Sept. 4, 1956 J. A. MERCIER ET AL 2,761,419

MULTIPLE COATING APPARATUS

Filed Feb. 23, 1955

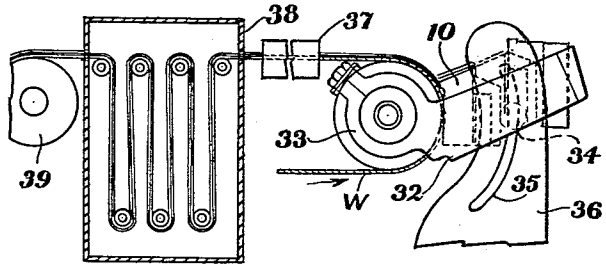


Fig. 1

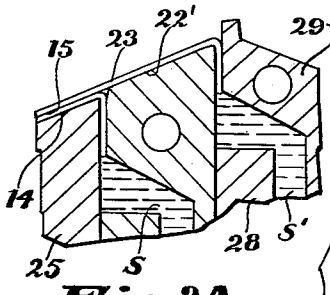


Fig. 2A

Fig. 2

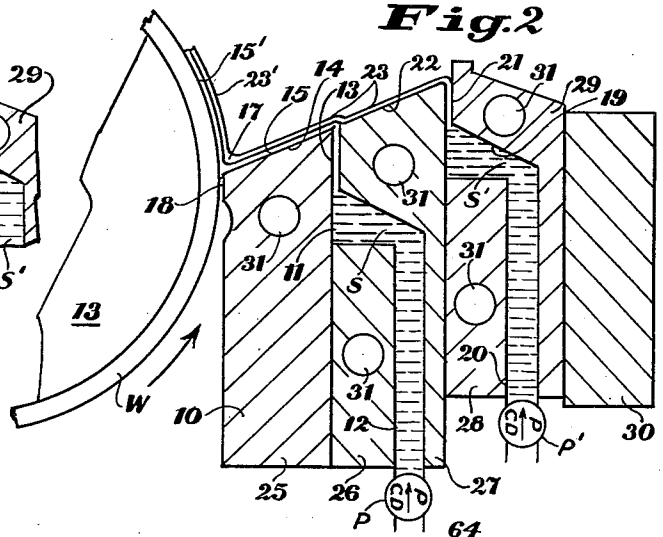
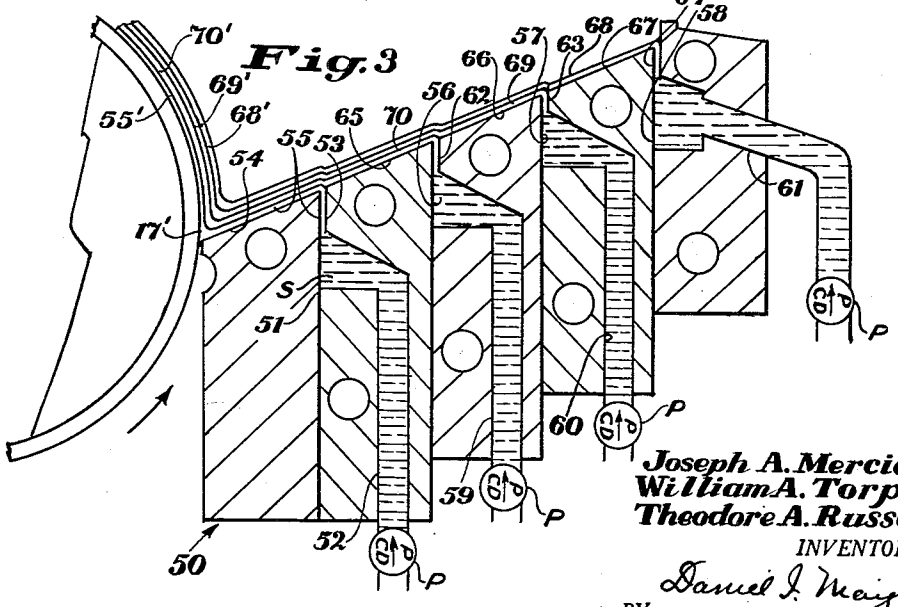


Fig. 3



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2,761,419

Patented Sept. 4, 1956

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MULTIPLE COATING APPARATUS

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Application February 23, 1955, Serial No. 489,969

4 Claims. (Cl. 118—412)

The present invention relates to a new coating apparatus for applying multiple coatings to the surface of a moving web, and particularly to a coating apparatus useful in carrying out the method of multiple coating a web described in U. S. application Serial No. 489,863, filed on even date herewith.

