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(54) Pretreated substrate for slide bead coating.

(57) An apparatus and method for stabilizing slide coating bead edges in which a pair of liquid stripes is applied in advance of the coating bead. Each stripe is positioned to coalesce with a respective edge of the subsequent slide coating bead. Slide bead coating is employed in the manufacture of single- and multi-layered elements such as photographic film.

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FIELD OF INVENTION

This invention relates to slide bead coating. More specifically, this invention relates to slide bead coating a liquid layer or layers onto a moving substrate.

BACKGROUND OF THE INVENTION

Slide-bead coating is a process well known in the art. It entails flowing a liquid layer or layers down an inclined slide surface to an efflux end, or lip, positioned a short distance from a moving substrate. The liquid forms a bridge, or bead, in the gap between the lip and the moving substrate. A vacuum chamber below the bead enables a pressure differential between above and below the bead to be controlled such that the bead position and shape is maintained and the flow through the bead is steady and uniform. The moving substrate carries away liquid from the inventory in the bead in the same layered configuration established on the slide. See, for example, Russell et al., U.S. Patents 2,761,791 and 2,761,419.

Typically, the width of the bead on the coater is controlled by edge guides situated on the inclined surface, and the efflux surface terminus or coating lip. As the liquid flows across the gap between the coating lip and the moving substrate, surface tension forces acting in the bead surface may destabilize the edges of the bead, pulling them away from the edge guide tips, and thus narrowing the coating width and increasing the thickness of the coating at its edges. To compensate for this, the width of the liquid layer on the coater is slightly greater than the desired final width of the film and the thicker edges of the coating are removed prior to drying by application of a slight vacuum. Under stable coating conditions, this arrangement works well to produce films of the desired final width and thickness.

If the coating bead is marginally stable, it contracts slightly greater and increases the thickness of the coating edges. The slight reduction in width may not encroach on the desired final width. But, the heavier edges may not be removed by the application of suction. In the subsequent drying step, these thicker edges are not dried completely because the drying conditions are optimized to the desired film thickness. The partially dried edges are unacceptably tacky causing problems in further processing.

If the coating bead edges are slightly more unstable, the reduction in width does encroach on the desired final width causing significant loss in yield. Ultimately, if the coating bead is sufficiently unstable, it can "unzip" catastrophically resulting in total disruption of the coating process.

Operating the vacuum chamber below the bead such as to create a greater differential pressure helps to stabilize the bead at the desired coating width. However, this method can be ineffective because the required vacuum can be so high as to cause undesirable ribbing patterns in the coating, or edge disturbances which result in a non-uniform coating.

U.S. Patent 4,265,941 discloses the use of a vacuum which is greater at the coating bead edges than along the bead width. This arrangement eliminates undesirable ribbing but still has limited benefit because the greater edge vacuum cannot sufficiently stabilize the edge in many cases and may actually cause edge region instabilities in others. In addition, it is difficult to achieve a beneficial spatial distribution of different vacuum levels since the edge regions affected by high vacuum must be minimized to avoid the aforementioned ribbing.

Another method of stabilizing coating edges utilizes additional flows of a usually low viscosity liquid along the edges of the coating flow on the slide surface. GDR Patent No. 161,033 introduces a low viscosity liquid at the edges of the flow on the coater slide surface via tube outlets positioned atop slide edge guides. In U.S. Patent No. 4,297,396 the low viscosity liquid is introduced at the edges of a coating bead via slots in the edge guides. And, in Japanese Patent Application Publication (A) 63-144347 a shear-thinning liquid is introduced at edges of the coating bead via additional narrow distribution slots on the slide and an additional pair of edge guides for channeling the edge flow. U.S. Patent No. 4,313,980 discloses the use of one or more layers that are wider than the desired coated width. With all of these methods that introduce additional edge flows on the slide, the combined flow must still traverse the gap. Accordingly, they might lessen, but certainly do not eliminate, the problems associated with stability and contracted heavy edges. Moreover, in practice, it is difficult to select suitable edge flow rates, edge liquid properties and a means of introducing the edge flows onto the slide that do not disturb the adjacent coating flow regions.

SUMMARY OF THE INVENTION

In a primary aspect, the invention is directed to a slide bead coating apparatus comprising:

a bead region wherein a flowing film-forming liquid layer or layers is continuously applied to a moving substrate;

a roller, and associated drive means, for conveying said substrate longitudinally through said bead region;

a means for continuously supplying said flowing liquid layer or layers to a slide surface of a coating head;

a coating lip tip at the terminus of said slide surface of said coating head and within said bead region; and

a means for forming a bead of said flowing liquid layer or layers between said substrate and said coating lip tip;

wherein the coating apparatus further comprises:

a stripe coater wherein the moving substrate is initially coated with two liquid stripes which coalesce with the edges of the subsequently applied liquid layer(s).

