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COATING METHOD AND APPARATUS FOR COATING LAYERS OF LIQUID MATERIAL ONTO A SUPPORT

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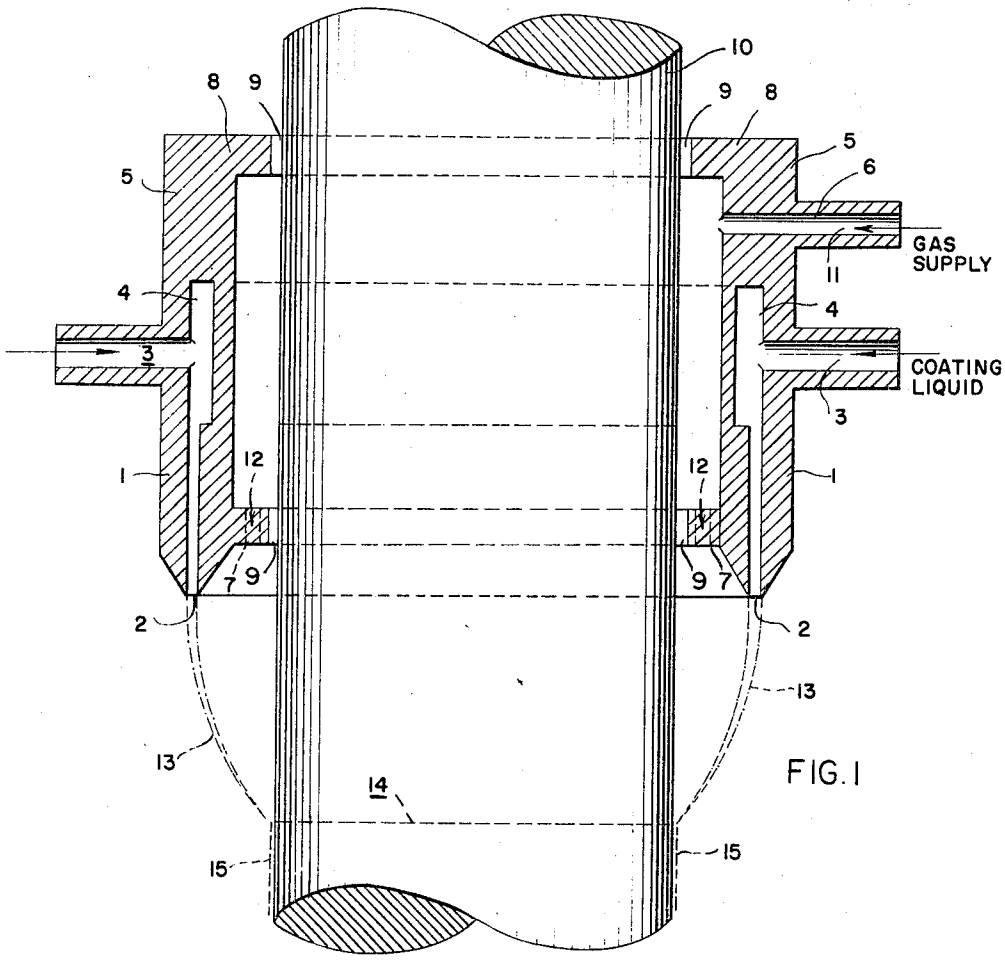