In said above-identified patent application there is disclosed a method of applying a plurality of separate coatings to the surface of a moving web which allows all of the layers to be applied to the web simultaneously while still maintaining a distinct layer relationship between the coatings after deposition. Essentially, it involves continuously forming each fluid composition into a layer of given thickness, bringing these layers into surface contact prior to the time they are applied to the surface of the web and then directing them in combined relation to a point of application where they are simultaneously applied to the web in the desired orientation and with no noticeable mixing or contamination at the interface of the layers.

The primary object of the present invention is to provide an apparatus by means of which this method of multiple coating a web can be carried out.

A further object is to provide a multiple hopper which forms each of several fluid coating compositions into individual layers and then brings them into surface contact prior to the time they are fed to a point of deposition where they are picked up on the surface of a moving web while the distinct layer relationship is maintained.

Another object is to provide a multiple slide hopper in which each of a plurality of separate coating compositions are individually formed into layers by individually pumping the compositions at a known rate onto separate downwardly inclined slide surfaces down which the compositions flow by gravity to form a uniform layer thereof, and arranging said slide surfaces so that layers formed on each one flow on top of one another and finally all flow in combined striated relationship from the last slide surface to a point of deposition where they are simultaneously picked up on the surface of a web moved continuously across said point of deposition.

And another object is to provide a coating apparatus of the type described wherein the end of the lowermost slide surface is slightly spaced from the surface of the web to be coated whereby a bead of coating is formed between the web surface and the lip of the last slide surface across and in contact with which the web moves to pick up the combined layers of coating compositions which are continuously flowing into said bead.

And still another object is to provide a multiple slide hopper of the type described wherein the individual slide surfaces are coplanar and are arranged one above the other.

And yet another object is to provide a multiple slide hopper of the type described wherein the individual slide surfaces are substantially parallel but not coplanar to facilitate movement of the successive layers of coating onto the top of one another.

And another object is to provide a multiple slide hopper of the type described which in effect comprises a single downwardly inclined slide surface which is broken up into a plurality of separate slide surfaces by means of elongated slots extending transversely thereof and spaced above one another along said surface and through which separate ribbons of coating compositions are fed out onto the slide surface.

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

Fig. 1 is a schematic showing of a coating apparatus including a multiple slide hopper constructed in accordance with the present invention;

Fig. 2 is a side view, partly in section, showing a double slide hopper constructed in accordance with the present invention in combination with a web supporting device and web to be double coated;

Fig. 2A is a sectional detail view showing another modification of the double slide hopper of Fig. 2; and

Fig. 3 is a view similar to Fig. 2, but showing a four-slide hopper by means of which four layers of separate coating compositions can be applied to the surface of a web.

In the manufacture of supports or continuous webs which require the application of two or more separate coatings in superposed layer relationship on one surface thereof, it has been the customary procedure to place each of the coatings on the support in succession and to set and/or dry each coating before the application of the next. Such a procedure has been deemed necessary in order to maintain a distinct relationship between the separate layers and to prevent mixing of the coatings or contamination of one by the other at the interface of the layers. It will be appreciated that such a procedure of applying a plurality of coatings to the surface of a support has been very time consuming and has involved the use of duplicate equipment for each coating. These two factors alone have added greatly to the expense of making such multiply coated supports.

In the above-mentioned patent application there is disclosed a method of coating which permits the simultaneous application of a plurality of separate coating compositions onto the surface of a web whereby the time and duplication of equipment involved in conventional coating procedures is reduced or eliminated, as the case may be. This novel method of coating is not dependent upon the use of any particular form of coating apparatus so long as it permits the formation of each of the coating compositions into layers of a given thickness and permits these layers to be brought into surface contact in the desired orientation prior to the time these layers are fed to the surface of the support in such combined relationship for simultaneous application to the surface. Experiments have shown that multiple coatings applied to the surface of a web in accordance with this method exhibit just as good results, both physically and chamically, so far as distinct layer relationship is concerned as multiple coatings applied by the conventional technique of successively applying the coatings with a complete curing or drying of each one before application of the next.