In a further aspect, the invention is directed to a method for forming a photographic element which comprises a substrate and a film including at least one hydrophilic colloid layer at least one of which is a photosensitive layer; said method comprising the steps of:

supplying a layer or layers of film-forming liquid to the slide surface of a coating head of a slide bead coating apparatus;

flowing said layer or layers into the gap between said substrate and the coating lip tip at the terminus of said slide surface thereby forming a bead region; and

longitudinally conveying said substrate through said bead region wherein said hydrophilic colloid is continuously removed from said bead region in the form of a liquid film coating on said substrate;

wherein the method further comprises:

initially coating two liquid stripes onto the substrate, the liquid in the stripes being capable of coalescing with the film-forming liquid, and the stripes being positioned to coalesce with the edges of the subsequently applied film-forming liquid layer(s); and removing the edges stripes and the volatile components of saidliquid film coating on said substrate thereby forming a substantially rigid hydrophilic colloid coating on said substrate.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a cross-sectional view of a conventional slide bead coating apparatus.

Figure 2 is a cross-sectional view of the bead region of a conventional slide bead coating apparatus.

Figure 3 is a view of one embodiment of the present invention showing the orientation of a liquid stripe to the coating solution and apparatus.

Figure 4 is a view of one embodiment of the present invention showing a nozzle applying a liquid stripe to the substrate.

Figure 5 is a cross-sectional view of the stripe coating region of one embodiment of the present invention.

Figure 6 is a view of one embodiment of the invention which shows the stripes and their relationship to the coating apparatus.

DETAILED DESCRIPTION OF THE INVENTION

Throughout the following detailed description, similar referenced characters refer to similar elements in all figures.

In conventional slide bead coating apparatus, as illustrated in Figure 1, the liquids to be coated, 1 and 2 flow down the inclined slide surface of the plates, 3 and 4, and traverse a gap, 5, between the closest plate, 3, and the substrate, 6, thereby coating the substrate. The substrate, 6, is conveyed by a coating roll, 7. Coating liquid is supplied by an appropriate number of supply pumps 8, 9 which feed into cavities 10, 11 and slots 12, 13 in plates 3 and 4. Coating additional layers requires additional plates and an appropriate number of pumps, cavities and slots. A chamber, 14, and associated pump, 15, controls the gas pressure on the lower surface of the liquid in the gap, 5, such that the pressure at the lower liquid surface is less than the pressure at the upper liquid surface.

Focusing on the gap, or bead, region depicted in Figure 2, coating liquids 1, 2 flow down the slide surface and over the coater lip tip, 16, to form a continuous liquid bridge between the lip surface, 17, and the substrate, 6. The closest distance between the lip tip, 16, and the substrate surface, 6, referred to as the coating gap, 5, is typically 0.1 to 0.5 mm. The differential pressure between the gas above the top liquid surface, usually at atmospheric pressure, and the gas below the bottom liquid surface as applied by chamber, 14, draws the liquid bead into the gap between the lip surface, 17, and the substrate, 6. Typical pressure differentials of 400 to 4000 dynes/cm^2 are applied. The applied differential pressure helps produce a stable bead with a spatially-stationary liquid wetting line, or static contact line, 18, on the coater lip surface, 17, and a spatially-stationary liquid wetting line, or dynamic contact line, 19, on the moving substrate, 6. Typical substrate speeds are 25 to 300 cm/sec.

The stripe coater in the Figure 3 embodiment is a nozzle, 22, with a small exit orifice, 23, and associated liquid supply means 24. The nozzle, 22, is positioned such that the orifice, 23, is close to the substrate, 6, at a lateral location which allows the edge of the bead, 21, to coalesce with the liquid stripe, 20.

Figure 3 depicts an embodiment of the present invention for one coating edge of the liquid layer(s). The other coating edge would be similarly stabilized and is not shown here. A single coating layer, 1, is depicted for clarity. A narrow liquid stripe 20, is first applied to the substrate, 6, via a stripe coater. The stripe-bearing substrate then contacts the coating bead, 21, carrying away a liquid film with the layered configuration established on the slide. The stripe coater in the Figure 3 embodiment is a nozzle, 22, with a small exit orifice, 23, and associated liquid supply means, 24. The nozzle 22, is positioned such that the orifice, 23, is close to the substrate, 6, at a lateral location which allows the edge of the bead, 21, to contact and coalesce with the liquid stripe.

Other methods for applying the advantageous stripes of the invention, other than the specific nozzle orifice depicted in Figure 3 are well known and can be implemented by one skilled in the art. Examples of these methods include, but are not limited to, spray coating such as via spray nozzles as shown in Figure 4, contacting the substrate with applicators of sponge or other porous and wicking material, and gravure wheel coating.

Amongst the various methods, stripe coating via an orifice located closely to the substrate is preferred. Stripes applied by this method are stable, easily controlled, and easily and precisely positioned.

Preferably, the clearance between the nozzle orifice and substrate is 0.05 mm to 0.50 mm, more preferably 0.05 mm to 0.25 mm. These narrow clearances allow the use of thinner and narrower stripes of liquid. Preferably the liquid stripes are approximately the same thickness (within 25%) as the subsequent nominal coating. Hence, the coated thickness of the pre-coated stripe is usually .020 mm to .250 mm but more typically is .05 mm to .100 mm thick. In some instances, it is desirable to coat stripes that are thicker than the subsequent coating. Similarly, in some cases it is desirable to pre coat stripes that purposely result in thick coating edge regions by substantially overlapping the pre-coated channels with portions of the coating bead edge regions. These arrangements may be advantageously used for stabilizing the coating edge. However, the subsequent thick edges usually must be removed prior to or during drying or they must be dryed.

