Papercoating, the certain future

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Most printing and writing papers consist of wood fiber pulp, of groundwood or TMP, CTMP or pressurized groundwood. Average wood free printing papers have from 1/2 to 2/3 hardwood fibers for better paper smoothness and printability and 1/2 to 1/3 softwood fibers for paper strength. Wood containing papers have from 50% (LWC) to 75% (SC papers), groundwood or pressurized groundwood and in case of TMP predominantly this material.

Softwood has predominantly one type of fibers, the tracheids rather long and slender fibers with excellent papermaking properties. Hardwood has a spectrum of fibers, small and big ones therefore yielding a more uniformly filled paper web of lower strength properties than the softwood paper and the large vessel segments being rather disturbing in all tack printing like letter press or offset. (1)

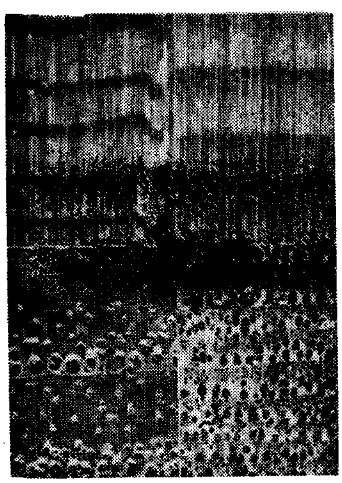

Fig. 1

(2 softwoods top, 2 hardwoods bottom note the large vessel cells in the hardwoods)

All strength properties of papermaking fibers depend upon the long chained cellulose molecules, which assemble in strings of appro. 2000 into the so called microfibrils, which again form larger and thicker strings, the so called fibrils, which can be seen in a light microscope or even with a good magnifying glass. In a tracheid the microfibrils are arranged into different wall layers as shown in picture (2). (3-5) show the micro- fibrilar structure of fibers and in the highly beaten state the microfibrils disintegrate into small pieces making up part of the papermaking "crill", useless elements in papermaking which only take up additives and increase cost. The pulp fibers collapse upon drying into various forms or the thicker walled summer fibers do not collapse at all (6). In hardly any case can one expect flat ribbons or noodles as the

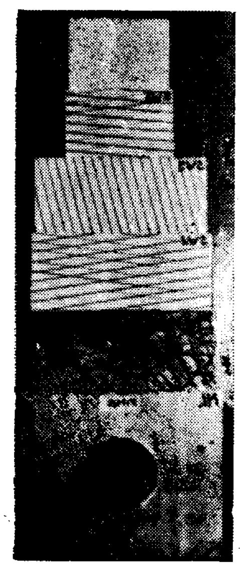

Fig. 2

(ML middle lamella PW primary wall
SW1 Secondary wall 1
SW2 „ „ 2
SW3 „ „ 3
or tertiary wall last, the warty layer of the lumen.)

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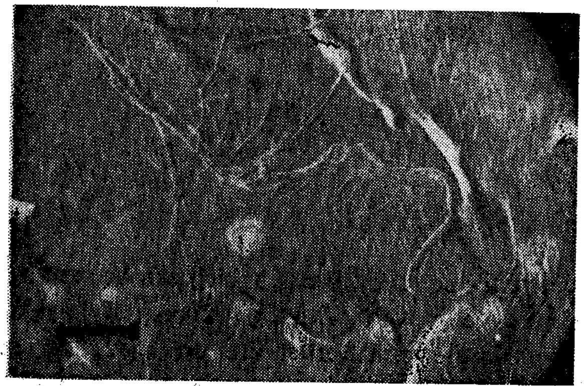


Fig. 3

(A lightly beaten sulphite pulp. The microfibrillar structure of the outer secondary wall 1 is well visible)

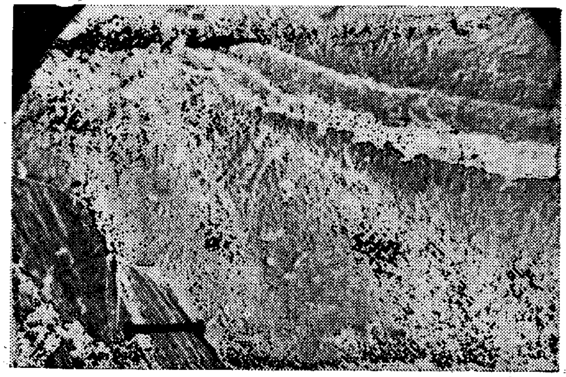


Fig. 5

(The same pulp after prolonged beating. Many microfibrills have desintegrated into small pieces which will be useless in papermaking and take up many wet end addittives because of their large surface. They form part of the useless "crill" in the paper furnish.)

Fig 4

(The same pulp as in 3 after more beating. The fiber structures disapper and microfibrillar bundals and lamellae from a dense and less porous sheet)

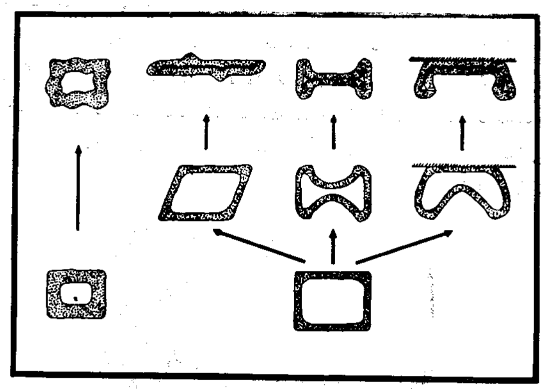


Fig. 6

(crosssection of springwood fiber, left, showing the various possibilities of fiber collapse during drying. Any other form in between is possible and one fiber may collapse into saveral of these forms. A thick walled summer wood fiber on the right will generally not collapse on drying but may do so on machine calendering in a dense paper area)

dried fibers but twisted structures with many ridges running along the outside. Thus the resulting paper made from the fibers will have them orientated rather at random (7) and will show flocs forming heavy and dense fiber areas and other areas deficient of fibers. In not or lightly beaten fibers the resulting paper will have approximately 50% voids with higher beating the paper becomes denser and therefore less opaque and shows poorer printing characteristies. Therefore most all printing grade papers, wood free or wood containing are very lightly beaten to preserve opacity, brightness and compressibility.

