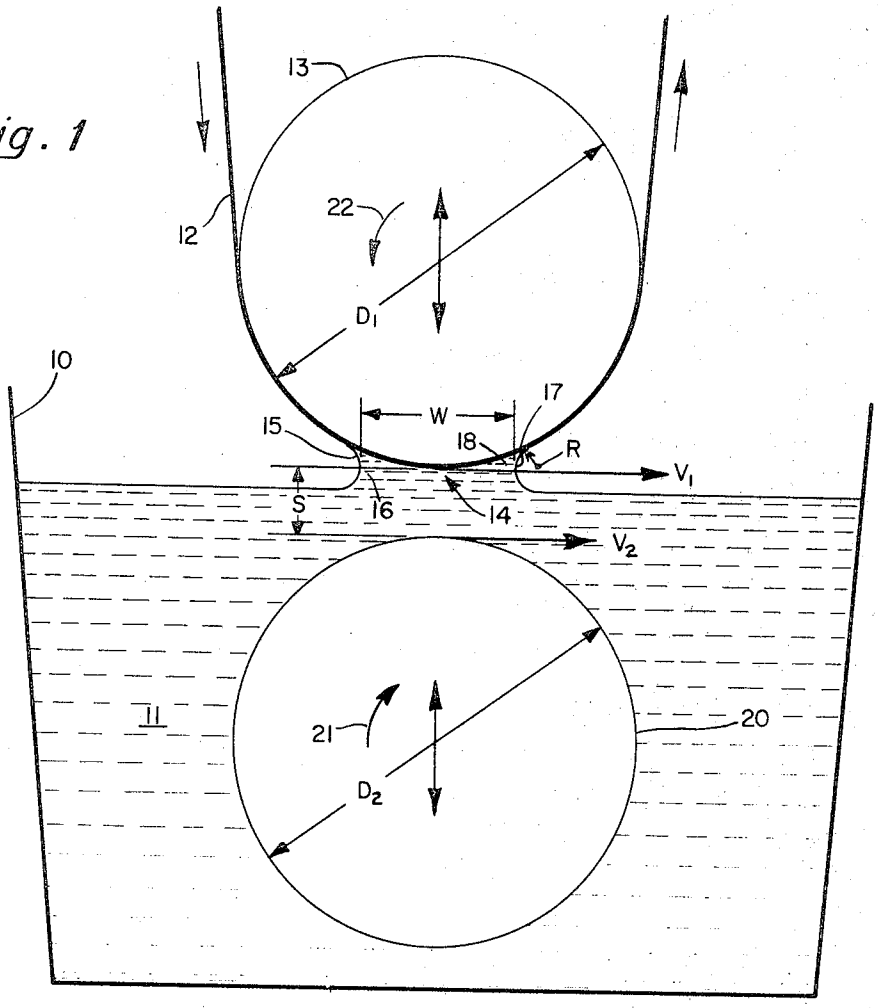
Sept. 1, 1970 A. C. SPENGOS ET AL 3,526,536

