

Feb. 11, 1947.

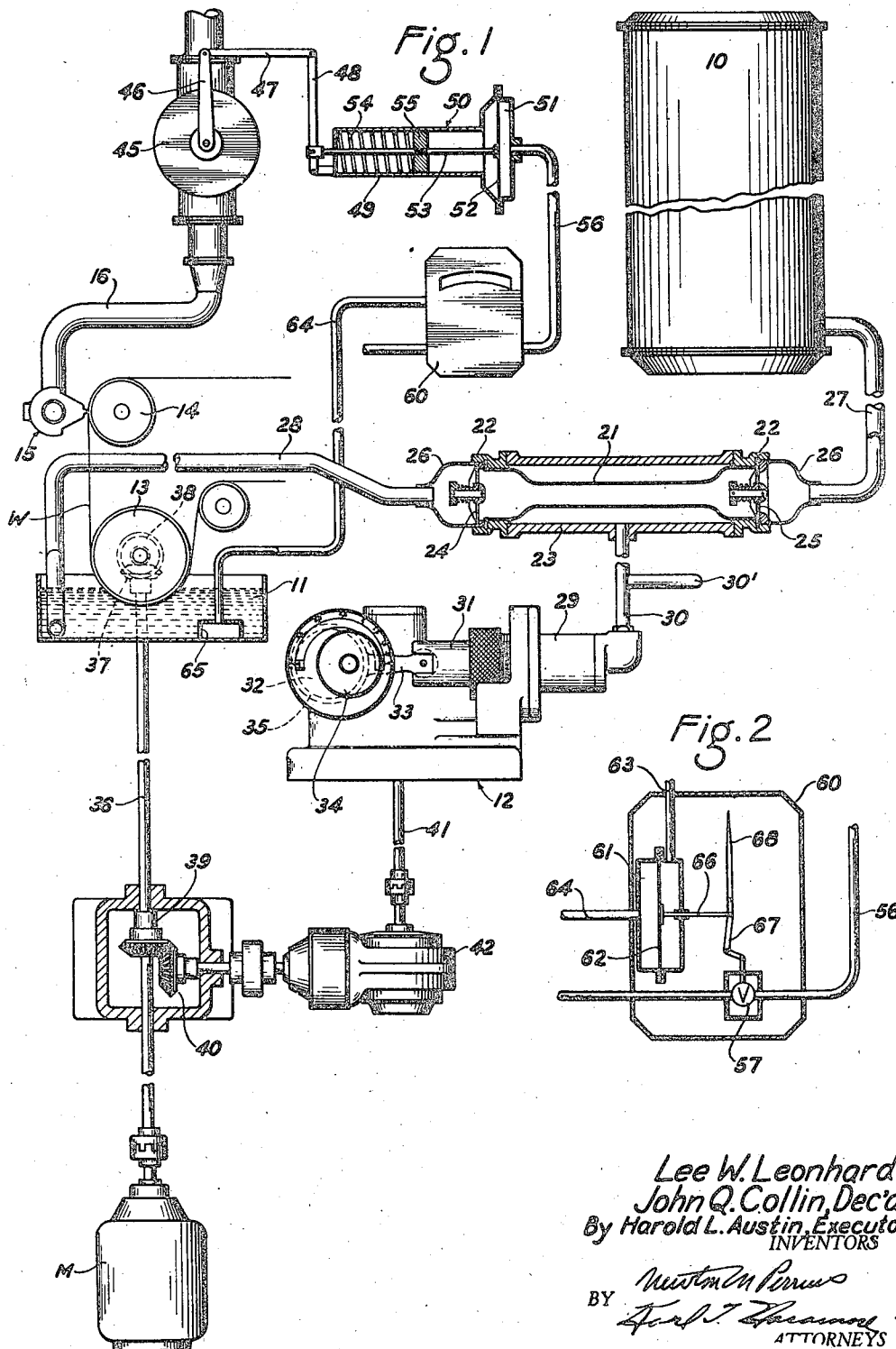
L. W. LEONHARD ET AL

2,415,644

METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A COATING TO A
WEB AND CONTROLLING THE THICKNESS OF THE SAME

Filed Nov. 16, 1942

3 Sheets-Sheet 1



Lee W. Leonhard
John Q. Collin, Dec'd.
By Harold L. Austin, Executor.
INVENTORS

BY *Newton M. Pines*
Carl W. Hammers
ATTORNEYS

Feb. 11, 1947.