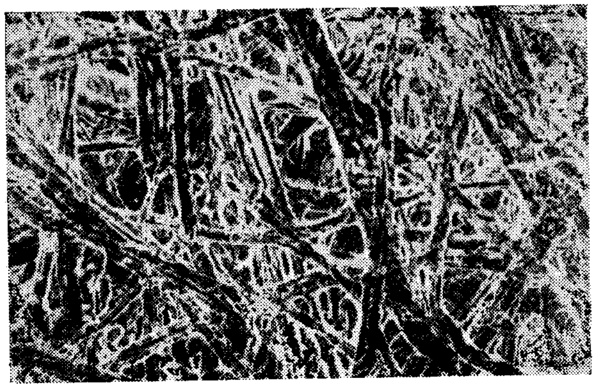


Fig. 7

(Basestock for coated printing paper. Note the randomness of fiber orientation, the flocks and the many pores, the latter forming half of the paper volume.)

In projection a tissue paper shows distinctly the wire marks and some flocculation. This becomes more pronounced in a 42 lbs (63g) woodfree printing coating raw stock (8) having very dense and open strucutres alternatingly. Passing such a paper covered by a carbon black paper through one light steel-steel calendering nip prints the carbon onto the densest flocks of the paper and makes the wire marks and the formation flocks very well visible (9). In transmittent light under the light microscope the areas are transparent because all the voids have been smashed in the machine calendering process (10). The action of the machine—and supercalendering on paper is shown in (11) where the fibers passing over flocks are flattened out visibly. Therefore also after machine—and supercalendering the surface of paper has still a considerable surface roughness and a varying ink receptivity due to the underlying density so that it prints badly in unpressurized printing procedures like rotogravure and poorly in the other procedures and here only with much printing ink still showing gloss mottle from the varying absorbency/fiber density. Improved ink holdout can be obtained by sealing the surface by surface sizing (12) but gravure printing is still very poor.

Thus the surface must be filled in with some material finer than the fibers and leveled all over with this material, which must be glued to the paper surface. This operation is done by the coating of paper. Average paper coating consists of pigment, binder and some rheological or other functional additives. Counting pigment as 100% the addition of binder is between 5 to 20% and the other addtives normally do not exceed 2%, all on a solid base. The major pigments used in paper coating are Kaolin(clay) and calcium carbonate, some aluminum hydroxide and aluminiumsilicates. The major binders are synthetic latices of the styrene-butadiene and the acrylics type and polyvinylacetate and starch in various forms of degradation and substitution, additives are polyvinylalcohol and carboxymethal cellulose, methyl cellulose, highly carboxylated acrylics and proteins.

A coating color is then made up from these ingredients by mixing them with water in high shear, low speed or high speed mixers add having coating solids in blade coating applications between 52 and 70% depending upon the final coatweight desired and the pigments used. Clay coating mostly range between 52 and 62% solids, viscosity adjustments being made by thickening additives Mixtures with finely ground carbonates and pure carbonate coatings dominate the upper solids region. of upto 70%. The specific gravity of the pigment, its particle shape, particle size and particle size distribution (packing density) are decisive factors for the coating solids obtainable. (33) Shows a clay-latex-starch coating in the electron microscope.

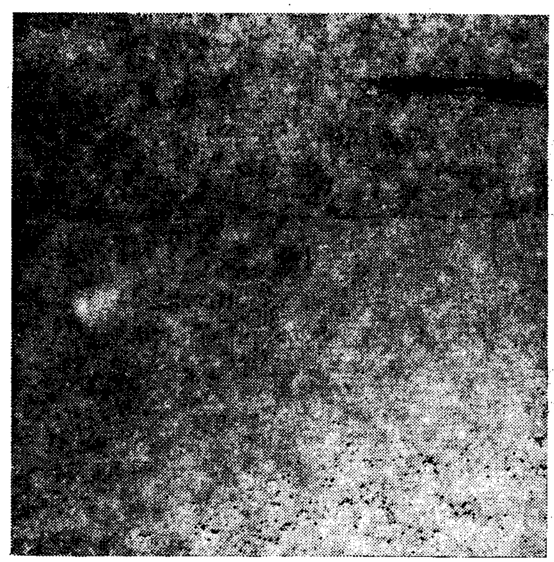


Fig. 8

(A 42 lbs coating basestock in the transmittent light. Formation flocks, wire marks, dense and light paper regions are well visible.)

