

for drying. The creping process is difficult to control and requires some downtime to change crepe blades. To overcome these issues and to provide a sheet with improved properties, the through-air-dried process was developed. This has recently led to a version in which the sheet is only through-air-dried (TAD) and is not creped.

The TAD is a large, open-type cylinder which is the full width of the machine. Hot air (400–500°F (477–533 K)) is blown through the sheet to dry it. Air can be blown from either the inside, with the sheet held against the TAD by a wire of some form, or it can be blown from the outside. This leads to two versions of TAD, commonly referred to as inside-out and outside-in. The main advantage of the TAD over the conventional creped Yankee dryer is that most, or all, of the water can be removed from the sheet by pressing the sheet. This leads to a bulkier sheet, as there is no press-related sheet consolidation.

In the early version of the TAD, the sheet was not completely dried on the TAD. Rather, it was taken to some intermediate dryness (around 60–70% solids) and drying was finished on a small, conventional-type Yankee dryer. The pressing necessary to adhere the sheet to the Yankee in this configuration was not damaging as the sheet was dry enough that the pressing did not consolidate the sheet. It did require a more complex machine, however, as now two drying cylinders (TAD and Yankee) were required and there was a need to transfer the sheet from the TAD to the Yankee. In addition to the drying, the Yankee was also needed to crepe the sheet to provide the desired surface characteristics.

A significant advance for the TAD process was the development of specialized forming and TAD fabrics. Conventional forming and early TAD fabrics were quite smooth, as the papermaking fabrics were designed to minimize the impression of the fabric design in the sheet itself. With TAD, it became possible, and even desirable, to leave some fabric impression in the sheet. These impressions can replace the crepe bars imparted by creping and contribute to desired bulk and surface characteristics. Operating the TAD at a slower speed than the forming section, called negative draw, can impart increased fabric impression in the sheet giving a surface with a visual texture similar to creping. This is commonly called fabric crepe and the negative draw may range from 3 to 15%. With the proper TAD fabric design, it is possible to eliminate the Yankee dryer altogether and impart surface characteristics with the fabric pattern, making full use of fabric crepe. This type of tissue making is called uncreped TAD.

While the uncreped TAD process eliminates the crepe dryer and the drawbacks associated with

creping, it is not without some disadvantages. As currently practiced, it requires several fabrics and usually two TAD cylinders. This means that there are several sheet transfers, which increase the risk of sheet breakage. The additional wires are also an additional operating cost. The actual design and operation of an uncreped TAD machine is a closely held trade secret, as well as being protected by multiple patents.

See also: **Papermaking:** Overview; Paper Grades; The History of Paper and Papermaking; World Paper Industry Overview.

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Coating

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Introduction

Coatings are applied to paper and paperboard for two essential reasons: to create a uniform surface for printing or to impart certain functional properties to the surface such as, grease resistance, water resistance, etc. Paper contains a series of holes formed by the overlaying of the fibers during the papermaking process. Coatings are applied to fill these holes and smooth the surface (**Figure 1**). Smoothing the surface enables the image carrier of the printing process to

make more intimate contact with the surface, which results in better transfer of the image to the surface, hence better image quality. Coatings also provide a more uniformly porous layer for receiving the inks. Paper suppliers can use the coatings as a means to provide a product that has the desired optical and ink receptive properties needed by the printer for a given print job. Since the characteristics of the inks, means of image transfer, and ink setting and drying mechanisms change from printing process to printing process, the characteristics of the coatings must also change. Coated paper and paperboard manufacturers

must therefore first understand the requirements of the coating for each of the printing process, before developing a coating formulation. A review of the four major printing processes (offset, flexographic, rotogravure, and nonimpact) is given elsewhere (see *Packaging, Recycling and Printing: Printing*).

Ingredients and Properties of Coatings

Coating consists of three major components: pigment, binder, and water. It is the pigments that are used to fill the voids between the interlaying fibers. White pigments are chosen in order to provide the highest print contrast between the coating and printed image. The higher the print contrast, the more 'snap' the image will have. This is why high-quality photographic papers are now being sold with brightness values greater than 100%. How this is accomplished will be discussed in the upcoming section on coating additives. But for now, it is evident, that brightness is one property used to judge the quality of paper. Other important properties used to classify the grade of paper are furnish type, basis weight, smoothness, gloss, and opacity. A summary of the properties used in classifying coated North American paper and board grades are given in **Tables 1 and 2**.

