June 15, 1954 A. E. BEGUIN 2,681,294

METHOD OF COATING STRIP MATERIAL

Filed Aug. 23, 1951

3 Sheets-Sheet 1

Fig. 1

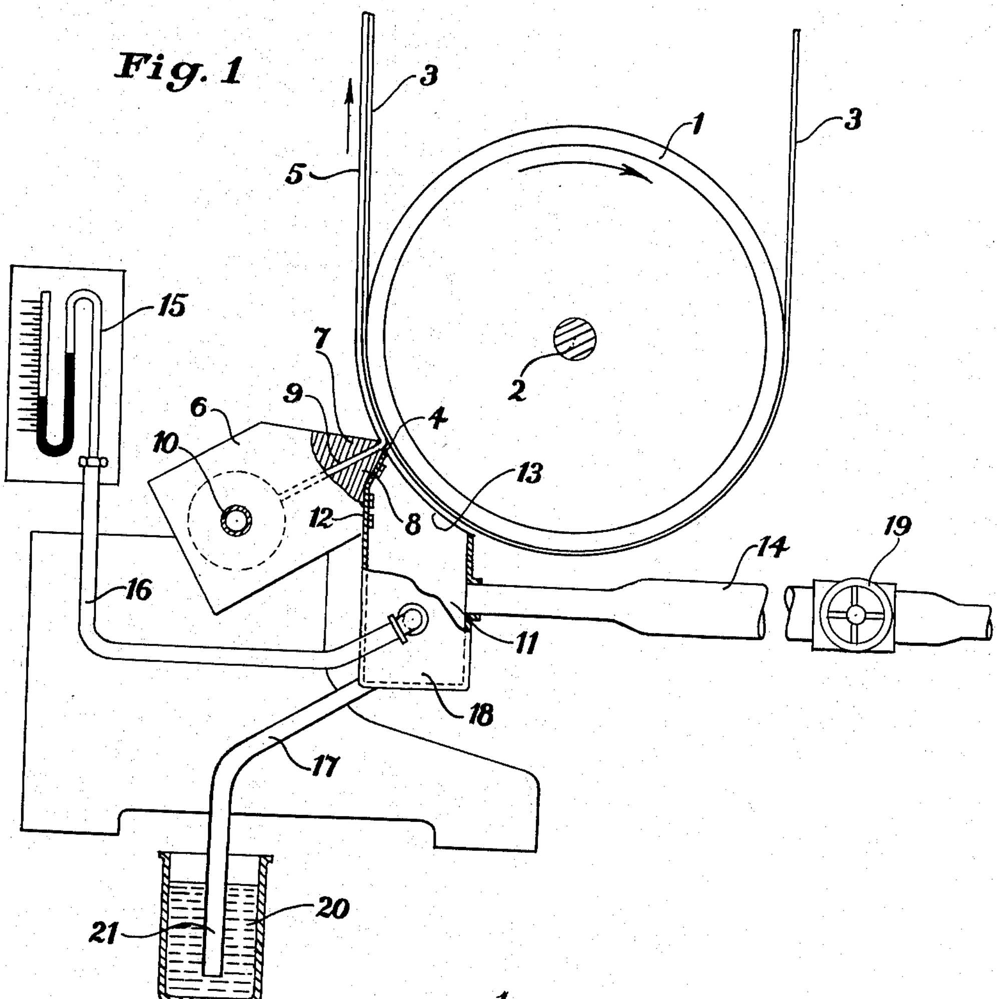
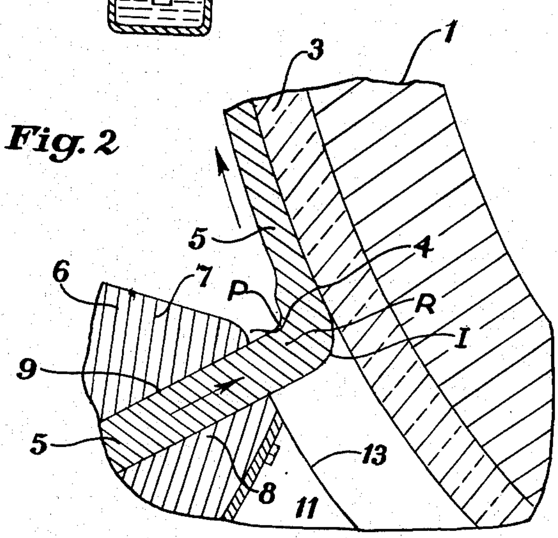


Fig. 2



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3 Sheets-Sheet 2

FIG. 3.

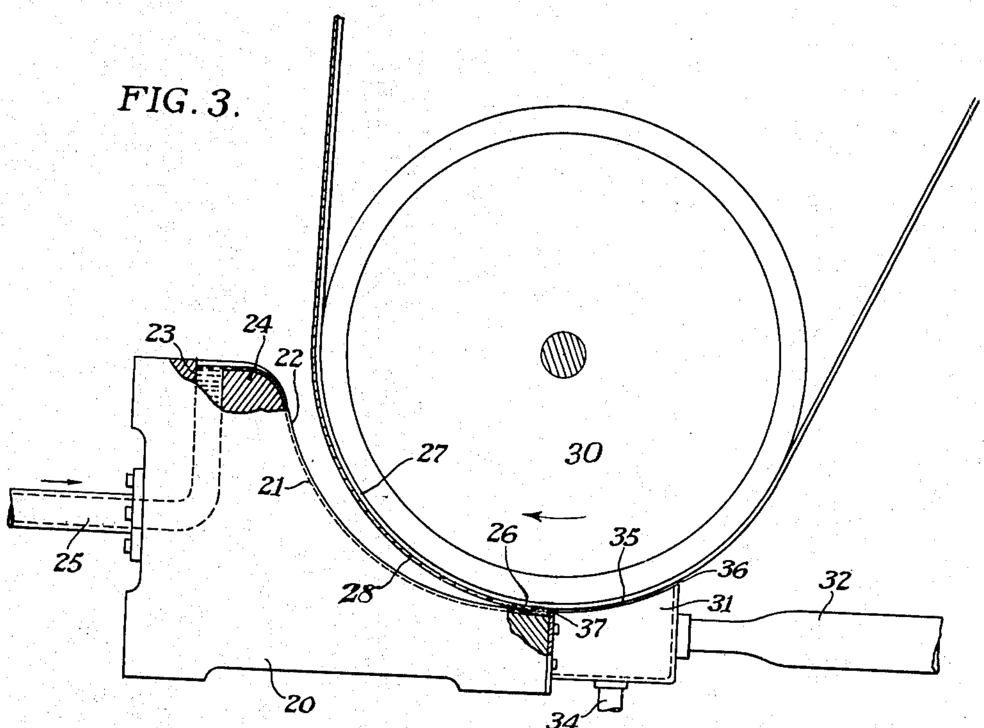

FIG. 5.