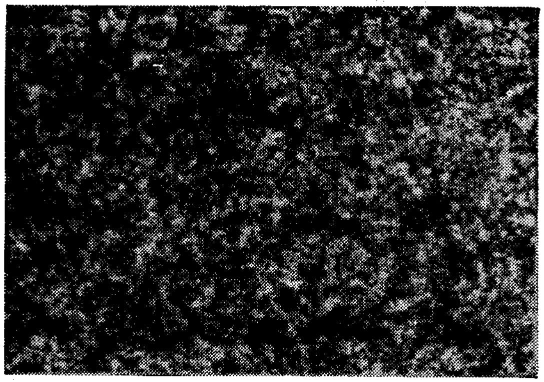


Fig. 9

(The same basestock passed with a carbon black paper facing it through a slight pressure steel-steel nip—The densest regions print the most carbon black, making formation flocs and wire marks well visible. The white areas indicate, that all load was borne by the black areas only, the white regions have never been touche in the calender nip. The resulting different paper densities will show gloss mottles and ink holdon differences)

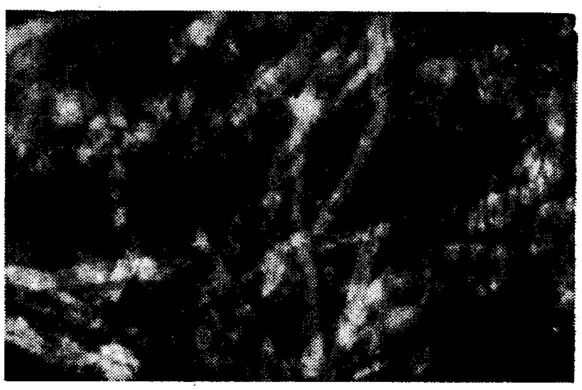


Fig. 10

(Light optical picture of macahine—and super-calendered paper in the transmittend light. White regions are denser than the black ones, because they are more transparent.)

Fig. 11

(A machine-and supercalendered paper, showing the calender load was borne by the fiber crossings which are flattened out.)

Fig. 12

(A surface sized and supered paper. The starch size forms a film which gives the paper better ink holdout.)

The paper surface is entirely covered by the coating i.e., the printing ink will touch only a uniform clay-binder surface with its very fine resolution of the clay particle size and its uniform clay-binder properties. Only in ink holdout (absorption) and in compressibility under the printing pressure will the underlying fiber structure still exert a (considerably) influence on the printing appearance in tha final picture.

Supercalendering (13) (or on machine soft calendering (14)) is a must for developing the coated papers surface into a good printing surface (15). (16) shows the coated wire side of the previously shown 42 lbs coating raw stock and the uncoated felt side underneath. In the uncalendered state both surfaces appear rough and porous, the coated side has the pores somewhat filled with the coating. Already at a light supercalendering, onepass at 400 pli, the coating is squeezed into the inter fiber pores and smeared rather uniformly over most of the paper fibers. (It is for this reason of their better yielding to pressure, that the latex colors give better smoothness and gloss than the starch only coating colors, the latter ones yielding no acceptable gravure printability without assisting the gravure printing process by electrostatic transfer, "electroassist"). The uncoated felt side of the paper in (16) shows still clearly porosity but a slightly smoother surface at 400 pli At 1800 pli the coated wire side shows no more open pores. The highly densified fiber areas appear black, because of their higher translucency not reflecting the illuminating light so much back Into the camera, which took the picture. The uncoated felt side shows smaller pores and also some compressed fiber regions being dark. The beneficial influence of blade coating and supercalendering on this paper is shown in (17) The blade coating acts like a knife with which one is spreading butter on a slice of bread. All the pores in the surface and all lower lying areas get more butter than the highest portions of the bread slice. The same holds true here for the clay coating. At medium supercalendering pressure both surfaces of the paper have become much smoother than in the uncalendered state, this being even more pronounced at the commercial finishing pressure of 1800 pli (300 dN/cm) The varying paper thickness is evidenced by the different depth of coating penetration into the raw stock. The more open, low density paper regions have gotten more coating, which will better seal this region and smoothness is increased, ink holdout and absorption have become more uniform, unprinted and printed gloss is more uniform and opacity of the sheet has been greatly improved and equalized. All these features are beneficial for all printing processes. Therefore a paper substrate must be coated in order to obtain maximal image reproduction on it. Again, the coating with its much more uniform properties and fine resolution is the print carrier and the paper underneath is the coating carrier.

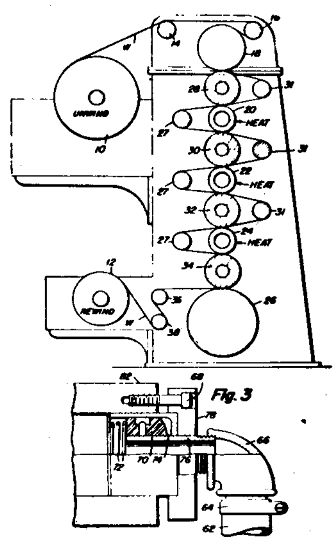


Fig. 13

(9 roll one side finishing super calender, this one being equipped with steam heated rolls (325°F) yielding much higher gloss and smoothness on coated paper.)

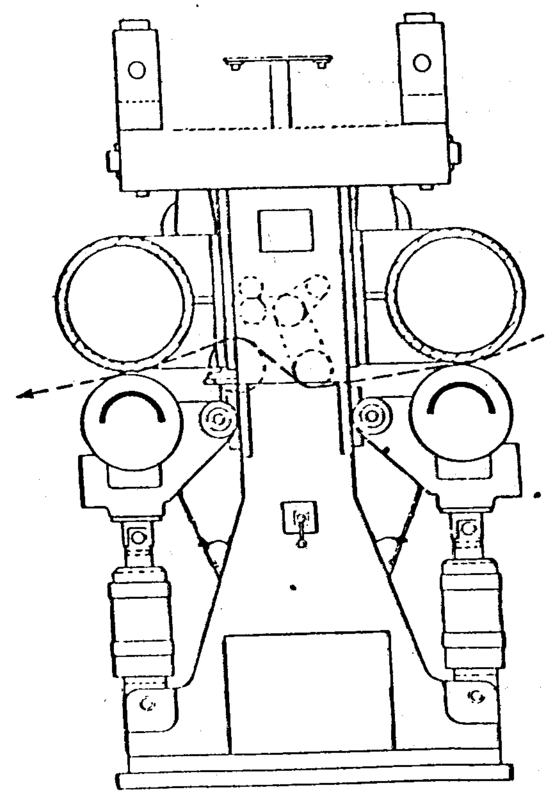


Fig. 14

(On machine soft roll calender (Kusters company, Krefeld, Germany) equipped with swimming rolls for uniform nip pressure. On machine calendering is useful for paper grades, which do not demand the high gloss possible.)