Pigments

The optical properties, smoothness, and ink receptive properties of a coating are determined by the types of pigments used in the coating formulation. The most

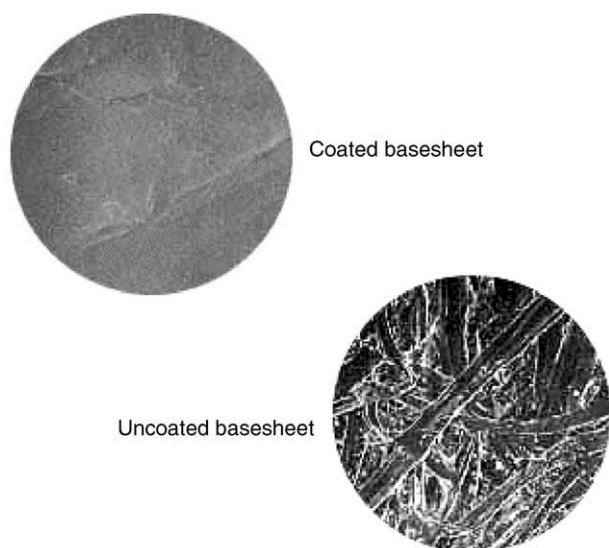


Figure 1 Microscopic views of a coated and an uncoated sheet of paper.

Table 1 Summary of North American coated paper grade optical and smoothness properties

Paper grades	Weight (g m^{-2})	Brightness (%)	Smoothness (μm)	Gloss (%)
MFC	55–60	75–78	2.0–2.5	25–30
FCO	52–60	68–70	1.0–1.4	45–50
LWC No. 5	45–70	69–71	1.0–1.4	48–50
MWC No. 4	74–118	75–78	1.0–1.4	58–62
No. 3 PUB	89–148	79–83	1.0–1.3	68–70
No. 2 PUB	89–118	83–85	1.0–1.3	78–82
No. 1 PUB	104–108	85–87	1.0–1.3	88–90

MFC, machine finished coated; FCO, film coated offset; LWC, lightweight coated; MWC, mediumweight coated; Pub, publication. Data from Gay JP, Al-Saimaani M, and Sharman P (1996) *International Papermaker* 59(5): 22–26.

Table 2 Summary of North American paperboard grade properties

Board	Grade	Basis weight (g m^{-2})	Stiffness ^a	Tear strength ^a	Surface finish ^a
Cartonboard	Newsback CRB	200–800	4	1	3
	Carrier CUBK	300–600	5	3	3
	Solid bleached	150–600	4	1	5
Foodboard	Solid unbleached	150–500	4	1	2

^a5-Best, 1-Poor CRB, coated recycled board; CUBK, coated unbleached kraft. Data from Ouellet J, Viswanathan G, Sharman P, Cross C, and Johnson S (1997) *PIMA's International Papermaker* 79(5): 17–21.

commonly used pigments in North America are clays, while in Europe, carbonates are more commonly used. This is mostly because of availability. Europeans also tend to prefer more of a matte finish than a glossy finish, which is accomplished by using more carbonate in the formulation than clay.

The properties of the pigment that are most important to the papermaker are particle size and distribution, particle shape, index of refraction, brightness, abrasivity, and of course cost. The particle size and distribution of the pigment(s) used influences the rheological qualities and runnability of the coating during application and metering and will influence the density of the coating layer after drying. The density of the coating layer influences the optical and ink receptive properties of the coating. The ink receptive properties of a coating are generally reduced when smaller particles, which pack more tightly, are used. However, the shape of the particle will also affect this property because it also influences the final packing density of the dry coating structure.

Gloss and smoothness generally increase with decreasing particle size. Smoothness tends to improve with decreasing particle size because the microdeviations on the surface decrease as the void spacing between the pigment particle decreases. There is some evidence that finer particle pigments require slightly more binder for sufficient adhesion and cohesion of the pigments to each other and the substrate.