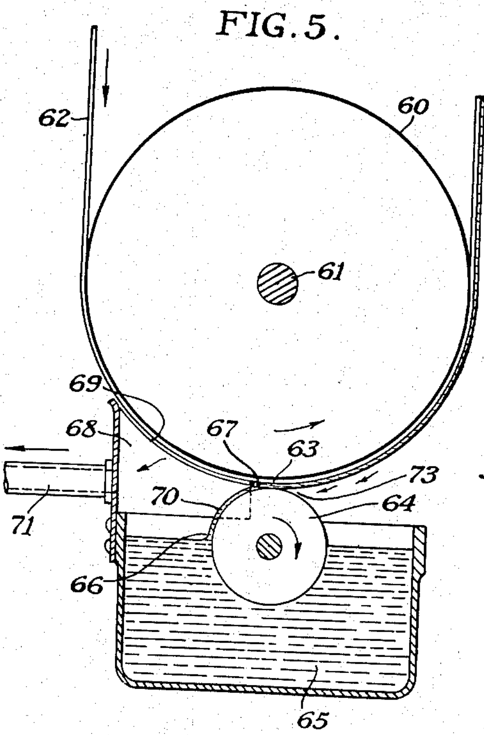

FIG. 4.

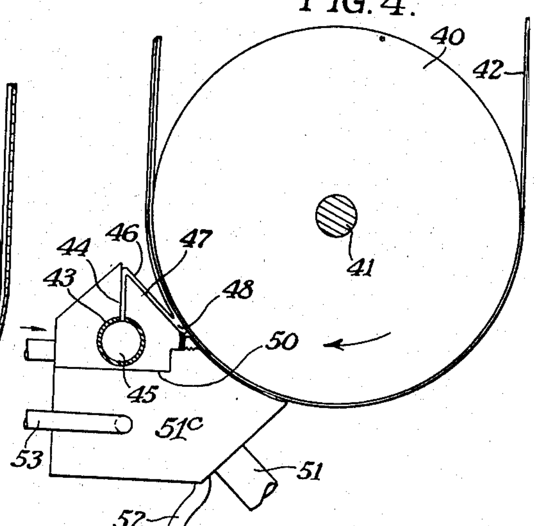

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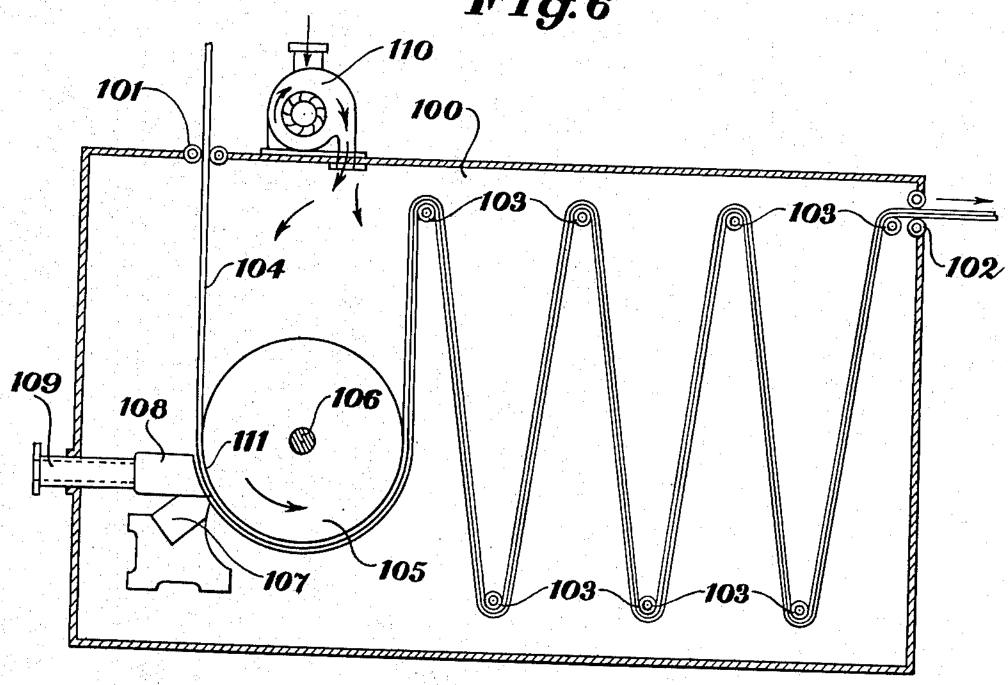
Fig. 6



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Patented June 15, 1954

2,681,294

UNITED STATES PATENT OFFICE

2,681,294

METHOD OF COATING STRIP MATERIAL

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Application August 23, 1951, Serial No. 243,257

18 Claims. (Cl. 117—34)

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This invention relates to improvements in the method of applying fluid materials or coatings to a moving strip of material to be coated.

It has been customary heretofore to apply fluid coatings by various different methods such as by dipping, applicator roll, or doctor blade, where fluid material is held against a moving web for the purpose of coating the surface of the web. Such coatings have also been applied by pumping the coating material through a slot of a hopper to a web to be coated. These methods have, in general, been satisfactory in that regular and usable coatings have been produced. Generally, however, these coating methods have been distinctly limited in speed. The reduction of thicknesses of coatings has been difficult. The quantities of coatings applied have been difficult to maintain precisely. In the photographic industry where many types of precise coatings are required on relatively nonporous supports such as film and baryta-coated paper such limitations have been serious. Obviously, multilayer coatings used particularly in making color films and printing papers have been time-consuming and difficult because of the number of these layers of coating required and because of the limitations of known coating methods.

There has heretofore been considerable waste in coating over spliced webs as in the past many methods used, particularly in photographic coating, have required movement of a coating device from and to the material being coated to allow a splice to pass. This caused many difficulties. An alert operator has been necessary to move the coating device promptly and to readjust the coating device quickly after the splice passes to coat the exact amount required. Sometimes many feet of coated material have been wasted before the coating can be made precisely after the coating device is moved over a splice and brought back accurately into a coating position again.

My improvement in coating methods has overcome many of the disadvantages and limitations of the known coating methods by greatly increasing the speed of coating, as from two to even ten or more times. This has been accomplished by a simple method which includes flowing a narrow ribbon of coating composition in a stream between a coating device and a surface to be coated while maintaining a greater pneumatic or other gaseous pressure on the ribbon on that side from which the coated material passes from the coating device than the pressure on that side of the ribbon from which the surface to be coated moves toward the coating device. The

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pressure differential need not be great—for instance, from .1'' to 5.00'' of water pressure is satisfactory for many coating compositions. This pressure differential appears to prevent the material to be coated from carrying air bubbles, air streams or the like, up into the flowing ribbon of coating material. It also tends to prevent the ribbon from following the rapidly moving surface to be coated and interrupting the coating. It further appears to hold the ribbon against vibrating and waving and in a coating condition.

Therefore, one object of my invention is to provide a method of coating which can be operated at much higher speeds than present known methods. Another object of my invention is to provide a method of coating suitable for applying precise coatings, both in coverage per square foot of the material to be coated and in accuracy of thickness. Still another object of my invention is to provide a method of coating over splices in the material to be coated which is less wasteful than with prior methods. Another object is to provide a method which can be carried out without paying any attention to splices in the strip material, and without moving the coating device relative to the surface to be coated. A still further object is to provide a coating method which is much more flexible than known methods. Other objects will appear from the following specification, the novel features being particularly pointed out in the claims at the end thereof.