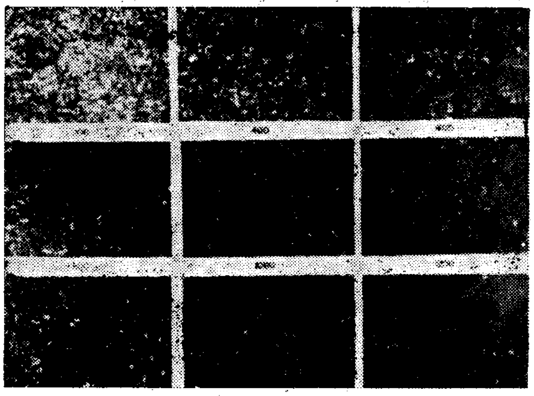


Fig. 15

(The effects of supercalendering on the coated wire side of the 42 lbs basepaper. The samples were then printed by letterpress with a starved ink film. The roughness of the paper is indicated by the white spots, decreasing with increasing supercalendering pressure.)

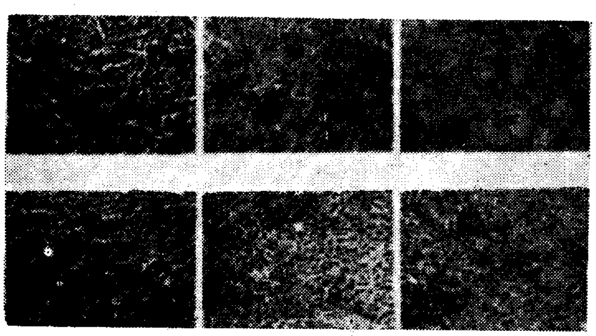


Fig. 16

(The coated wire side (top) and the uncoated felt side of the 42 lbs base stock at 0,400 and 1800 pli or 0,70,300 dı/cm (kg/cm). At 0 pli the wire side is steel very rough, but becomes distinctly smoother already at 400 pli and verv smooth at the commercial finishing pressure of 1800 pli. The porous uncoated felt side is somewhat smoothened and densified but the pores remain.)

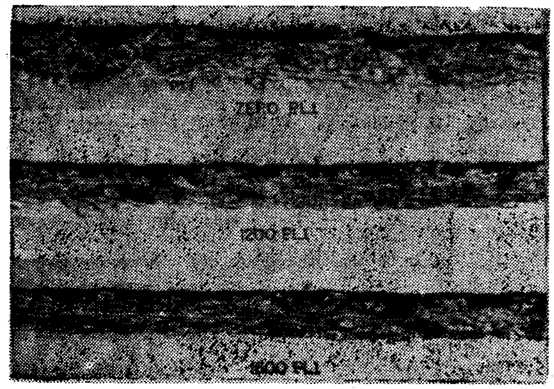


Fig. 17

(Cross section through the wire side coated paper at 3 different supering pressures, 0,1200, 1600 pli. Note penetrated into the pores by the blade coating process)

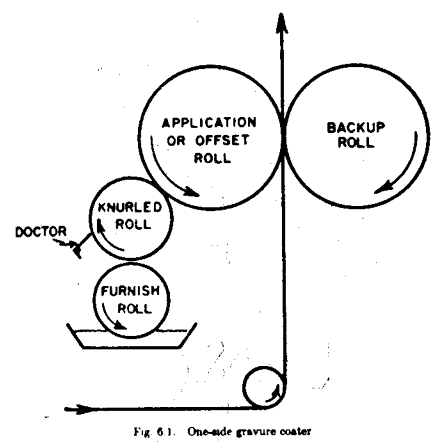


Fig. 18

(The offset-gravure roll coater. The grvure cell roll normally runs up to one month before needing seknurling. The coater is extremely reliable and runs problemfree on machine. The transfer of the knurl pattern can be minimized by slight speed differential between the rubber covered offset-applicator roll and the knurled roll.)

Let us have a look at the most common coating procedures. In the begining of coating the paper was painted with brushes mounted on oscillating carriers. In the early 1930s printing methods were used to apply coating. Massey was the first to use the letterpress printing system with its ink transfer rollers as a coating device (Massey Coater, St. Regis coater, Mead-Kimberly-Clark coaters). Westvaco introduced the gravure coater (18,19). All printing coaters suffer from various shortcomings. They apply the same amount of coating all over the web, squeeze it onto the web, whereby pores, exceeding in depth the coating film thickness offered, do not receive any coating into the deep regions thus leaving them absorbent. When the coating roll parts from the web after the coating nip the non absorbed coating is split 50/50 between the two parting surfaces. The viscous coating pulls into strings before it splits snapping back onto both surfaces paper and roll in an even manner and leaving a fine coating mottle like ridges (20) or pimples (21) the letter being called an orange peel pattern. Therefore surface smoothaess of a roll coated paper will never reach the quality of a bladecoated paper. The advantage of roll coaters is their very good runnability They are used mostly as on machine coaters. Their speed is limited to approx. 500 m/min.