Stripe width is usually 0.1 mm to 10.0 mm, more typically 1.0 mm to 5.0 mm wide. Wider stripes can be beneficial but are less desirable because the additional liquid must eventually be removed. Furthermore, effective stripe positioning becomes difficult as the strip widens since stripe edge stability and contraction of the stripes themselves become problematic.

In a preferred embodiment, the stripe applicator is located at a point along the substrate path closer to the coating lip rather than farther away. The stripes must be present, in liquid form and in contact with the coating bead edges during the coating process to stabilize the coating bead edges. If the stripe applicator is affixed to the structure of the coating head, as depicted for example in Figure 3, stripes coating can commence during start-up when the coating head and substrate are nearly in relative coating position. In most cases, the stripe starts coating the substrate more readily than does the coating bead liquid. An applicator closer to the lip will provide a stripe that subsequently contacts the liquid at the coater lip edge earlier than would occur otherwise. This has the benefit of starting the bead coating at edges earlier than would normally occur without stripes and therefore reduces film loss at coating operation start. In other cases where the bead liquid rapidly coats the substrate, the closer stripe applicator will assure coating bead edge stabilization during the coating start transient before the bead edges become vulnerable to contraction. The stripe applicator embodiment of the type depicted in Figure 3, is preferably positioned within 100 mm of the coating lip. More preferably, they are positioned within 25 mm. Of course, stripe application methods that can apply the stripes continuously regardless of the proximity of the strip applicator to the substrate and/or methods that are not as sensitive to the proximity such as with the spray nozzle in Figure 4 are not subject to these preferences as would be obvious to one skilled in the art. However, stripes applied prior to the vacuum chamber structure by one of the alternate means can have potential detrimental interference with the vacuum chamber structure.

Figure 5 is a cross-section view of a most-preferred embodiment of a stripe application. The nozzle, 32, directs a stream of the stripe liquid, 29, toward the moving substrate, 6. A liquid inlet, 33, is attached to the nozzle for introduction of the stripe liquid, 29. The liquid flows into the open cavity, 30, formed between the nozzle face, 31, and the substrate, 6, and is carried away by the moving substrate. In this embodiment the nozzle is conveniently integrated with the coater structure, 3, facilitating precise alignment with coater edges and attainment of precise clearance with the substrate. Furthermore, the stripe is coated very close to the edge of the coating bead, stabilizing the coating bead edges substantially before they can become vulnerable to contraction after starting the coating process by bringing the coating head and substrate into functional coating clearance.

The location of the stripe liquid inlet, 33, with respect to the entire apparatus is shown in Figure 6 for the most-preferred embodiment of Figure 5. The inlet is preferably adapted to accept a removable couple from a supply means. Any coupling means known in the art such as a threaded bore, compression fitting, quick snap fittings and the like can be employed. Standard supply means such as a direct hookup to a standard water supply line, a reservoir and pump, or the like, which are suitable. Preferably, a flowmeter is included within the supply means as known in the art. The nozzles can be supplied and controlled either individually or in tandem.

The liquid used for the stripes can be any liquid that will wet the substrate and coalesce with the coating bead. Coalescing of the bead edge with a liquid stripe requires that the two are in contact. A meeting of the edges of both or a slight overlap are usually sufficient contact. Preferably, this coalesce is accomplished by choosing a stripe liquid upon which the coating bead liquid will tend to spread. More preferably, the stripe liquid will also be miscible with the coating bead liquid. In addition, the stripe liquid should be suitable for removal either by subsequent drying occurring simultaneously with the drying of the coating in the film drying oven and/or by selective removal either by mechanical means such as by suction or scraping or by focused drying limited to the stripe region such as can be accomplished with, for example, microwave or jet impingement drying. For use with aqueous coatings in particular, the liquid can be water or a predominantly water solution such as a dilute gelatin solution. Surfactants and/or viscosity modifiers such as shear-thinning ingredients can also be included.

The invention described herein is useful for a myriad of flowing liquids including, but not limited to, those with photosensitive and or radiation sensitive layers. These photosensitive and/or radiation sensitive layers may be any which are well-known for imaging and reproduction in fields such as graphic arts, printing, medical, and information systems. Silver halide photosensitive layers and their associated layers are preferred. Photopolymer, diazo, vesicular image-forming compositions and other systems may be used in addition to silver halide. Typically, the desired compositions are formulated into emulsions with hydrophilic colloids. A hydrophilic colloid or gelatin functions as a binder for the composition.