These objects can be carried out by the use of apparatus shown in the accompanying drawings, wherein like reference characters denote like parts throughout.

Fig. 1 is a schematic part side elevation, part section, of a preferred form of apparatus with which my improved method may be carried out;

Fig. 2 is a greatly enlarged fragmentary sectional view showing the ribbon of coating composition being applied from a coating device to a surface to be coated;

Fig. 3 is a fragmentary side elevation, parts being shown in section, showing a cascade type of coating apparatus with which my improved method may be readily carried out;

Fig. 4 is a view similar to Fig. 3 but of a somewhat different type of hopper;

Fig. 5 is a schematic sectional view through a typical roller applicator device with which my method may be carried out; and

Fig. 6 is a schematic side elevation, partially in section, showing another embodiment of my invention in which the differential pressures are obtained without the use of subatmospheric pressure.

Referring to Fig. 1, a typical hopper provided with a slot through which the coating material is supplied, and hereinafter referred to as an extrusion hopper, may include a supporting roller 1 which may turn on shaft 2. A strip of material 3, such as film or paper, may be passed about the roller 1 and past a coating station designated broadly as 4. Thus, as the uncoated strip material 3 passes to the coating station, it receives the coating material 5 at the station 4 and passes away from the roller 1 for the necessary drying operations.

The coating hopper 6 may be of a known type in that it has two hopper blades 7 and 8 which may be spaced apart a short distance, such as, for instance, .015'', so that a flow of coating composition may pass through the opening 9 between the blades 7 and 8. The coating composition is passed into the hopper 6 through a pipe 10 at the required rate to produce the required coating 5 on the sheet material.

To this extrusion-type hopper I have added an enclosure 11 of generally box-shape except that there is no top wall. This enclosure 11 may be attached at 12 to the coating hopper and may be spaced at 13 from the surface being coated a slight distance such as .015'' on the incoming side. Thus, the roller in effect forms a top wall for the enclosure. The enclosure 11 is connected to a pipe 14 which may lead to a means for reducing pressure. A valve 19 may be employed to regulate the degree of pressure reduction in chamber 11 which may be indicated by a manometer 15 which is connected by pipe 16 to the chamber 11. Thus, if a partial vacuum equal to 2'' of water is required, the valve 19 may be adjusted until the proper degree of vacuum is indicated on the manometer 15. The bottom 18 of the chamber 11 may be attached to a drain pipe 17 through which the spillage of coating composition may pass, there being a liquid trap diagrammatically shown at 20 at the lower end 21 of this pipe 17 to maintain the partial vacuum in chamber 11.

Referring to Fig. 2, it will be noticed that there is a thin flow or stream of coating material passed through the lips 7 and 8 of the hopper to the surface to be coated which, in this case, is the film 3. This flowing coating composition is of the width of the desired coating. In this case the ribbon R extends between the coating device and the surface to be coated and this is the ribbon to which a pressure differential is applied. In accordance with my preferred embodiment, reduced pressure is applied on that side I of the ribbon to which the material to be coated is approaching the coating station 4. On the opposite side P of the ribbon from which the coated surface passes from the coating device, there is atmospheric pressure and this difference in pressure is the means for maintaining the ribbon in its coating position, while the wheel or roller 1 moves the strip material 3, preferably at a relatively high speed. This speed may be in the order of 500 feet per minute or more according to the type of coating solution being applied. Slower, or sometimes higher, speeds can advantageously be used for both thick and thin coatings.

With many of the well-known coating methods it is necessary to approach the web being coated to within a distance of about the same magnitude as the thickness of the coating applied. With my method, however, it is possible to successfully operate at a distance of several times the thickness of the applied coating. This is possible because by applying different pressures to the two sides of the flowing ribbon of coating material it can be maintained in coating position at these wider spacings as is shown in Fig. 2. This is one of the more important features of my improved method because in many cases this spacing can be made sufficient to permit a splice in the web to pass the coating station without moving the hopper away from the surface being coated. On the other hand, without applying differential pressures, it is generally necessary to move the lips of the coating hopper so close to the surface of the strip material being coated that the hopper must be moved away from the surface being coated each time a splice passes the coating station. This is a difficult operation for an operator and, if the time of moving the hopper away from the surface is not carefully gauged, as a splice passes the coating station, many feet of film are wasted by improver coating. It is, of course, even more difficult to move the coating device back into a coating position precisely after a splice has passed.

In the form of the invention shown in Fig. 3, coating solution may be pumped over a so-called cascade type of hopper 20. This hopper has a downwardly-curving edge 21 over which a layer of coating solution 22 may flow after passing over a dam 24. The coating solution may be pumped into the hopper 20 through reservoir 23 and pipe 25. A constant flow pump is preferably employed. In this instance, a narrow ribbon 26 of coating solution lies almost tangent to the strip material 27 being coated but, nevertheless, a differential pressure is applied to the two sides of the ribbon. Here, a coating roller 30 supports a film or paper strip 27, this strip being drawn past a coating station 26. The band 27 moves about the roller and outwardly away from the coating station with a layer of coating solution 28 on the outside as indicated in Fig. 3.

A chamber or enclosure 31 is provided with the upper edges 35, preferably slightly spaced from the surface material 27 to be coated, and this is connected to a vacuum line by a pipe 32, similar to the pipe 14 in Fig. 1. There is also preferably a drain 34 and there may be a manometer 15 (not shown in this view), as indicated in Fig. 1, to show the degree of vacuum in the chamber 31. Here, again, the ribbon 26 is preferably submitted to a partial vacuum (but other differential pressures may be used) which tends to draw off air moving with the sheet and which acts on one side of the ribbon 26, that is, the side facing the approaching material to be coated. On the opposite side of the ribbon 26, or that side facing the outgoing coated material, atmospheric pressure provides a greater pressure on the outgoing than on the incoming side of the ribbon.

Fig. 4 is much like Fig. 3, although the apparatus for coating again is somewhat different. Here, a roller 40, carried by shaft 41, supports a strip 42 to be coated, the coating in this instance being carried out by means of a hopper 50, having a slot 44 through which the coating material may be pumped through a pipe 45. There is a smooth, thin layer of coating composition 46 which runs down the inclined surface 47 and forms a ribbon 48 of coating composition. This ribbon lies between the coating device 50 and the surface to be coated and on the incoming side of the ribbon a partial vacuum is obtained through the chamber 51c which may be partially evacuated through pipe 51. This chamber may include an emulsion drain 52 and a pipe 53 leading to a manometer to determine the degree of vacuum.

In Fig. 5, a roll-type coating is arranged in which a roller 60 supports a moving strip 62 to be coated, this roller turning on the shaft 61. An applicator roll 64 dips into a bath 66 of coating solution and carries up a layer of this solution into a ribbon 67. A chamber 68 on one side of the ribbon can be partially evacuated through a pipe 71, leading to a reduced pressure line or to the intake side of a blower so that a reduced pressure may be applied to the incoming side of the ribbon and atmospheric pressure is applied at 73 on the outgoing side of the ribbon. The chamber 68 includes a curved upper wall 69, preferably lying out of contact with the material to be coated by a small distance as, for instance, .015''.