FIG. 1

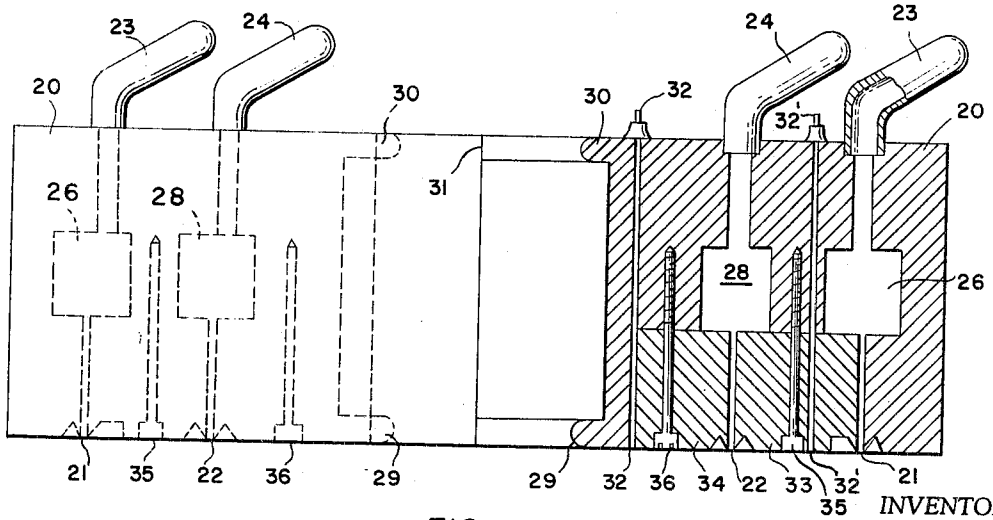

FIG. 2

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U.S. Cl. 117—94 5 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for coating a rod-like support with a layer of liquid which comprises continuously feeding the liquid in a manner to form a uniformly thick annular curtain having the same cross-sectional profile as the support to be coated and which curtain falls freely in a vertical direction. The support to be coated is continuously moved downwardly concentrically within the annular curtain of liquid and becomes coated therewith as the curtain contracts into contact with the periphery of the support. Two or more layers of the same or different liquid can be applied to a support in this manner by forming a free falling annular curtain from each liquid, and concentrically arranging them so that they will all contract upon the surface of a support moved downwardly in concentric relation within the innermost annular curtain.

The present invention relates to a new method and apparatus for coating layers of liquid material onto a support; and more particularly this invention relates to a method and apparatus for forming a highly uniform coating on a support by contracting an annular liquid curtain of the liquid material onto the periphery of a continuous elongated support. Even more particularly this invention relates to a method for forming a flat, coated support by coating a tubular shaped support with an annular curtain of liquid material, and slitting the tubular shaped, coated support to produce a flat sheet with a highly uniform coating on at least one surface.

It is well known in the prior art to coat single or multiple layers of liquids on flat sheet of support by slide or extrusion hoppers such as described in U.S. Pat. No. 2,761,791 issued Sept. 4, 1956, U.S. Pat. No. 2,761,417 issued Sept. 4, 1956, and U.S. Pat. No. 2,761,419 issued Sept. 4, 1956. The hoppers as disclosed in these patents spread photographic emulsions in thin layers across the width of the base material as it travels through the coating machine. There are several disadvantages inherent in the slide and extrusion hopper systems. The evenness of the coating is largely dependent on the precision of the hopper, the emulsions are applied as flat sheets which have inherent edge effects (thick lines of emulsion usually form at the edges of the coating and can be a source of considerable waste), and the speed of coating is limited by the stability of the meniscus between the hopper and base material which inhibits the use of high viscosity emulsions which facilitates quick drying because of the lower water content.

It is also well known in the prior art to coat a layer of liquid onto the surface of an elongated support by passing the support through a liquid reservoir which, in effect, applies a dip coating to the support. In most methods of this type the support is introduced into the tank through a packing below the liquid level in the tank. This coating system also has several inherent disadvantages. The process is limited to a single layer coating unless each successive coating is cured before the next coating is applied. The system is limited to rather low viscosity liquids which will adhere to the support; the low viscosity coatings often result in relatively non-uniform coatings as they are subject to the effects of gravity and uneven air currents during the curing step. The support is also subject to being scratched or marred as it passes through the packing and moreover, the packing is subject to extensive wear during the coating operation causing substantial leakage of liquid from the tank.