The film support for the emulsion layers used in the novel process may be any suitable transparent plastic or paper. Examples of suitable plastics include, but are not limited to, cellulosic supports, e.g. cellulose acetate, cellulose triacetate, cellulose mixed esters, polyethylene terephthalate/isophthalates and the like. The above polyester films are particularly suitable because of their dimensional stability. During the manufacture of the film it is preferable to apply a resin subbing layer such as, for example, the mixed-polymer subbing compositions of vinylidene chloride-itaconic acid, taught by Rawlins in U.S. Pat. No. 3,567,452, or antistatic compositions as taught by Miller U.S. Patents 4,916,011 and 4,701,403 and Cho U.S. Patent 4,891,308.

The coated element of a photographic film is dryed by liquid medium evaporation. The evaporation is preferably accelerated by conduction, convection and/or radiation heating. Heat transfer can occur through the support such as by physical contact with a heated drum or roller or by direct contact with a gaseous medium such as warm air. Jet impingement of the coated layers with a gaseous medium provides both a heat and mass transfer medium. Radiation to which the photographic element is relatively insensitive can be used to facilitate liquid medium evaporation, and microwave heating.

The invention as described herein is further illustrated in the following examples which are not intended to limit the scope of the invention so described.

EXAMPLES

Two liquid layers were simultaneously slide-bead coated onto a substrate moving at 150 cm/sec. In each case, the upper layer was a 9.2% gelatin-water solution (viscosity = 21 cp) and the lower layer was an 8.8% gelatin solution with 7% AgBr in colloidal suspension (viscosity = 18 cp). The slide coater was equipped with a slide surface approximately 14 cm-wide between edge guides, inclined approximately 23° from horizontal and positioned such that a 0.25 mm gap separated the coating lip and substrate surface. As reported in Table 1, the total flow rate was different for each example and ranged from 8.4 cc/sec to 16.4 cc/sec. In each case, 75% of the total flow rate was underlayer flow and 25% overlayer flow. At each flow rate, a coating was commenced with a differential pressure sufficient to give a continuous, steady coating of width only slightly narrower than that between the edge guides. The differential pressure was then reduced to a critical value below which the coating destabilized. As described previously, increased differential pressure helps to stabilize coating bead edges. Conversely, decreasing differential pressure destabilizes coating bead edges. The critical differential pressure is thus an indication of relative coating bead edge stability. Table 1 displays the critical differential pressure corresponding to coatings at different coating flow rates without the benefit of edge stripes.

TABLE 1

REFERENCE DIFFERENTIAL EXAMPLE	COATING FLOW RATE (cc/sec)	CRITICAL PRESSURE (dynes/cm^2)
1	16.4	1120
2	14.4	1370
3	10.4	1650
4	8.4	2050

Examples 1-4

The reference examples were repeated but with edge stripes coated approximately 20 mm in advance of the coating lip and positioned so that the stripe edge would approximately align with the edge of the edge guide.. The stripes were coated with tap water at a flow rate of 0.19 cc/sec from 1.6 mm diameter exit holes in small blocks. Clearance between the blocks and the substrate was about 0.25 mm. The resultant channel of water on the substrate was 2-3 mm wide.

Table 2 lists the critical differential pressures. In each case, the mode of instability was an excessive stretching of and subsequent disturbance to the coating bead first starting at the central region of the bead width and quickly spreading toward each edge. The disturbance gave the impression of air draw-under and did not appear to be directly associated with the edges in any way. Note that the critical differential pressures in Table 2 are significantly reduced relative to corresponding values for the reference examples in Table 1 and that the realized instability mode is not associated with the edges. This means the edges are significantly stabilized by the presence of the coalescing water stripes.

TABLE 2

EXAMPLE	COATING FLOW RATE (cc/sec)	CRITICAL DIFFERENTIAL PRESSURE (dynes/cm^2)
1	16.4	170
2	14.4	250
3	10.4	370
4	8.4	250

Claims

1. A slide bead coating apparatus comprising:

a bead region wherein a flowing film-forming liquid layer or layers is continuously applied to a moving substrate;

a roller, and associated drive means, for conveying said substrate longitudinally through said bead region;

a means for continuously supplying said flowing liquid layer or layers to a slide surface of a coating head;

a coating lip tip at the terminus of said slide surface of said coating head and within said bead region; and

a means for forming a bead of said flowing liquid layer or layers between said substrate and said coating lip tip;

wherein the coating apparatus further comprises:
a stripe coater wherein the moving substrate is initially coated with two liquid stripes which coalesce with the edges of said subsequently applied liquid layer or layers.

2. The apparatus of Claim 1 wherein said liquid stripes are supplied by nozzles, the exit orifice of which is 0.05 mm to 0.50 mm from the substrate.

