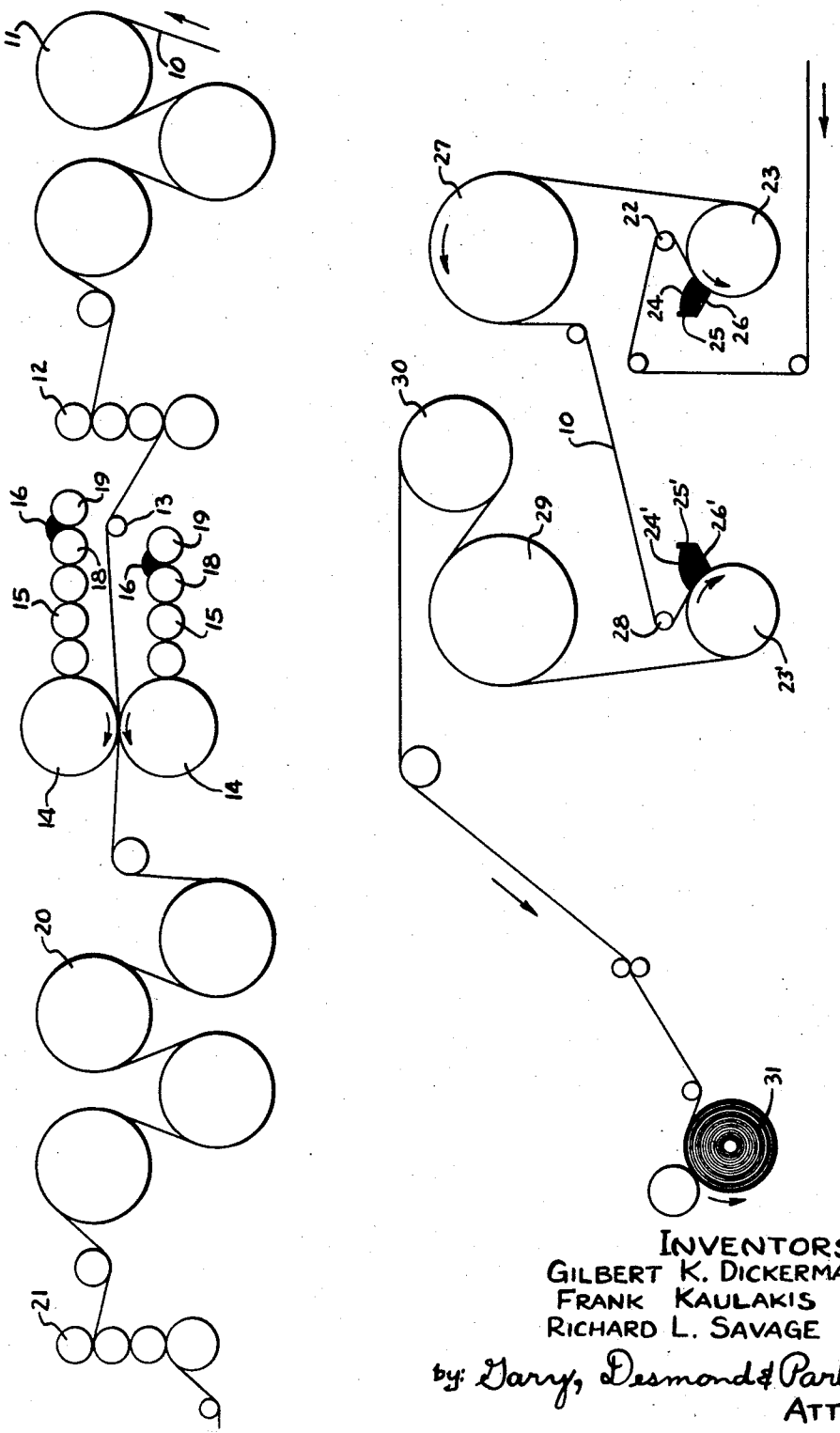
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METHOD OF MAKING PRINTABLE COATED PAPER

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METHOD OF MAKING PRINTABLE COATED PAPER

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This invention relates to the coating of paper by a novel method comprising a plurality of interrelated steps.