Opacity will increase moderately with decreasing particle size, due to the increase in the number of air to pigment interfaces, which will refract more light. This holds true up to a particle size of about 0.3 μm . This has to do with the ability of light to see the pigment particle. For the most effective scattering of visible light, the diameter of the pigment particle should be about 40% of the light that is desired to be scattered. The visible light spectrum ranges 400 to 700 nm or 0.40 to 0.70 μm . Thus, a pigment particle diameter of 0.16–0.28 μm will scatter the incident light most effectively. The ability of a pigment to reflect light diminishes under 0.16 μm particle diameter.

So, as it may appear, the papermaker must balance the desired optical, smoothness, and ink receptive properties of the coating to the costs and processability requirements of the mill and customer.

Pigment Selection

Pigments are classified according to their brightness and weight percentage below 2 μm (Table 3). The particle size distribution and shape influence the ability of the particles to flow in the wet and to pack together in the dry state. So in the wet state, the rheological

properties of the coating are greatly affected by the distribution and shape of the pigment particles.

The shape of a pigment is determined by the crystalline structure of the mineral from which it is obtained. The crystalline structure and chemical composition of the pigment are what also determines the refractive index and abrasivity properties of the pigment. The surface finish characteristics of a sheet are heavily influenced by the shape of the pigment particle.

Clay

Clay is a naturally mined pigment. The most significant deposits of clay are found in Georgia (USA), Cornwall (UK), Jari River (Brazil), and southern and northeastern Australia. The major constituents of clay are kaolinite and montmorillonite, hence the term kaolin clay. Chemically, clays are alumina silicates, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$, which have platy hexagonal structures (Figure 2). Its platy structure is what enables clays to develop gloss upon calendering. During calendering, the platelets align in the machine direction to improve the smoothness and gloss of the finished surface.

A perfect clay particle would be as shown in Figure 2. However, particles are rarely perfect and tend to be irregular six-sided platelets. Above 2 μm , they tend to exist as stacks of two to three platelets. By using a high shear extruding process (Figure 3), these platelets can be separated to produce a special grade of clay called delaminated clay. The individual platelets provide a smoother and more closed coating structure than standard clays upon calendering. For this reason, they are commonly used for solvent-based lightweight coated rotogravure printing grades.

Table 3 Classification of pigment

Premium brightness	Solids (%)	Brightness (%)	<2 μm (%)
Ultrafine	70	90–92	95–100
No. 1	70	90–92	90–94
No. 2	70	89.5–92	80–86
<i>Standard brightness</i>			
Ultrafine	70	86–88	94–98
No. 1	70	86–88	90–94
No. 2	70	85–87	78–84

Data from Hagemeyer R (1997) *Pigments for Paper*, TAPPI Press, Atlanta, USA.



Figure 2 Perfect rhombohexagonal clay platelets.

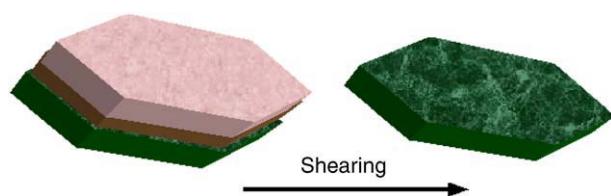


Figure 3 Shearing action to produce delaminated clay.

Selective fine clay particles can be structured into larger particles to enhance the light scattering and ink receptive properties of the particles. The structuring of clay can be performed by either a chemical or thermal treatment processes. The most commonly structured clay is called calcined clay. Calcined clay is obtained by calcifying the clay at temperatures above 1000°C. The high temperature treatment sinters the fine particles together and drives the hydroxyl groups from the chemical structure, which converts the clay to a noncrystalline aluminum silicate, $\text{Al}_2\text{O}_3\text{--}2\text{SiO}_2$. The new thermal structure can be described as a ‘popcorn’ type structure. Like popcorn, the structure contains many voids between the sintered particles. These voids improve the opacifying properties of the pigment, but rheologically make them more difficult to handle. Unlike standard clays, they can only be slurried up to 60% solids. Standard clays can be slurried up to 70% solids. The difference is significant to those wishing to apply high-solids coatings. Calcification also increases the abrasitivity of the pigment. They are most used in coated board grades where coverage is needed to cover the darker base sheet and to improve the absorption properties of grades to be printed with water-based inks.