Applicants have found a new method and apparatus by which highly uniform layers of liquid material can be coated on a support without the inherent limitations apparent in the prior art. According to the present invention there is provided a method of coating a tubular support with a layer of liquid. This method comprises feeding the liquid in a manner whereby it falls continuously around a substantially vertical axis. The liquid has a surface tension such that the curtain contracts inwardly as the curtain passes downwardly. A tubular support or an elongated rod-like solid support is continuously passed downwardly and centrally within the curtain of liquid. The support meets the contracting curtain of liquid whereby it is coated over the entire periphery as it passes this point of contact with the curtain.

The present invention further provides a tube coating apparatus comprising a housing having two or more annular slots in the base thereof for feeding one or more coating liquids vertically downwards from the housing in closed curtains extending along the slots, each slot being substantially centrally placed within the next outer slot, and conduits for supplying the coating liquid or liquids uniformly to the slots, the housing having an aperture with the innermost conduit through which a tubular body can be fed vertically downwards within the innermost curtain.

In a preferred form of the tube coating apparatus of the present invention a conduit is provided in the housing for supplying gas, under slight pressure, to the space between the tubular body and the inner curtain of coating composition. In this form of the invention, means such as an annular flap may be provided to prevent the gas under pressure from escaping between the inner wall of the aperture housing and the tubular body.

Accordingly an object of this invention is to provide a novel method and apparatus for coating a continuous layer of coating onto the periphery of a support.

It is still another object of this invention to provide a novel method and apparatus to coat a multiple number of layers successively or simultaneously on the periphery of a continuous support.

It is another object of this invention to provide a novel method and apparatus for coating a tubular support with at least one layer of liquid.

Furthermore, it is an object of this invention to provide a method and apparatus for coating a layer of liquid

on a continuous support whereby edge effects may be eliminated and high viscosity liquids may be applied at high coating speeds.

Further objects of this invention will become apparent from the examination of the following description and claims.

The novel features characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and mode of operation, together with the objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIG. 1 is an elevational view in section of an apparatus of the invention having one annular slot for single layer coating.

FIG. 2 is an elevational view in part section of an apparatus of the invention having two concentric annular slots for simultaneously applying two coatings.

In FIG. 1 there is shown an apparatus which was successfully used to apply a single coating to a tubular support. Many of the novel features of this invention are clearly examplified in this embodiment of the invention. Referring to FIG. 1, an annular housing **1** has flanges **7** and **8** extending inwardly at top and bottom of the housing, respectively, to form a pair of vertically spaced and aligned apertures **9** which are of a diameter great enough to permit a tubular support **10** to pass downwardly through the apertures with slight clearance between the edges of the flanges **7** and **8** and the support **10**. The edges of these flanges **7** and **8** may be coated with an abrasive resisting coating, e.g. Teflon, to reduce any wear they might encounter as the result of contact with the tubular support **10**. A conduit **11** is used to supply gas under pressure through the wall of the housing **1** into an enlarged annular space between the upper and lower flanges **7** and **8**. The lower flange **7** contains a plurality of circumferentially spaced conduits **12** to allow gas between flanges **7** and **8** to escape to the space below the housing **1** between the exit from the annular slot **2** and the tube **10**.

The housing **1** has a plurality of circumferentially spaced second conduits **3** leading to the annular chamber **4** which in turn communicates with slot **2**. The annular chamber **4** in an enlarged extension of the slot **2** and functions as a reservoir for the liquid which is in turn extruded through slot **2** to form a liquid curtain around the tubular support. It will thus be seen that conduits **3** and chambers **4** and slot **2** constitute an extrusion type hopper by means of which an annular curtain of the coating liquid can be continuously extruded.

A tubular support is coated by the apparatus shown in FIG. 1 by feeding the coating liquid through conduits **3** into chamber **4** and down through the annular slot **2**. The number and spacing of the conduits **3** into the chamber **4** is such as to ensure an even supply of the composition along the entire length of the slot **2**. The composition thus emerges from the slot **2** in a curtain **13** extending continuously along the slot **2** and commences to contract inwardly as it falls freely. If no tubular body is being fed through the apparatus this liquid curtain will, at some point below the center of the aperture in the housing, contract into a single solid column of liquid.