PROCESS AND APPARATUS FOR BEAD COATING A WEB

Filed Aug. 28, 1967 2 Sheets-Sheet 1

Fig. 1



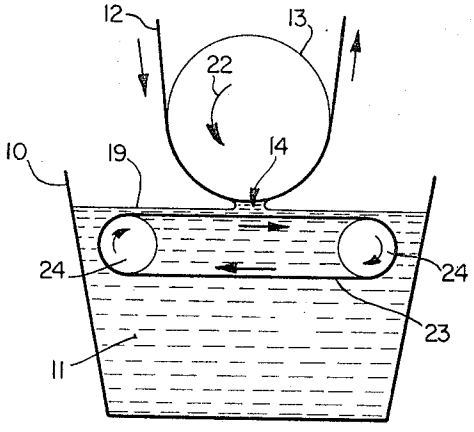


Fig. 2

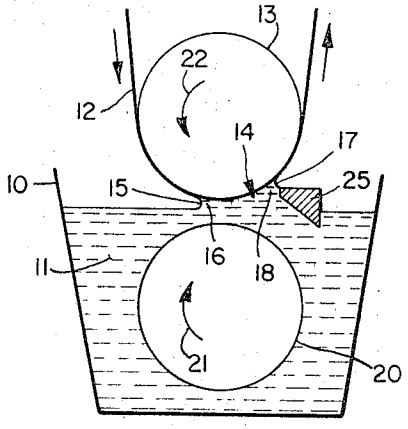


Fig. 3

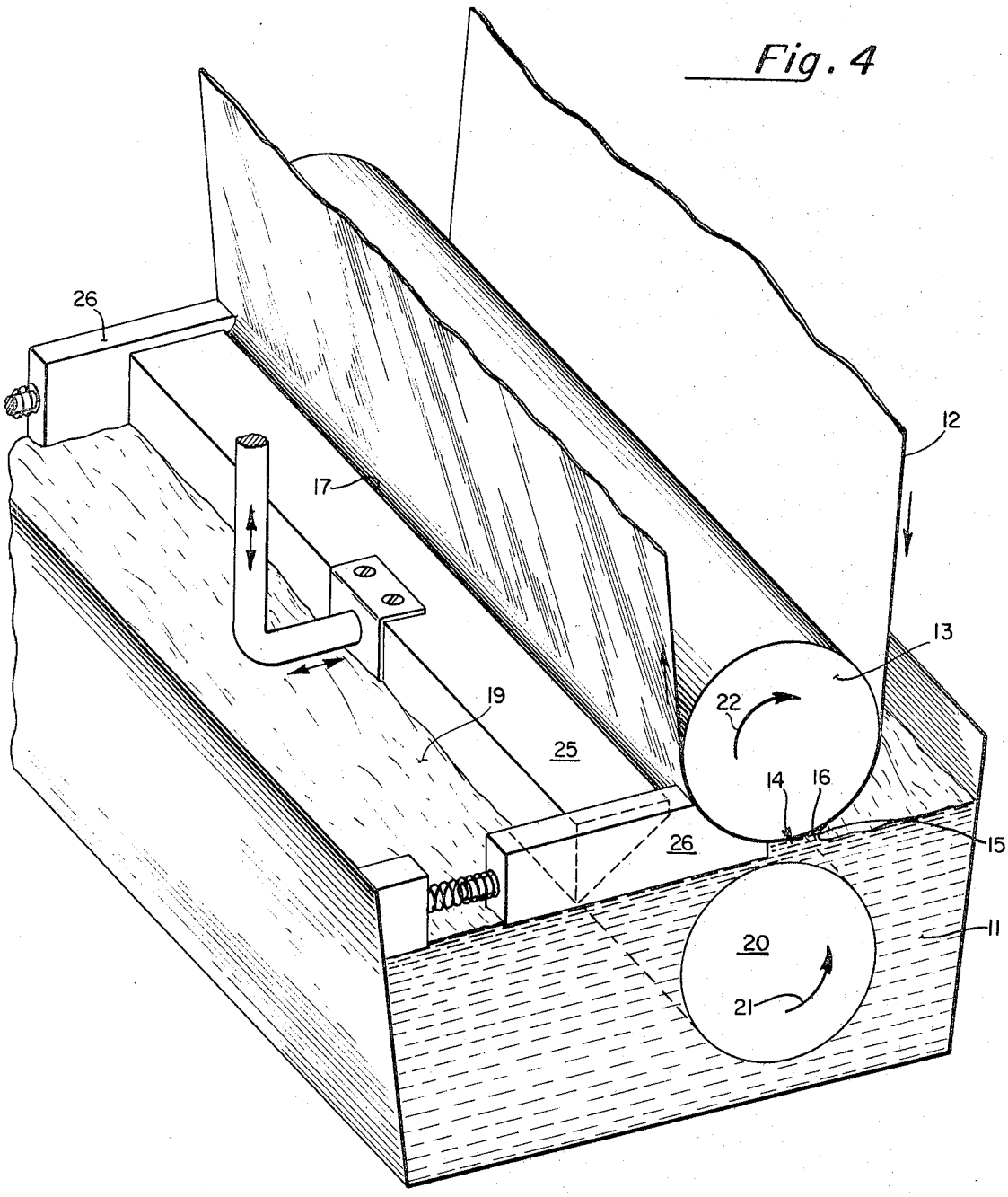
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PROCESS AND APPARATUS FOR BEAD COATING A WEB