Calcium Carbonate

Naturally ground calcium carbonate (GCC) is produced from chalk, limestone, or marble by either a wet or dry grinding process. The basic mineral of both chalk and marble is calcite, whose crystals are rhombic in structure. A rhombic structure is best described as a cube, which unlike the platelets of clay, do not produce gloss as readily during calendering. As a result, calcium carbonates are used more in the production of matte grades. However, fine ground and ultra fine ground calcium carbonates (UFGCC) are now available for gloss grades. Calcium carbonate reacts readily with acid and acid salts so carbonate coated broke can not be mixed with acid sized furnishes. They are therefore used in mills producing neutral or alkaline sized papers.

As a coating pigment, calcium carbonate produces a high brightness, high opacity coating. The rheological properties of calcium carbonate enables it to be supplied in slurry form at greater than 70% solids,

which allows paper mills to run at higher solids. Unlike clays that have a yellow tint, carbonates have a bluish tint, which causes it to appear brighter in a coating. This property enables it to achieve a brighter coating more economically than clay. It is used significantly in wood free grades and matte grades. The rhombohedral particles pack more tightly than the two to three stacked platelets of standard clay. The resulting tight packing structure tends to dust more while printing. A blend of clay and carbonate is therefore more generally used for matte grades. Glossy grades are produced using little or no GCC or using an UFGCC with 90% finer particles less than 2 microns.

Another form of calcium carbonate that is being commercially sold in smaller quantities to the paper industry as a coating pigment is precipitated calcium carbonate (PCC). The switch from the acid to alkaline papermaking process has increased the usage of precipitated calcium carbonate in paper coatings, but its cost has limited its use. The conversion from acid to alkaline papermaking led to the development of satellite PCC mills next to the paper mills. PCC is produced from the limestone generated from the kraft chemical recovery process. The particle and shape of the PCC are determined by the precipitation conditions used, such as pH, temperature, degree of agitation, and use of additives. By controlling the conditions, either calcite or aragonite forms of PCC can be produced. The main advantage of PCC over GCC is the control of particle size, shape, and particle size distribution. They are mainly used for grades that can justify the increase in cost for the properties gained. The rheological properties of some of these grades also limits the ability to slurry them at high solids.

Specialty Pigments

Besides clay and calcium carbonate, there are many other types of pigments used in paper coatings that due to their lower usage levels are considered specialty pigments. These include titanium dioxide, plastic pigments, talc, alumina trihydrate, and silica, just to mention a few. The properties that prevent these materials from being used in larger quantities are one of cost and ease of application. Several of the above-mentioned pigments are difficult to disperse at high solids. They are therefore only used in applications where they have a special part to play.

Comparison of each pigment’s properties in **Table 4** show the distinctive properties of some of these pigments. Besides differences in particle shape and refractive index, density is another distinguishing characteristic that can play an important role in the selection process for a coating. The density of a

Table 4 Summary of distinguishing pigment properties

Pigment	Dry bright (%)	Refractive index	Specific gravity	Crystal form
Clay	70–90	1.55	2.65	Rhombohedral
GCC	90–95	1.49–1.66	2.72	Rhombohedral
PCC	95 +	1.49–1.68	2.72–2.94	Rhombic, acicular, scalenohedral
TiO ₂	97–98	2.70 (Rutile)	4.20	Tetragonal
TiO ₂	98–99	2.55 (Anatase)	3.90	Tetragonal
Solid plastic (polystyrene)	97 +	1.59	1.05	Spherical

GCC, ground calcium carbonate; PCC, precipitated calcium carbonate; TiO₂, titanium dioxide.

