Aug. 8, 1961 C. F. LE CLAIRE 2,995,469

APPARATUS AND PROCESS FOR COATING A FLEXIBLE WEB

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FIG. 1

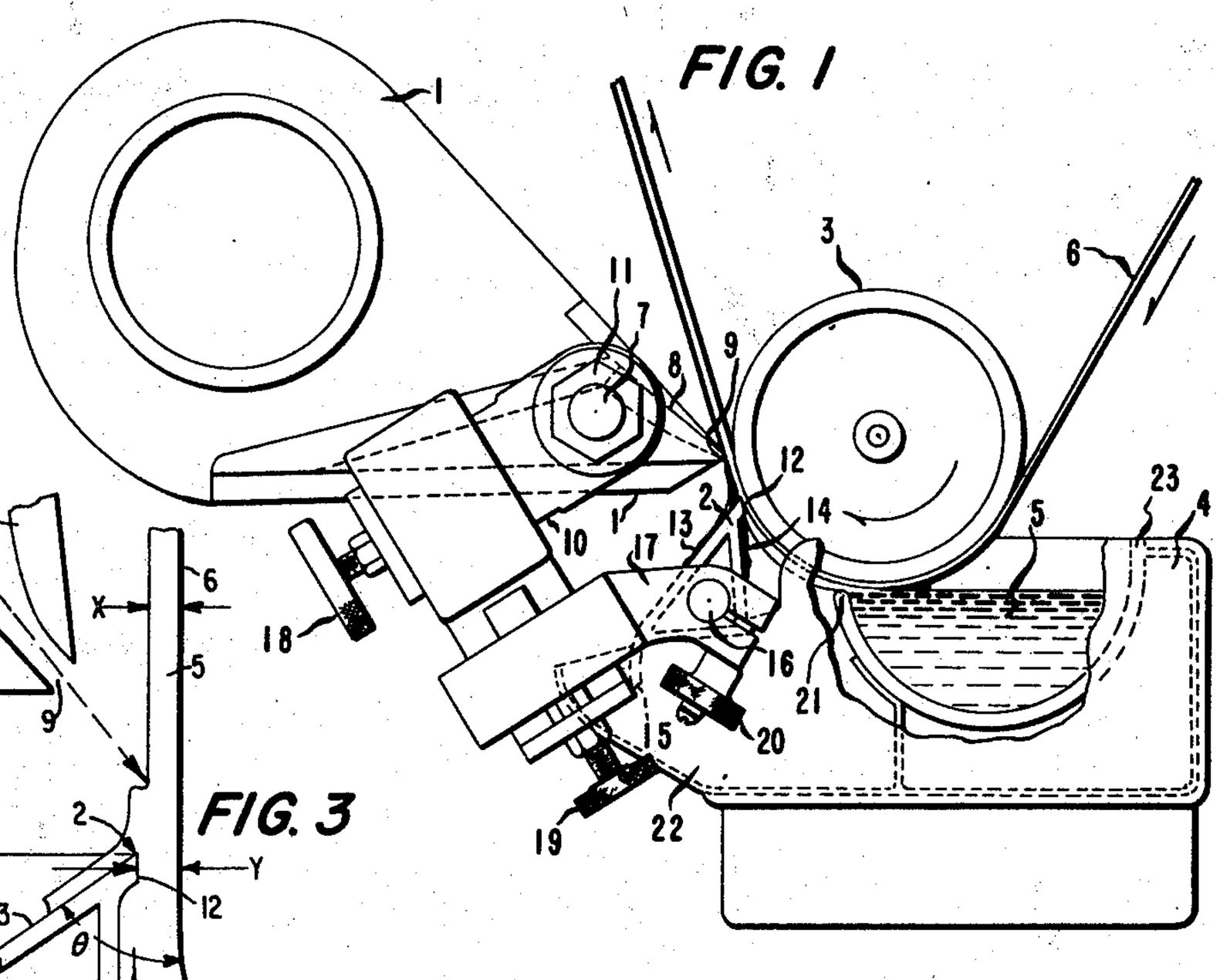
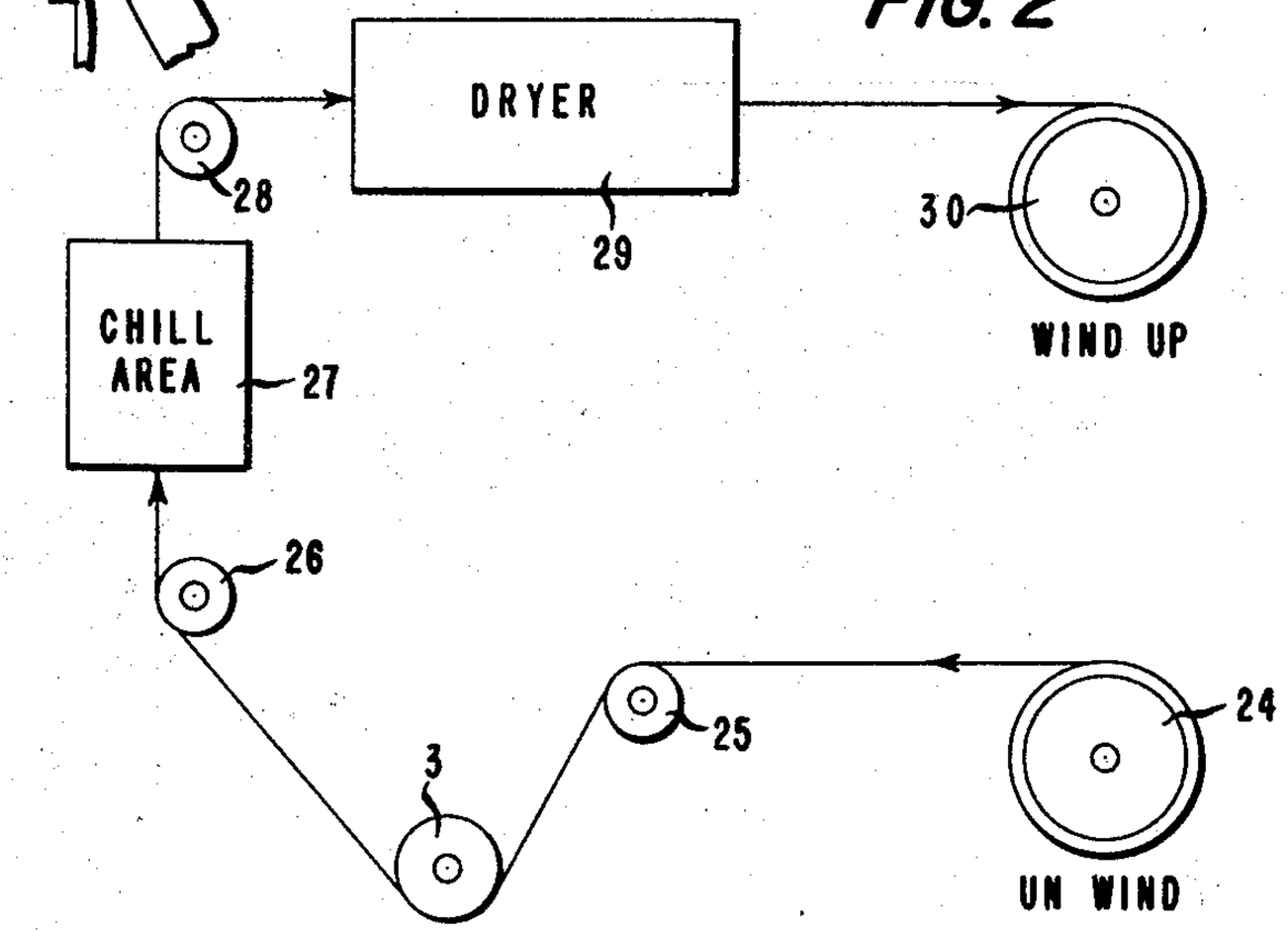