These various coating devices, as will be readily apparent, can be altered in many ways. For instance, if it is desirable to move film in an opposite direction from that shown in Fig. 1, the vacuum chamber 11 could be placed above, instead of below, the hopper. Also, it would readily occur to those skilled in the art that it might be desirable to have two vacuum chambers, one on each side of the hopper applying the ribbon of coating solution, the incoming side having a greater vacuum as, for instance, equal to four inches of water, than the outgoing side which may, for instance, include a partial vacuum equal to only two inches of water. Thus, there would be a difference between the two pressures which would both be less than atmospheric pressure which would tend to maintain the ribbon in its coating position.

If desired, it is not necessary to use a subatmospheric pressure. As illustrated in Fig. 6, there may be an enclosure 100 having a relatively air-tight entrance 101 and exit 102 for a strip of material 104 to be coated. This material may be led over a coating roll 105 adapted to turn on suitable trunnions 106. From the coating roll the coated strip may be led about a plurality of guide rolls 103 before passing out of the pressure chamber over the exit rollers 102. The entire chamber 100 may be put under pressure by means of a pump 110 passing air into the chamber 100. In this instance, the coating device 107 may be exactly like that shown in Fig. 1 with the exception that there is a pressure chamber 108 (here shown as atmospheric) on the incoming side adjacent the coating station. The chamber 108 may be connected to a pipe 109 leading out to ambient atmospheric pressure so that while the pressure in chamber 108 is atmospheric, the pressure in the enclosure 100 is greater than atmospheric and the required differential in pressure on the two sides of the ribbon 112 of the coating material can readily be obtained. The effect on the coating ribbon will be the same as in the other described embodiments of my invention in that on the incoming side the ribbon is subjected to a lower pressure than on the outgoing side and, consequently, the ribbon may be maintained in coating position for the reasons given above.

It may be pointed out in all these embodiments that the degree of vacuum or pressure difference is relatively slight and, consequently, some leakage between the edges of the vacuum chamber and the rest of the apparatus is immaterial since this can be readily made up by removing some of the air from the vacuum or reduced pressure chamber.

It will be noticed that the same method is employed throughout the different types of hoppers which may be used in accordance with my invention. In each case, there is a strip of material having a surface to be coated moving rapidly with respect to a coating device. In each case, the coating device is spaced from the surface to be coated a short distance. In each case, a ribbon of flowing coating material is bridged across the space between the coating device and the surface to be coated and, in each case, a different pressure is applied to the two sides of the ribbon, the lower pressure being on the side from which the surface to be coated approaches the coating device. In all cases, this ribbon is maintained accurately in a coating position while the coating operation is being carried out.

While not limited to photographic coatings on the usual supports such as film base or paper, my improved method is particularly adapted for use in such coatings. Both film base and bartya-coated papers cannot be considered as porous materials. No appreciable amount of air is entrapped in any interstices in such sheets. The ribbon of flowing coating composition is normally maintained by surface tension forces. The pressure differential acts as an aid to these forces.

With photographic coatings, for example, such as a light-sensitive emulsion using the open pan coating method of the prior art, the following table shows a typical example in pounds per square feet of material which may be applied and shows the typical viscosities of emulsions which may be used, it being kept in mind, however, that coatings of other viscosities may also be applied:

Emulsion Viscosity, Centipoises	Emulsion Would Coat out of open pan, Lbs. 100 ft.^{2}	Temperature, °F.
6	6.2	100
12	8.8	100
18	11.4	100
22	12.6	100
33	16.5	100

Known types of machines may be used to coat emulsions of the above viscosities in the indicated pounds per hundred square feet at speeds which may reach 40 feet per minute.

With another type of coating device known in the prior art as an "extrusion hopper," thinner coatings may be aplied and these machines may be operated at a higher speed, usually the maximum being about 100 feet per minute. The following table shows typical examples in pounds per square foot of coatings having the same viscosities as the above compositions and applied to a film base:

Emulsion Viscosity, Centipoises	Minimum Hopper Coats, Lbs. 100 ft.^{2}	Temperatures, °F.
6	2.5	100
12	3.5	100
18	4.6	100
22	5.1	100
33	6.5	100

In each of these two prior art examples, the speed of the coating operation is definitely limited, approximately to the speeds given of 40 and

100 feet per minute because, if these speeds are exceeded, the flow of coating composition to the sheet becomes irregular, and streaks or breaks in the coating appear. Unfortunately, these upper limits in speed greatly restrict the amount of coating which can be applied in a given time and this naturally limits the output of the coated product. This is particularly true where a single film such as color film may require quite a number of coatings.

Where the old style pan or dip type of coating method is employed, film is passed continuously under a coating roll which dips into a pan of emulsion. The thickness of the coating or the weight of the coating in pounds per square foot is determined by two factors; one, the viscosity of the coating solution, and, two, the rate of movement of the film. If either or both the coating speed or the viscosity of the coating material is increased, the amount of coating applied and carried away also increases.

Photographic emulsions in most instances contain a vehicle (usually gelatin) in proportion to the amount of silver salt present. This vehicle imparts considerable viscosity to the emulsion which sets a definite limit on how fast the emulsion can be coated out of an open pan without exceeding the desired amount of silver salt on the film.

When color films became popular, there was a great need of a faster means for coating the multiple layers which they required. In addition, these layers have to be extremely precise in thickness in order to maintain color balance so that the need for a more versatile coating method has become of paramount importance. The so-called "extrusion hopper" was a desirable advance in coating in that the coating speeds could be increased, but even with these hoppers, 100 feet per minute appears to be about the greatest practical speed which can be obtained. The accuracy of covering the strip with coating, the coating thickness, and uniformity all have to be maintained to very close tolerances for best results. It is also noted that color films can well utilize extremely thin coatings which are, of course, much more difficult to apply precisely.

My improvement includes providing a flowing stream of coating composition and providing a ribbon or band of coating composition between a coating device and a surface to be coated while moving one relatively to the other. By ribbon or band, I mean a relatively thin flowing area of coating composition extending completely across the area to be coated and upsupported on both sides by any apparatus. The ribbon may have a reasonably uniform cross section or the cross section may vary as have been shown in the examples described above and shown in the drawings. The ribbon is that portion of the coating composition lying in the interface zone of the coating to which the coating moves from the coating device and from which the coating moves away with the coated surface, preferably at comparatively high speeds. The roller and coating device may be of known types in which there is a slight separation between the coating device and the surface to be coated, this separation being bridged by the narrow band or ribbon of flowing coating solution moving from the coating device to the surface to be coated. On that side of the ribbon which faces the surface to be coated which is approaching the coating device, I subject the ribbon or coating composition to a lesser pressure (pressure differential) than on the op-

posite side of the ribbon from which the surface to be coated moves after the coating has been applied.

This difference in pressure can readily be accomplished by applying a partial vacuum such as, for instance, equal to from .10'' to 4'' or 5'' of water, to that side of the ribbon which faces the incoming surface to be coated and by subjecting the opposite side of the ribbon, or the side from which the coated material passes from the coating device, to a higher pressure, such as normal atmospheric pressure. There are other ways of obtaining the desired pressure differential. If desired, the two pressures may be atmospheric or above, providing the pressure on the incoming side is less than that on the outgoing, or both pressures may be reduced pressures such as different degrees of vacuum, although here again the difference must include the greater pressure on the outgoing side of the ribbon. Hence, by pressure differential, I contemplate several ways of accomplishing the aforesaid result.