More particularly, the present invention relates to the coating of a paper web on the machine, that is, in a continuous paper making process and at high paper making speeds, such as up to about 2000 feet per minute, in a plurality of steps whereby there is initially applied to a newly formed paper web a mineral-pigment composition having a relatively high adhesive content, so as to cover the fibers and fill the interstices of the paper to strengthen and prime it for the second step. In the second step the primed web is coated with another mineral-pigment composition, preferably having a relatively low adhesive content, the latter composition remaining essentially on the surface of the pretreated paper where it is leveled to provide a remarkably smooth surface.

The foregoing generally described process enables the production of high-gloss book, label or box cover paper of improved brightness, opacity, smoothness, and enhanced printability. The process further enables the obtaining of coatings of relatively high weight, such as up to 10 to 20 pounds per side per ream if desired, without such defects as straight or branched ridges lying approximately parallel to the machine direction, or other pattern-effect surface imperforations known as "cat tracks" and "orange peeling" characteristic of coatings formed by other processes.

These objects and advantages are further accomplished in an economical manner, in that this process does not require the excessive use of high cost pigments or high supercalender pressures. The ability to employ moderate supercalender pressure is particularly conducive to the retention of high brightness, opacity, strength, and desirable bulk.

Our process comprises the employment in the first coating step of what is generally known as the print or transfer type roll coater, to apply to the paper a pigment-binder composition of about one-half the weight usually applied in one-step coating by said means, and which for the present process has a relatively higher binder, and a relatively lower pigment content than is usual when employing said machine roll coater alone. By this means the initial coating component can be of high viscosity character and of closely controlled weight, so as to film-coat, fill and densify the base sheet, to thereby provide a good foundation for the second coating component.

The binder content in the first step coating composition, which as indicated is preferably relatively high, is essentially for binding the pigment to the fibers, for binding the fibers together, and to cover the fibers and fill not only the voids in the base sheet but also any surface irregularities resulting from the high speed paper making process, to thereby provide a level surface of substantially uniform receptivity. This also serves to limit subsequent penetration of the top coating into the sheet and permits the use of a lower level of adhesive in the second coat than would be required for a single step coating composition, since adhesive is not so much needed there for binding the fibers but rather for binding the pigment particles together and to the prefilled base web.

Although the prime coat, in accordance with the present invention, is formulated primarily to provide optimum operability of the second or blade coating step under a wide latitude of conditions, other benefits are gained through variations in the prime coat. Thus, for example, in adidtion to the base sheet being strengthened by forcing the prime coat into the base paper, the amount of adhesive in the prime coat will determine the increase in strength characteristics, such as mullen strength and resistance to picking and splitting. An advantage of this is that complete reliance on mechanical refining is not necessary, and reduction in degree of mechanical refining improves dimensional stability of the paper and decreases its tendency to cockel and curl.

The indicated second step comprises what is sometimes designated as blade or trailing blade coating of the "puddle type," in that coating composition is applied to one exposed surface of the web while the other is in contact with, and is carried downwardly by a resilient surfaced roll through a pool of coating composition maintained thereat, and then the excess promptly removed by a flexible doctor blade as the web emerges from the pool. This doctor blade has a flexible, resilient, knifelike edge which smooths the surface of the coated sheet as it is drawn through the nip, formed by the blade edge and roll, to produce a composite film characterized by an exceptionally smooth, pattern-free surface.