FIG. 3

FIG. 2



INVENTOR
CHARLES FRANCIS LeCLAIRE

BY John Ellsworth Griffiths

ATTORNEY

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APPARATUS AND PROCESS FOR COATING A FLEXIBLE WEB

Charles Francis Le Claire, Little Silver, N.J., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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9 Claims. (Cl. 117—102)

This invention relates to web coating apparatus and more particularly to apparatus for applying to continuous webs viscous aqueous solutions as layers of high uniform quality in the manufacture of photographic films and papers. Still more particularly, it relates to such apparatus for coating viscous water-permeable colloid silver halide dispersions by skim coating onto continuous flexible photographic film supports.

The use of air knives, also referred to as air jets and air doctors, is known in the art of coating photographic material onto supporting webs. The use of doctor blades and similar scrapers or metering contact-type devices for smoothing and regulating thickness of applied coatings is also known.

I have now found that a particular arrangement of a combination of such devices effects a surprising improvement in the smoothness and uniformity of quality of the applied coating. The apparatus according to this invention also unexpectedly permits an increase in coating speed by as much as 300% or more without sacrifice of quality.

An object of this invention is to provide an improved coating apparatus for producing a smooth uniform coating of material onto a travelling web. Another object is to provide such apparatus that permits the coating of viscous liquid materials onto continuous webs over a wide range of speeds. Yet another object is to provide such apparatus that is easily adjustable and accessible for cleaning and maintenance. A further object is to provide such apparatus that eliminates the necessity for spray deflectors and baffles of prior art devices to prevent mist and flying particles from contaminating the coated area of the web. A still further object is to provide such apparatus whereby excess coating material is recycled, reducing the volume and expense of coating material required from the source of supply.

A particular object is to provide improved apparatus having a novel arrangement of component elements by which viscous water-permeable colloid silver halide dispersons can be coated continuously as a thin layer onto a continuous web at a coating speed as high as 400 feet per minute to produce a photographic film element of commercial quality and uniformity having satisfactory sensitometric and other photographic properties. Still other objects will be apparent from the following description of a preferred embodiment of the invention, which will now be detailed with reference to the accompanying drawing, wherein:

FIG. 1 is a side elevation view of the component parts of the apparatus in operational relationship, with a portion of the coating pan broken away for clarity; and

FIG. 2 is a schematic side elevation view illustrating the production of a coated photographic film utilizing the web coating apparatus of FIG. 1.

FIG. 3 is a schematic side elevation view illustrating the relationship between certain parts of the web coating apparatus of FIG. 1.

Referring now to the drawing, the principal elements of the apparatus of this invention include an air knife **1**, a metering device **2**, a coating roll **3** and a coating pan **4**, arranged to apply a thin layer of viscous liquid coating material **5** by the skim coating method to the flexible web **6** continuously advancing in the direction indicated by the arrows.

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The air knife **1** is positioned on and secured to a suitable frame (not shown). The air knife is adjustable as in the prior art to impinge a planar stream of air at any desired angle onto the coated web. A trunnion **7** is fastened at each end of end plate **8** of the air knife near the air oriffice **9**. Trunnions **7** extend a short distance from the end plate **8** to hold upper brackets **10** of the adjusting mechanism for the metering device **2**. The trunnions **7** are threaded to receive nuts **11** for securing the upper brackets **10**.

The metering device **2** is positioned so that its metering lip **12** is parallel to the surface of the coating roll **3** and extends laterally across the roll for a distance at least as great as the width of the web **6** being coated. The metering device is of rigid construction and may be solid or hollow. Besides the metering lip **12**, which is preferably a machined projecting portion adjacent the coating roll as illustrated, the metering device has upper surface **13** and lower surface **14** for guiding excess coating material back into the coating pan. Upper surface **13** is shown sloping downwardly in an arcuate projection **15** to further direct excess material off surface **13** into the coating pan. Trunnion **16** for securing the metering device **2** to its adjusting mechanism is secured at each lateral end of the metering device by means of threads and nuts or, as illustrated, by pinch fits.

The adjusting mechanism is mounted on the air knife so that the precise location of the metering device can be adjusted independently of the air knife. As illustrated in FIG. 3, it is important to be able to adjust accurately the distance Y of the metering lip **12** from the on-running web **6**, the distance Z between the metering device and the air orifice **9**, and the angle θ that the plane of the web forms with the upper surface **13** of the metering device.