When the tubular body **10** is passed downwardly through the apertures **9** in the housing **1** it contacts the inner surface of the liquid curtain **13** at a level below the lower aperture **9** indicated by the dotted line **14**. Instead of the liquid contracting into a single column it forms a layer **15** on the surface of the tube **10**. This layer **15** being formed from a curtain of liquid **13** extending all the way round the tube **10** covers the entire periphery of the tube **10**. The position of the level **14** where the liquid makes contact with the tube **10** is dependent on the rate at which the liquid contracts horizontally as it falls

and also on the radial distance of the slot **2** from the tube **10**. It is also dependent on the gas pressure between the tube **10**, and the slot **2**, the flange **7** and the curtain **13**. The gas pressure may be atmospheric or it may be varied to change the point of contact between the liquid curtain and the support. Preferably, the downward speed of the feed of the tubular support **10** is adjusted so that it is equal to the downward fall of the liquid at level **14**. The liquid, in fact, actually contracts onto the tube since there is no relative vertical movement of the liquid and the tube. It has been found that the layer **15** is very uniform in thickness, both peripherally and longitudinally with respect to the support. The gas supplied through conduit **6** under pressure through the wall of the housing **1** into the enlarged annular space between the upper and lower flanges **7** and **8** positions the support concentrically within the flanges **7** and **8** and concentrically of the annular liquid curtain falling from the slot **2**.

The type of gas fed into conduit **6** is dependent on the coating liquid and the final product. Compressed air is normally used for economical reasons, but inert gases, such as nitrogen can be used if the coating reacts with the oxygen in compressed air. The use of inert gas prevents the formation of deleterious materials at the interface of the coating and the tubular support.

The apparatus according to this invention can be used to coat the same liquids and with a similar manner of preparation of the liquids as disclosed by U.S. Pat. 2,761,-791 issued Sept. 4, 1956, U.S. Pat. 2,761,417 issued Sept. 4, 1956, and U.S. Pat. 2,761,419 issued Sept. 4, 1956 which are incorporated herein by reference. These liquids include aqueous gelatin solutions and liquids of similar viscosity. The liquids need not be homogenous; for example, silver halide emulsions can be coated by the method of the present invention. Solutions from which film base, e.g. cellulose acetate, and other sheet materials are cast can be coated onto the surface of a tubular support by the present method. The coated tube can then be fed through a solvent evaporating chamber and the cast film then slit and stripped off or, preferably, the cast film while still on the casting tube is coated to form a photographic multilayer film in further steps based on the method of this invention. Furthermore the casting of the film base and the coating thereof with photosensitive emulsion can be carried out with one coating housing having multiple annular slots as will be set forth in greater detail in the remainder of this disclosure. The supports which can be coated by this novel method can be either hollow or solid. A solid support, such as an electrical wire, can be coated with either single or multiple layers. For example, the method and apparatus of the present invention can be used to coat cables with polyvinyl chloride or other insulating materials. The shape of the support can also be varied by adapting the coating hopper to conform to the shape of the support. A solid ellipsoidal support can be coated with a uniform layer by forcing the coating liquid through an ellipsoidal slot of relative size and shape to the support. Also, an extruder can be used to supply a hollow tube or continuous flat web may be formed into a tube by bringing the edges together, the tube then being fed through the coating apparatus. Such a tube can be supported by air nozzles throughout the subsequent drying or setting steps to avoid contact of the coating with abrasive rollers or guide means. It can be appreciated that a hollow flexible tube coated by this invention can be slit longitudinally and formed into a flat coated sheet exhibiting no edge effects.

The term "edge effects" as used in this application is used to describe the formation due to surface tension, of a thick bead of coating composition, e.g. silver emulsion, along one or both edges of a flat film or paper base; this bead requiring extra drying time and subsequent removal of that part of the base. The elimination of edge effects is particularly valuable in preparing photographic

film and paper since avoidance of edge effects results in appreciable savings of material, drying capacity and time.