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Fig. 4



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3,526,536

PROCESS AND APPARATUS FOR BEAD COATING A WEB

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Int. Cl. B05c
U.S. Cl. 117—120 18 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus are disclosed for applying a liquid to the surface of a web, for example, applying a light-sensitive coating to a plastic strip or film, by the dip coating and bead coating processes. Improvements are disclosed which reduce or eliminate problems experienced in bead coating in which a web to be coated is held by a guide roll in a position where it forms a bead with a liquid to be applied to the web. A moving surface element such as a rotatably mounted roll is employed generally beneath the bead and spaced from the web to be coated, the moving surface element having a direction of motion generally corresponding to the general direction of motion of the web through the liquid in the bead. This imparts motion to portions of the liquid generally beneath the bead and between the surface of the moving web and the moving surface element in a direction corresponding to the general direction of motion of the web through the liquid in the bead. In this manner, the liquid beneath the bead has a more uniform velocity profile. The method and apparatus of the invention reduce or eliminate undesirable streaking of the coating on the web which very often occurs in bead coating. Also disclosed is the incorporation of control means adjacent the web and above the surface of liquid in the reservoir which, in conjunction with the moving surface element, permits coating of a web with a liquid at considerably higher speeds without streaking. The control means is adapted to elevate the meniscus on the trailing side of the bead to a point where it is more remotely spaced from the surface of the liquid than is the meniscus on the leading side of the bead. By regulating the height of the meniscus at the trailing side of the bead, the radius of curvature of the meniscus at the trailing side of the bead along the line of contact between the liquid and the web is controlled and, correspondingly, the thickness of the liquid coating on the web is controlled.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to coating and, more particularly, to a method and apparatus for applying a liquid to a moving web. The method and apparatus of the invention are particularly suitable for the coating of plastic films with light-sensitive materials in liquid form in a manner which reduces or eliminates streaks in the coating even when performed at relatively high speeds.

Description of the prior art

In coating a web with a liquid, it is customary to run the web about a guide roll and into contact with the liquid either by submerging or dipping the web into the liquid in some cases or by creating a coating bead between the surface of the liquid and the web, while the web is supported upon the guide roll. The latter form of coating is conventionally used for preparing light sensitive film materials in which plastic film strips are coated with light-sensitive liquid resins. In both types of coating, it is usually desirable to avoid applying coating material to

the back side of the plastic film, that is, the side of the film contacting the guide roll. One of the problems with dip coating such materials, where total submergence of successive transverse portions of the film occurs, has been the inability to seal the edges of the moving strip to reliably prevent the application of fluid to the back side thereof.

One of the problems experienced with the use of the above-described processes and apparatus in coating films has been the formation of coating abnormalities and imperfections in the resulting coated film. Typical imperfections involve areas of differential coating thickness across the width of the coated web which appear as hills and valleys in the surface of the freshly coated web. In the case of photographic films, when the coating on the web is dried, during which volatile solvents in the coating are evaporated, greater amounts of photosensitive material are deposited in the areas beneath the hills on the surface of the coated web. These heavier deposits of photosensitive materials appear as "streaks" upon subsequent development of the film. Such defects have been more prevalent when the coating has been performed at higher speeds, that is, on the order of 15 feet per minute and higher. Various attempts have been made to eliminate these problems but these have been largely unsuccessful in the past.

Another problem which has hampered any increase in the speed of coating by the above-described method and apparatus has been runback or "curtaining" of the coating down the film surface when it emerges from the liquid. It has been postulated that this problem could be overcome by employing some means of doctoring the liquid coating to remove excesses from the surface of the film as it emerged from the liquid. Although some degree of control has been achieved in this manner, the results have been largely unsatisfactory and speed increases have been minimal. Furthermore, the action of a conventional doctor blade or an air doctor has been damaging to the coating uniformity. None of the prior art processes or apparatus has made it possible to closely regulate and controllably vary the thickness of the coating applied to the web without destroying the coating uniformity and forming streaks.

It is an object and advantage of the present invention to provide a method and apparatus for coating which improves both the speed and the uniformity of coating.

It is a further object and advantage of the invention to provide a method and apparatus for controlling the thickness of a liquid coating applied to a moving web and which reduces or eliminates streaking.