L. W. LEONHARD ET AL

2,415,644

METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A COATING TO A
WEB AND CONTROLLING THE THICKNESS OF THE SAME

Filed Nov. 16, 1942

3 Sheets-Sheet 2

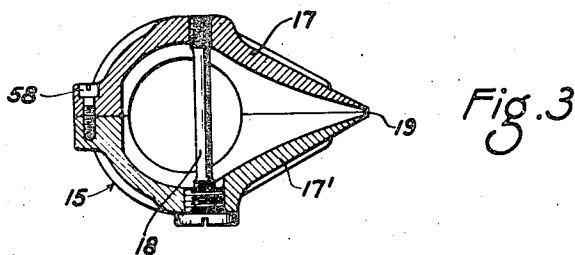


Fig. 3

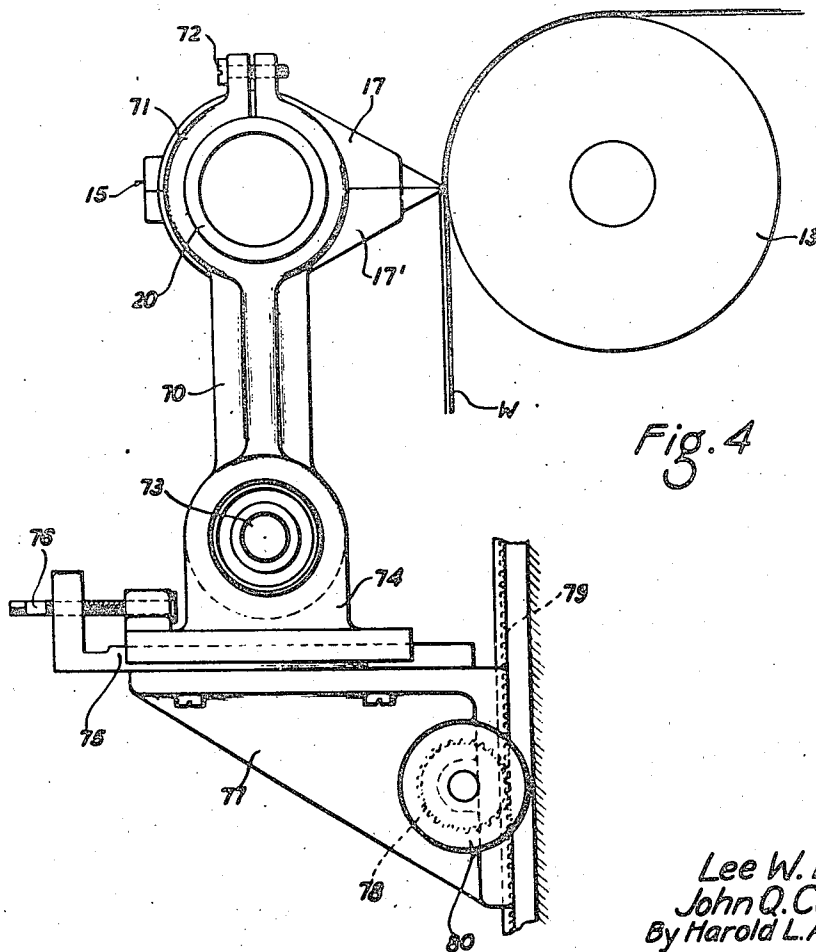


Fig. 4

Lee W. Leonhard
John Q. Collin, Dec'd.
By Harold L. Austin, Executor.
INVENTORS

BY *Weston M. Perdue*
Harold L. Austin
ATTORNEYS

Feb. 11, 1947. **L. W. LEONHARD ET AL** **2,415,644**
METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A COATING TO A
WEB AND CONTROLLING THE THICKNESS OF THE SAME
Filed Nov. 16, 1942 3 Sheets-Sheet 3

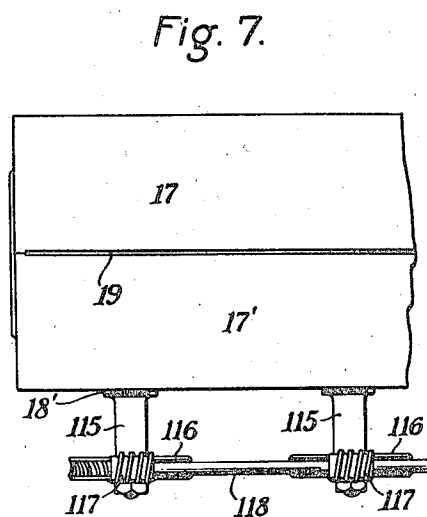
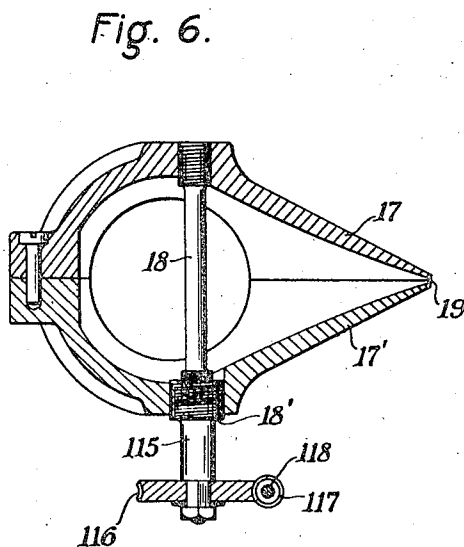
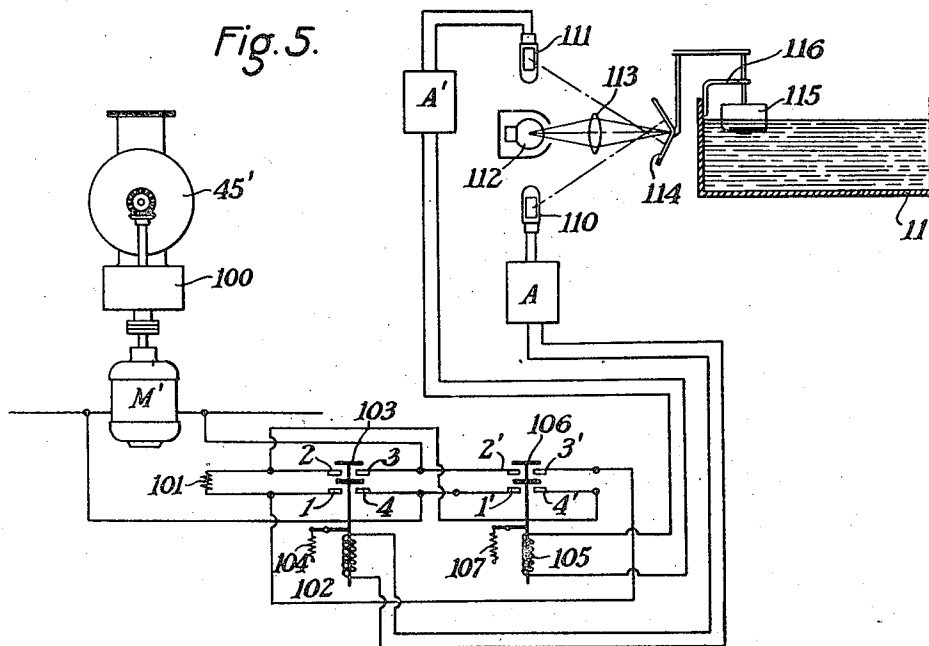
2,415,644

METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A COATING TO A
WEB AND CONTROLLING THE THICKNESS OF THE SAME

WEB AND CONTROLLING THE THICKNESS OF THE SAME

Filed Nov. 16, 1942

3 Sheets-Sheet 3



BY *Newton M. Brown*
Paul J. Harmer
ATTORNEYS

BY

UNITED STATES PATENT OFFICE

2,415,644

METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A COATING TO A WEB AND CONTROLLING THE THICKNESS OF THE SAME

Lee W. Leonhard, Rochester, N. Y., and John Q. Collin, deceased, late of Rochester, N. Y., by Harold L. Austin, executor, Rochester, N. Y., assignors to Eastman Kodak Company, Rochester, N. Y., a corporation of New Jersey

Application November 16, 1942, Serial No. 465,714

11 Claims. (Cl. 117—102)

1

The present invention relates to the application of fluid coating material to a web, and particularly to the control of the thickness of a coating applied continuously to a web.