Historically the next coating device was the air brush or the air knife coater (22). Here an excess of coating is applied to the sheet by an applicator roll and passes then through an impingent air jet from the air knife, which blows all coating off which still has low viscosity, leaving a rather uniformly thick coating layer all over the paper, following is ups and downs. An air knife coater is therefore a contour coater. This has beneficial effects in relation to ink absorbency and holdout; to uniformity, if it is a functional or colored coating, and in uniformly covering underlaying brightness differences i.e. on board containing waste paper. Smoothness after supering is inferior to blade coating. Its greatest drawback however is the need for very low solids coatings with resulting long drier sections and high energy need and the misting of the color blown off at the air knife. These two problems are overcome in the reverse roll coater (23) which also applies a uniformly thick coating layer without pressure. It is not problem free either, as it shows runnability and coating defects at commercially interesting high speeds. The importance of coating thickness uniformity in functional coatings like Electrofax, Non-carbon copy papers, Thermographic papers, Dielectric papers, Colored papers is still best satisfied by these two coaters. The development of a high speed contour coater would be a challenging task to coating machinery builders.

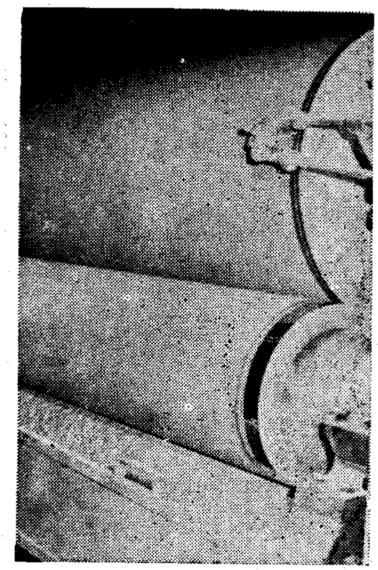


Fig. 19

(The same coater on machine. The furnish roll in the bottom brings up the coating into the nip. The doctor for the knurled roll is on the other side, not visible. The applicator roll offsets the coating from the knurled roll to the web.)

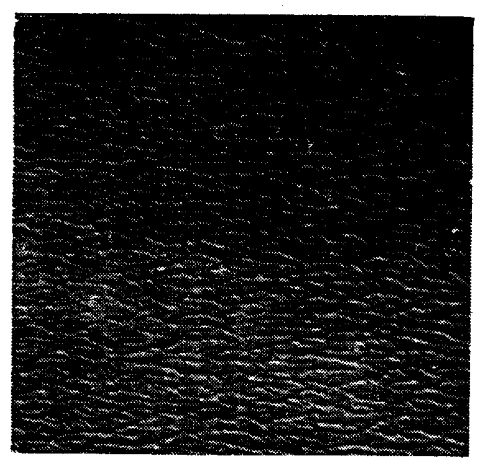


Fig. 20

(Ridges on the coating surface originating by the film split in a roll coater.

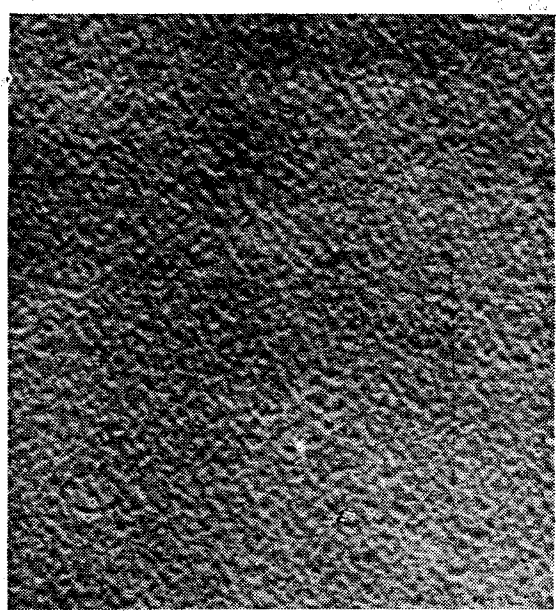


Fig. 21

(Pimples are an other film split cattern in roll coating, called "orange peel" pattern. 20 and 21 are photographically enlarged 20 times. The pattern can be seen with the naked eye and shows up even more pronounced in solid printing areas.)

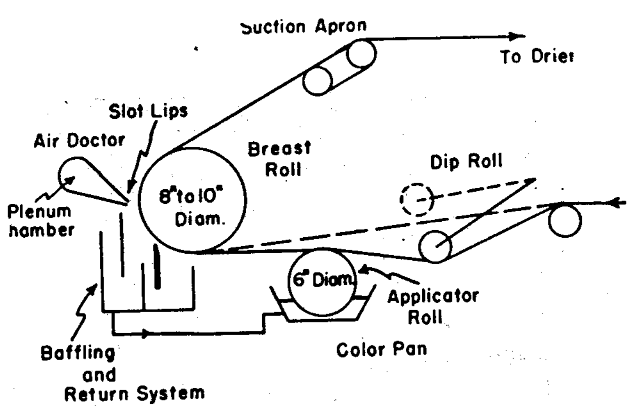


Fig. 8.1. Diagram of the air doctor coating process

Fig. 22

(The air knife or air doctor coater the picture is self explaining)

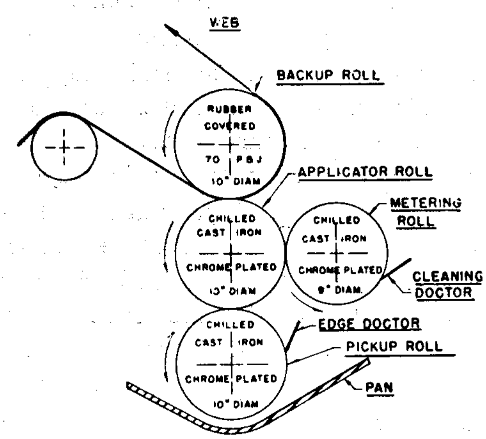


Fig. 23

(The reverse rollc oater also applies a uniformly thick coating layer to the paper without any pressure and at higher solids than the air knife.)