The adjusting mechanism in the illustrated embodiment has upper brackets **10** and lower brackets **17** suitably interconnected. Adjusting screw or screws **18** mounted on the upper brackets enable precise advancing and retracting of the metering device to adjust the distance Y of the lip **12** from the web. Adjusting screw or screws **19** similarly enable precise advancing and retracting of the metering device in a perpendicular direction to adjust the distance Z between the metering device and the air orifice. Rotative adjustment of the metering device about its pivotal mount on trunnions **16** serves to regulate the desired angle θ between the web and the upper surface **13** of the metering device. The angle is held by any suitable means such as adjusting screw **20**.

The coating pan **4** can be of conventional design but is preferably divided into separate sections as shown. A reservoir of coating material **5** is supplied from any suitable source such as through an inlet pressure feeding from a source outside the pan. The overflow of coating material over wier **21** flows into trough **22** which serves as a collecting container for the overflow over wier **21** as well as excess coating material flowing down surfaces **13** and **14** of the metering device. The wier **21** is parallel to the surface of the coating roll **3** and is somewhat lower than the back edge **23** of the pan so overflow from the reservoir will occur only in the direction of travel of the web. Coating material collected in trough **22** is led by any suitable means (not shown) back into the flow of coating material feeding to the reservoir, thus eliminating waste and loss of material. The coating pan can be adjustable in a vertical direction and in a right and left direction to permit positioning of the coating pan at the precisely desired location during operation.

Maintenance of the variables referred to above within critical defined limits of position to produce the surprising results herein described will now be set forth.

The coating pan must be in a position relative to the web to apply a surface coating of the coating material

onto the web in a thickness of at least 200% of the final wet coating thickness X desired. It is preferred that a thickness of coating material of from 450% to 550% of the final wet coating thickness be left on the web as it leaves the coating pan. It is preferred that the thickness of the coating applied at the coating pan be controlled by using the wier or forward edge of the coating pan as a metering or doctoring blade.

The metering device **2** is preferably positioned with its metering lip **12** adjacent the web at the place where the web changes direction of forward travel from an arcuate path around the coating roll to a straight planar path leading to subsequent web handling equipment. In other words, it is preferred that the metering lip **12** be located immediately preceding the point at which the outrunning web leaves contact with the coating roll. In this preferred position, the jet from the orifice **9** impinges on the coating material on a portion of the web which is still in contact with coating roll **3**.

It is essential that the metering lip **12** be positioned close enough to the web that the lip acts to remove a part of the freshly applied excess coating material. The outstanding results obtainable according to this invention require that there be no gap or space between the lip and the coating material on the web. It is important that no air, particularly from the air knife, be permitted to pass between the lip and the web. It has been found necessary to position the lip **12** so that it permits an excess of coating material to pass the lip **12**. In particular, the amount of coating allowed to pass the lip as illustrated in FIG. 3 (or, in other words, the distance Y from the lip **12** to the web **6**) must be at least 120%, and preferably 120% to 150%, of the final wet coating thickness X.

The material that is metered by the lip **12** flows down the lower surface **14** of the metering device **2** in a smooth stream to the trough **22**. The angle of position of the lower surface **14** will depend on the shape and construction of the metering device and is not critical.

The air knife must be positioned to direct a stream of air against the coated web at an angle, measured from the plane of the outrunning web (or from the plane of tangents to the roll through the line of impingement of the air stream, if applicable), of from 35° to 90°, and preferably from 45° to 55°. This angle is measured counter-clockwise from the plane of the outrunning web.

The distance Z from the line of impingement of the air stream to the lip **12** may vary depending on such variables as the viscosity of the coating material and the coating speed, and can readily be determined by persons in the art in accordance with the teachings set forth herein. The distance Z for most coating operations generally will be from 1.0 to 5.0 times, and preferably from 2.0 to 3.0 times, the final wet coating thickness.

The angle θ formed by the upper surface **13** of the metering device **2** and the plane of the web at the line of metering by lip **12** has been found to be critical. This angle is measured counter-clockwise from the upper surface **13** and is herein referred to as the angle between the upper surface of the metering device and the plane of the web. It is important that this angle between the upper surface of the metering device and the plane of the web be at least as large, and preferably 5° to 15° larger, than the angle at which air impinged on the coating material is reflected away from the coated surface of the web. Operating in this relative position insures the stability of the flow of air and excess coating material, which is passing downwardly over surface **13**. It should be pointed out that the angle of impingement of air from the air knife will not necessarily be equal to the angle of reflection of the air stream.