In the application of a fluid coating material to a web there is always present the problem of properly controlling the desired thickness of the coating. In well-known methods of coating where the web to be coated is moved into contact with a supply of coating material, generally referred to as immersion or "skim" coating, the thickness of the coating is affected by the viscosity of the coating material and the speed of the support passing through the coating solution. It follows that if the viscosity of the coating solution remains constant and the speed of the web is kept constant the thickness of coating for any combination of these two variables should be constant. Furthermore, it would appear to follow that by properly adjusting the speed of the web and the viscosity of the coating solution, any desired thickness of coating could be obtained and readily maintained. In practical commercial operation, and particularly in instances where thin coatings are desired, the problem is not solved as easily as this; first, because it is commercially impractical to feed the web slowly enough to obtain thin coatings, and secondly, it is not always feasible to reduce the viscosity of the coating solution sufficiently without impairing the quality of the solution and the final coating. Furthermore, in order to reduce the drying load on the machine it is desired to eliminate as much of the water or solvent in the coating solution as possible and this increases the viscosity, which for a given coverage requires a reduced speed.

Consequently, in order to maintain the speed of coating within commercially practical limits, it is common practice to coat at speeds which initially place an excess of coating material on the web and then wipe off the excess coating by means of a doctor blade or air knife. The disadvantages of a wiping doctor blade in the application of thin uniform coatings are many and well known, and the use of an air knife is recognized as much more efficient for this job. In the past, however, air knives have been set up to remove a given amount of excess coating applied to the web based on constant speeds of coating and constant viscosity of the coating solution. It is well known that certain coating solutions, for example, light-sensitive emulsions, vary in viscosity over the period of a given run despite all possible efforts of control in this direction. And it is also known that changes in speed of the web

2

are bound to occur regardless of effort made to prevent such occurrence. For these reasons, therefore, air doctors, or air knives, as previously used have been incapable of giving thin coatings of uniform thickness because they were incapable of accounting for varying amounts of excess coating due to uncontrollable variation in the viscosity of the coating solution over a run and speed of coating.

The primary object of the present invention is to provide a method of coating by the use of which the thickness of the final coating applied to the web is positively controlled independently of changes in viscosity of the coating solution or the speed of coating.

Another object of the invention is to provide a method of coating a web wherein the web is moved into contact with a supply of coating solution so that an excess of coating is applied to the web, removing the excess of coating and leaving the desired thickness of coating by obstructing the flow of the excess coating with the web, and varying the degree of obstruction in accordance with changes in speed of coating and/or change in viscosity of the solution to leave the desired amount of coating on the web.

A further object is the provision of a method of coating of the type set forth wherein the degree of obstruction to the application of excess coating is varied in accordance with a change in liquid level of the supply of coating material from a given point.

And another object is a method of coating of the type set forth wherein the degree of obstruction to the application of excess coating to the web is automatically varied in response to changes in level of the coating supply.

And yet another object is the provision of a method of coating of the type set forth wherein the obstruction is an air jet directed against the coated surface of the web while the coating is still fluid.

And another object is a method of coating of the type set forth wherein the pressure of the air jet is automatically varied in response to changes in level of the coating supply.

A further object is the provision of an apparatus for carrying out the method of coating set forth above.

The novel features that are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best

3

be understood from the following description of specific embodiments when read in connection with the accompanying drawings in which,

Fig. 1 is an elevational view, partly in section, of a preferred embodiment of an apparatus for carrying out the method of coating according to the present invention,

Fig. 2 is an enlarged sectional detail illustrating the function of one form of liquid level controller, or static pressure controller, which might be used in the present apparatus for carrying out a method of coating constituting the present invention,

Fig. 3 is an enlarged vertical sectional view of the air nozzle or air knife for directing a jet of air against the coated web,

Fig. 4 is an enlarged elevational detail showing the mounting of the knife which permits it to be readily adjusted relative to the coated surface of the web,

Fig. 5 is a diagrammatic showing of an electro-optical system of control which might be used instead of the static pressure controller set forth in the preferred embodiment, and

Figs. 6 and 7 are a vertical section and a side elevation, respectively, of the air knife, and showing how the width of the discharge orifice might be varied to control the pressure of the thin sheet of air emitted from the knife.

Like reference characters refer to corresponding parts throughout the drawings.

In accordance with the present invention an amount of coating in excess of that finally desired on the web is applied to the surface of the web by moving the same into contact with a supply of coating solution and the excess is then removed from the web while still fluid by obstructing the flow of the same with the web by directing a jet of air against the coated surface and permitting the excess removed to return to the supply. A quantity of coating solution in accordance with that finally desired on the web is continuously fed to the supply so that the liquid level should remain constant if the web is retaining the desired amount. Any variation in the liquid level of the supply will readily indicate when too much or too little coating is being applied to the web, whether it be due to change in speed of the web or change in viscosity of the coating solution, or both, and this change in liquid level of the supply is utilized to vary the degree of obstruction to the flow of excess coating with the web by varying the pressure on the air knife in accordance with, or automatically in response to, changes in the liquid level of the supply of coating solution.