SUMMARY OF THE INVENTION

The coating apparatus of the invention includes a reservoir containing a liquid to be applied to a web and a guide roll rotatably mounted above the reservoir. The guide roll is adapted to guide and support a web to be coated with the liquid as the web moves through a position where it creates an elongate elevated bead of liquid between the web and the remainder of the liquid in the reservoir. The elevated bead of liquid is sustained by surface tension effects and extends transversely across at least a portion of the web. The apparatus includes a moving surface element submerged within the liquid and disposed generally beneath the bead. The moving surface element is adapted to impart motion to liquid between it and the web in a direction corresponding to the general direction of motion of the web through the liquid in the bead. In a preferred embodiment, the moving surface element is a rotatably mounted roll but, in other embodiments, comprises other structures such as a continuous belt mounted for movement along a path beneath the bead. The most preferred embodiment of apparatus of

the invention includes control means disposed adjacent the web and above the surface of the liquid, which control means are adapted to elevate the meniscus on the trailing side of the bead to where it is more remotely spaced from the surface of the liquid than is the meniscus on the leading side of the bead. The control means are movable relative to the surface of the liquid in the reservoir and to the guide roll, enabling regulation of the thickness of the coating being applied to the web. In some embodiments the moving surface element is included in an arrangement of the above-described coating apparatus in which the web is moved through a position where it is submerged in the liquid rather than creating a bead with the liquid.

In the method of the invention, an elongate bead of liquid is formed between the surface of the moving web to be coated and the surface of the liquid to be applied to the web, which bead extends transversely across at least a portion of the width of the web. Motion is imparted to the liquid disposed generally beneath the bead and spaced from the surface of the moving web in a direction corresponding to the general direction of motion of the web through the liquid. This causes the liquid beneath the bead to flow with a more uniform velocity which is believed to eliminate eddies and which reduces or eliminates streaks in the resulting coating. In another embodiment of the method of the invention, the meniscus on the trailing side of the bead is elevated to where it is more remotely spaced from the surface of the liquid than is the meniscus on the leading side of the bead. A more particular embodiment of the method of the invention involves controllably regulating the radius of curvature of the meniscus at the trailing side of the bead along the line of contact between the liquid and the web. This enables regulation and control of the thickness of the liquid coating applied to the web.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional elevation view of coating apparatus of the invention,

FIG. 2 is a schematic sectional elevation view of an alternative embodiment of the apparatus of the invention,

FIG. 3 is a schematic sectional elevation view of a still further embodiment of coating apparatus of the invention, incorporating control means, and

FIG. 4 is a schematic perspective view of the coating apparatus shown in FIG. 3 illustrating one manner in which the ends of the elevated meniscus of the bead are blocked.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a reservoir **10** is shown containing a liquid **11** to be applied to a web **12**. Typically, the liquid **12** may be a light-sensitive resin coating of the type used as a coating upon photographic films. A guide roll **13** is mounted for rotation above the reservoir **10** and generally above the liquid **11** contained therein. The rotational axis of the guide roll **13** is generally horizontal with the surface **19** of the liquid **11** contained in the reservoir **10**. The web **12**, which may be a continuous strip of sheet material, such as metal, paper, or plastic, is fed downwardly into partial wrapping engagement about guide roll **13** and withdrawn in a generally upward direction from the opposite side thereof away from the reservoir **10**.

A bead **14** is formed with the liquid **11** in the reservoir **10** and comprises an elongate upstanding quantity of liquid **11** held against the surface of web **12**, which is supported upon guide roll **13**, and elevated above the surface **19** of liquid **11** in reservoir **10** by surface tension affects creating a meniscus **15** on the leading side **16** of bead **14** and a meniscus **17** on the trailing side **18** of bead **14**.

A moving surface element which is shown as a rotatably mounted roll **20** in FIG. 1, is disposed generally beneath the bead **14**, the roll **20** being driven by drive means (not shown). The direction of rotation of roll **20** is shown by the arrow **21** while the direction of rotation of the guide roll **13** is shown by the arrow **22**. The directions of motion of successive transverse portions of their respective surfaces momentarily facing each other correspond so that the direction of motion of the lowermost portion of web **12** carried upon guide roll **13** corresponds generally to the direction of motion of that portion of the surface of the roll **20** momentarily closest to web **12**.