In operation, the flexible web is passed around the coating roll, coating material to be applied is delivered

to the coating pan, and the various elements of the apparatus are positioned as described above to effect the coating of a thin layer on the web. With the wier acting partially as a doctor blade, coating material metered by it remains in the coating pan. Coating material metered by the lip **12** flows smoothly and steadily downwardly on surface **14** into the trough. Excess coating metered by the air stream from the air knife, which in prior art air knife coating installations may run back down the web or fly from the web as a spray, mist or fog of particles, is returned to the coating pan in a smooth stream flowing downwardly along the upper surface **13** of the metering device. The possibilities of streaks being formed by the coating material running down the web and the spray, mist or fog settling on and injuring the smoothed portion of the coating are eliminated by this invention.

This invention is particularly useful in the coating of aqueous photographic materials. It is especially useful in the coating of aqueous silver halide dispersions in the various types of natural and synthetic water-permeable colloids as binding agents for the light-sensitive silver halide grains, including gelatin, albumin, agar-agar, water-permeable polyamides, polyvinyl alcohol, partially hydrolyzed polyvinyl esters, hydrophilic polyvinyl acetals including those containing color-former nuclei, and other types of viscous aqueous solutions, particularly those containing colloids.

A preferred use for this invention is in the coating of gelatino silver halide emulsions. FIG. 2 of the drawing schematically represents a convenient arrangement of operations conventionally used for such coating.

Referring to FIG. 2, a supply of web, e.g., film base or paper, from unwind source **24** travels around guide roller **25** in the direction indicated, around the coating roll **3** at the coating station (see FIG. 1), past guide roller **26**, through a conventional chill area **27** where the emulsion is set, around guide roller **28**, through a conventional dryer **29**, and then to windup **30** or other processing operation. Other arrangements may of course be used, as will be readily understood by persons in the art.

While not wishing to be limited by the following explanation, it is believed that the reason for the outstanding results obtainable under the conditions outlined above is that the air stream from the air knife, after it has "cut" off the last excess coating material, is stabilized by the metering device **2** after the air is reflected from the coating and travels in a smooth non-turbulent stream along the upper surface **13** of the metering device. This appears to effect the holding of the excess coating material on the upper surface **13** and directs the flow of the material evenly and smoothly into the trough of the coating pan.

An additional reason for the excellent results, particularly at high coating speeds, is believed due to the fact that, as the excess coating material is cut from the web by the air stream from the air knife, a small puddle or bead of material is formed at the upper part of the juncture between the outrunning web and the upper edge of the metering device. This puddle in effect serves as a reservoir supplying material to any voids which exist in the coating. In this manner, a uniform surface of coating material is presented to the air stream, thereby preventing non-uniformities which might result from flow patterns appearing at the air stream. Without this puddle, these flow patterns would not be eliminated by the air knife action. Thus the attendant advantages of meter blade coating, air knife coating and coating from a bead or puddle are obtained in this novel combination.

Furthermore, the preferred arrangement of component parts has been found to stabilize the air stream, thus preventing an objectionable feature of air knife coating commonly known as air jet chatter.

The invention will be further explained but is not intended to be limited by the following examples:

Example I

Apparatus as illustrated in FIG. 1 of the drawing is arranged with the air stream directed to impinge on the coated web at an angle of about 52° from the plane of the outrunning web. The air knife is positioned 0.1 inch from the web. The air knife pressure is 5.78 inches of water using an orifice of 0.025 inch. The metering device is adjusted with the metering lip 12 at a distance of 0.013 inch from the web. The distance between the line at which the air stream from the air knife impinges on the coating and the upper edge of the lip of the metering device is 0.030 inch. The angle formed between the plane of the web (as defined above) and the upper surface of the metering device is about 68°. A cellulose acetate film base moving at a speed of 220 feet per minute is coated with a gelatino silver bromochloride light-sensitive photographic emulsion having a viscosity of 10.6 centistokes at a temperature of 100° F. and a solids content of 16% by weight. A coating of about 139 mg. of solids per square decimeter is obtained. The resultant emulsion-coated film has excellent quality and uniformity of sensitometric and other properties.