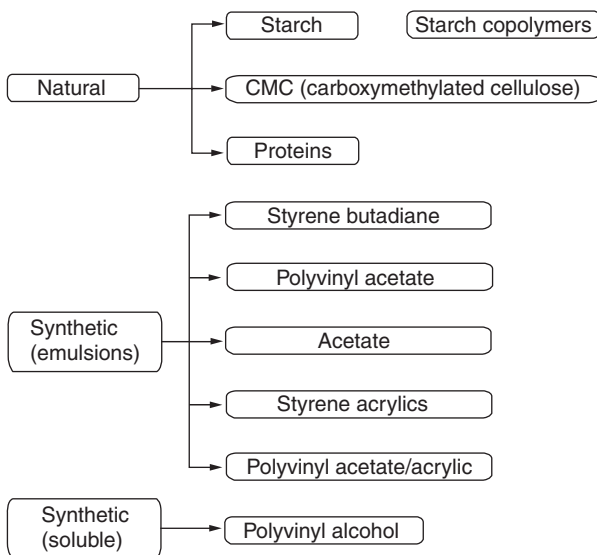
pigment is especially important for lightweight coated grades of paper. In these grades, lower-density pigments are preferred to keep the weight of the coating down. For this reason, synthetic plastic pigments are often used for opacity and improved finishing and printing properties in these grades. Synthetic pigments are made from a variety of synthetic polymers, but styrene and copolymers that possess glass transition temperatures above 50°C dominate the commercial market.

The selection of pigment(s) for a coating will have a profound effect on the runnability, printability, and optical properties of the finished product. The right combination of pigments must be chosen to meet the end-use requirements and cost constraints of the customer. At the same time, it must be capable of being run on the manufacturer's available coating equipment. The same requirements must be met by the binder, which is the second largest component within any coating formulation (besides water).

Binders

The role of the binder is to provide the properties of cohesion and adhesion to the coating. Cohesion refers to the binding of two like surfaces, such as pigment-to-pigment bonds. Adhesion refers to the binding of two unlike surfaces, such as pigment-to-fiber bonds. The strength of the bond between any two surfaces strongly depends on the type of binder used and the amount of contact between the two surfaces. It is important to say that these are not the only factors, but since they are the two that can be controlled through the selection process, they are the only two that will be discussed at this time.

A summary of the different types of binders used in paper coatings is given in **Figure 4**. The bonding strength of the binder is to a large extent influenced by the length and flexibility of the polymer chain. The more flexible the polymer chain, the more flexible the bond. The chemical composition of the polymer and the amount and type of chemical conversions performed on the polymer control the flexibility and length of the binder's polymer chains.

**Figure 4** Summary of different paper coating binders.

A binder is a special kind of adhesive. Its role in a coating formulation is to adhere the pigments to one another and to the substrate. The binder also serves to control the porosity, and the water and solvent resistance of the coating. The gloss of the coating can also be greatly influenced by the type of binder used.

Binder Selection

When selecting a coating binder, the binding strength is not the only property that must be considered. The flexibility of the binder after drying is also very important as well as its film forming properties. A flexible binder will form a flexible, continuous film upon drying and flexible bonds between any two solid surfaces. A nonflexible binder will form a rigid film, resulting in rigid bonds that are nondeformable. A rigid structure that will not deform under the action of the calender will not attain a high level of gloss. On the other hand, a very flexible binder might become tacky and stick to the rolls of the calender. As a result, the two properties must be balanced to yield the final desirable coating properties.

The level of binder used depends on the 'binder demand' of the pigment. Binder demand means the amount of binder required to obtain the desired surface strength properties of a coating. Binding strength is very important, but it is very difficult to quantify because just as each binder has a particular strength, each pigment has its own binder demand. The binder demand of the pigment will depend on the shape of the pigment, particle size and particle size distribution.

So, when selecting a binder the formulator must consider the binder demand of the pigment, the bonding strength of the binder, the desired coating properties (optical and print properties), the demands of the printing process on the surface strength of the coating, and of course cost. Formulators seek to minimize the amount of binder needed not only for cost considerations, but also because the binder can interfere with the optical properties of the coating. The presence of excess binder reduces the number of air voids available to scatter light and receive the carrier solvents in the printing inks.

There are two major classes of binders used in paper coatings; natural and synthetic. The two predominant types of natural binders are starch and protein. Starch is composed of two high molecular weight polymers called amylose and amylopectin (**Figure 5**); it is easy to see that amylose is linear like cellulose while amylopectin is branched.

To enable the starches to be prepared at higher solids, the molecular weight of the starch can be reduced or the starch depolymerized. The depolymerization of starch involves the chain cleavage of the anhydroglucose units, which results in shorter, lower molecular weight polymer chains. Consequently, the viscosity of starch decreases and they can be prepared at higher solids.

