

INTRODUCTION TO FORMULATING COATINGS FOR LINERBOARD

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INTRODUCTION

Pigment coatings are applied to linerboard to improve appearance and to improve printability. The purpose of this presentation is to provide an introduction to the art and science of formulating pigmented coatings.

The coating formulator needs to deal with a variety of objectives and concerns, including:

- Covering a dark base sheet
- Uniformity of optical appearance
- Uniformity of ink acceptance
- Rapid absorbency of the ink vehicle for direct post print
- Gluability
- Coefficient of friction (COF)
- Minimizing tendency toward metal/coin marking
- Scuff resistance
- Resistance to cracking of the coating

These objectives are often conflicting, and tradeoffs may be inevitable. The coating formulator is also expected to hold the cost of the coating formulation to the minimum practical amount that will meet quality criteria.

Most linerboard is printed via flexography. However, it is worthwhile to start with a discussion of the sheet surface properties required for the various printing methods.

SHEET SURFACE PROPERTIES REQUIRED FOR THE VARIOUS PRINTING METHODS

There are differences in the sheet surface properties required for each of the various printing methods.

Flexo (flexography) is typography using resilient plates. In most cases, flexo inks are water based. Surface smoothness is a desirable characteristic for flexo printing. The desired degree of ink hold out is dependent on whether the flexo press is equipped with dryers. When the printing press includes dryers, as is the case on a preprint press, high holdout is desirable. In cases where direct post print is done on corrugated, for example on a flexo folder-gluer or case making machine, there is no drying, and the sheet surface must provide absorption for the ink vehicle to prevent smudging. The coated sheet surface must also provide good gluability.

Offset (offset lithography) is planography; the entire sheet surface is contacted by a blanket roll, which places high Z-direction stress on the sheet surface. The sheet alternately faces oil based inks and water based fountain solutions. When multicolor offset printing is done, increasing ink tacks are used to provide trapping. Thus the most important characteristics of a surface for offset printing are surface strength and wet rub resistance. Smoothness is also desirable. The coated sheet surface must also provide good gluability.

Rotogravure (intaglio) is a process where ink is contained in the recesses of an engraved printing plate. Most gravure inks are oil based. The most important sheet surface characteristics for gravure printing are smoothness and resiliency. Gravure printing does not place as much Z-direction stress on the sheet surface as offset, and water sensitivity is not as critical as with offset or flexo.

The balance of this presentation will be limited to formulating coatings for flexo printing.

COATING FORMULATION COMPONENTS, TERMINOLOGY AND CALCULATIONS

The components of a coating formulation include:

- A. Pigments
- B. Binders
- C. Additives

Pigments are minerals which serve to provide optical and printability properties. White pigments provide opacity to cover the dark surface of the paperboard and brightness to obtain the desired degree of whiteness. High refractive index pigments such as titanium dioxide and calcined clay are very effective in scattering light and covering the dark surface of the paperboard. Another key function of pigments is to control the degree of ink receptivity; this is dependent on the shape and size of pigment particles (morphology). Using the proper combination of pigments controls the mean pore structure and smoothness of the coated sheet surface. Some pigments, such as fine particle size clay, are capable of being aligned to provide uniform low angle reflectance of light upon calendering in an elastic nip; this is how gloss is developed. Other pigments provide an open coating structure which can be the key to providing bulking and coating porosity; examples of pigments with higher than average open area include calcium carbonate and calcined clay. Pigment formulations are expressed in terms of dry parts, with the total dry parts of pigment in a given formulation always equal to 100. Other coating components are expressed in parts as a ratio to 100 parts pigment.

Binders are adhesives which hold the pigment particles together and also bond the coating to the base sheet or precoating. Binders may be either natural or synthetic materials. Examples of natural organic binders include starch and proteins such as soy protein or casein. Examples of synthetic binders include latices such as styrene-butadiene, vinyl acrylic copolymers, and polyvinyl acetate. Starch is a binder which tends to form a dense and relatively brittle film. In coating of paperboard, starch is used primarily for surface sizing or pigmented surface size precoating; the rigidity, tight surface, and relatively low binding strength of starch limit its use in pigmented coating of paperboard. Protein and casein binders have high binding strength and form relatively open coating structures; they also provide excellent water holding properties to improve coater runnability. The limiting factor on use of protein binders is their high cost. They are normally used as cobinders in combination with latex. Styrene-butadiene (SBR) latices provide high binding strength and excellent film forming; the tight film forming properties of SBR can cause gluability problems in paperboard coating operations. For this reason, SBR latices are seldom used as the sole latex in paperboard coating, but they may be blended with acrylic or acetate latices. Acrylic and acetate latices provide a more open coating structure, which aids gluability, binding, and score cracking properties; they also cause less brightness depression than SBR latices.