Referring now to the drawings, and particularly Fig. 1, we have shown a preferred embodiment of an apparatus for carrying out our novel method of coating as comprising a tank 10 in which a reserve of fluid coating solution may be stored and from which tank the solution is adapted to be fed at a known and constant rate to a coating reservoir 11 by any suitable form of metering pump indicated broadly at 12. The web of material W to be coated is wrapped around the coating roll 13 which moves the web in contact with the coating solution in the reservoir so that a quantity of solution is picked up on the surface of the web in a well-known manner. The coating roll may be located relative to the reservoir so that the surface of the web just "skims" the surface of the coating solution in the reservoir, this procedure being generally referred to as "skim coating," or

4

the roller may be so located as to immerse the web in the solution, as shown, and which procedure is generally known as immersion coating. In either instance, it may be desirable to use what are known in the art as spaced edge cups, not shown, to prevent the coating solution from running onto the back side of the web passing over the roll.

As is well known in the art, when a web is coated by moving the surface of the same in contact with a supply of coating solution in the manner set forth, the amount of solution picked up by the web varies in direct proportion to the speed at which the web is moved and the viscosity of the coating solution. The coating applied to the surface of a web in this manner is not particularly uniform in thickness and is generally substantially thick if the web is moved at a speed which is commercially practical. Therefore, when a thin, uniform coating is desired it is common practice to apply an amount of coating to the web in excess to that finally desired and to wipe this excess from the surface of the web by means of a rigid doctor blade or an air knife to leave the desired uniform, thin coating on the web. Inasmuch as air knives, nozzles admitting a thin jet of air under pressure, have been found to possess many advantages over rigid doctor blades, we have made use of such a knife in our present method of coating.

Referring again to the drawings, it will be observed that the web W after passing over the coating roll 13 is directed in an upward direction and thence over guide roller 14 to a drying station, not shown. The guide roller 14 is situated close enough to the coating station so that the coating solution on the web is still fluid when reaching this point. At the guide roller 14 an air knife, indicated generally at 15, directs a jet of air under pressure against the coated surface of the web and removes the excess coating from the web permitting the same to flow back down the upwardly moving region of the web to the coating reservoir 11. It will be readily appreciated that the air knife extends across the entire width of the web and is so designed that air under pressure supplied to one, or both ends of the knife through supply pipe 16 is emitted from the knife in a thin jet of air of uniform pressure throughout the length of the knife.

As clearly indicated in Fig. 3, the air knife may comprise a plenum chamber formed by two identical cast elements 17, 17' which may be held together by a plurality of adjustable tie bolts 18 spaced longitudinally of the knife, and a plurality of locking bolts 58 joining the rear edges of the elements in fixed relation. The cast elements 17, 17' are sufficiently long to form an orifice 19 equal in length to the coating roll 13, and the walls of the elements forming the throat of the nozzle are curved toward one another to give a high velocity thin jet of air which strikes the web without any divergence. The width of the orifice 19 of the air knife may be adjusted over a limited range by means of the adjusting tie bolts 18 which act to deform the portions of the elements 17, 17' which form the orifice 19 of the knife. One, or both, ends of the air knife may be open for connection to the air supply duct 16 and preferably include a sleeve portion 20 for adjustably mounting the knife as hereinafter fully set forth.

In accordance with the present invention proper coverage of the web, or proper thickness of coating, is controlled by constantly feeding the amount of coating solution to the reservoir in

proportion to the speed of the web that is finally desired on the web. The air knife is relied upon to remove the excess of solution picked up by the web and the run back of this excess to the reservoir should maintain an exact level in the reservoir if the proper amount of coating is being left on the web. This is controlled by the air pressure on the knife which is changed by moving a special damper in the supply duct to the knife. The damper is positioned by a damper motor which is controlled by any suitable form of liquid level controller available on the market and which is connected up to vary the supply of power to the damper motor rather than the supply of liquid to a reservoir as is the usual procedure.

The coating solution may be fed from the tank 10 to the reservoir 11 by any suitable form of metering pump, but we have found that a pulsator of the type set forth is particularly adapted for this job. This pulsator is one of a well-known type and may comprise a flexible tube 21 shown in the drawings as a round tube on each end where it enters the cap 22 and is flattened for the rest of its length as shown in cross section. The end caps 22 are molded, or otherwise securely fastened, to the casing 23 to form a strong and leak-proof joint, and are also suitably joined to the end of the tube 21. The discharge valve 24 and the inlet valve 25 are mounted in any suitable way at opposite ends of the flexible tube 21. Suitable end caps 26 are provided on each end to connect the inlet and outlet pipes 27 and 28, respectively. The cylinder 29 is preferably mounted at some distance from the casing 23, and suitably connected to the casing by a stout pipe 30 including an expansion joint 30'. A piston 31 having a close fit within the cylinder 29 is connected to a crank 32 by a connecting rod 33. The cylinder 29, the casing 23, and the pipe 30, are filled with oil or other suitable fluid, and generally referred to as the transmission liquid.

When the crank is rotated, the piston 31 will travel longitudinally of the cylinder 29 causing the volume of the transmission fluid to decrease and increase in the casing 23. As the volume increases in the casing 23, the flexible tube 21 will be deformed, and its cubic content will be decreased by the same volume as the volume of transmission fluid entering the casing 23 from the cylinder 29. It will be seen that the volumetric capacity of the pump will be governed by the swept volume of the cylinder 29, and this may be conveniently changed by adjusting the length of stroke of the connecting rod 33 by an adjusting knob 34 connected to an eccentric 35 on the crankshaft, as is well known. The end of the outlet pipe 28 preferably extends to and along the bottom of the reservoir 11 so that the incoming solution does not agitate the liquid level of the reservoir. Inasmuch as the speed of the web and the amount of solution fed to the reservoir are dependent upon one another and vary in direct proportions, we have shown the coating roll 13 which in this instance feeds the web, and the pulsator, operated from a common source of power. As shown, the motor M drives the coating roll 13 directly through shaft 36 and bevel gears 37, 38, while the power for the pulsator is transmitted from the shaft 36 through bevel gears 39, 40 to shaft 41 through a suitable transmission 42.