The opposite concept to the contour coater is a coater applying a perfectly smooth coating layer with varying thickness according to the underlying paper surface. This is done by the so called cast coating process (24). Coating is applied to the paper and the web passes then through a nip formed between a huge chromium plated cylinder and a pressure roll, applying slight pressure, just enough to squeeze off the excess coating from the web. The coated side fronting the chrome plated drum is dried in contact with the heated drum like photographic drier drums are drying high gloss photographs. The drums have diameters from 3 to 6 m and are rotating at such a (low) speed, that the coating is dried after one revolution of the drum. It is then taken off the drum and wound into a reel. The coating shows a mirror finish to the eye and is used for expensive packaging, label paper and advertising as "cast coated paper or board", The process is slow and the product therefore rather expensive. Rather competitive quality grades are being made by using special softening coating formulations and finishing them against a heated drum of high finish either in a remoistened state or by thermoplasticity. Thermal finishing of coated board by a heated "gloss calender" is to-day standard in most coated board fabriction.

The most succesful coatings for all printing paper and board are provided by levelling or metering coaters in which an excess of coating applied by the coating applicator is metered off by a counter-rotating rod or a thin trailing blade. These coaters are filling all the voids and give a uniformly smooth coating layer in the moist state, which, unfortunately, shrinks upon drying to its solids thickness Double or even triple coating improves dry smoothness, but increases the danger, that contaminants get lodged under the blade and cause a streak or a scratch, which generally shows up in printing and especially on glossy board. The beneficial effects of the different thickness coating distribution has already been discussed. The blade coater (25-29) is to-day the most commonly used high speed coater applying coat weights from 5 to 20 g per side. Production speeds are up to 1400 m/min.now and experiments have been run up to 2000 m/min. The coater is best at medium high speeds from 600 to 1000m, below 300 m it scratches more badly and above 1200 m coating gets through the blade nip in many instances and causes "weeping and bearding", two undesirable features, which are not yet fully understood. The counter-rotating rod is commonly used in board coating and in some special papergrades. It is a low speed coater up to 500 m. It causes no scratches but produces a slightly less smooth surface and has a minor film split pattern whereas blade coaters have none. Coat weight applied by the blade coating process is dependent upon coating color characteristics (solids viscosity, rheology) but mainly upon the blade pressure and the blade angle the minimal coat weight achievable even under highest blade pressure is dependent upon the surface roughness of the paper under compression and is, 4-5g/m² in the case of printing papers at coating solids around 58%.

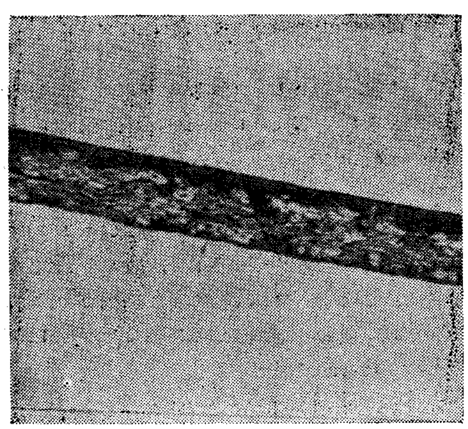


Fig. 24
(Crosssection through a cast coated paper. The coating surface is a replica of the chrome plated casting drier drum.)

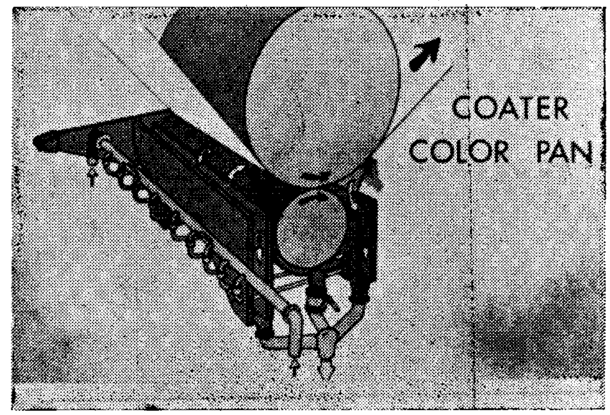


Fig. 25

(The inverted blade coater on the applicator roll blade coater, the most widely used coater in the paper industry.)

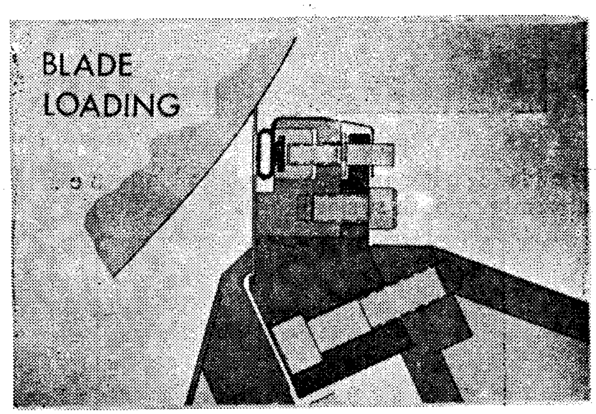


Fig. 26

(A variable angle blade and holder. The angle is effected by turning the entire holding system. The blade is loaded by an air hose behind it. At long blade extension this can also influence the blade angles give higher coat weights and less scratching at the same blade load.)