The ribbon of coating composition may be extremely thin. A typical example for photographic coatings, for instance, being .002'' in thickness, and the spacing between the coating device and the surface to be coated may also be slight, such as .015''. These figures are purely by way of illustration since the thickness of the thin stream of coating composition being flowed toward the surface to be coated may be varied within reasonable limits and in accordance with the amount of coating composition which may be required on the strip material.

I have found that the difference in pressure on the two sides of the ribbon of coating composition may be comparatively slight as, for instance, a partial vacuum of from .1'' to 5.00'' of water, and I have found that changes can be made in the degree of vacuum without noticeably changing the coating applied to strip material in evenness, quality, or quantity of the coating applied. With my improved method of coating, a much thinner coating may be applied more precisely than with most of the standard methods heretofore used and with photographic emulsions, for instance, or coating materials having viscosities of from, say, 5 to 35 centipoises (as mentioned above) coatings of from .5 pound to 2 pounds per hundred square feet may be readily applied. Examples to be given later indicate a still greater range in viscosities as, for instance, from .75 centipoise to 500 centipoises may be successfully coated with my improved method. Thus, extremely thin coatings, as may be required for multilayer color films, for instance, can be applied with extreme accuracy as well as rapidity by my improved method.

Generally speaking, thin coatings are almost always more difficult to apply properly than more normal, thicker coatings and, while my method is extremely suitable for applying very thin coatings (such as .0001''), thicker coatings can also be readily applied. Likewise, precise coatings at very high speeds are much more difficult to obtain than at slower speeds. I have been able to coat precisely-controlled coatings at two to ten or more times the more usual coating speeds mentioned above and, under certain conditions, even these speeds may be greatly exceeded. My method, however, is not limited to fast or high-speed coating, as improved results may also be obtained with this method at more normal or slower speeds, particularly in applying very small quantities of compositions to large areas. Greatly improved results are obtainable with my improved method when coating spliced supports.

As pointed out above, if in the prior art open pan and extrusion-type hopper coatings the upper limit of speed, usually in the neighborhood of 40 feet per minute for the former and 100 feet per minute for the latter, were exceeded, the layer of coating composition applied to the support would become irregular as higher speeds were tried. Such imperfections frequently take the form of streaks in which some areas of the strip material to be coated are coated more heavily than other areas and, at times, these streaks would even break through the coating, leaving some coated areas and some totally uncoated areas. The exact cause of this is not definitely known, although it may be due to the fact that, when a surface to be coated moves at a high speed past a coating device, some air may be carried up into the coating ribbon, causing it to fluctuate and perhaps eventually break, thereby spoiling the coating. It may well be that air adjacent the surface of these strip materials may move with the surface to be coated into the ribbon of coating material and spoil the coating.

Typical examples of the various coating compositions which are particularly suitable for coating with my improved method are hereinafter described, although I do not wish to be restricted to these materials, and they are cited by way of illustration only.

Example 1.—Example of coating a photographic emulsion at high speed

A sensitized gelatin-silver halide photographic emulsion of the positive type, consisting of silver halides suspended in an aqueous solution of gelatin, was applied to a safety film support .008'' in thickness using a hopper such as shown in Fig. 1. The viscosity of the emulsion used was 7 centipoises at 95° F., and the speed of coating was 446 feet per minute. The pressure differential used was equal to approximately 1.00'' of water. The amount of emulsion coated was .015 pound per square foot of film surface.

When the differential pressure was not used, it was found necessary to reduce the speed of the machine to 40 feet per minute to obtain a continuous coating of the same thickness and quality.

Example 2.—Example of the effect of low air pressure differential on the speed of coating

This example shows the effect of low air pressure differential on the speed of coating. A positive type gelatino silver halide emulsion having a viscosity of 9 centipoises was required to be coated with a coverage of .023 pound of wet emulsion per square foot on a cellulose acetate support .005'' in thickness at a temperature of 95° F. By a conventional method of coating, such as an immersion roll, the maximum speed which could be reached without introducing defects was 9 feet per minute.

With a hopper such as shown in Fig. 1 with no application of diminished pressure under the hopper, it was possible to coat the same coverage as above at a speed of 20 feet per minute. Utilizing an air pressure differential of .1'' of water, my improved method was employed and it was found possible to coat the same coverage as before at a speed of 52.4 feet per minute.

Example 3.—Example of the effect of low air pressure differential on thickness of the coating

To show the effect of low air pressure differential on thickness of coating, a negative-type gelatino silver halide emulsion of 6 centipoises viscosity was coated on a safety-type film support at 50 feet per minute at 95° F., using an immersion roll, to give a coverage of .045 pound per square foot of wet emulsion per square foot of support. When a lower coverage was attempted, the coating was defective because of streaks.

By the use of a hopper of the type shown in Fig. 4, it was possible to coat at the same speed to give a coverage of .035 pound of wet emulsion per square foot of surface. When a lower coverage was attempted, the coating was defective because of streaks.

When a pressure differential of .1'' of water was applied to the hopper of Fig. 1, it was found possible to coat at the given speed of 50 feet per minute with a coverage of as little as .018 pound of wet emulsion per square foot of surface.

In the past it has been possible to obtain such extremely thin layers by properly diluting the material to be coated. This technique added greatly to the subsequent drying load and drying time. By the process of my invention, as shown above, it is possible to coat materials in extremely thin layers without resorting to such dilution. This allows the use of high coating speeds which my method provides without the need to increase the drying capacity of the dryer which must be used to dry the coated material.

It has been found possible to greatly increase coating speed or reduce thickness as desired with even less pressure differential than has been shown in the above examples, for instance, highly mobile fluids tend to be affected more readily by these slight differentials.

Example 4.—Coating with a water solution of a dye

An aqueous dye solution, prepared by dissolving a small amount, such as .01% of tartrazine dye in water and adding a suitable spreading agent, was applied to the dry surface of a clear gelatin layer previously coated on a cellulose ester support. The viscosity of the water solution was approximately .75 centipoise at 95° F. It was coated from a hopper such as shown in Fig. 1. The coating speed was 110.5 feet per minute. The rate of application of the solution was such that the resulting layer contained .008 pound of water per square foot of gel surface. The air pressure differential used under the hopper was .25''.

Example 5.—Coating a resin vehicle photographic silver halide

A sensitized photographic emulsion, which was prepared by dispersing a silver halide in an aqueous 3% solution of polyvinyl alcohol to which was added a suitable amount of α-naphthol to form a rigid gel at lower temperatures, was applied to a transparent, flexible, subbed support. The viscosity was approximately 20 centipoises when coated at 110° F. from a hopper such as shown in Fig. 1. The emulsion was coated at such a rate that the resulting layer contained less than .035 pound of emulsion per square foot of film and the air pressure differential was .5'' of water at a speed of 100 feet per minute.