The full benefit of blade coating application, however, cannot be realized with an unprimed base sheet. Due to the doctoring action of the blade, the coat weight applied with a blade coater is limited to about six–eight pounds per side per ream (25x38—500). As a result of migration of coating into an unprimed base stock and the relatively low coating weight applied, complete masking of the base sheet fibers in such case is not obtained. Because of the inherent roughness of the felt side, many fibers remain exposed in a single blade coating operation. Therefore, although the surface of the coated paper is somewhat smoother than a roll coated sheet having an equal coat weight, the potential gloss, smoothness, and printing quality of the sheet is not attained.

In the present invention, penetration of the top coat vehicle is markedly reduced through the described prime coating of the paper prior to blade coating, it being possible thereby to employ coatings of high solids via the blade coater without developing streaks caused by excessive strike-in of top coat vehicle, the second coating composition application remaining essentially on the surface, where desired and where it can be leveled to provide a remarkably smooth, flat surface.

This two-step coating process enables the burying of the fibrous surface of the base paper, permits compensating for fiber density or distribution irregularities, and provides a smooth, continuous, mineral pigment surface which results in an excellent medium for printing.

The present two-step coating process also provides a convenient method for increasing the pick resistance of the paper. The adhesive content in single coated paper governs both the pick resistance and the finishing properties. As the adhesive level is raised to increase the pick resistance, the surface of the coated paper becomes harder and more resistant to finishing to a high gloss on supercalendering. In the present two-step coating the high adhesive level in the prime coat provides the necessary pick resistance while the low adhesive level in the top coat is conducive to high gloss development in supercalendering.

In our two-step coating process, the prime coat provides a smooth, uniform surface which limits penetration of the top coating color. Held out on the surface of

the sheet, the top coating provides better hiding power, easier finishing, and an exceptionally smooth surface. Due to the density and continuity of the coating film, our present two-step coated paper exhibits high ink holdout and uniformly good printing quality. The full fiber coverage of the coated sheet promotes easy finishing to a high gloss and smoothness at relatively low supercalender pressures. For example, a 40-pound single-step roll coated publication paper requires a bottom nip pressure of 1600 pounds per linear inch in supercalendering to achieve a Bausch & Lomb gloss meter reading of 42. A two-step roll-blade coated sheet, in accordance with the present invention, can be supercalendered at 1200–1300 pounds per linear inch to obtain a similar B & L gloss. A supercalendering pressure of even as low as about 1000 pounds can be used if lower gloss is desirable, while still retaining the high surface smoothness provided by the present invention. Supercalendering at the lower pressures improves the bulk, opacity, brightness, and color of the two-step coated paper over that of a single-step coated sheet.

As is known, keeping all other factors constant, increase of supercalender pressure causes loss in brightness and opacity. The process of the present invention permits the employment of relatively low or moderate supercalender pressures and therefore avoids excessive loss of brightness and opacity.

Other objects and advantages of the present invention will be apparent from a consideration of the following specification and accompanying drawing which diagrammatically illustrates an arrangement for carrying out the process thereof.

Referring to the drawings, the reference numeral **10** indicates a paper web passing over the final drum dryers **11** at the dry end of a conventional paper making apparatus, such as that employing a Fourdrinier wire. The web can be composed of conventional bookpaper stock containing up to about 15% of mineral filler particles resulting primarily from the return to the beater of "broke," i.e., spoilage or paper waste from the process, and is thus substantially unfilled and porous. The paper as it leaves the last drum dryer **11**, in the present process, is substantially dry and has a moisture content of 5% to 8% as it enters the nips of the calender stack **12**. The web **10** may pass through the three nips illustrated of the calender stack **12** which, as is conventional, is composed of all stainless steel alloy or chilled iron rolls. In the alternative, the calender stack may be omitted.

On leaving the last nip of the calender stack **12**, the web moves over the roll **13** where it is guided to and between the nip of the reslient surfaced rolls **14, 14** of the print or transfer type roll coater, wherein coating composition is applied to the opposed faces of the web **10** by transfer of preformed films thereof from the rolls **14, 14** under the pressure of the top roll against the bottom roll of about 100 pounds per linear inch in the absence of loading, or with loading up to about 150 pounds per linear inch. As is conventional with roll coaters of the indicated type variously designated as "machine," "transfer," or "print" type roll coaters, the coating is transferred to each roll **14** through a series of distributing rolls **15** from pools of coating composition **16** metered in controlled amount by the gate rolls **18** and **19**.