The present invention relates to a particular type of apparatus adapted for carrying out this new method of multiple coating. Generally speaking, this apparatus includes a multiple feed hopper which in this instance is a multiple slide hopper by the use of which the layers of the separate coating compositions are formed by allowing them

to flow by gravity down an inclined slide surface for each coating composition, and all of the slide surfaces are arranged so that the layers formed thereon flow into stratified relation with one another as they move toward the coating point so that by the time they leave the last slide surface they are all combined in layer relationship and in this combined relation flow into a coating bead maintained between the end of the last slide surface and the web to be coated. The web in moving across and in contact with this bead of coating simultaneously picks up the combined layers of coating compositions on its surface and the layers of the separate coating compositions maintain their distinct layer relationship after deposition on the web surface.

Referring now to Figs. 1 and 2, there is shown an apparatus constructed in accordance with the present invention which was successfully used to apply two separate coatings to a support in the manufacture of photographic film. Here there is shown a double slide hopper 10 having a cavity 11 into which one fluid coating composition S is continuously pumped at a given rate by a metering or constant discharge pump P through inlet 12. The coating composition S is then forced from cavity 11 through a narrow vertical slot 13 in the form of a ribbon and out onto a downwardly inclined slide surface 14 down which it flows by gravity in the form of a layer 15 into a coating bead 17 formed between the surface of the web W to be coated and the lip or end 18 of the slide surface. The web W is backed up at this point by a roll 13 which may serve as a means of continuously moving the web across and in contact with the bead 17 as well as serving as a means for supporting and holding the web smooth while passing across the bead of coating.

This bead technique of coating is well known in the coating art and is characterized by the formation of a "puddle" or "bead" between the lips of the coating hopper and the surface to be coated which tends to pile up or "puddle" on that side of the coating device from which the web leaves. This pile up or bead extends completely across the width of the web being coated and is generally referred to in the art as a coating bead or a bead of coating. In Fig. 2 we have shown the form of bead believed to exist with the present double slide hopper, as well as the paths taken by the individual layers of coating composition in passing therethrough. However, it is pointed out that this is merely a speculation since it has proven practically impossible to actually see what occurs within the bead. It can be seen that with this bead coating technique the coating is not in fact deposited directly onto the web surface by the hopper, but that the hopper merely maintains the coating bead and the web is coated therefrom. With the bead technique of coating the actual thickness of the coating laydown on a web moved thereacross will be determined by the action of the bead and will vary with the speed of web movement, etc. and will not necessarily be equal to, or directly dependent upon, the thickness of the ribbon of coating composition fed to the slide surface or the thickness of the layer formed in flowing down the slide surface.

The second fluid coating composition S' is continuously pumped into a second cavity 19 at a given rate by a second metering or constant discharge pump P' through inlet 20. From this cavity the composition is forced through a narrow vertical slot 21 in the form of a ribbon and out onto a downwardly inclined slide surface 22 down which it flows by gravity in the form of a layer 23. If slide surface 22 is coplanar with slide surface 14, as shown in Fig. 2, then layer 23 of coating composition S' will flow up onto the top of the ribbon of coating composition S leaving slot 13 when it reaches this point and then the two layers 15 and 23 of the separate coating compositions will flow down slide surface 14 in combined layer relationship without mixing.

As shown in Fig. 2A, the slide surface 22' may be raised above slide surface 14 by an amount substantially equal to the thickness of layer 23 so that layer 23 will flow onto the top of layer 15 without any, or with little, change in direction if such is desired. The only requirement in this respect is that the two slide surfaces 14 and 22' be substantially parallel to one another and not be relatively offset by such an amount that the two layers would be brought together in such a way as to provoke a turbulent effect which might cause the two to mix.