It has been found that upon rotation, roll **20** imparts motion to the liquid **11** disposed generally beneath the bead **14** and imparts a more uniform velocity to liquid beneath the bead **14**. It has further been found that this reduces or eliminates streaks in the coating applied to the film or web **12** believed to be caused by eddies or other disturbances in the liquid **11** resulting from movement of the surface of the web **12** to be coated through the coating liquid **11** which was previously somewhat stationary. Roll **20** is driven by means (not shown) at a predetermined rotational velocity where its surface speed V_2 bears a predetermined relationship with the speed V_1 of the surface of guide roll **13** which is substantially equal to the speed of the exposed surface of web **12** to be coated. That is, the ratio of V_1 to V_2 is preferably within a predetermined range within which good results are obtained. The diameter D_1 of the guide roll **13** may vary within wide limits as may also the diameter D_2 of the roll **20**.

The roll **20** is generally disposed beneath the bead **14** and spaced from the lowermost transverse portion of the guide roll **13** by a distance *s* generally greater than 0.1 inch. In practice, with a roll **20** having a D_2 of about 3 inches, an *s* of about .5 inch has given the best results. In that instance, a guide roll **13** having a D_1 of about 3 inches was used creating a bead **14** having a *w* of about .75 inch at a coating speed of 20 feet per minute and a *w* of .6 inch at a coating speed of 15 feet per minute.

FIG. 2 illustrates an alternative embodiment of apparatus of the invention in which the moving surface element is in the form of a continuous belt **23** mounted for movement along a path about rolls **24** beneath the bead **14**. The outwardly-facing surface of belt **23** functions in a similar manner as the surface of the rotatably mounted roll **20** functions and generaly increases the velocity of the fluid **11** between the bead **14** and the surface of the belt **23**, thereby promoting flow uniformity and reducing or eliminating streaks in the resulting coating.

Several factors have been found to alter the effect of the moving surface element upon the uniformity of coating. For example, it has been found desirable to maintain the velocity of motion V_1 of the moving surface element at from about 20% to about 150% of the surface velocity V_2 of the guide roll **13** and of the web being coated. There are several factors which affect the precise nature of these limits to some degree, such as relative size of the moving surface elements, viscosity of the liquid, for example, which will be apparent to those skilled in the art. Similarly, the spacing of the moving surface element relative to the web **12** at its closet position should be at least as great as 0.1 inch and preferably is greater than at least 0.3 inch. At positions closer than 0.1 inch, eddies or other flow distortions in the liquid **11** appear to be created causing considerable nonuniformity in the coating. At spacing greater than 0.3 inch, that is up to 0.5 inch and even 0.75 inch, excellent results have been obtained under commercial coating conditions.

It is desirable to utilize generally smooth surfaces on the moving surface elements to promote uniform flow. Surfaces ranging from a high polish down to a roughness approaching various grades of abrasive paper such as sandpaper have been utilized satisfactorily. The degree of roughness desired depends to some extent upon the viscosity of the liquid being coated as well as the closest spacing between the surface of the web being coated and the moving surface element. The use of moving surface

elements having extremely rough surfaces of a coarse nature results in the creation of eddies in the coating liquid and accentuates streaking effects and other nonuniformities in the coating.

The above-described apparatus can be used for performing one embodiment of the method of the invention in which the elongated bead **14** of liquid **11** is formed between the surface of the moving web **12** and the surface of the liquid **11** to be applied to the web. The bead **14** extends transversely across the width of the web **12**. The method also involves imparting motion to the liquid **11** disposed generally beneath the bead **14** and spaced from a surface of the moving web **12** in a direction corresponding to the general direction of motion of the web through the liquid in the bead at the point where the web is closest to the moving surface element. This causes the liquid beneath the bead to flow with a more uniform velocity. In other words, motion is imparted to the liquid **11** in a manner which minimizes the creation of eddies and other disturbances in the liquid **11** adjacent the web **12** and within the bead **14** so that a substantially uniform coating is obtained on web **12** free from streaks or other nonuniformities. Other forms of apparatus might also be utilized to perform the method of the invention which include other means for causing portions of the liquid **11** beneath and within the bead to move in a direction and at a velocity more closely approaching the direction and velocity of the web being contacted by the bead **14** and coated with liquid **11**.

In laboratory tests using a guide roll having a diameter of 3 inches, variations in the radius of curvature of the meniscus at the trailing side of the bead were observed at a series of locations along the bead where the roll surface was withdrawn from the liquid in the bead. The variations in the radius of curvature of the meniscus along the bead resulted in the formation of arcuate ridges which were more noticeable at higher speeds, that is, more noticeable as the velocity of the surface of the guide roll was increased from about 10 feet per minute to about 50 feet per minute and higher. It was observed that the spacing between the arcuate ridges was unequal and the average spacing seemed to decrease with an increase in speed. The arcuate ridges appeared to have a weaving motion so that their locations along the bead continuously changed.