As pointed out above, when the pressure on the air knife is properly adjusted, it will remove all excess coating material from the web and leave just the amount on the web which is desired, and since the amount finally desired on the web is

equal to that pumped into the reservoir, the excess coating removed by the air knife and flowing back down the web to the reservoir should maintain the level of the reservoir constant. If, however, the knife is removing too little or too much, the level of solution in the reservoir will rise or fall, respectively, indicating that the desired coverage is not being obtained. If the level falls it indicates that the knife isn't removing enough solution and, therefore, requires an increase in pressure, while if the level rises it indicates that the knife is taking off too much and the pressure thereon should be decreased. A change in the amount of solution a web will pick up will be brought about by a change in speed of the web and/or a change in viscosity of the coating solution. While the feed of the web may be fairly well controlled, a change in the viscosity of a coating solution during a given run is not always constant or controllable. For instance, we have found that certain light-sensitive emulsions which are widely used as coating solutions increase in viscosity from 11 to 28 centipoises over a 60-minute coating run. The reasons for this change in viscosity are not fully known and this change is uncontrollable from a commercial standpoint. With our novel coating method, for a given coverage and speed of web, we have been able to account for a change in viscosity of the range above indicated by increasing the pressure on the air knife from 1-inch to 3½-inches of water.

One way which we have found desirable for varying the air pressure on the knife in accordance with changes in liquid level in the reservoir is to do it automatically in response to changes in static head on the reservoir. To this end, the control valve, or damper, 45 is inserted in the supply duct 16 of the air knife. This control damper is so formed that it has a straight-line characteristic, or, in other words, equal increments of movement of the damper permit equal increases in the volume of air capable of passing therethrough. As shown, the control damper 45 is preferably one of the rotary type and is operated by a linkage including the damper arm 46, and pivoted levers 47 and 48, the end of the latter being pivoted to a stationary support, such as the casing 49 of an air motor 50. The air motor 50 may be of any well-known type, and, as shown, may comprise a casing 49 having an enlarged pressure chamber 51 at one end divided by a flexible diaphragm 52. To one face of the diaphragm 52 is fastened one end of an operating rod 53, and the other end of the rod is pivotally connected to the lever 48. The rod 53 is biased in one direction by a coil spring 54 confined between the end of a casing 49 and a block 55 pinned to the rod and slidably mounted within the casing. Air under pressure is introduced into the pressure chamber 51 of the casing 49 on the side of the diaphragm opposite that to which the rod 53 is attached so that as the pressure of the air entering the chamber increases or decreases the diaphragm flexes to open and close the control valve or damper 45.

Air under pressure is adapted to be introduced into the pressure chamber of the air motor 50 through a feed-pipe 56 and which pipe is connected to a source of supply which is under sufficient pressure to operate the motor 50 and fully open the damper 45 when the valve 57, see Fig. 2, in the line is fully opened. According to the present invention, any well-known type of liquid level controller is arranged to operate the valve

67 in response to changes in the liquid level of the reservoir 11 and thereby alter the pressure on the air knife to maintain a desired coverage on the web.

To this end, there has been shown a well-known type of liquid level controller operating on static pressure principle connected to the reservoir and adapted to operate the valve 57. Inasmuch as the liquid level controller per se is well known, and can be procured from the Taylor Instrument Company of Rochester, New York, we will not go into the details of construction and operation of the complete instrument, but have shown and will set forth only the operation of the part of the same necessary to a complete understanding of the present invention. This instrument includes a case 60 within which is situated a chamber 61 well known in the art as a Hayes element. This Hayes element comprises a chamber separated by a flexible air-tight diaphragm 62 of suitable material. One side of the chamber 61 is open to the atmosphere by a pipe 63, and the other side of the chamber is connected by the tube 64 with a pressure cup 65 fixed in the bottom of the reservoir 11. This pressure cup 65 is in communication at one end with the reservoir, and when a coating solution is placed in the reservoir air is trapped in the cup 65 and tube 64. The pressure in the trapped side of the Hayes element will be constant when the liquid level in the reservoir, or head on the pressure cup, remains stationary. Any rise or fall of the liquid level of the reservoir will cause a change in pressure on the trapped side of the Hayes element and the diaphragm 62 will flex back and forth in response to these changes in pressure. To one face of the diaphragm is connected an operating rod 66 which moves longitudinally as the diaphragm flexes, and the flexing movement of the diaphragm is caused to actuate a pointer 68 movable over a suitable pressure indicating scale, and to open and close the valve 57, through a suitable amplifying relay mechanism operated by said rod 66 and indicated broadly as 67. It will be readily appreciated that suitable means are provided to calibrate the liquid level controller to open the valve 57 a given amount when operating at a desired liquid level in the reservoir, and that from then on any change in liquid level in the reservoir will open and close the valve in response to variations in the liquid level from the desired point.

The operation and use of the apparatus set forth may be briefly summarized as follows: To maintain the proper web coverage the air knife obstructs the flow of excess coating solution with the web which causes enough solution to flow back to the coating reservoir to maintain an exact level in the reservoir. This is controlled by the air pressure on the knife which is changed by moving damper 45 in the air duct to the air knife. This damper is positioned by a damper motor 50 which is controlled by the liquid level controller 60. The correct amount of solution as desired on the web is continuously pumped into the reservoir 11. The web will pick up more of the solution than is desired which lowers the liquid level of the coating solution. This lowered level is picked up immediately by the liquid level controller through the pressure cup 65. As soon as the liquid level controller receives the impulse of the lowered level it opens valve 57 and releases more air to the damper motor which in turn opens the damper 45 to increase the pressure on the air knife which cuts into and obstructs more

solution on the web causing it to run back into the reservoir to build up the solution level to the desired point. If the air knife causes too much solution to flow back into the reservoir, so that the resulting coating is too thin, the solution level in the reservoir immediately rises. This raise in level is picked up by the liquid level controller which closes the damper 45 through the damper motor. As the damper closes, the air knife pressure decreases allowing more solution to remain on the support. An equilibrium between these two points is quickly reached and an exact coverage of the web is obtained, completely independent of either speed or viscosity within practical operating ranges of the air knife pressure.