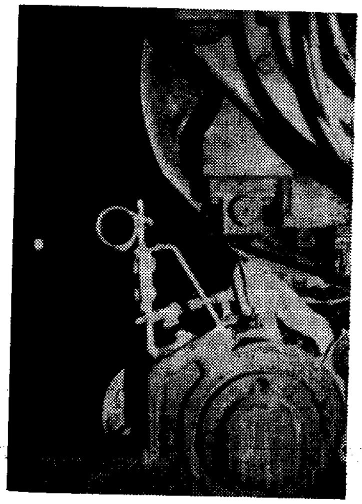


Fig. 27
(The inverted blade coater in operation. Note, how the coating colors thrown against the blade, which meters all excess off.)

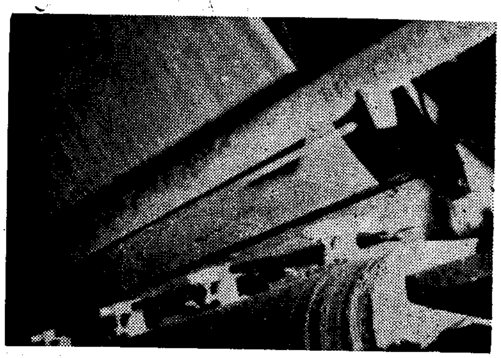


Fig 28
(The blade coater in operation. the blade meters a uniformly smooth surface in the wet state.)

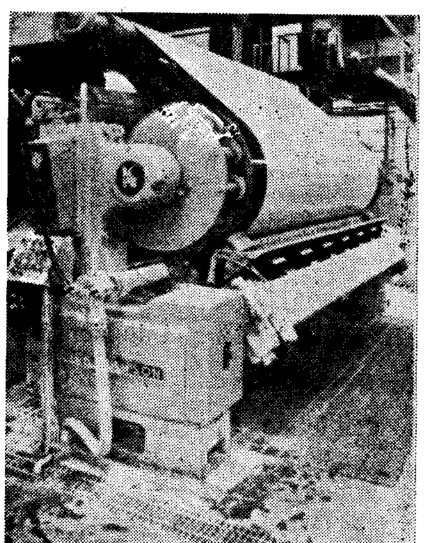


Fig. 29
(In fountain blade coaters the applicator roll is replaced by a non moving device, which feeds the coating through a slot uniformly against the web.)

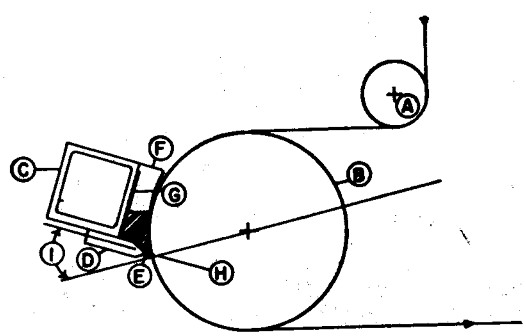
A different type of blade coater is the pond type blade coater (30), where the blade forms the bottom of a trough open against the web, which is filled with the coating color. This coater scratches much less than an inverted blade coater and is therefore most common in board coating, especially as the top coater. The coat weight is dependent upon the solids content of the coating color and to some extent upon the height of the pond in the trough. Lowering the pond further and further permits less contact time between coating color and the web, therefore less absorption of color into the sheet. Such short pond coaters have been designed in such a way, that the color is applied upwards against the blade in the 4 or 8 o'clock position the application area being very short before the blade meters the coating. They are therefore called "Short dwell coate s SDC, or short dwell time applicators SDTA" and are becoming increasingly more common as on machine-coaters in papercoating. Because they are applying a lower coat weight at comparable coating solids than the inverted blade coaters, one can run at higher solids content to apply i.e. 5 g/m² onto a very (ultra) light weight coated paper (ULWC, final coated paper weights are between 40 and 50 g/m²) and such a coating gives a better holdout at the surface that a comparable 5g thin coating on an inverted blade coater. The coater is not free from problems either. Its runnability at very high speeds is inferior to the inverted blade coater resulting in uneven and streaky coat weight applications. The newest blade coaters in the market are therefore combinations of both which can be easily switched over. A fountain coating applicator is in the market in which the applicator can be moved around the backing roll from long dwell application to short dwell application.

An other "off spring" of the pond type coater is the Billblade coater, (31) also a low pond coater where the web is led through the pond and coated on both sides, one side being metered by the blade, the other by the backing roll as the web is immediately led away from the backing roll after the blade nip This coater is mostly used to apply a base coat on machine to paper followed by other coating devices to apply subsequent coating(s) on or off-machine.

Board is mostly coated on machine, as web breaks occur seldomly and speed is low to medium. Paper was mostly coated off machine so that a break in either the papermachine or the coater does not affect the other.

Paper breaks occur more often in the coater section, therefore the off-machine coaters are running at higher speed than the papermachine in order to avoid much backlog between the two. The cost of winding, rewinding and unwinding between the two units is, nevertheless, some factor in the ever narrowing profit margins and high labour cost. Thus on machine coating was already practized for a long time in the US and is being introduced, mostly with variable dwell time coaters, now also in Europe. Common European LWC papermaking-off-machine coating systems are now around 7.6 m wide, papermachine speed is up to 1200 m/min followed by a 2 or 4 station coater with speeds up to 1500 m/min producing around 450 tons of coated paper per 24 hrs.

Pictures 32 to 37 give some further insight into the matters discussed above.