Correlation was established between the formation of arcuate ridges in the meniscus and the presence of streaks in the film coated under those conditions. Apparatus adapted to produce local changes in the radius of curvature on the meniscus on the trailing side of the bead was used during the coating of samples of photographic film with a light-sensitive material. Well-defined coating streaks were found on the film at locations corresponding to the arcuate ridges formed by the above apparatus.

It has been hypothesized that such arcuate ridges are an organized flow instability produced by a particular type of flow pattern beneath the meniscus surface. For such analysis directed to systems similar to meniscus or bead coating see Pearson, J. R. A., "The Instability of Uniform Viscous Flow Under Rollers and Spreaders," J. Fluid Mechanics, 7, 1960, pp. 481–500; and Pitts, E., and Greiller, J., "The Flow of Thin Liquid Films Between Rollers," J. Fluid Mechanics, 11, 1961, pp. 33–50. The common element in each system is the fluid pressure decreasing toward the underside of the meniscus. A disturbance in the meniscus surface is fed by fluid moving into it in response to the pressure gradient. The liquid has a stagnation point at the meniscus surface and in each case there is flow impinging on the underside of the meniscus which forces fluid into a disturbance in the surface. The growth of the disturbance is opposed by surface tension forces, and if the conditions required for an organized instability exist, arcuate ridges will be formed as described above.

In arriving at the method and apparatus of the invention, relation of the flow pattern under the meniscus to the arcuate ridges and of the arcuate ridges to coating streaks was attempted. Apparatus was devised which was effective in improving coating uniformity by changing the flow pattern under the meniscus so that conditions producing arcuate ridges were eliminated. The tendency for a disturbance in the meniscus to be fed and amplified by the flow under the meniscus was reduced or eliminated. It was found that such action could be achieved by a device which reduced the severity of the velocity gradient in the coating fluid directly under the bead. If the coating speed was to be kept constant, the device had to set a portion of the liquid in the reservoir in motion with a velocity in the general direction of web travel within the bead. Although the exact manner in which the apparatus of the invention alters the flow pattern is not known, it is believed that the flow is altered in one or more of the following ways:

(1) The stagnation point is moved down along the meniscus toward the surface of the liquid in the reservoir.

(2) The stagnation point is moved into the bead from the meniscus surface, and flow at all parts of the curved meniscus is in an upward direction.

(3) The conditions bringing about the movement of the stagnation point into the bead, initially or simultaneously, cause a decrease in the stagnation pressure at the stagnation point.

A modified embodiment of the method of the invention includes elevating the meniscus **17** on the trailing side **18** of the bead **14** to where it is more remotely spaced from the suface **19** of the liquid **11** than is the meniscus **15** on the leading side **16** of the bead **14**, while motion is imparted to the liquid **11** disposed generally beneath the bead **14** and spaced from the surface of the moving web **12** in a direction and in a manner described above. In employing the above method, it has been found possible to control the thickness of the liquid coating applied to the web **12**. This is done by controlling the radius of curvature of the meniscus **17** at the trailing side **18** of the bead **14** along the line of contact between the liquid **11** and the web **12**. It is believed that the radius of curvature of the meniscus **17** controls or has an effect upon the surface tension force exerted upon the layer of liquid **11** being applied to the web **12** and, correspondingly, governs the thickness of this coating. The radius of curvature of the meniscus **17** may be changed by varying the height of the meniscus **17** above the surface **25** at the trailing side **18** of the bead **14**.

The following equation, taken from a reference by V. G. Levich, entitled Physicochemical Hydrodynamics, published in 1962 by Prentice-Hall, relates the coating thickness to other variables of a meniscus or bead coating system:

$$h_0=\frac{0.93}{\sqrt{1-\cos \text{ alpha}}}\cdot\frac{(\eta v)^{2/3}}{(\rho g)^{1/2}\sigma^{1/6}}$$

where

h_0=coating thickness
η=dynamic viscosity
σ=surface tension
v=coating speed
ρ=coating fluid density
g=gravitational constant
alpha=angle of withdrawal of coated surface.