After the prime coated web leaves the transfer rolls **14, 14** it passes over a second set of drying drums **20** which may be similar in character to drying drums **11**, to dry the web to a moisture content of about 5–8%, after which the paper web may be guided through a second calender stack **21** for minor smoothing or fiber-laying purposes.

After leaving the calender stack **21** the thus primed web **10** is then finish-coated with a second coating composition.

Thus, as the paper web advances it then passes to guide roll **22** wherefrom it is brought into contact with and moves downwardly against the face of the resilient surfaced roll **23**. There it passes through a puddle or pool of coating composition **24** continuously maintained by an overhead supply (not shown) in the trough defined by the backing member or blade holder **25** to which there is secured the flexible blade **26**. This blade resiliently bears against the exposed or outer surface of the paper web **10** as it passes downwardly in contact with the resilient surfaced roll **23** and through the pool of coating composition **24**, the blade **26** serving to doctor or meter the coating composition **24** applied to the web **10**. The pool of coating composition **24**, which is continuously augmented as used, is maintained in agitated condition by its contact with the downwardly-moving exposed face of the paper web **10**, so that the uniformity of the pool coating composition is constantly maintained. It will be understood, although not shown, that lateral dam means are provided for confining and maintaining a pool of coating composition between the metering rolls **18** and **19** as well as between the roll **23** and blade **26**.

After leaving the roll **23** the web **10** is dried to a moisture content of 5–8% as it passes over drying means **27**, which in the present diagrammatic illustration is shown as a single roll, although a plurality of such drying drums or rolls may be employed which, if desired, can be aided by other heating means, such as banks of infrared lamps or air jets.

When the web is to be coated on both sides it then proceeds continuously over a second resilient surfaced roll **23'** to which it is brought into contact by the reversing guide roll **28**. Here the web **10** passes downwardly into contact with the roll **23'** through the pool or coating composition **24'** maintained in the trough provided by the member **25'** and the resilient flexible doctor blade **25'** similar to the "puddle type" trailing blade coating means previously described, the composition **24'** being generally the same as the composition **24**, although it will be apparent that variations may be made therein consistent with the requirements of the inherently different character of the web surfaces originally formed.

The thus dual coated web is then brought into contact with another drying drum **29** with the freshly coated surface outermost, after which its coated surface may be brought into contact with a secondary drying drum **30**. Added banks of lamps or air jets for secondary drying (not shown) may be employed if required.

The final drying of the web is to a moisture content of about 5–6%, after which the web is guided to the reel **31** where it is wound up before being subjected to supercalendering.

As will be understood, the second coating step is applied sequentially to the opposed faces of the primed paper web for bookpaper purposes, or to a single face thereof when the web is to be employed as a label or box cover paper, it being understood that in such event coating **16** is applied to only one face of the web at the rolls **14, 14**.

The web from the reel **31** may then be subjected to conventional supercalendering such as by passing it between the rolls of a conventional calender stack composed of eight rolls, the intermediate rolls having resilient surfaces of fibrous material such as paper, cotton, etc., disposed between rolls having hardened steel surfaces, so that as the web is passed between successive nips of the rollers it is subjected to a limited densification by means of the rolling pressure and combined frictional and flexure effect caused by indentation of a metal roll into a fiber roll. Normally, to obtain a high gloss it is necessary to employ supercalendering pressures of 1600 to 1700 pounds per linear inch and higher at the lowest nip of the rolls. In accordance with the practices of the present invention a similar gloss may be obtained with pressures of 1200 to 1300 pounds per linear inch and without the reduction in bulk, as is the

case with higher pressures, with the result that the paper has better opacity, with smoothness high enough to permit satisfactory line or halftone printing even with supercalendering as low as about 1000 pounds per linear inch.