Example II

Example I is repeated except that the air knife pressure is 3.7 inches of water, the distance between the metering lip and the web is 0.020 inch, and the metering device angle with respect to the web is about 65°. An aqueous gelatino silver iodo-bromide light-sensitive photographic emulsion of the X-ray type having a viscosity of 26 centistokes at a temperature of 100° F. and a 16% by weight solids content is coated onto a gelatin subbed polyethylene terephthalate web moving at about 150 feet per minute. A coating of about 227 mg. of solids per square decimeter having excellent quality and properties is obtained as in Example I.

Example III

Example I is repeated except that the distance between the metering lip and the web is 0.007 inch. A web of paper of the light weight document stock type moving at about 150 feet per minute is coated with a gelatino silver bromochloride light-sensitive photographic emulsion having a viscosity of 8.4 centistokes at a temperature of 100° F. and an 11% by weight solids content. A coating of about 30 mg. of solids per square decimeter having excellent quality and properties is obtained as in Example I.

The coating operation is not limited to skim coating methods but is also useful wherein the application of the coating material to the web is accomplished by other methods utilizing an air knife to effect smoothing of the coating. In addition to skim coating, such methods include dip coating, nip roll coating, reverse roll coating, extrusion coating, etc.

In addition to silver halide emulsions, the invention is useful in the application of such coating materials as gelatin sublayers, gelatin filter layers, antiabrasion layers, antistatic layers, etc. The invention is also useful in applying pigmented layers to films and paper webs. Other uses will readily occur to persons in the art.

It will be understood that use of the apparatus of this invention, and equivalent apparatus in the herein described manner, is directed to a novel process for coating a continuous flexible web to apply a coated layer of coating material having a preselected desired final thickness (conveniently referred to as measured while wet, although dry thickness calculations could readily be used with corresponding changes in the ranges set forth below). The process comprises applying to the moving web coating material in a relatively thick layer having a thickness of

at least 200%, and preferably 450% to 550%, of the desired final wet thickness, metering at a first line transverse across the web the relatively thick layer to a lesser thickness of at least 120%, and preferably 120% to 150%, of the desired final wet thickness, impinging at a second line transverse across the web a stream of air against the layer of lesser thickness at an angle of 35° to 90°, and preferably 45° to 50°, measured from the plane of the web at the second transverse line to doctor the layer of lesser thickness to the desired final thickness, the second transverse line being at a distance from the first transverse line of about 1.0 to 5.0 times, and preferably from 2.0 to 3.0 times, the desired final wet thickness, and guiding the air stream reflected from the second transverse line away from the web at an angle measured from the plane of the web at the first transverse line of at least as large, and preferably 5° to 15° larger, than the angle of the reflected air stream also measured from the plane of the web at the first transverse line, while preventing the passage of any air from the impinging or reflected stream from effecting contact directly with the inrunning web at any portion preceding the first transverse line.

A preferred embodiment of the process of this invention, with unexpectedly advantageous results from the standpoint of the sensitometric and photographic quality of the resultant product, is obtained by carrying out the above process wherein the coating material is an aqueous gelatino silver halide dispersion.

If desired, the apparatus described in Lehman, U.S. application Serial No. 642,849, filed February 27, 1957, now U.S. Patent 2,901,376 issued August 25, 1959, may be advantageously used in combination with this invention.

An advantage of the present invention resides in the prevention of the coating material being metered from the web by the metering device from returning along the surface of the web, thus obviating a defect of prior art coating apparatus and methods, namely, the defect which appears as bands of coating material of a thickness heavier than desired running in the direction of the web travel. By carrying out the present invention, these longitudinal bands or stripes are eliminated. Another advantage is that by controlling the path of the coating material doctored by the air knife, no material is thrown from the web at high speeds as spray, mist or fog, thus reducing the danger of coating material contaminating and/or otherwise injuring the smoothed coating surface. Yet another advantage resides in the fact that coatings can be made over a wide range of speeds by apparatus that is easily adjustable and accessible for cleaning and maintenance. A further advantage is that excess coating material is not wasted but can be conveniently recycled, thus reducing the amount needed and the expense of complicated salvaging equipment. A still further advantage is that the air stream from the air knife is completely deflected so that it cannot disturb the surface of the coating material in the coating pan at the point at which the web contacts the coating material in the pan.