Example 6.—A nonaqueous cellulose nitrate coating

A dilute type of subbing solution was prepared by dissolving cellulose nitrate to make a 1% solution, consisting largely of methyl alcohol and acetone and small quantities of other materials. The viscosity of the solution was 2 centipoises at 80° F. The solution was applied to the unsubbed safety film at 101 feet per minute using a hopper such as shown in Fig. 1. Coatings were applied using reduced pressure of .5'' of water, and the solution was applied at such a rate that the coated layer contained .009 pound of solution per square foot of film.

Another coating of the same composition was applied at a reduced pressure of .1'' of water at such a rate that the coated layer contained .02 pound of solution per square foot of film.

Example 7.—An antiabrasion coating over wet photographic emulsion

Application of gelatin layers over previously coated wet set layers of gelatin emulsion is difficult. Heretofore it has been necessary to carry out this operation at rigidly defined speeds because of the danger of either remelting the previously applied layer when low speeds were used or causing breaks in the top coating when attempts were made to coat at higher speeds. Such applications have usually been coated at speeds up to 40 feet per minute.

By the method of our invention, it is possible to make such coatings at speeds which prevent remelting and at the same time do not break and cause nonuniformity of the top lever. An example of such a coating process was as follows:

A negative-type roll film emulsion was applied to a safety support by conventional means and set by application of cool air. After setting, but before drying of the emulsion layer, an abrasion protective gelatin layer containing a spreading agent, such as saponin, was applied from a 1% water solution at 100° F. and at a viscosity of 3 centipoises with a hopper such as shown in Fig. 1. The coating was applied using a diminished air pressure of 1'' of water at a speed of 75 feet per minute. Although the thickness of the applied coating was less than .0001'' (dry), nevertheless, it was uniform and was satisfactory in providing abrasion protection. The use of diminished pressure allowed the application of a uniform extremely thin antiabrasion layer using a more concentrated solution. Previously such layers had to be coated with highly diluted solutions because of the limitations of conventional coating methods.

Example 8.—A multiple coating

A gelatin-silver halide photosensitive emulsion of a cine-positive type was applied to a dry, subbed cellulose acetate support using a hopper such as shown in Fig. 1. The viscosity of the emulsion, when coated at 100° F., was 11 centipoises. A coating was applied using a diminished air pressure of 2.5'' of water, and the emulsion was applied at such a rate the coating contained less than .016 pound of emulsion per square foot of film surface at a speed of 101 feet per minute. This layer of emulsion was dried, and a second and different emulsion was then applied as follows:

A high-speed cine-negative type gelatin-silver halide emulsion, prepared by suspending silver halides in a gelatin water solution to which was added spreading, sensitizing, and plasticizing materials in suitable quantities, was applied to the dry surface of the above-described undercoat with a hopper such as shown in Fig. 1. The emulsion, when applied at 100° F., had a viscosity of 11 centipoises and was coated at such a rate

that the layer contained .05 pound of emulsion per square foot of film surface. The coating was made at a speed of 300 feet per minute using a diminished pressure of .5'' of water. Applying emulsion over a layer of dry emulsion is often more difficult than applying it directly to the support because of the highly water-absorbent properties of the dried gelatin surface which prevents spreading of the top emulsion layer in a normal manner, but the reduced pressure principle has been found useful in overcoming this.

Example 9.—A pigmented resin coating

An opaque composition was made from a 45% emulsion, prepared by suspending finely divided carbon in a water solution of polyvinylidene chloride to which had been added a suitable defoaming agent. This composition was thixotropic but gave an apparent viscosity of approximately 500 centipoises when measured under low rate of shear conditions at 80° F. This composition was applied at 80° F. to a celloulose acetate support with a hopper such as shown in Fig. 1 at a speed of 101 feet per minute. The differential air pressure was equal to 2'' of water. The thickness of the applied coating was only .001'' (dry) but was satisfactory in completely preventing the transmission of light. This composition was also applied to kraft paper under similar coating conditions to furnish a product suitable as an interleaving layer for roll film.

Example 10.—Barium sulfate coating on photographic paper base

A sizing coat was applied to raw double-weight photographic paper. The coated material was a 45% suspension of barium sulfate in an aqueous gelatin solution to which was added a suitable defoaming agent such as butyl alcohol. The suspension viscosity was 18 centipoises at 80° F., and it was coated from a hopper such as shown in Fig. 1 at a speedof 101 feet per minute. The diminished air pressure under the hopper ranged from .1'' to 1.75'', and the rate of application of the suspension was such that the coated layer contained from 3 to 5.8 pounds of suspension per hundred square feet of paper surface.

Example 11.—A positive-type gelation emulsion on dry subbed support

A gelatin silver halide positive-type emulsion prepared by suspending silver halides in a water solution of gelatin to which had been added suitable quantities of spreading, sensitizing, and plasticizing agents was applied to a dry, subbed safety support over a coating speed range of 100 feet per minute to 300 feet per minute, using a hopper such as shown in Fig. 4. The temperature of the emulsion, when coated, was 100° F., and the viscosity was 16 centipoises. Coatings were applied using a diminished air pressure range of .25'' to 3.00'' of water, and the emulsion was applied at such a rate that the coating contained less than .035 pound of emulsion per square foot of film surface. The concentrated emulsion could not be coated at any of the speeds used without the application of diminished pressure.

Example 12

An antihalation gelatin layer was coated on the back of safety support at 130 feet per minute from a water solution of gelatin containing a spreading agent, such as saponin, and a suitable dye. The viscosity of the gelatin solution, when coated at 120° F., was 18 centipoises. This was coated from a hopper such as shown in Fig. 1. The gelatin solution was applied at such a rate that the coated layer contained less than .035 pound of gel per square foot of film surface. The air pressure differential was 1.5″ of water. This method of coating permitted the use of more concentrated solutions, thereby permitting considerably higher coating speeds and shorter drying times.

Example 13.—Coating multilayer color film

A gelatin-silver halide differentially color-sensitive emulsion comprising silver halides dispersed in an aqueous gelatin solution, to which was added a coupler and the necessary agents to give it the desired coating and desired sensitometric properties, was applied to a dry, subbed safety support from a hopper such as shown in Fig. 1 using a reduced pressure of .25″ of water. The viscosity was 5 centipoises at the coating temperature of 95° F. and the rate of application such as to form a layer containing .02 pound of the emulsion per square foot of film. The coating speed was 154 feet per minute. The emulsion was set with chilled air and dried.

Example 14.—Light screening coatings

A solution possessing light screening properties, which was prepared by dissolving a dye of the proper light absorption in an aqueous solution of gelatin and adding a suitable spreading agent, was applied to the dry surface of the emulsion which had been coated as described above. The solution viscosity was 3 centipoises at the coating tempreature of 95° F. The rate of application of the solution was such as to produce a layer containing less than .02 pound of solution per square foot of film. The diminished pressure used on the hopper was .4″ of water and the coating speed was 198 feet per minute. The light screening layer was then congealed by applying cold air and then drying with warm air.

A gelatin-silver halide emulsion sensitive to another part of the visible spectrum comprising a silver halide suspended in an aqueous gelatin solution, to which was added a coupler and suitable spreading and sensitizing agents, was applied to the dry surface of the light screening layer described above. The emulsion viscosity was 5 centipoises at the coating temperature of 95° F., and the rate of application was .02 pound of emusion per square foot of film when using a reduced pressure of 1″ of water. The coating speed employed on this layer was 260 feet per minute. The reduced pressure principle is particularly useful in applying the second and successive layers of a multilayer film because coating on an emulsion surface is often more difficult than on the surface of uncoated support.