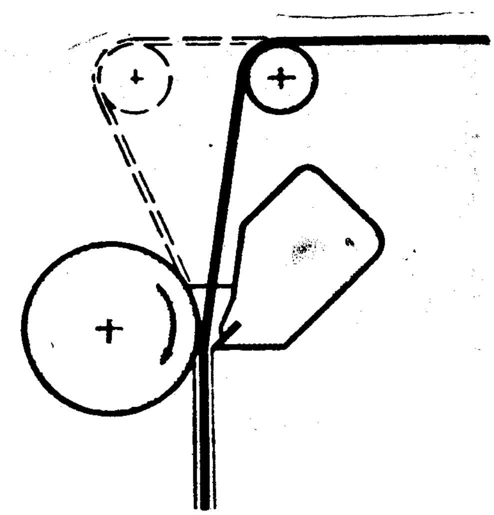


(A) Lead-in roll
(B) Backup roll
(C) Coating head
(D) Blade jaw
(E) Blade
(F) Dikes
(G) Dikes mounting rail
(H) Blade centerline
(I) Blade angle

Fig. 9.1 Puddle type trailing blade coater

Fig. 30

(The pond or puddle type coater contacts the moving web according to its pond height, which influences the coat weight besides the coating solids. There is no immobilized layer forming on the web as in the inverted, blade coater, the main reason for less scratching in this coater. As web breaks are much in this coater it is rarely used on paper but mostly on board.)



BILLBLADE Standard BC

Fig. 31

(The Bill Blade is also a pond type coater. If the web is to be coated both sides it is led through the pond contacting the backing roll only at the blade tip, where the coating is metered on both sides.)

Fig 32

(Cross section through a web taken from the wet end and dried without pressure.)

Fig. 33
(Clay coated paper surface after medium supering of 900 pli. the lower left is over a flock area in the paper and is flattened out much more than the upper right, which is over a low density area.)

Fig. 34
(Coating surface on paper applied by a roll coater. Because of the film splitting between the coatar and the paper the surface is much less smooth than in blade coated paper.)

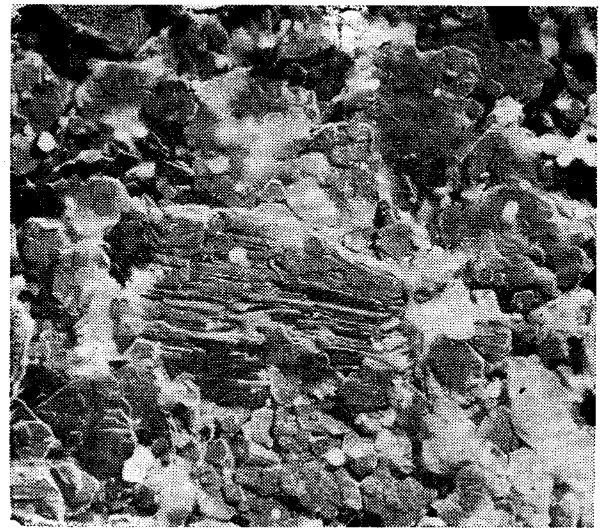


Fig. 35
(Clay coated unfinished paper surface. Note the large clay stack or booklet in the middle indicating, that it must have fit into a deed pore underneath.)

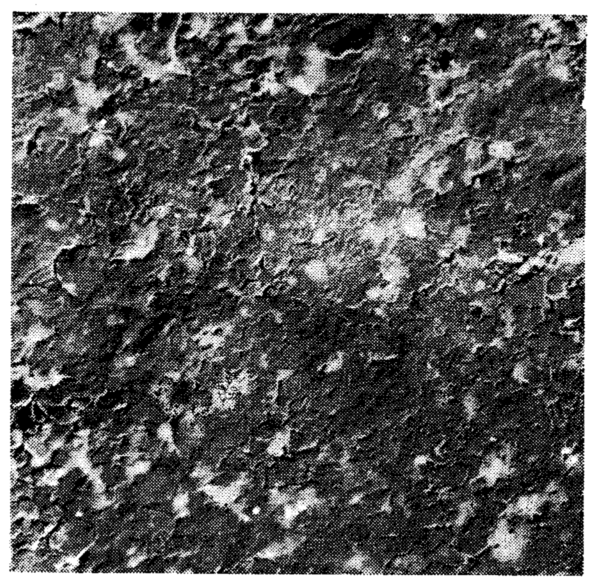


Fig. 36
(Clay, latex and starch coated surface of the 42 lbs base-stock discussed earlier in the publication. This sheet has been fully supercalendered several nips at 1803 pli. Note the smoothnees of the surface. The clay platelets visible in 33-35 have disappeared into a homogenous surface structure of pigment and binder.

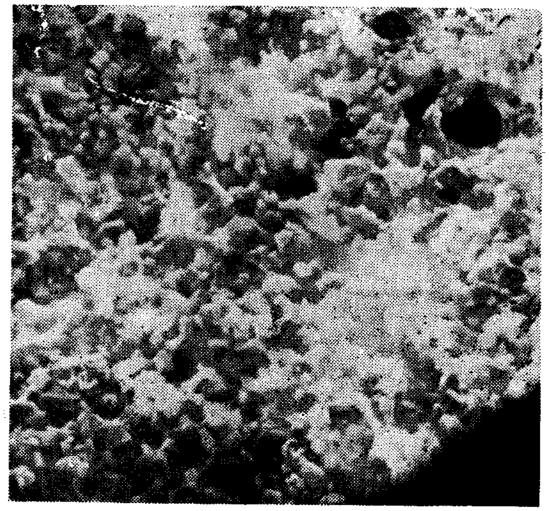


Fig. 37

(Surface of a zincoxide coated electrofax paper. Note the roughness of the prism shaped pigments. They can never pack as smoothly as the clay platelets in the other picture. The surface will be abrasive and dull)

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All other pictures were taken by author and his coworkers during his affiliation with Westvaco Corp. at Laurel and Luke/MD, USA.

also compare :

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