This ability to moderate the amount of supercalendering pressure results from the extremely smooth surfaces obtained in accordance with the practices of the present invention, and the novel, substantially pattern-free and grain-free character of the extremely smooth surface obtained.

Although single-step coating by the conventional transfer or print type roll coaters generally comprises the employment of coating compositions of relatively high solids content, such as up to about 60–65% by weight and bordering on or being of thixotropic character and of moderate adhesive or binder content, such as about 16–20% by weight of the mineral pigment, the coating compositions employed in the practice of the present invention for the providing of a prime coat have a slightly lower solids content, i.e., from about 40% to about 60%, and preferably from about 45% to about 55%, with binder content from about 20% to as high as 30–35% by weight of the mineral pigment, and viscosities of preferably from about 10,000 to about 20,000 centipoises.

In the present invention each coat and its respective composition complements the other, neither of which would be entirely desirable if applied as the sole and entire coating composition by a single coating step. Thus, for example, where the prime coating composition is applied by the print type roll coater it can comprise 100 parts by weight of clay, 30 parts by weight of binder, and about 0.1 part of a plasticizer such as ammonium stearate; the top or finish coating composition can comprise about 15 parts of a binder such as starch per 100 parts of clay or other mineral pigment, and about 0.8 part of plasticizer.

The finish coating compositions 24, 24′ are also maintained at a high viscosity, such as preferably from about 5,000 to about 10,000 centipoises, so that they do not swell the fibers of the base web, this viscosity range being generally somewhat lower than that of base coating 16. The binder content of the top coats 24 and 24′ is generally from about 5% to about 15% by weight of the mineral pigment, but can be as high as 25% for some purposes, such as, for example, formulations requiring good varnishing qualities such as might be needed for label papers. The solids content of these top coats can, in general, be of the same order as that of base coat 16, and is related to the desired top coat weight.

The coating composition 16 is of a generally free-flowing character, composed of mineral pigment such as clay, calcium carbonate, titanium dioxide, lithopone, and the like or mixtures thereof, together with binders such as dextrin, enzyme converted or oxidized starches, synthetic rubber latices, casein or other proteinaceous materials and the like, together with dispersing or deflocculating agents for the mineral pigments such as tetrasodium pyrophosphate, sodium metasilicate, sodium hexametaphosphate and the like, the whole being dispersed in water in an amount to provide a solids content of from about 40% to about 60% by weight.

Typical examples of coating compositions suitable for this prime coating applied by means of the indicated roll coater are the following:

(A) BASE COAT FORMULAS

No. 1

Coating clay	parts	100
Enzyme converted corn starch	do	18
Ammonium stearate	do	0.4
Tetrasodium pyrophosphate	do	0.2
Water	do	124
Total solids	percent	48

No. 2

Coating clay	parts	100
Oxidized corn starch	do	30
Ammonium stearate	do	0.2
Sodium polyphosphate	do	0.2
Water	do	105
Total solids	percent	54

No. 3

Coating clay	parts	50
Calcium carbonate (precipitated)	do	50
Dextronized corn starch	do	30
Sodium stearate	do	0.8
Sodium hexametaphosphate	do	0.4
Water	do	98
Total solids	percent	56

No. 4

Calcium carbonate (precipitated)	parts	100
Soya protein	do	20
Sulfonated tall oil	do	0.4
Ammonium hydroxide	do	2
Dicyandiamide	do	2
Hexamethylenetetramine	do	0.5
Tetrasodium pyrophosphate	do	0.5
Water	do	109
Total solids	percent	52

By splitting the coating into two applications more economical use may be made of expensive pigments, adhesives and dyes in the coating by limiting their use to the top coat. Such applications would be mainly those giving improved surface properties. Examples of such use in top coats are addition of titanium dioxide to obtain higher brightness; addition of fluorescent dye to improve brightness; low adhesive content coatings obtained by use of high strength adhesives; and waterproof top coatings for offset printing paper. Illustrative of these are the following:

(B) TOP COAT FORMULAS

No. 1

Fluorescent dye solution	parts	1
Coating clay	do	42
Titanium dioxide	do	8
Calcium carbonate (precipitated)	do	50
Oxidized corn starch	do	10
Styrene-butadiene latex (stabilized with 3% ammonium caseinate)	do	5
Ammonium stearate	do	0.8
Tetrasodium pyrophosphate	do	0.4
Water	do	85
Total solids	percent	55

No. 2

Coating clay	parts	100
Enzyme converted corn starch	do	16
Sodium stearate	do	0.8
Sodium tripolyphosphate	do	0.2
Water	do	131
Total solids	percent	46

No. 3

Coating clay	parts	100
Casein	do	8
Acrylic latex	do	8
Calcium stearate	do	0.8
Sodium hydroxide	do	0.4
Formaldehyde	do	2
Tetrasodium pyrophosphate	do	0.3
Water	do	77
Total solids	percent	56

No. 4

Coating clay	parts	50
Calcium carbonate (precipitated)	do	30
Lithopone	do	20
Soya Protein	do	14
Ammonium stearate	do	0.6
Ammonium hydroxide	do	2
Dicyandiamide	do	2.5
Hexamethylene tetramine	do	0.7
Sodium polyphosphate	do	0.4
Water	do	103
Total solids	percent	52

No. 5

Coating clay	parts	100
Enzyme converted corn starch	do	3
Polyvinyl alcohol	do	2
Sodium polyphosphate	do	0.2
Ammonium stearate	do	0.8
Water	do	82
Total solids	percent	55

No. 6

Coating clay	parts	66
Calcium carbonate (precipitated)	do	30
Titanium dioxide	do	4
Enzyme converted corn starch	do	12
Ammonium stearate	do	0.8
Total solids	percent	56

The following is a specific working example for the purpose of illustrating the process of the present invention and is not to be considered in limitation thereof:

A mixed chemical pulp furnish, having a mineral particle or pigment content of 8.0% resulting from the addition of broke and added filler to the beater was sheeted out on the wire of a Fourdrinier paper making machine at a speed of 700 feet per minute, and dried to a moisture content of 5.0%. This newly formed dry web was then passed through three nips of a calender stack, and then between the nip of oppositely rotating transfer rolls of a print type roll coater whereby the metering rolls were regulated to provide a prime coating of 7.5 pounds per side of coating composition made up in accordance with Base Coat Formula No. 3.

After passing through the transfer rolls the web was again dried by passing its surfaces alternately in contact with a plurality of drum dryers to dry it to a moisture content of 5.0%. The thus filled and primed web after passing through three nips of a calender stack still had a dull matte finish by reason of low surface coating, and lack of any other treatment such as supercalendering at this point.

One surface of the continuously forwardly moving primed web was then brought downwardly into contact with a resilient roll, and a coating composition, made up as in Top Coat Formula No. 6, was applied to the outer face of the web at this point by passing it through a trough terminating at its lower edge in a flexible, resilient blade pressed against the resilient roll. Excess coating composition was doctored off the outer surface of the web and the residue thereon smoothed and leveled by the flexible blade, leaving an added amount of 5 pounds of coating solids per ream on this side of the web. This top coated web side was dried by bringing its dry side in contact with a heating drum so as to dry the web to a moisture content of about 8.0%. Continuing the forward movement of the web the opposite side was top-coated in a similar manner, with the same top coating composition applied to the other side and with the same weight of coating solids pick-up, and the web again dried in a similar manner, this time to a somewhat lower moisture content of 5.5%. At this time the web had acquired a total coating solids weight of 12.5 pounds per side per ream, and was rolled up.