Starches can be depolymerized (degraded) enzymatically with enzymes, or chemically using hypochlorite or hydrogen peroxide to oxidatively depolymerize the starch. Another chemical method is acid hydrolysis. The degradation can be made either on-site at the mill, or by the starch supplier. Hypochlorite, hydrogen peroxide, and acid hydrolysis are usually performed by the supplier. Starches can also be thermochemically modified. Thermochemical starches are prepared on-site by the mill using a continuous jet cooker. A starch slurry containing oxidizing agents, usually ammonium persulphate or hydrogen peroxide, is cooked in a jet cooker to a desired viscosity.

Another problem associated with using starch in comparison to synthetic binders is that it must be cooked to get it into solution and the temperature of the solution maintained at an elevated level to prevent retrogradation or gelling. To limit the effects of retrogradation and improve the solubility of starch, starches are chemically modified. The most commonly used derivatized starch in paper coatings

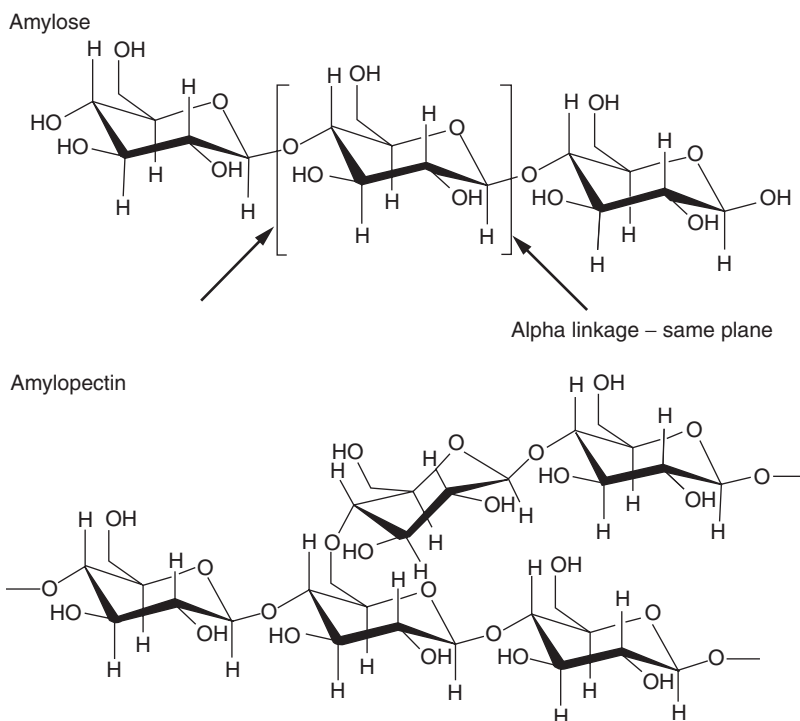


Figure 5 Structures of amylose and amylopectin.

is hydroxyethylated starch. Although more expensive, hydroxyethylated starch offers the advantages of more stable viscosity control, better film clarity and flexibility, and better water-holding properties.

Although these advantages come with a price, the economics are still better than that of synthetic binders. Unfortunately, regardless of the functionality added and the properties gained by the derivatization process, the solids at which these products can be made down are still limited to less than 30%. This limits the amount that can be used in high solids coatings.

Proteins

Proteins are obtained from natural sources such as milk casein and soybeans. But today almost all protein used by the paper industry is derived from soybeans.

The structure of protein is much more complex than starch. Protein contains 19 different amino acids, which are held together in a coiled structure by hydrogen and disulfide bonds. Proteins are amphoteric polymers. This means they contain positive (cationic) and negative (anionic) functional groups. Because most pigments are anionic, proteins interact strongly with pigments. This interaction causes a more open and bulkier coating to form.

Proteins can be modified to provide different bulking and viscosity characteristics. Like starch, they can be hydrolyzed to reduce the molecular weight, hence enabling them to be prepared at higher solids, due to less viscosity at given solids. They can also be carboxylated to improve their solubility and alter their degree of interactivity consequentially altering their bulking properties. They are mostly used in coatings for unbleached kraft board grades where bulk is needed to provide good coverage of the lower brightness base sheet.