The particular apparatus set forth has been found to be very sensitive and quickly responsive to the slightest changes in liquid level in the reservoir. In fact, we found that a liquid level controller of the type set forth can be made sensitive enough to respond to the changes in liquid level of .001 of an inch. It was found that when the liquid level controller was this sensitive it responded to pulsations in the reservoir caused by the pulsating type of meter shown herein, and that a pulsation dampener, not shown, had to be placed in the outlet pipe 28 of the pump to keep the controller from constantly working to overcome changes in liquid level due to such pulsations. It will be readily appreciated that the sensitiveness and responsiveness of this apparatus will depend upon both the construction of the individual elements making up the complete combination and the association of the different elements. For instance, to insure a rapid response, the air knife should be placed as close to the coating reservoir as possible so that the time required for the excess solution, removed from the web to run back to the reservoir is reduced to a minimum. However, the proximity of the air knife to the coating reservoir may be limited because it is undesirable to have the diverging air blast enter the reservoir and cause agitation of this level; and with some coating solutions a smooth run back of the excess solution to the reservoir has a noticeable effect on the quality of the final coating.

We have found that the air knife may be directed at right angles to the web, inclined in the direction of movement of the web, or inclined counter to the direction of movement of the web, and work in the manner set forth. It is pointed out, however, that it has been found that the direction, and the character of the air jet issuing from the knife depends largely upon the characteristics of the coating solution being used. For instance, it has been found that when using a light-sensitive emulsion as the coating solution the best results are obtained when the air blast is directed at right angles to, or inclined in the direction of movement of, the coated web. When the air blast is directed counter to the direction of movement of the web using this type of coating solution it has been found that while the excess coating is properly removed, for some reason, bubbles are formed in the solution which are very objectionable. On the other hand, when a coating solution of blanc fixe is used it has been found that the air blast can be directed counter to the direction of movement of the web without any difficulty whatsoever.

It has also been noted that the width of the jet of air issuing from the knife is limited by the characteristics of the coating solution. For in-

stance, when too thin a jet is used when coating with light-sensitive emulsions, which are water solutions containing gelatin, it was found that "foaming" of the solution occurred in the coating regardless of the direction in which the air blast was directed in the web. This undesirable occurrence was not prevalent when coating solutions of blanc fixe were used with the same thin air jet. It has also been noticed that if a thin jet of air and a thicker jet of air are both impinging upon a coated web with the same effective pressure, the thicker jet of air will remove less solution from the web than the thin one. The only explanation we can give to this phenomenon is to compare the two jets with a sharp and a dull knife. The sharp knife with the application of a given pressure will cut deeper into an object than a dull one.

In order to adapt the apparatus for use with coating solutions having different characteristics and for the application of different thicknesses of coating, we have shown the air knife so mounted that its orifice 19 can be conveniently adjusted relative to the path of the web to obtain the most efficient operation of the knife. Looking at Fig. 4, the air knife 15 as a whole is rotatably mounted in a pair of spaced arms 70 by having the sleeve 20 on each end of the knife held within a clamping ring 71 formed on the end of the arms. The clamping ring 71 may be adjusted by a tie bolt 72 for freeing or clamping the knife relative to the arms. Each arm 70 is pivoted at 73 to a slide 74 mounted on a track 75 so that the knife can be moved to and from the path of the web by adjusting the screws 76. For vertically adjusting the knife, the track 75 is mounted on a supporting bracket 77 on which are rotatably mounted a pair of pinions 78 arranged to engage a stationary vertical rack 79. The pinions 78 may be rotated by a handwheel 80.

While one particular form of apparatus for carrying out the method of coating according to the present invention has been shown it will be readily understood that the method is not limited to the particular apparatus shown but may be carried out by apparatus other than that specifically disclosed. For instance, known types of liquid level controllers other than the one of the type set forth could be used, or more specifically, one which would operate on the float principle rather than in response to the change in static head on the reservoir. It will be readily appreciated that the specifications as to the sensitivity of the different elements making up the complete apparatus and the speed of their response to changes in liquid level will vary with the particular coating problem in question. For instance, in the coating of a web with a light-sensitive emulsion it is imperative that the coating be fairly thin and very uniform in thickness so that the apparatus for carrying out the method must be very sensitive to slight changes in thickness of coating and be quick to respond to such changes when indicated. On the other hand, if the coating problem has to do with the application of a size or glue to paper where the coating need not be so thin or of such uniform thickness, the several elements making up the complete apparatus would not have to be of a type which would be so sensitive and quick to respond.

It is also pointed out that the method could be carried out by using a photoelectric control for picking up changes in the liquid level of the reservoir instead of the liquid level controller as set forth. One easy way of accomplishing this would

be to have one light-sensitive cell located above the desired liquid level and another light-sensitive cell located below the desired liquid level. A mirror onto which a light beam is constantly directed could be made to float up and down with the liquid level and alternately direct its beam onto one or the other of the light-sensitive cells only when the liquid level deviated from its desired point. Energization of the cell above the desired liquid level would close a normally opened circuit to a motor for closing the damper 45 in the air duct of the air knife, while energization of the cell below the desired liquid level would close a normally opened circuit to a motor for opening the damper in the air duct.

A structure for accomplishing this is shown in Fig. 5 wherein the reservoir for the coating solution is indicated at 11', and a reversible shunt wound motor M' is shown connected to the damper 45' through a suitable reduction gearing 100. The shunt field 101 of the motor M' is connected across the usual reversing switch which is normally open, and which is adapted to be closed by two different relays in response to the level of the reservoir raising and lowering with respect to a given point. To show this diagrammatically we have shown the reversing switch of the motor M' comprising four pairs of contacts 1, 2, 3, 4 and 1', 2', 3', 4' connected across the shunt field of the motor M'. These contacts are so arranged as to be normally separated.

The first set of contacts 1, 2, 3 and 4 are arranged to be closed by a relay 102 the actuating arm 103 of which is normally held in a raised position by spring 104. When this relay is energized, the actuating arm 103 thereof is pulled downwardly and connects contacts 2 and 3, and 4 and 1 which causes current to flow through the shunt field in one direction. The second set of contacts 1', 2', 3' and 4' are arranged to be closed by a relay 105, the actuating arm 106 of which is normally held in a raised position by a spring 107. When this relay is energized the actuating arm 106 thereof is pulled downwardly and connects the contacts 2' and 1', and 3' and 4', which causes the current to flow through the shunt field in the other direction, and drive the motor in a direction reverse of that caused by closing the other set of contacts.