It will thus be seen that the two layers 15 and 23 of the separate coating compositions S and S' are combined in surface relationship prior to the time they flow into the bead 17. When the two combined layers reach the coating bead, this distinct layer relationship must be maintained within the bead, despite the apparent deformation of the bead, since an enlarged cross-section of the coated web after being dried showed that the two layers were distinct, extremely free of contamination or mixing at their interface, and possessed a relative thickness commensurate with the rate at which each composition was pumped into the hopper. Since, for reasons pointed out above, the thickness of the layers when deposited on the web may, and usually will, be different from the thickness of the same layers when they move into the bead, due to the bead action, the layers of coating after application to the web have been designated by the same reference characters as the layers formed by moving down the slide surfaces 14 and 22 with the exception that the deposited layers have been designated by a prime (') to indicate that the thickness of the layers after deposition might be different than during the initial formation.

Although it is conceivable that the hopper 10 could be made from a single block of metal so that the slide surfaces 14 and 22 would in fact constitute a single slide surface broken into two separate slide surfaces by the vertical slot 13 entering transversely thereof, from a practical standpoint of milling out the cavities and slots, this is out of the question. Accordingly, we have shown the hopper made up of a plurality of individual blocks 25—30 which are suitably machined so that when they are assembled as shown, the cavities, vertical slots and inlets will be formed. These individual blocks can be held in assembled relation by any suitable means not shown. With such a construction the slide surfaces 14 and 22 would be formed on blocks 25 and 27, respectively, and would be completely separate parts. In the event the coating compositions used are of the type which must be heated or cooled in order to keep them in a suitable fluid condition, the hopper, or the blocks making up the same, may be provided with interconnected conduits 31 through which a fluid heating or cooling medium may be circulated. If the vertical slots 13 and 21 are of the same width, then the relative thickness of the two layers of coating composition deposited on the web will depend upon the rate at which they are pumped into their respective cavities 11 and 19.

Using a double slide hopper of this type, a gelatino silver halide photographic emulsion and a protective coat of clear gelatin have been simultaneously coated onto a baryta-coated paper 42 inches wide at a speed of 100 feet per minute to produce a commercial photographic paper having as good physical and and photographic characteristics as the same product on which the two coatings were applied successively and with a complete drying of the emulsion coat prior to application of the protective gelatin coat. When coating at this speed, it was found advantageous to use a vacuum on the bead, as disclosed in U. S. Patent 2,681,294 to eliminate excessive vibration and/or rupture of the bead. This example clearly shows that this apparatus is not limited to the coating of narrow width sheets and the use of slow coating speeds, but is equally adapted for the multiple coating of commercial width product at high coating speeds. While there is no known limitation as to the thickness of coatings which can be applied by this hopper, it is par-

ticularly adapted for the application of thin layers, i. e. one micron to .025 inch in thickness.

The hopper **10** may be provided with any suitable form of adjustable mount so that the position of the lower end of the lowermost slide surface relative to the web being coated may be adjusted for the best results. To this end the hopper **10** may be carried by a frame **32** provided with bearings **33** rotatably mounted on the axle of the roll **13** to swing concentrically of the roll so that the position of the hopper as a whole may be shifted around the roll periphery, see Fig. 1. It is adapted to be locked in any adjusted position by clamping screw **34** engaging an arcuate slot **35** in the support **36**. The hopper may be pivoted to the frame **32** for critical adjustment around the periphery of the roll, and may be slidably mounted on the frame for adjustment toward and from the roll periphery by any suitable means not shown.

After the web W has been coated, it may be necessary to set and dry the coatings applied thereto. In the manufacture of photographic film or paper, the coatings applied may be of the type which are set by cooling prior to drying in order to limit the amount of relative flow between the layers themselves or between the bottom layer and the support. In such a case the web W after being coated can be passed through a chill box **37** and then through a drying chamber **38**. If the coatings applied are of the type which do not require chilling before drying, then chill box **37** can be omitted or by-passed. The web may be pulled from the drying chamber **38** by a feed or guide roller **39**.