One web thus produced was subsequently introduced to the uppermost nip of an eight-roll supercalender stack wherein the pressure was 600 pounds per linear inch at the upper nip and 1200 pounds per linear inch at the lowermost nip, after which the paper was rolled up and ready for use. A second web similarly produced was subjected to a supercalendering pressure of 1600 pounds per linear inch.

These finished sheets had high ink holdout, good mullen strength, excellent resistance to picking or splitting even on repeated flexing, improved dimensional stability, and reduced tendency to cockel and curl.

The following is a comparison of the properties of paper coated in accordance with the foregoing specific example of the present process compared to a one-step coated paper:

A 70-pound double coated letterpress enamel paper was made using prime coat formula No. 3 and blade top coat formula No. 6. The double coated sheet was supercalendered at 1200 and 1600 p.l.i. (pounds per linear inch), while a single coated paper, prepared by a print type roll coater, used for comparison was supercalendered at 1600 p.l.i.

Supercalender Pressure	Single Coated, 1,600 p.l.i.	Double Coated, 1,600 p.l.i.	Double Coated, 1,200 p.l.i.
Basis Weight	70#	70#	70#
Base Coat Weight		15#	15#
Top Coat Weight	25#	10#	10#
G.E. Brightness	81.0–81.3	81.2–81.4	81.8–82.0
B&L Gloss	54–58	68–69	60–63
Opacity (T.A.P.P.I.)	95.3	95	95.5
Densometer (Gurley)	65	120	90
Bekk Smoothness	450–465	870–840	740–760
Wax Test (Dennison)	4–3	5–4	5–4

The base coat formula No. 1 with 18 parts of starch is used to advantage on a lightweight publication sheet where a lightweight top coat is being applied. With this type of paper of about 40–43 pounds' weight (25 x 38—500 ream) a prime coat of 2.5 to 3 pounds would be applied. Adequate pick resistance for letterpress printing is obtained for this low coat weight with 18 parts of starch. With higher coat weights and particularly for offset papers the base coat adhesive level is increased to obtain necessary pick resistance.

The base coat adhesive level influences the operability of the blade coater. With high solids content of the top coat, any substantial degree of dehydration of the coating due to absorption of water into the paper will cause streaking due to formation of semidry lumps of coating at the blade-paper interface. A high level of adhesive in the prime coat will reduce the dehydration.

We claim:

1. The method of making printable coated paper having a high degree of smoothness, brightness, opacity, and increased ink holdout, which comprises first applying onto the surface of a forwardly moving uncoated dry paper web, in a continuous paper-making process at paper-making speed, an aqueous coating composition comprising mineral pigment and adhesive by transferring said composition thereto from a resilient rotating surface, coated with a metered amount of said composition providing less than the desired final weight of coating but sufficient to prime-coat the web by covering fibers thereof and filling voids and surface irregularities therein to leave a level surface of substantially uniform receptivity and limited penetrability for a sequentially applied top coating, drying the resulting coated and filled web, carrying it forward by a resilient downwardly moving rotating surface and through a pool of a top aqueous coating composition of relatively lower viscosity than said first coating composition comprising mineral pigment and a proportion of a compatible adhesive to mineral pigment relatively lower than that in said first composition but sufficient to bind the pigment particles therein to-

gether and to the prefilled paper web and providing the balance of the desired final amount of solids and weight of coating, doctoring the resulting coating with a flexible blade upon emergence from said pool to level and smooth it and to remove excess while the web is carried by said resilient roll, and drying the resulting filled and coated web.

2. The process of claim 1 wherein the filled and coated web is subjected to supercalendering.

3. The process of claim 1 wherein the resulting filled and coated web is subjected to a maximum supercalendering pressure of less than about 1300 pounds per linear inch.

4. The process of claim 1 wherein the web is coated with said prime-coat and top coating on each of its opposed faces.

5. The process of claim 1 wherein the uncoated dry web has a maximum mineral filler content of about 10% to about 15% and a moisture content of from about 5% to about 8% by weight.

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