The coating achieved by this method and apparatus are particularly desirable as a sufficiently smooth and uniform coating can be obtained for most purposes without the use of doctor blades, air knives or similar devices. Thus, one skilled in the coating art can readily appreciate the simplicity of this apparatus in the achievement of layers of critical thickness.

In further explanation of the coating process according to the invention it is to be noted that the speed of fall of the liquid increases with the distance it falls freely before contacting the tubular body (hereinafter called the tube for convenience). Preferably, for uniformity of coating, the speed and direction of movement of the tube and the liquid at the point of contact are most nearly alike. If the tube is moving downwardly faster than the liquid, the coating will be thinner than the curtain; the downward speed of the tube is preferably not so high, however, that the coating becomes discontinuous. If the tube is moving more slowly than the liquid at the point of contact, the coating will be thicker than the curtain but will also tend to form ridges around the tube. The initial speed of fall of the liquid can be increased by increasing the pressure of liquid in the slot.

For evenness of coating in the present invention, the liquid encircling the tube is allowed to fall before contacting the tube for a period preferably long enough to allow the liquid to stabilize which is indicated by a horizontal section of the liquid acquiring a uniform thickness. This period can be increased by causing the liquid to follow a more outwardly curving path, e.g., by creating a gas pressure inside the curtain, that is in the space between the tube and the curtain, or by using a tube of smaller diameter in which case the liquid falls further before it contacts the tube. This same effect can, of course, be achieved by the use of a hopper with a large slot diameter in which case the annular liquid curtain will fall further before it contracts to a point when it meets the tube. It will be noted that to create a gas pressure inside the curtain, gas must be supplied continuously to replace that which escapes if there is an appreciable gap between the tube and the flanges on the housing.

The distance the liquid falls before contacting the tubular body also controls the thickness of the curtain of coating at the coating point. The annular slot of a coating apparatus of the invention may have, for example, a width of 0.010 inch and such a slot may be used to form a coating 0.001 inch thick with adjustment of the downward speed of the tubular body at a rate approximately 10 times the downward speed of the curtain as it leaves the slot.

By allowing the liquid in the curtain to stabilize before contacting the tube and adjusting the relative speeds of the falling liquid and the downwardly moving tube so that they are most nearly alike at their point of contact, coatings of very uniform thickness can be obtained. The similarity in speeds of liquid and tube at the point of contact reduces the shear in the liquid at the point of contact with the tube and makes possible the production of satisfactory coatings using liquids of high viscosity, e.g. of 80 c/stokes.

The methods of the present invention may be modified to form a multilayer coating on the tube. According to the present invention there is provided a method of coating a tubular body with at least two superimposed layers of one or more liquids which comprises feeding the liquid or liquids so that they fall continuously round a substantially vertical axis, the liquid or liquids having surface tensions such that the curtains contract inwards as the liquids fall and continuously feeding the tubular body downwards along said axis and centrally within the innermost curtain of liquid whereby the tubular body meets the contracting curtains successively from the innermost to the outermost and is thereby coated over its entire periphery with successive layers of the liquids as it passes its points of contact of the curtains.

In the multilayer coating method of the invention the liquid or liquids may fall in concentric curtains without touching one another, thereby to contact the tubular body at different points, or may fall at first in concentric separate curtains and then in at least one combined curtain formed by an outer curtain contracting inwardly onto an inner curtain before the liquid in the inner curtain contacts the tube. The combined curtain consists of an outer layer of the liquid in the original outer curtain and an inner layer of the liquid in the original inner curtain.

This coating process can be used very effectively to simultaneously coat a number of photographic emulsion layers on a support. The annular hopper is designed to have an equal number of annular reservoirs and slots which correspond with the number of layers being coated on the support.