For the geometry of the meniscus bead coating system of the invention, a static force balance across the meniscus produces the following relationship:

$$1-\cos \text{ alpha}=\frac{\sigma}{2\rho g}\cdot\frac{1}{R^2}$$

where R=the radius of curvature of the menicus where the coating film leaves the bead.

Substitution of the above relationship into the coating thickness equation presented above yields:

$$h=1.32R\left(\frac{\nu\eta}{\sigma}\right)^{2/3}$$

From the above, it can be seen that the coating thickness therefore, is determined by the meniscus curvature, the coating speed, and the viscosity and surface tension of the solution. From the above, it was also reasoned and subsequently established by test that if the elevation of the menicus **17** at the trailing side **18** of the bead **14** is controllably regulated above the surface **19** of liquid **11** in reservoir **10**, the angle of withdrawal of the surface of web **12** being coated from the liquid in bead **14** is controllably regulated. This results in controlled regulation of the radius of curvature of the meniscus and, correspondingly, controlled regulation of the thickness of the coating applied to web **12**. In the above instance, the viscosity and surface tension of the liquid **11** were held constant.

FIGS. 3 and 4 illustrate an alternative embodiment of the apparatus of the invention capable of carrying out the method of the invention described above. The apparatus includes control means in the form of a blocking member **25** which is disposed adjacent to the web **12** and extends from beneath the surface of the liquid **11** to a point above the surface of the liquid **11**. The blocking member **25** is part of an alternative embodiment of the coating apparatus described with reference to FIG. 1, and like parts have been designated with like reference numerals. The blocking member **25** is adapted to elevate the meniscus **17** on the trailing side **18** of the bead **14** to a point where it is more remotely spaced from the surface **19** of the liquid **11** in the reservoir **10** than is the meniscus **15** on the leading side **16**. That is, when the bead **14** is formed, the space between the blocking member **25** and the bead **14** is filled with liquid **11**. Surface tension between the liquid **11** and the blocking member **25** as well as between the surface of the web **12** and the liquid **11** holds the meniscus **17** on the trailing side **18** of the bead **14** above the surface **19** of the remainder of the liquid **11** in the reservoir **10**. It has been found that when this arrangement of apparatus is utilized for the coating of a web **12**, much higher speeds can be achieved without the creation of undesirable streaks or other uniformities in the web coating.

FIG. 4 illustrates the manner in which the bead **14** extending above the surface of the liquid **11** in the reservoir **10** is retained at each end of the blocking member **25** and at each side of the web **12** being coated. End plates **26** are disposed perpendicularly to the blocking member **25** and extend from the blocking member **25** into sealing contact with each edge of the web **12** wrapping guide roll **13** and passing through the liquid **11**. The end plates **26** contact the web **12** from a point below the meniscus **17** at the trailing side **18** of the bead **14** and extend above the upper surface of the elevated portion of the bead **14** forming meniscus **17**. The end plates **26** are preferably constructed of a material which minimizes friction between the web **12** and the end plates **26** and are preferably resiliently mounted to urge them under light force against the web **12** being coated.

By moving the control means upward or downward while maintaining a predetermined spacing of the portion of the control means adjacent the web being coated, it is possible to control the height of the meniscus at the trailing side of the bead and, correspondingly, its radius of curvature which enables control of the thickness of the coating being applied.

What is claimed is:

1. In coating apparatus, including a reservoir containing a liquid to be applied to a web, and a guide roll rotatably mounted above said reservoir, where said guide roll is adapted to guide and support the web to be coated with said liquid as the web moves through a position where it is submerged in said liquid, said web creating a meniscus with said liquid both as it enters and as it emerges therefrom, the improvement comprising:

a moving surface element submerged within said liquid and disposed generally beneath the submerged portion of said web, said moving surface element being adapted to impart motion to liquid between it and said web in a direction corresponding to the general direction of motion of said web through said liquid.

2. The improvement in coating apparatus according to claim **1**, including control means disposed adjacent said web and above the surface of said liquid, said control means being adapted to elevate the meniscus created between the liquid and the emerging surface of the web to a point more remotely spaced from the surface of said liquid than the meniscus created between the liquid and the entering surface of the web.