Coating Additives

Additives are minor constituents that are added to a coating in relatively small amounts (less than 2% on weight of dry pigment) to improve the runnability of the coating on the machine or to enhance the final properties of the coatings. Some of the different types of coating additives used, just to name a few are defoamers, lubricants, rheology modifiers, crosslinkers, optical brightening agents, colorants, biocides, and dispersants. The name of the additive for the most part describes the role it plays within the coating. Although additives constitute only a minor part of the overall coating mix, their use is often critical to the overall performance of the coating in both the dry and wet state. A full discussion of their chemistry and application is too extensive to cover in this article.

Coating Processes

There are various methods for applying and metering a coating on to paper and board. Regardless of the method, the main objective is the same, to apply a uniform coating layer in a controlled manner.

All coating processes can be separated into three different operations: application, metering, and leveling. The type of application and metering devices used determine the stresses placed on the basesheet, the uniformity of the coating layer, the coat weight, range and possibility of operating problems such as scratching, ribbing, whiskering, misting, etc. Coatings can be applied on-machine and off-machine.

Size Press and Metered Size Press

The size press is the most common on-machine coater. It is mainly used to apply film forming materials such as starch and polyvinyl alcohol to the sheet to improve surface strength, alter the absorptive properties of the sheet, or impart a special functional property. When used to apply a pigmented coating, it is normally used to apply a low coat weight precoat. Three different flooded nip size press designs are shown in Figure 6.

The size press can be thought of as a simple roll coater or film transfer coater. Film transfer coaters all experience the same runnability problems at high speed, ribbing and misting. Both problems are influenced by the thickness of the wet coating layer as it is transferred from the roll to the paper. During the transfer process, the coating layer is split. As shown in Figure 7, part of the coating remains on the roll and part of the coating is transferred to the paper. The amount of ribbing and misting that occurs depends on the thickness of the wet coating layer before it splits, the rheological properties of the coating, absorptive properties of the base sheet and machine speed. Therefore to prevent the onset of ribbing and misting at higher speeds, it is desirable to minimize the thickness of the wet coating layer prior to the film transfer process. This understanding led to the evolution of the film transfer coater design from the flooded nip size press to the gate roll coater to the modern day premetered size press shown below in Figure 8. The premetered size press utilizes a short-dwell coating

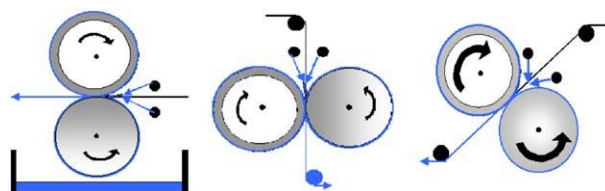


Figure 6 Three different size press designs: vertical, horizontal, and inclined.

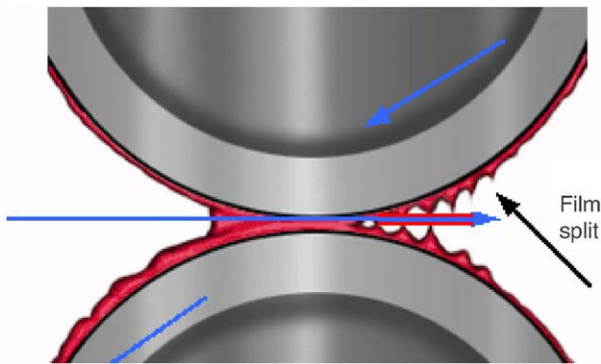


Figure 7 Film split between size press rolls and paper.

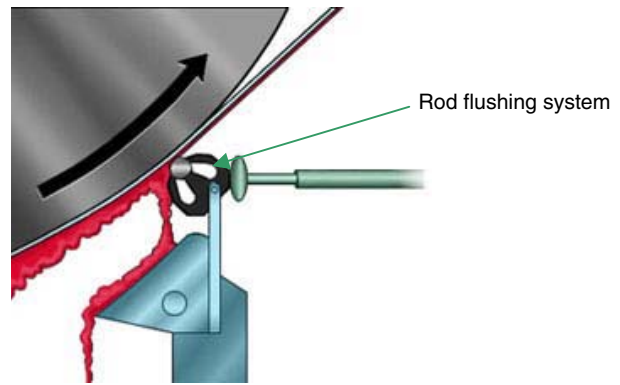


Figure 9 Example of rod holder and flushing system set-up.