Referring to FIG. 2, an annular housing **20** has two concentric annular slots **21** and **22** at the base thereof and pairs of conduits **23** and **24** entering the top of the housing **20**. The pair of conduits **23** is arranged to enter the housing **20** at diametrically opposed points above the slot **21** and the pair of conduits **24** to enter the housing **20** at diametrically opposed points above the slot **22**. Each pair of conduits **23** and **24** leads down into an annular chamber; the pair **23** into chamber **26** and the pair **24** into chamber **28**. The chamber **26** is directly above and opens through its base directly into the slot **21** and the chamber **28** is directly above and opens directly into the slot **22**. The chambers **26** and **28** are reservoirs for the coating liquids. The number of pairs of conduits associated with each slot is sufficient to ensure that the coating liquids are distributed evenly to each slot. Only two pairs of conduits, namely **23** and **24**, are shown in this figure. Instead of annular chambers **26** and **28** as shown, a plurality of circumferentially spaced chambers may be provided above each of the slots **21** and **22** which may be fed by a plurality of circumferentially spaced conduits **23** and **24** to insure a uniform distribution of the coating liquid along the entire length of each of slots **21** and **22**.

The annular housing **20** has flanges **29** and **30** extending inwardly from the bottom and top of the housing to form aligned apertures **31** which are of a diameter great enough to allow a cylindrical tube, not shown, to pass downwardly through them with a slight clearance between the edges of the flanges **29** and **30** and the tube. The housing **20** also comprises two vertical gas conduits **32** and **32'** which are disposed inwardly of the slots **21** and **22** respectively to permit gas to be passed through the housing to the spaces below the housing on the insides of the liquid curtains which emerge from the slots **21** and **22** respectively to permit gas to be passed through the housing to the spaces below the housing on the insides of the liquid curtains which emerge from the slots **21** and **22** respectively.

It will be found convenient in constructing the apparatus shown in FIG. 2 to form the slots **21** and **22** by inserting annular rings **33** and **34** into a suitably recessed housing. These rings **33** and **34** are held in place by retaining screws **35** and **36** which are tapped into the upper part of the housing **20**.

To use the apparatus shown in FIG. 2, one coating liquid is fed through conduits **23** down through mixing chamber **26** and out of slot **21**. Another coating liquid is fed through conduits **24** and mixing chamber **28** and down to and out of slot **22**. Each coating liquid forms a curtain which extends along the entire length of its corresponding slot and which completely surrounds the aperture **31**. As each liquid falls it forms a continuous circular curtain which contracts. The tube to be coated is fed continuously downwards through apertures **31** and meets the contracting curtains at a point or points

below the housing **20** and is fed past these points carrying the multilayer liquid coating thereon.

According to the present invention there is also provided a tube-coating apparatus comprising a housing having an annular slot in the base thereof for feeding a liquid vertically downwards from the housing in a closed curtain extending along the slot and a conduit for supplying the coating liquid uniformly to the slot, the housing having an aperture within the slot and conduit through which a tubular body can be fed vertically downwards within the curtain of liquid.

The annular slot in the coating apparatus of the invention need not be circular; it may be elliptical for example. The slot need not be continuous but if it is not continuous the separate parts of the slot must be close enough together to enable the parts of the liquid curtain falling therefrom to coalesce to form a closed curtain. The slot may not be continuous because of constructional requirements; for example, struts across the slot may be required for strength. However, the slot is preferably sufficiently long along the direction of flow of the liquid to allow the composition to achieve even flow before it leaves the slot.

Although the invention has been described in considerable detail with reference to certain preferred embodiments thereof, it will be understood that variations and modifications can be effected without departing from the spirit and scope of the invention as described hereinabove and in the appended claims.