An additional advantage is that the air stream is stabilized, eliminating air jet chatter by the proximity of the upper surface of the metering device to the line of impingement of the air stream, and by maintaining the thickness of the layer to be air doctored relatively constant by the action of the metering device. Yet a further advantage is that the entire smoothing apparatus can be conveniently moved out of operating position and returned to operating position with the air knife in a single motion. A particular advantage resides in the fact that light-sensitive photographic emulsions can be applied to photographic film base at speeds as high as 400 feet per minute to obtain coated photographic films of outstanding smoothness and uniformity of quality, with satisfactory sensitometric and other photographic properties. Still other advantages will be apparent from the above description of the invention.

The invention claimed is:

1. A process of web coating comprising applying to a flexible moving web coating material in a relatively thick layer having a thickness of at least 200% of the desired final wet thickness, metering at a first transverse line across the web said relatively thick layer to a lesser thickness of at least 120% of said desired wet thickness, impinging at a second transverse line across said web a stream of air against said layer of lesser thickness at an angle of 35° to 90° measured from the plane of said web through said second transverse line to doctor said layer of lesser thickness to said desired wet thickness, said second transverse line being at a distance from said first transverse line of about 1.0 to 5.0 times said desired wet thickness, and guiding said air stream reflected from said second transverse line away from said web at an angle, measured from the plane of said web at said first transverse line, at least as large as the angle of said reflected air stream measured from the plane of said web at said second transverse line, while preventing the passage of air from said impinging stream and said reflected stream from effecting contact with the inrunning web at any portion of said web preceding said first transverse line.

2. A process as set forth in claim 1 wherein said coating material is a viscous aqueous solution of a water-permeable colloid.

3. A process as set forth in claim 2 wherein said coating material is an aqueous gelatino silver halide dispersion.

4. A process as set forth in claim 1 wherein said relatively thick layer has a thickness of 450% to 550% of said desired wet thickness.

5. A process as set forth in claim 1 wherein said layer of lesser thickness has a thickness of 120% to 150% of said desired wet thickness .

6. A process as set forth in claim 1 wherein said angle of said stream of air is 45° to 55°.

7. A process as set forth in claim 6 wherein said distance is 2.0 to 3.0 times said desired wet thickness.

8. A process as set forth in claim 6 wherein said guiding is at an angle of 5° to 15° greater than the angle of said reflected air stream.

9. In an apparatus for coating a moving flexible web to a desired wet thickness (X) comprising a coating roll for guiding said web, coating means for applying to the web while the web is moving around said coating roll a layer of coating material, a rotatably mounted air knife doctor having an air orifice adjacent to the traveling web for directing a stream of air against the coated layer at an impingement line transverse to the direction of web travel, said angle of impingement ranging from 35 to 90° from the plane of the outrunning web at the impingement line, the combination with said air knife doctor of a metering device, said metering device being connected to said air knife doctor and being located between said coating means and said air knife doctor, the metering device comprising an upper fluid deflecting surface and a lower liquid smoothing surface having a lip portion adjacent and parallel to the surface of the web, said lip portion forming an apex with the upper fluid deflecting surface, said metering device being precisely adjustable horizontally, vertically and rotatively in relation to the web independently of the air knife doctor by an adjusting mechanism having separate screw adjustments, said adjusting mechanism being mounted on the air knife doctor whereby the distance (Y) of the metering lip from the web, the distance (Z) from the apex of the metering device and the air orifice of the air knife doctor range from 1.2X to 1.5X and X to 5X, respectively, and the angle θ measured from the said upper fluid deflecting surface counterclockwise to the plane of the web as the web passes the metering lip is at least as great as the angle of the air being deflected from the coated surface of the web.

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