In Fig. 3 there is shown a four-slide hopper **50** by the use of which four separate layers of the same or different fluid coating compositions can be simultaneously applied to the surface of a web. Structurally this hopper **50** is practically identical with the double hopper **10** shown in Fig. 2, and differs therefrom primarily in that two double slide hoppers have been combined in such a way that the four layers of separate coating compositions are individually formed and brought into layer relationship prior to introduction into the coating bead **17'**.

In this four-slide hopper the first fluid coating composition S is continuously pumped at a known rate into a cavity **51** through inlet **52** and from which it is extruded through a narrow vertical slot **53** in the form of a ribbon onto a downwardly inclined slide surface **54** over which it flows by gravity to form into a layer **55**. Likewise other coating compositions are continuously pumped into cavities **56**, **57** and **58** through inlets **59**, **60** and **61**, respectively, and are extruded in the form of ribbons from narrow vertical slots **62**, **63** and **64**, respectively, onto slide surfaces **65**, **66**, and **67**, respectively, down which they flow by gravity to form separate layers **68**, **69** and **70** of the different compositions. Each coating composition is continuously fed into the hopper by a separate metering pump of the constant discharge type as shown. The four slide surfaces are coplanar, or substantially so, so that as the layers of the separate coating compositions flow down their respective slide surfaces they are brought together in overlapping relation, and by the time the four layers reach the coating bead **17'**, they are combined in the desired stratified relationship. The distinct layer relationship is maintained throughout the bead so that as the web W is moved across and in contact with the bead, it takes up on its surface the four layers of coating in the desired orientation and with the layers distinctly separate from one another and having a relative thickness commensurate with the rate at which each was pumped into the hopper. So far as we have been able to ascertain, there is no limit as to the number of separate layers of coating compositions which can be simultaneously laid down on the surface of a web with a multiple hopper of this type.

We are unable to explain why two or more layers of coating composition when simultaneously coated onto a web in accordance with the present invention do not mix

but maintain a layer relationship as distinct and as free of mixing and contamination at the interface of the layers as when the same compositions are coated successively with a complete drying of each coating before the next one is applied thereto. It is not based on the fact that the different coating compositions are physically or chemically non-compatible because, as the examples show, the same results are obtained if all of the coating compositions are identical both physically and chemically, except that a dye or carbon dispersion was incorporated in one to give visible proof of this phenomenon.

In attempting to explain the reason why the different layers of coating composition do not mix when coated according to the present invention, the question of whether it was because a form of liquid motion known as "laminar flow" was involved as distinguished from a form of motion known as "turbulent flow" has been considered. According to the Reynolds theory of fluid motion (R. C. Binder, "Fluid Mechanics," Prentice-Hall, 1943, p. 71), when two separate streams of water are passed through a pipe, they will stay separated due to a condition of laminar flow so long as the critical velocity is not reached and after the critical velocity is reached, the flow becomes turbulent and the streams will mix. Reynolds showed that the critical velocity depended on the diameter of the pipe, the velocity of the fluids passing through the pipe, its density, and its viscosity, and that if these four factors were combined in one way, and one way only, a function known as the Reynolds number would be obtained giving the critical velocity for the flow of a fluid through a pipe. While this theory might be applied to explain the reason why the separate layers would not mix in passing in combined relation through the exit slot in an extrusion type hopper, on the basis that the flow is laminar because the Reynolds number is not high enough to reach the critical velocity, it does not seem to apply when the multiple slide hopper technique is used, nor does it explain the maintained separation of the layers through the coating bead and after deposition on the web until they are dried, because the layers are not moving through a pipe nor are they totally confined in any way. The one explanation for this phenomenon which might be advanced is that normally it takes an appreciable time for two solutions to mix even if they are brought together in such a way as to provoke turbulence, and with the method of coating involved here the different layers are not in combined layer relationship long enough, before being deposited on the web, to allow noticeable mixing to take place even if the conditions of flow are such as to be conducive to such a mixing. As to why the layers of coating maintain their separate relationship between the time they are deposited on the web and they are completely dried is unexplainable except in the case of those coating compositions which are capable of being set by chilling, heating, or by chemical action immediately after deposition on the web surface and prior to drying. Here again the element of time might be the critical factor since the time elapsing between the deposition of the layers on the web and the time the coating is dried is relatively short and perhaps less than the time required for the coatings, or the materials dispersed therein, to diffuse into one another.