What is claimed is:

1. A method for applying a layer of coating liquid onto one periphery of an elongated rod-like support comprising the steps of:

continuously feeding said liquid into an annular orifice to form an annular curtain thereof having a cross section corresponding in configuration to, but larger than, the periphery of said support;

directing said annular curtain in a substantially vertical downward direction without physical restriction so that the surface tension of the liquid contracts said curtain uniformly toward its axis as it moves downward;

moving said support concentrically within and along the axis of said annular curtain in the direction of movement of said curtain until said curtain contracts onto the periphery of said support while continuously supplying a gaseous fluid to the region between said support and the liquid curtain, and controlling the pressure of said gaseous fluid to vary the point at which the liquid coat contracts onto the periphery of the support.

2. A method for coating the periphery of an elongated rod-like support with multiple layers of liquids comprising the steps of:

feeding each of said liquids through separate and concentrically arranged orifices to form annular curtains of each liquid which are concentric with one another and each having a cross-section corresponding in configuration to, but larger than, the periphery of said support;

directing each of said annular curtains in a substantially vertical downward direction without physical restriction so that the surface tension of the liquids contract said curtains uniformly toward their common axis as they move downward;

moving said support concentrically within and along the axis of the innermost of said annular curtains in the direction of movement of said curtains until the curtains contract onto the periphery of said support in superposed relation while continuously supplying a gaseous fluid to the regions between the innermost curtain and the support and between the respective concentric liquid curtains;

and controlling the pressure of said gaseous fluid to vary the point at which the innermost liquid curtain contacts the support and to vary the point at which each of the other liquid curtains contacts the liquid curtain immediately within it.

3. Apparatus for coating an elongated rod-like support with a uniform layer of liquid as it moves continuously downward in a substantially vertical direction and comprising:

an annular hopper adapted to encircle said support;

means for continuously supplying the coating liquid for said hopper;

an annular discharge orifice communicating with the interior of said hopper encircling and spaced radially from said support, said discharge orifice so shaped and directed downward as to form the liquid issuing therefrom into a free falling annular curtain of liquid corresponding in shape to said support and which, by reason of the surface tension of the liquid, will, as it falls, contract uniformly toward its vertical axis until it engages and becomes coated on the periphery of said support;

and means for supplying a gaseous fluid under pressure to the region between the support and the liquid curtain to vary the point of contact of the liquid on the support.

4. Apparatus for coating an elongated rod-like support with a uniform layer of liquid as it is moved continuously downward in a substantially vertical direction and comprising:

an annular hopper adapted to encircle said support;

said hopper including two axially spaced flanges which closely embrace said support and are bounded by a longitudinal wall to form in combination with the support an air chamber having restricted outlets;

means for continuously supplying the coating liquid to said hopper;

an annular discharge orifice communicating with the exterior of said hopper encircling and spaced radially from said support, said discharge orifice so shaped and directed downward as to form the liquid issuing therefrom into a free falling annular curtain of liquid corresponding to said support and which, by reason of the surface tension of the liquid, will, as it falls, contract uniformly toward its vertical axis until it engages and becomes coated on the periphery of said support;

and means for supplying a gaseous fluid under pressure to the air chamber to position the support concentrically of the annular liquid curtain by the gas supplied to the air chamber.

5. Apparatus for coating an elongated rod-like support with multiple layers of liquid materials as it is moved continuously downward in a substantially vertical direction and comprising:

an annular hopper adapted to encircle said support;

at least two separate reservoirs in said hopper;

means for continuously supplying one liquid to one reservoir and another liquid to the second reservoir;

a separate annular discharge orifice communicating with each of said reservoirs and being concentric and spaced relation to each other and said support, each of said discharge orifices so shaped and directed downwardly as to form the liquid issuing therefrom into a free falling annular curtain of liquid corresponding in shape to said support and which curtains, by reason of the surface tension of the liquids, will, as they fall, contract uniformly toward their common vertical axis until they engage and become coated on the periphery of said support in superposed relation;

and means for supplying a gaseous fluid under pressure to the region between the innermost annular curtain and the support to vary the point of contact of that curtain on the support;

and means for supplying a gaseous fluid under pressure to the region between adjacent annular cur-

tains to vary the point of contact of said curtains with one another.

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