil **2** has the surface **21** projected in the direction of the discharge of the gas in a horizontal plane for a short distance from the left-hand quadrant **22** of the foil which has been indicated in FIG. **3** with dotted lines. The radius of the right-hand quadrant **23** of the foil **2**, also indicated with dotted lines, is illustrated as one-half inch and is the same radius as the radius of left-hand quadrant **22** although it is not essential that these radii always be the same. The foil plate **24** projects from the wall **25** of plenum chamber **26** at an angle of 45° with respect to the horizontal radius of airfoil **2**. The remainder of the nozzle and plenum chamber construction correspond to that of FIG. **2** and need not be again described.

With the extended flat surface the of airfoil **2** as illustrated in FIGS. **3** and **4**, there is pressure on the side of the web **6** opposite foil **2** forcing the web **6** as it passes over airfoil **2** and surface **21** toward foil surface **21** over an extended area since the velocity of the gas on the foil side of web **6** remains at the lower static pressure over the extended surface **21** of THE foil **2**. The velocity of the gas of course will drop off at some line or point on surface **21** at which the pressures on both sides of the web **6** will then become equalized. However, the result is that the extended surface **21** provides a longer stabilizing effect on web **6** to the line of separation of the gas from the foil than in the case of the construction shown in FIG. **2**.

In order to impart greater turbulence to the discharged gas such as when the nozzle is employed in the drying of webs, as illustrated in FIG. **4**, the surface of airfoil **2** adjacent the discharge orifice **4** may be provided with an interrupted surface such as a wire or corrugations **27** as shown in FIG. **4**. In addition, in order to boost the velocity of the stream of gas along the foil surface **21** to thereby further extend the line or point of separation of the discharged gas from the foil surface one or more discharge orifices **28** may be provided in the foil surface **21** corresponding to orifice **4** from which the gas is initially discharged.

The airfoil nozzles **1** of the invention have been shown and described with respect to nozzles located on the lower side of the web **6**. However, the nozzles **1** may be located on both sides of web **6** or solely on the upper side of web **6**. The location and use of nozzles **1** depend upon the job to be done and the nozzles may be employed in coating, drying, cleaning, stabilizing or other operations and the web **6** or other surface may move with the nozzles fixed or in some applications web **6** or other surface may be fixed and the nozzles **1** are moved.

The web **6** also is shown as travelling past the nozzles **1** in a direction parallel to the horizontal radius line of the upper quadrants of the airfoil. However, the web **6** or other surface being treated and the nozzles **1** may have relative movement where the movement is not in a parallel plane, but offset therefrom or with either the web **6** or nozzles **1** moving along a curved path relative to the other.

Nozzles **1** can be made in different ways with the foil being a hollow pipe and separate from the foil plate, or of the construction shown in the drawing and described herein.

I claim:

1. An airfoil nozzle for the treatment of surfaces by the discharge of gas from the nozzle without physical contact between the nozzle and surface wherein there is a relative movement between the nozzle and surface being treated with the gas discharged from the nozzle being directed toward said surface, said nozzle comprising a foil of a length to extend across the surface being treated with the gas discharged from the nozzle, a foil member extending along one side of the foil and operatively disposed relative to the foil to provide a restricted orifice between the foil and foil member for passage of gas therethrough at a high velocity toward the surface being treated, a source of supply for said gas connected to said orifice, said foil being curved away from the mouth of the orifice to provide an airfoil effect such that the high-velocity gas tends to follow the curvature of the foil and thereby provides a cushion of gas between the foil and surface being treated, and the high velocity of the discharged gas effecting a decrease in the static pressure of the gas adjacent the foil to a pressure lower than that on the side of the surface being treated opposite the foil tending to force the latter surface toward the foil and to ride on the cushion of gas out of contact with the foil.

2. The airfoil nozzle of claim **1**, in which the source of supply is adapted to supply gas to said nozzle at a velocity of not less than 3,300 feet per minute.

3. The airfoil nozzle of claim **1**, in which the radius of the foil varies from ½ to ¾ inches.

4. The airfoil nozzle of claim **1**, in which the foil member is a plate which extends tangentially to the foil and terminates at a radius disposed at an angle of 30° and 45° relative to the horizontal base line of the upper quadrant of the foil.

5. The airfoil nozzle of claim **1**, in which the foil extends for a substantial distance beyond the orifice of the nozzle and thereby provides a greater area over which gas flows in contact with the surface being treated.

6. The airfoil nozzle of claim **1**, in which the foil member is located with respect to the foil to provide a tapered passage leading to the discharge orifice.

7. The airfoil nozzle of claim **1**, in which the foil downstream of the exit end of the orifice of the nozzle is provided with an interrupted surface to thereby impart greater turbulence to the discharged gas as it passes over the foil.

8. The airfoil nozzle of claim **1**, in which the surface of the foil is provided with at least one restricted orifice opening removed from the first-named orifice and faced in the same direction as said first-named orifice to impart additional velocity to the discharged gas tending to follow the surface of the foil and thereby further project the line of separation of the gas from the foil.

Disclaimer

3,587,177.—*William F. Overly*, Winneconne, and *Kenneth J. Pagel*, Neenah, Wis. AIRFOIL NOZZLE. Patent dated June 28, 1971. Disclaimer filed Dec. 10, 1976, by the assignee, *Overly, Inc.*

Hereby enters this disclaimer to claims 1, 2, 5 and 6 of said patent.

[*Official Gazette February 8, 1977.*]