3. The apparatus of Claim 2 wherein said stripes exit orifice is positioned 0.05 mm to 0.25 mm from the substrate.

4. The apparatus of Claim 1 wherein said stripes are 0.1-10.0 mm wide.

5. The apparatus of Claim 5 wherein said stripes are 1.0-5.0 mm wide.

6. The apparatus of Claim 1 wherein the coated thickness of said stripes is 20 μm to 250 μm.

7. The apparatus of Claim 6 wherein the coated thickness of said stripes is 50 μm to 100 μm.

8. The apparatus of Claim 1 wherein the liquid stripes comprise water.

9. A method for forming a photographic element which comprises a substrate and a film including at least one hydrophilic colloid layer at least one of which is a photosensitive layer; said method comprising the steps of:
supplying a layer or layers of film-forming liquid to the slide surface of a coating head of a slide bead coating apparatus;
flowing said layer or layers into the gap between said substrate and the coating lip tip at the terminus of said slide surface thereby forming a bead region; and
longitudinally conveying said substrate through said bead region wherein said hydrophilic colloid is continuously removed from said bead region in the form of a liquid film coating on said substrate;
wherein the method further comprises:
initially coating two liquid stripes onto the substrate, the liquid in the stripes being capable of coalescing with the film-forming liquid, and the stripes being positioned to coalesce with the edges of the subsequently applied film-forming liquid layer or layers; and
removing the edge stripes and volatile components of said liquid film coating on said substrate thereby
forming a substantially rigid hydrophilic colloid coating on said substrate.

10. The apparatus of Claim 9 wherein said liquid stripes are supplied by nozzles, the exit orifice of which is 0.05 mm to 0.50 mm from the substrate.