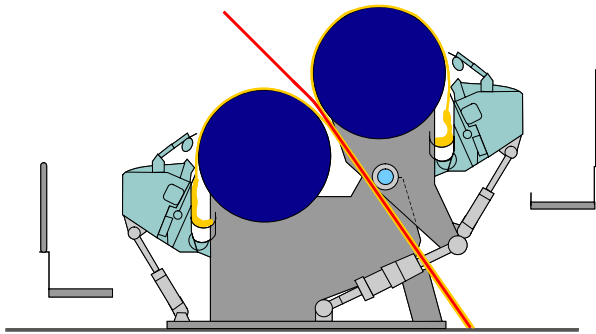


Figure 8 Modern metered size press.

head design, which holds a blade or rod metering device. In the short-dwell applicator, coating is pumped into a reservoir immediately upstream from the metering device. The pneumatic loading of the metering device controls the final coat weight.

Short-Dwell Coater

The short-dwell coater was originally designed as an off-machine coating method to coat lightweight grades of paper. The short contact time between the coating and paper surface reduced the number of sheet breaks experienced running these grades as a result of the loss in sheet strength due to the rewetting of the basesheet upon application of the coating. However, vortex flows in the low pressure reservoir have been linked to coating nonuniformities caused by the entrainment of air.

Blade Coaters

Although it provides the smoothest surface, the blade coater applies the greatest stress to the paper web. The stress applied to the web can cause web breaks, which results in costly machine down time. Scratches and streaks are also more prevalent with this method of coating.

Rod Coaters

Rod coaters are also rigid metering device coaters, but their cylindrical design stresses the base sheet less than a blade. It also enables the rod to be rotated against the web during its operation. This enabled a flushing system to be incorporated into the rod holder (Figure 9). This reduces the tendency for scratching and streaking which is especially beneficial to grades containing larger amounts of recycled fiber and lower surface strength, but the finished surface is not as smooth as a blade finished one.

Air Knife Coaters

Air knife coating is a noncontact coating application method, which uses a jet of air to meter the coating from the substrate. Since it is a noncontact coating method, it does not have the disadvantages of stressing the web and is not prone to scratching and streaking. The disadvantage to this coating method is in its limitation to applying low coat weights. It is mostly used to coat board. The smoothness of the coating layer is lower than that of a blade or rod coater.

New Coating Methods

Two new coating methods that are gaining industrial interest are curtain and spray coaters. Curtain coaters utilize a flow element, such as a die or extruder, to meter a coating onto the substrate. The coat weight is controlled by the slot width of the die and pressure drop in the coating line. New designs are currently being studied to reduce the problems associated with running these coaters at higher speeds and coating solids. The problems are mostly associated with the entrainment of air in the coating at higher web speeds. The advantage with this system is that good coating coverage can be achieved with little stress to the base sheet.

Spray coating is the newest commercially available coating method available. The method uses several spray nozzles that can be rotated during operation for cleaning to prevent down time. With spray coating, a wide range of coat weights are possible. Good coverage with minimal stress to the base sheet can be obtained. As with curtain coating, several issues remain with regard to formulation and uniformity of the final coating layer. However, each method shows promise as lower stress coating methods.

Concluding Remarks

The introduction of new coating technologies and new coating materials into the market place is increasing the level of competition between coated grades. Machines are running faster and more efficiently. Quality is improving and printers are reaping the benefits as they continue to demand and receive more from their suppliers. Advances in printing technology will continue to drive the coated paper markets as printers seek to print more colors using multiple printing technologies. To keep pace, the papermaker must stay knowledgeable of not only innovations in coating material and process technology, but also new printing technologies and trends.

See also: **Packaging, Recycling and Printing:** Packaging Grades; Printing. **Papermaking:** Overview; Paper Grades; Paperboard Grades.

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Diseases of Forest Trees

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Introduction

Plant diseases have been recognized for as long as plants have been cultivated. There are many references to plant diseases in early Greek and Hebrew