The above illustrative examples give a plurality of different coating compositions which may be readily applied to strip material in accordance with my improved method. While my method is entirely suitable for applying a wide variety of coating compositions, it is particularly suitable for (1) applying coatings at high speeds, (2) coating with solutions of compositions where a thin layer is required, (3) coating spliced materials to avoid wastage at the splice, (4) applying photographic layers such as light-sensitive silver halide emulsions such as a dispersion of silver halide (silver chloride, silver chlorobromide, silver bromide, silver bromoiodide, etc.) in a water-soluble or water-permeable colloid, e. g. gelatin, hydrolyzed cellulose acetate, polyvinyl alcohol, (5) coating other light-sensitive layers such as bichromated gelatin, light-sensitive dyes, bichromated shellac compositions, bichromated gum arabic, and the like, (6) coating a dispersion or solution of dye or other light screening substance in a water-permeable colloid, (7) coating a dispersion or solution of a hydrophobic polymer material, e. g., cellulose acetate, cellulose nitrate, polyvinyl acetal resins, polyacrylate resins, polystyrene, polyacrylonitrile, in a suitable medium, e. g., acetone, methyl alcohol, benzene, dimethylformamide, chloroform, carbon tetrachloride, (8) coating a dispersion of a pigment, e. g., finely-divided carbon, colored pigments, in a suitable medium, e. g., water or an organic solvent, and (9) coating a dispersion of sizing materials, e. g., barium sulfate in a suitable medium such as a water solution of a water-soluble colloid, e. g., gelatin, polyvinyl alcohol, hydrolyzed cellulose acetate, etc.

It will thus be seen that I have provided a method of coating by which the several objects of my invention may be achieved and a method which is well adapted to meet the conditions of practical use.

While I have mentioned quite a number of preferred examples of coating compositions which may be applied by my improved method to strip materials, it is to be understood that these are to be taken as illustrative only, and not in a limiting sense.

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

1. A method of coating strip material from a coating device which comprises moving the strip material adjacent and relative to the coating device, and passing a ribbon of coating composition from the coating device to the strip material transversely of the material while bridging the ribbon of coating composition between the coating device and the strip material to be coated, holding the ribbon of coating composition from movement in the direction of travel of the moving strip material by subjecting each of the faces of the ribbon of coating composition extending transversely of the strip material to a different pressure, the pressures being selected to retain the ribbon of coating composition in a coating position between the coating device and the strip material and to maintain a uniform coating on the strip material, the pressure on that side of the ribbon of coating composition toward which the strip material approaches for coating being less than the pressure on the opposite side thereof.

2. A method of coating strip material from a coating device which comprises moving the strip material adjacent the coating device and relative thereto, and passing a ribbon of coating composition from the coating device to the strip material and transversely of the strip material, retaining the height of the ribbon of coating composition between the coating device and the strip material to more than twice, but less than three times the thickness of the strip material to be coated for passing a splice therethrough, holding the ribbon of coating composition against movement in the direction of movement of the strip material by subjecting that side of the ribbon extending transversely of the strip material to be coated and facing the strip material approaching the coating device to a re-

duced pressure selected to maintain the ribbon of coating composition in a coating position while the opposite side of the ribbon is subjected to atmospheric pressure.

3. A method of coating which comprises forming a ribbon of flowing coating composition of the desired width between a coating device and strip material to be coated while the strip material is carried by a support, moving the strip material relative to the coating device, the strip material approaching the coating device and moving from the coating device and the ribbon of coating composition extending transversely of the strip material and bridging the ribbon of flowing coating composition between the coating device and the strip of material to be coated, subjecting both sides of the ribbon extending transversely of the strip material to subatmospheric gaseous pressures, the gaseous pressure on the side of the ribbon from which the strip material approaches to be coated being somewhat less than the subatmospheric pressure on that side of the ribbon from which the coated strip material moves from the coating device to maintain the ribbon of coating composition between the coating device and the strip material and to provide a uniform coating on the strip material.

4. A method of coating which comprises forming a ribbon of flowing coating composition of the desired width between a coating device and strip of material to be coated while the strip material is carried by a support, moving the strip material relative to the coating device, the strip material approaching the coating device and moving from the coating device and the ribbon of coating composition extending transversely of the strip material, bridging the ribbon of flowing coating composition between the coating device and the strip of material to be coated, and subjecting both sides of the ribbon extending transversely of the strip material to different gaseous pressures to maintain the ribbon in a coating position and to provide a uniform coating on the strip material, the gaseous pressure on the side of the ribbon from which the strip material approaches to be coated being less by a selected degree than the gaseous pressure on that side of the ribbon from which the strip material moves from the coating device to maintain the ribbon of coating composition in a coating position between the coating device and the strip material.

5. A process of forming a substantially continuous coating on a rapidly moving surface of strip material by procedure including continuously depositing said coating angularly on the rapidly moving surface from a supply of coating material by forcing a ribbon of coating material from the supply of coating material to the rapidly moving surface of strip material, and causing the ribbon of coating material to bridge the distance from the supply of coating material to the surface of the strip material being coated, the improvement which comprises applying a substantial differential pressure between the pressure on one side of the ribbon of coating applied to the rapidly moving surface of strip material and the pressure applied to the other side thereof at the intersurface zone of the ribbon of coating material with the moving surface of the strip material, with the lesser pressure on that side of the ribbon from which the surface of the strip material approaches the supply of coating material for coating whereby air and other gaseous molecules are removed from said intersurface zone, thereby facilitating the speed of forming the coating and improving the quality thereof.

6. The process in accordance with claim 5 wherein the differential pressure is reduced pressure.

7. A process of forming a substantially continuous coating on a rapidly moving surface of strip material by procedure including continuously depositing and coating angularly on the rapidly moving surface from a supply of coating material by forcing a ribbon of coating material from the supply of coating material to the rapidly moving surface of strip material, and causing the ribbon of coating material to bridge the distance from the supply of coating material to the surface of the strip material being coated, the improvement which comprises applying a substantial differential pressure between the pressure on one side of the ribbon of coating applied to the rapidly moving surface of strip material and the pressure applied to the other side thereof at the intersurface zone of the ribbon of coating material with the moving surface of the strip material, with lesser pressure on that side of the ribbon from which the surface of the strip material approaches the supply of coating material for coating, wherein the differential pressures are superatmospheric.

8. In a process of forming a substantially continuous coating of a coating material on a rapidly moving surface of strip material by procedure, including continuously depositing a ribbon of said coating material angularly and transversely of the strip material from a supply of the coating material spaced from the strip material for depositing the coating material on said moving surface of the strip material, the improvement which comprises bridging a ribbon of the coating material between the spaced supply of coating material and the rapidly moving strip material, applying a substantial differential pressure on opposite faces of the ribbon of coating material at the intersurface zone of the ribbon of coating material with the moving surface of the strip material, the pressure being greater on that side of the ribbon of coating material from which the strip material moves after coating with provision for the escape of gas at the intersurface zone of the ribbon of coating material with the moving surface whereby air and other gaseous molecules are removed from said intersurface zone, the lesser pressure being applied to that side of the ribbon of coating material from which the strip material approaches the supply of coating material to be coated, thereby facilitating the speed of forming the coating and improving the quality thereof.