11. The apparatus of Claim 10 wherein said exit orifice is positioned 0.05 mm to 0.25 mm from the substrate.

12. The apparatus of Claim 9 wherein said channels are 0.1-10.0 mm wide.

13. The apparatus of Claim 12 wherein said channels are 1.0-5.0 mm wide.

14. The apparatus of Claim 9 wherein the coated thickness of said channels is 20 μm to 250 μm.

15. The apparatus of Claim 14 wherein the coated thickness of said channels is 50 μm to 100 μm.

16. The apparatus of Claim 9 wherein the miscible liquid comprises water.

FIGURE 1

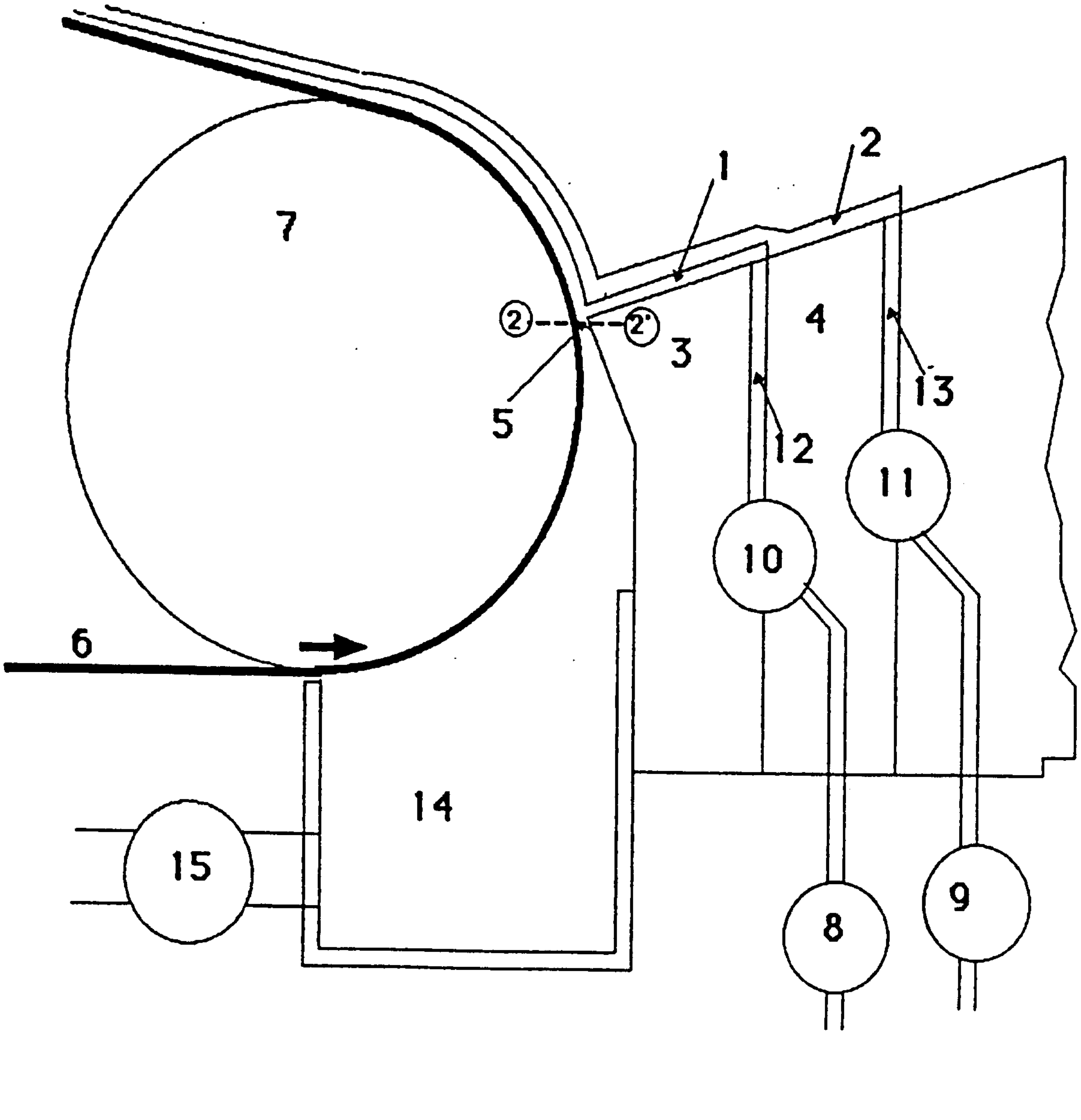

FIGURE 2

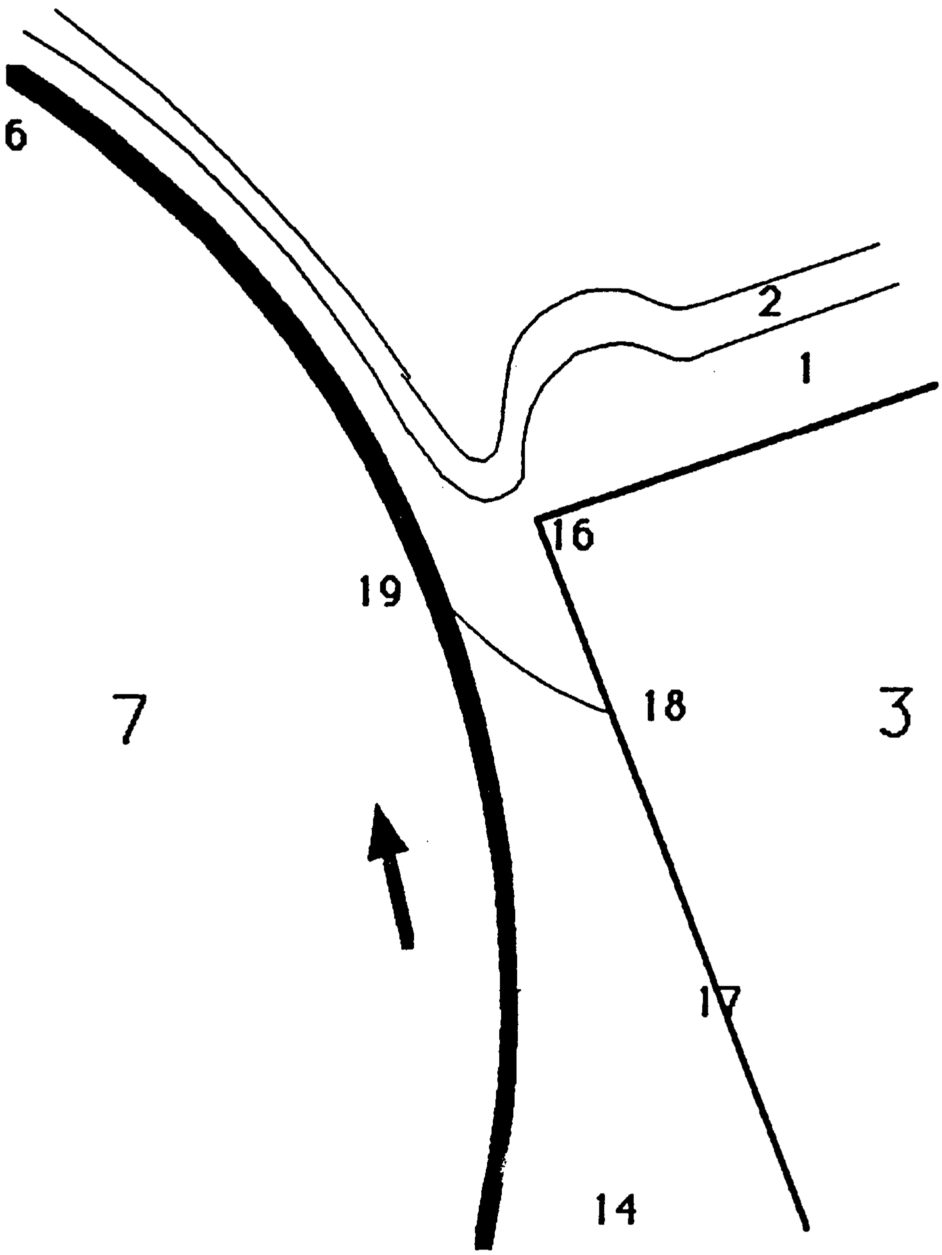

Figure 3

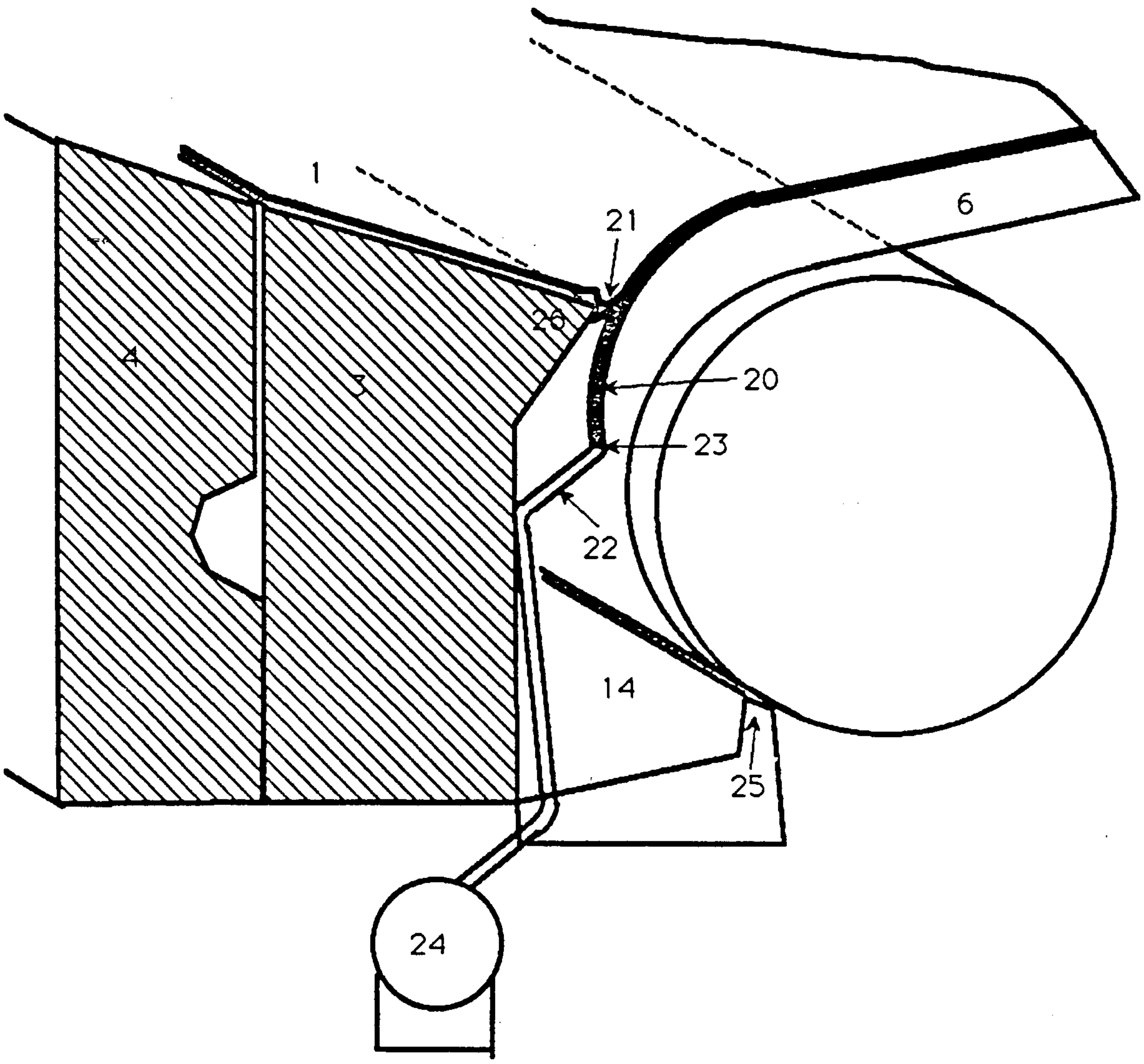

FIGURE 4.