The two relays 102 and 105 receive their exciting current from light sensitive cells 110 and 111, the circuits of which include suitable amplifiers A and A', respectively. The two light sensitive cells are normally dark when the liquid level of the reservoir is at a given point, and they are alternately activated by a light beam as the level in the reservoir varies from a given point. To this end, light from a shielded lamp 112 is focused to a point by a lens 113. An angular mirror 114 connected to a float 115, floating in the liquid in the reservoir and guided by a guide member 116 is adapted to move across said point of light. The light source and mirror are so adjusted that when the level in the reservoir is correct, the light beam strikes the vertex of the mirror and is not reflected to either light sensitive cell, and consequently the driving motor for the damper 45' is at a standstill. As the mirror moves up or down with respect to the light beam due to a rise or fall of the level of the reservoir, the beam strikes one or the other of the two mirror surfaces and is alternately directed to one or the other of the light sensitive cells, as indicated by the dotted lines in Fig. 5, which causes the motor switch to be closed in the right

direction to cause the motor to drive the damper in the proper direction to correct for the coating condition which caused the variation in the level of the reservoir. With this arrangement of parts the device is very sensitive to changes in liquid level of the reservoir because only the vertex of the angular mirror, which is in effect a line, is the dead spot so far as reflection of light to one or the other of the light sensitive cells is concerned. If the device need not be so sensitive the central portion of the mirror, or that adjacent the vertex, could be masked off to any desired extent.

It is further pointed out that instead of varying the air pressure to the air knife in the manner and for the purpose set forth, this same result could be accomplished over a more limited range by constructing the air knife so that the width of the orifice 19 could be changed in accordance with, or in response to, changes in liquid level of the coating reservoir. Increasing and decreasing the width of the knife orifice would not only cause a decrease and increase of the pressure on the jet, respectively, but at the same time would in effect dull or sharpen the air jet, considering it as a knife proper as above set forth, and the effect of this dulling and sharpening of the jet would be additive to the effective change in pressure of the jet in removing excess coating solution from a web in accordance with changes in liquid level of the coating reservoir.

This could be readily accomplished by the arrangement shown in Figs. 6 and 7. As previously set forth the cast elements 17 and 17' of the air knife may be adjusted over a limited range by means of the adjusting tie bolts 18 which act to deform the portions of the elements 17 and 17' which form the orifice 19 of the knife. These tie bolts are spaced along the length of the knife at regular frequent intervals, and to enjoy the adjustment of the width of the orifice desired they must all be capable of adjustment at one time by equal amounts. To this end, the tie bolts are threaded into sleeves 18' which are in turn threaded into the element 17'. These sleeves 18' have an extension 115 to the lower end of which is fixed a gear wheel 116. Referring to Fig. 7, each of these gear wheels are engaged by one of a plurality of worms 117 mounted on a common shaft 118 adjustment of which will cause the desired adjustment of the width of the discharge orifice throughout the length of the knife.

Notwithstanding the fact that we have shown the air pressure on the knife automatically adjusted in response to changes in liquid level of the coating reservoir it will be readily appreciated that if desired the damper 45 could be adjusted by hand in accordance with observed variations in the liquid level. In such a case there could be a floating indicator on the coating reservoir which would move over a scale as the liquid level changed, and the damper adjusting arm could be moved over a scale calibrated in accordance with that one over which the floating indicator would move to facilitate the proper adjustment of the damper for different changes in the level of the reservoir.

From the above description it will be apparent that we have provided a method of coating wherein the thickness of the coating applied to a web is readily controlled in a positive way independently of the speed of coating or changes in the viscosity of the coating solution. In ad-

dition to giving an accurate and positive control to the amount of coating solution applied to a web, this method of coating provides a substantial saving in coating solution. This can best be pointed out by considering previous methods of coating in which known increases in the viscosity of the coating solution resulted in what is known as "a pyramid coating." In order to insure the minimum amount of coating being applied to the web at the start of a coating run the apparatus had to be set to leave this amount of coating on the web. Then as the run progressed, and the viscosity of the solution increased in an uncontrollable manner, the coating kept getting thicker and thicker toward the end of the run. The result was that the major portion of the web might have several times the desired amount of coating thereon, and even if this condition was tolerable, it constituted a considerable waste in coating solution. With the present method, however, the minimum coating can be applied to the web from the start to finish regardless of any change in viscosity which might occur in the coating solution during the run. Furthermore, by our method of coating it is possible to obtain a thin uniform coating on a web while maintaining a speed of coating which is commercially practical.

Although we have shown and described certain specific embodiments of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore, is not to be limited to the precise details shown and described, but is intended to cover all modifications coming within the scope of the appended claims.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. The method of controlling the thickness of coating solution applied to the surface of a web and comprising the steps of continuously moving a web in contact with a supply of coating solution so that it will pick up an amount thereof in excess of that desired in the final coating, continuously feeding a quantity of coating solution to said supply in accordance with the amount desired on the web, directing an air blast against the coated surface of said web while the coating is still fluid to regulate the amount of coating left on said web after passing said air blast, and substantially simultaneously altering the character of said air blast to vary the wiping action thereof on said coating material in accordance with changes in liquid level of said supply of coating solution, increasing the wiping action of the blast when the level falls and decreasing it when the level rises.

2. The method of controlling the thickness of coating solution applied to the surface of a web and comprising the steps of continuously moving a web in contact with a supply of coating solution at a known rate so that it will pick up an amount of coating in excess of that desired in the final coating, continuously feeding a quantity of coating solution to said supply commensurate with the amount desired on the web, directing an air blast against the coated surface of said web while the coating is still fluid to regulate the amount of coating left on said web after passing said air blast, returning the removed excess of coating directly to said supply, and automatically substantially simultaneously altering the character of said air blast to vary the wiping action thereof on said coating material in response to changes in liquid level

of said supply of coating solution, increasing the wiping action of the blast when the level falls and decreasing it when the level rises.