9. A method of applying a liquid composition comprising a water-permeable colloid to a relatively moving strip material carried by a support which comprises forming a flowing stream of water-permeable colloid, bridging a ribbon of the water-permeable colloid between a coating device and transversely of an area of a strip material to be coated while one is moving relative to the other, subjecting the ribbon to a greater pressure on that side from which the coated strip leaves the coating device while subjecting the other side of the ribbon to a lesser pressure, the pressure differential on the two sides of the ribbon being in the order of .1'' to 5.00'' of water and tending to hold the flow of water-permeable colloid in coating position.

10. A method of applying a liquid composition comprising a hydrophobic resinous material to a relatively moving strip of material comprising forming a flowing stream of a hydrophobic resinous material of the width of a desired coating, bridging a ribbon of the flowing hydrophobic resinous material between a coating device and a movable support carrying a strip of material to be coated and transversely of the strip material, subjecting that side of the ribbon extending transversely of the strip material to which the strip to be coated approaches the coating device to subatmospheric pressure of from .1'' to 5.00'' of water while the opposite side thereof is subjected to atmospheric pressure to maintain the ribbon in coating position.

11. A method of coating a solution of dye to a rapidly moving strip of material carried by a support comprising forming a flowing stream of a solution of a dye, passing the stream through a coating device, bridging a ribbon of the solution of the dye between the coating device and the movable support carrying the strip of material to be coated and extending transversely thereacross while subjecting one side of the ribbon to a gaseous pressure less than that on the other side of the ribbon, the greater pressure lying on that side of the ribbon from which the dyed support moves away from the coating device to maintain the ribbon of the solution of dye in a coating position, the difference in the two pressures being in the order of from .1'' to 2.00'' of water.

12. A method of coating a moving strip of nonporous flexible material with a photographic light-sensitive emulsion coating having viscosity of between three and thirty-five centipoises comprising flowing a thin layer of said emulsion from a coating device to the strip of nonporous material forming a ribbon of emulsion therebetween extending transversely of the nonporous flexible material while the strip material is moving toward and away from the coating device, and maintaining a subatmospheric pressure equal to less than five inches of water on the side of the ribbon from which the strip material moves to be coated while maintaining atmospheric pressure on that side of the ribbon from which the coated strip moves away from the coating device.

13. A method of coating a moving strip of nonporous flexible material with a photographic light-sensitive emulsion coating having viscosity of between three and thirty-five centipoises comprising flowing a thin layer of said emulsion from a coating device to the strip of nonporous material forming a ribbon of emulsion therebetween extending transversely of the flexible material while the flexible material is moving toward and away from the coating device, and maintaining a subatmospheric pressure between .10'' and 5.00'' of water on that side of the ribbon from which the strip material approaches the coating device while maintaining atmospheric pressure on the opposite side thereof.

14. A method of coating a moving strip of substantially nonporous flexible material of a type adapted to contain splices of a thickness approximately twice the thickness of a single strip of material with a photographic coating composition having viscosities of between three and thirty-five centipoises comprising flowing a thin layer of said emulsion from a coating device to the strip of nonporous flexible material forming a ribbon of emulsion therebetween extending transversely of the flexible material, said ribbon having a height of several times the thickness of the flexible material while passing from the coating device to the strip material and while the strip material moves toward the coating device and away from the coating device, the improvement which comprises maintaining the ribbon in a coating condition by applying a differential in gaseous pressures on the two sides of the ribbon extending transversely of the strip material, the pressure on that side of the ribbon from which the strip material moves toward the coating device being somewhat less than the pressure on that side of the ribbon from which the flexible strip of material goes away from the coating device, the difference in pressures being selected to hold the ribbon of photographic coating against movement with the strip of flexible material and thereby maintain the ribbon in a coating position.

15. A method of coating strip material from a coating device which comprises moving the strip material adjacent and relative to the coating device, and passing a ribbon of coating composition from the coating device to the strip material transversely of the material while bridging the ribbon of coating composition between the coating device and the strip material to be coated, holding the ribbon of coating composition from movement in the direction of travel of the moving strip material by subjecting each of the faces of the ribbon of coating composition extending transversely of the strip material to a different pressure, the pressures being selected to retain the ribbon of coating composition in a coating position between the coating device and the strip material and to provide a uniform coating on the strip material, the pressure on that side of the ribbon of coating composition toward which the strip material approaches for coating being subatmospheric and the pressure on the opposite side thereof being atmospheric.

16. A method of coating strip material from a coating device which comprises moving the strip material adjacent and relative to the coating device, and passing a ribbon of coating composition from the coating device to the strip material transversely of the material while bridging the ribbon of coating composition between the coating device and the strip material to be coated, holding the ribbon of coating composition from movement in the direction of travel of the moving strip material by subjecting each of the faces of the ribbon of coating composition extending transversely of the strip material to a different pressure, the pressures being selected to retain the ribbon of coating composition in a coating position between the coating device and the strip material and to provide a uniform coating on the strip material, the pressure on that side of the ribbon of coating composition toward which the strip material approaches for coating being a partial vacuum and the pressure on that side from which the coated strip material leaves the coating device being atmospheric, the difference between the two pressures being less than 5.00'' of water.

17. A method of coating which comprises forming a ribbon of flowing coating composition of the desired width between a coating device and strip of material to be coated while the strip material is carried by a support, moving the strip material relative to the coating

device, the strip material approaching the coating device and moving from the coating device and the ribbon of coating composition extending transversely of the strip material, bridging the ribbon of flowing coating composition between the coating device and the strip of material to be coated and subjecting both sides of the ribbon extending transversely of the strip material to different gaseous pressures, the gaseous pressure on the side of the ribbon from which the strip material approaches to be coated being less by a selected degree than the gaseous pressure on that side of the ribbon from which the strip material moves from the coating device to maintain the ribbon of coating composition in a coating position between the coating device and the strip material and to provide a uniform coating on the strip material, the gaseous pressure on that side of the ribbon facing the oncoming strip of material to be coated being atmospheric and the pressure on that side of the ribbon from which the strip material moves from the coating device being superatmospheric.

18. A method of coating a moving strip of nonporous flexible material with a photographic silver halide light-sensitive emulsion coating having a viscosity of between three and thirty-five centipoises comprising flowing a thin layer of said emulsion from a coating device to the strip of nonporous material forming a ribbon of emulsion therebetween extending transversely of the flexible material while the flexible material is moved toward and away from the coating device, and maintaining a subatmospheric pressure between .10" and 5.00" of water on that side of the ribbon from which the strip material approaches the coating device while maintaining atmospheric pressure on the opposite side thereof.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,253,060	Clearman	Aug. 19, 1941
2,369,484	Nadeau	Feb. 13, 1945
2,439,802	Francis	Apr. 20, 1948
2,471,330	Knight	May 24, 1949
2,474,691	Roehm	June 28, 1949