3. In coating apparatus, including a reservoir containing a liquid to be applied to a web, and a guide roll rotatably mounted above said reservoir, where said guide roll is adapted to guide and support the web to be coated with said liquid as the web moves through a position where it creates an elongate elevated bead of liquid with the remainder of said liquid in said reservoir, said elevated bead of liquid extending transversely across at least a portion of said web, the improvement comprising:

a moving surface element submerged within said liquid and disposed generally beneath said bead, said moving surface element being adapted to impart motion to liquid between it and said web in a direction corresponding to the general direction of motion of said web through said liquid in the bead.

4. The improvement in coating apparatus according to claim **3**, wherein said moving surface element comprises a rotatably mounted roll.

5. The improvement in coating apparatus according to claim **4**, wherein the rotational axis of said rotatably mounted roll is substantially parallel to the rotational axis of said guide roll.

6. The improvement in coating apparatus according to claim **3**, wherein said moving surface element comprises a continuous belt mounted for movement along a path beneath said bead.

7. The improvement in coating apparatus according to claim **3**, wherein said moving surface element is spaced from said web at its closest position by at least 0.1 inch.

8. The improvement in coating apparatus according to claim **3**, wherein said moving surface element is spaced from said web at its closest position by at least 0.3 inch.

9. The improvement in coating apparatus according to claim **3**, wherein said bead has a leading side and a trailing side, the leading side and the trailing side of said bead each terminating the said web in a meniscus, and wherein said apparatus includes control means disposed adjacent said web and above the surface of said liquid, said control means being adapted to elevate the meniscus on said trailing side to where it is more remotely spaced from the surface of said liquid than is the meniscus on said leading side.

10. Coating apparatus according to claim **9**, wherein said control means include means for retaining liquid at such end of said bead in a position above the surface of the remainder of said liquid in said reservoir in a manner preventing flow of liquid from said bead onto the back side of said web.

11. Coating apparatus comprising

a reservoir containing a liquid to be applied to a web,

a guide roll rotatably mounted above said reservoir, said guide roll being adapted to support a web to be coated with said liquid in a position where said web creates an elongate elevated bead of liquid with the remainder of said liquid in said reservoir, said bead extending transversely across at least a portion of the width of said web and having a leading side and a trailing side, the leading side and the trailing side of said bead each terminating at said web in a meniscus, and

control means disposed adjacent said web and above the surface of said liquid, said control means being adapted to elevate the meniscus on said trailing side to where it is more remotely spaced from the surface of said liquid than is the meniscus on said leading side.

12. A method for coating a web with a liquid comprising:

forming an elongate bead of liquid between the surface of a moving web and the surface of a liquid to be applied to said web, said bead extending transversely across at least a portion of the width of said web, and

imparting motion to said liquid disposed generally beneath said bead and spaced from the surface of said moving web in a direction corresponding to the general direction of motion of said web through said liquid, whereby the liquid beneath said bead flows with a more uniform velocity.

13. A method according to claim **12**, wherein motion is imparted to said liquid in a manner which minimizes the creation of eddy currents in the liquid adjacent said web and within said bead, whereby a substantially uniform coating is obtained.

14. A method according to claim **12**, wherein motion is imparted to said liquid in a manner resulting in more uniform flow velocity along a line extending downwardly from said web through said bead.

15. A method according to claim **12**, wherein said bead has a leading side and a trailing side, the leading side and the trailing side of said bead each terminating at said web in a meniscus, and including the step of:

elevating the meniscus on said trailing side to where it is more remotely spaced from the surface of said liquid than is the meniscus on said leading side.

16. A method according to claim **12**, wherein said bead has a leading side and a trailing side, the leading side and the trailing side of said bead each terminating at said web in a meniscus, and including the step of:

controlling the radius of curvature of the meniscus at the trailing side of said bead along the line of contact between the liquid and the web so as to control the thickness of the liquid coating applied to said web.

17. A method according to claim **16**, wherein said radius of curvature is controlled by changing the height of the meniscus at the trailing side of said bead above the surface of said liquid in said reservoir.

18. A method according to claim **12**, wherein said motion is imparted to the liquid by a moving surface element submerged within said liquid and disposed generally beneath said bead, and wherein said method includes moving said surface element at a velocity of from about 20% to about 150% of the surface velocity of said web.

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RALPH S. KENDALL, Primary Examiner

U.S. Cl. X.R.

117—111, 115; 118—407, 419, 429