3. The method of controlling the thickness of coating solution applied to the surface of a web and comprising the steps of continuously moving a web in contact with a supply of coating solution so that it will pick up an amount thereof in excess of that desired in the final coating, continuously feeding a quantity of coating solution to said supply in accordance with the amount desired on the web, directing an air blast against the coated surface of said web while the coating is still fluid to remove the excess of coating solution and to regulate the amount of coating left on said web after passing said air blast, returning the removed excess of coating directly to said supply, and substantially simultaneously varying the pressure of said air blast in accordance to changes in liquid level of said supply of coating solution, increasing the pressure of the air blast when the level falls and decreasing it when the level rises.

4. The method of controlling the thickness of coating solution applied to the surface of a web and comprising the steps of continuously moving a web in contact with a supply of coating solution so that it will pick up an amount thereof in excess of that desired in the final coating, continuously feeding a quantity of coating solution to said supply in accordance with the amount desired on the web, directing an air blast against the coated surface of said web while the coating is still fluid to wipe off the excess of coating and to regulate the amount of coating left on said web after passing said air blast, and automatically substantially simultaneously varying the pressure of said air blast in response to changes in liquid level of the supply of coating solution, increasing the pressure of said air blast when the level falls and decreasing it when the level rises.

5. The method of controlling the thickness of coating solution applied to the surface of a web and comprising the steps of continuously moving a web in contact with a supply of coating solution so that it will pick up an amount thereof in excess of that desired in the final coating, continuously feeding a quantity of coating solution to said supply in accordance with the amount desired on the web, directing an air blast against the coated surface of said web while the coating is still fluid to wipe off the excess of coating solution to regulate the amount of coating left on said web after passing said air blast, returning said wipe-off excess to said supply, and automatically substantially simultaneously varying the pressure of said air blast in response to changes in static head on the supply of coating solution, increasing the pressure of the air blast when said static head decreases and decreasing it when said static head increases.

6. The method of controlling the thickness of coating solution applied to the surface of a web, and comprising the steps of continuously moving a web in contact with a supply of coating solution so that it will pick up an amount thereof in excess of that desired in the final coating; continuously feeding a quantity of coating solution to said supply in accordance with the amount desired on the web; moving the web subsequent to coating, and while the coating thereon is still fluid, in an upward direction; directing a jet of air under pressure against the coated surface of the web in the upwardly moving reach thereof

for the purpose of removing the excess of coating solution from the web and permitting it to flow directly back to the supply, and automatically substantially simultaneously varying the character of said jet of air to vary the wiping action afforded thereby in response to changes in the liquid level of the supply of coating solution, increasing the wiping action of said jet as the liquid level recedes from a given position and decreasing the wiping action as the liquid level rises above said position.

7. Apparatus for coating a web and controlling the thickness applied to the web and comprising in combination, a reservoir of coating solution, means for continuously feeding a web in contact with the coating solution whereby the same is adapted to pick up an amount of coating in excess of that desired in the final coating and for moving the web in an upward direction immediately after the application of coating thereto, means for continuously supplying coating solution to said reservoir in a quantity commensurate with the speed of the web, a nozzle for directing a thin sheet of air against the upwardly moving reach of web where the coating material is still fluid, and adapted to remove the excess of coating from the web to permit it to return to said reservoir, means for adjusting the pressure of the thin sheet of air emitted from said nozzle, and means for automatically adjusting said last mentioned means in response to changes in the liquid level of the reservoir.

8. Apparatus for coating a web and controlling the thickness of coating applied to the web and comprising in combination, a reservoir of coating solution, means for continuously feeding a web in contact with the coating solution whereby the same is adapted to pick up an amount of coating in excess of that desired in the final coating and for moving the web in an upward direction immediately after the application of coating thereto, means for continuously supplying coating solution to said reservoir in a quantity commensurate with the speed of the web, a nozzle for directing a thin sheet of air against the upwardly moving reach of web where the coating material is still fluid, and adapted to remove the excess of coating from the web to permit it to return to said reservoir, means for adjusting the pressure of the thin sheet of air emitted from said nozzle, said means including a control member responsive to changes in static head in said reservoir.

9. Apparatus for coating a web and controlling the thickness of coating applied to the web and comprising in combination, a reservoir of coating solution, means for continuously feeding a web in contact with the coating solution whereby the same is adapted to pick up an amount of coating in excess of that desired in the final coating and for moving the web in an upward direction immediately after the application of coating thereto, means for continuously supplying coating solution to said reservoir in a quantity commensurate with the speed of the web, a nozzle for directing a thin sheet of air against the upwardly moving reach of web where the coating material is still fluid, and adapted to remove the excess of coating from the web to permit it to return to said reservoir, means for adjusting the pressure of the thin sheet of air emitted from said nozzle, said means including a damper in the supply line to said nozzle, an air motor for opening and closing said damper, an air supply for said motor, a valve in said last

mentioned air supply, and a control member responsive to changes in the static head on said reservoir for operating said last mentioned valve.

10. Apparatus for coating a web and controlling the thickness of coating applied to the web according to claim 7 in which an electro-optical means is used to detect a change in the liquid level of the reservoir and to cause a change in the pressure of the thin sheet of air emitted from the nozzle in response to such change in level.

11. Apparatus for coating a web and controlling the thickness of coating applied to the web according to claim 7 in which the pressure of the thin sheet of air emitted from the nozzle is varied by means for adjusting the width of the nozzle orifice.

LEE W. LEONHARD.

HAROLD L. AUSTIN,

Executor of the Estate of J. Q. Collin, Deceased.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,140,873	Carter -----	May 25, 1915
1,590,417	Brunk -----	June 29, 1926
1,980,923	Sebel -----	Nov. 13, 1934
2,135,406	Macdonald -----	Nov. 1, 1938
2,177,323	Kirkendall -----	Oct. 24, 1939
2,252,204	Reilly -----	Aug. 12, 1941