While we have shown and described certain specific embodiments of our invention, we are 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 is new and desire to secure by Letters Patent of the United States is:

1. In an apparatus for simultaneously applying a plurality of fluid coating compositions to the surface of a web in superposed and distinct layer relationship the combination with a web guiding surface over which the web

to be coated is adapted to be continuously moved and held in a smooth condition, of a multiple-layer slide hopper comprising a slide surface inclined downwardly toward the web guiding surface and terminating in a lip spaced from the guide surface by an amount slightly greater than the thickness of the web to be coated, a plurality of discharge slots extending from the interior of said hopper and opening onto said slide surface through which the separate coating compositions are adapted to be extruded in the form of layers, said discharge slots arranged so that the lowermost is spaced above said lip and the others are spaced from it and one another to provide uninterrupted slide portions below each slot down which the layer extruded from any slot flows by gravity to form a smooth layer of uniform thickness prior, in the case of all but the lowest slot, to the time it reaches the next lowest slot and flows onto the top of and along with the layer of coating composition extruded therefrom, and, in the case of the lowest discharge slot, before it and the layers on the top thereof reach the lip, and means for continuously feeding a fluid composition into each of said discharge slots at a given rate commensurate with the thickness desired for each of said layers after coating.

2. A coating apparatus according to claim 1 in which said slide surface of the hopper is composed of a plurality of individual slide surfaces separated by said discharge slots and positioned in adjacent relationship, the planes of all of said slide surfaces being substantially parallel to one another and each slide surface being spaced above the plane of the next lowest slide surface by an amount substantially equal to the layer of coating composition to be extruded from the latter so that the layer of coating composition sliding down the higher surface can flow onto the top of the layer of coating composition extruded from the next lower discharge slot with substantially no deformation of the uppermost layer.

3. A multiple-layer hopper for feeding a plurality of fluid coating compositions in superposed and distinct layer relationship to a point of deposition where they are simultaneously deposited onto the surface of a web moving relative thereto in such strata relationship, and comprising a block, a slide surface on said block inclined downwardly and terminating in a lip adjacent said point of deposition, a plurality of separate cavities within said block, one for each coating composition, a narrow discharge slot extending from each cavity to said slide surface through which a thin layer of coating composition is adapted to be extruded from each cavity and onto said slide surface, the lowermost of said discharge slots

spaced from said lip and the remaining discharge slots spaced above this lowest slot and from each other to provide an uninterrupted slide portion below each slot over which the layer of coating composition extruded therefrom flows by gravity to form a smooth layer of uniform thickness before, in the case of all but the lowest slot, it reaches the next lowest discharge slot and flows onto the top of, and along with, the layer of coating composition extruded therefrom, and, in the case of the lowest discharge slot, before it reaches the lip, and means for continuously feeding a fluid coating composition into each of said cavities and from the associated discharge slots at a given rate commensurate with the thickness desired for each of said layers after coating.

4. A dual-layer hopper for feeding two fluid coating compositions in superposed and distinct layer relationship to a point of deposition where they are simultaneously deposited in such strata relationship onto the surface of a web moving relative thereto, and comprising a hopper provided with two separate cavities, a slide surface inclined downwardly toward said point of deposition and terminating in a lip adapted to be spaced from the surface of the web to be coated, a narrow discharge slot connecting each cavity with said slide surface through which a thin layer of coating composition is adapted to be extruded from each cavity and onto said slide surface, one of said slots opening into said slide surface at a point spaced from said lip whereby a slide portion is provided below said slot over which the layer of coating composition is adapted to flow by gravity to smooth out and obtain a uniform thickness, the second slot opening into said slide surface at a point above said other slot to provide a slide portion over which the layer of coating composition extruded therefrom may flow by gravity to smooth out and obtain a uniform thickness prior to flowing onto the top of the layer of coating composition extruded from said other slot after which both layers flow together in superposed relation over said first-mentioned slide portion and to the lip of the slide surface, and means for continuously feeding a fluid coating composition into each of said cavities at a given rate commensurate with the thickness desired for each of said layers after coating.

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