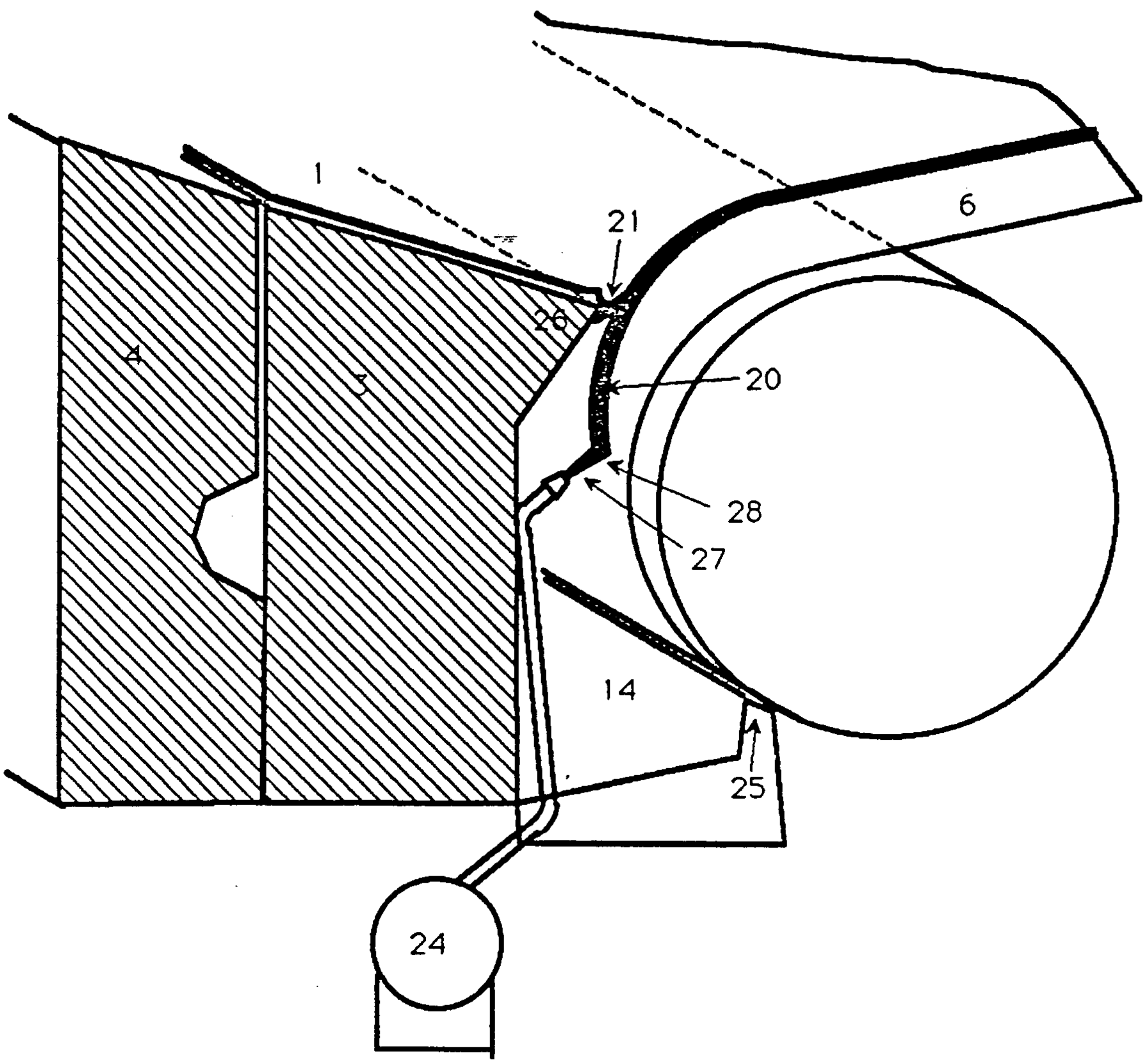

FIGURE 5.

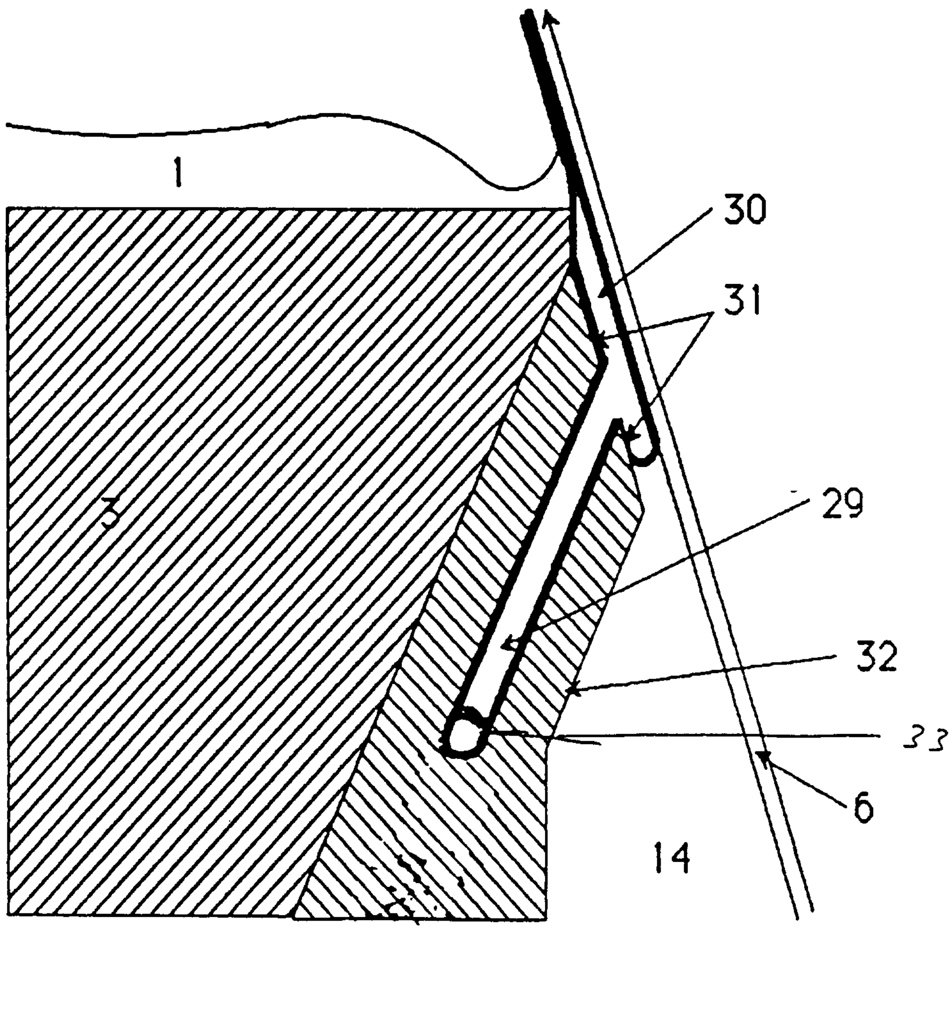

FIGURE 6.