A number of additives are used in coating formulations:

- A. Dispersants
- B. Lubricants
- C. Thickeners/rheology modifiers/water holding agents
- D. Insolubilizers or cross linking agents
- E. Alkalis for pH adjustment
- F. Defoamers
- G. Preservatives

Dispersants are anionic charged short chain polymers or complex inorganic phosphates. Coating pigments also have anionic surface charge. When a dispersant is dissolved in water used to slurry pigment, the anionic charges repel one another, helping to keep the pigment particles in suspension and allowing make down of a high solids pigment slurry. The most effective dispersants are sodium polyacrylates.

Lubricants allow the pigment particles to slip over one another during calendaring and bending to help prevent dusting. They can also aid in gloss development. Because lubricants tend to close the coating structure, they must be used with care in direct print flexo coatings. The most commonly used lubricant is calcium stearate. Polyethylene emulsion is a common synthetic lubricant.

Rheology modifiers are used to control viscosity and improve leveling of the coating after application. They also aid in water retention to reduce the amount of water transport into the base sheet between coating application and metering. Natural organic thickeners include carboxy methyl cellulose (CMC) and alginate. Common synthetic thickeners are acrylate gums.

Insolubilizers are used to cross link natural binders such as proteins or starches to make them resistant to fountain solutions in offset printing or wet rub in other applications. Common insolubilizers include formaldehyde resins, glyoxal, and glyoxalated resins. Ammonium zirconium carbonate (AZC) is an inorganic insolubilizer which helps to provide an open coating structure, especially when used in coating formulations using protein or casein as a cobinder.

It is desirable to run most paperboard coating at an alkaline pH in the range 8.5-9.0. Alkalis are used to adjust pH up to the desired range. Sodium hydroxide is a "permanent" alkali; when the dried coating is exposed to water, the surface remains alkaline. Ammonium hydroxide is a "fugitive" alkali; when the coating is dried, ammonia is vaporized, and the dried coating remains cross linked even when subsequently exposed to water.

Defoamers are used to control foam in the coating. Because defoamers can have adverse effect on certain coating performance properties, they should be used sparingly and only when necessary.

Preservatives are microbiocides which are added to the coating color as necessary to prevent spoilage from bacterial action. In the USA, only one type of preservative is approved by the Food and Drug Administration (FDA) for use in coatings on paperboards intended for use in packaging foods; this material is an organo-sulfur compound. A recommendation of preservative will not be included in the starting formulations presented below.

Coating formulations are usually express in the following terms:

Component Dry Parts % Solids Wet Parts

A Component is an ingredient such as a pigment, binder or additive.

A Dry Part is one dry part of the given component.

% Solids is the percentage concentration of the component expressed as a decimal fraction.

A Wet Part is equivalent to a dry part of a given component divided by the per cent solids of that component. Wet parts are the actual amounts of various components weighed into a given coating formulation. The total amount of each component is determined by ratio division of the desired total coating batch size and subsequent multiplication of the wet parts of each component.

Following is an example of a coating formulation commonly used for rod coating of recycled white top linerboard in the U.S.A.:

<u>Component</u>	<u>Dry Parts</u>	<u>% Solids</u>	<u>Wet Parts</u>
No. 2 Coating Clay	40	0.70	57.14
Calcium Carbonate - 90%<2μ	40	0.72	55.56
Titanium Dioxide	20	0.70	28.57
Latex Binder - Acrylate	16	0.50	32.0
Protein Binder	4	0.90	4.44
Aqua Ammonia	0.28	0.27	1.04
Lubricant - Calcium Stearate	1	0.55	1.82
Dispersant - Sodium Polyacrylate	0.1	0.4	0.25
Crosslinker - AZC	1	0.5	2.0
Totals	122.38		182.82
Desired Solids		0.60	
Water needed for 60% solids	0.0		21.15
Total batch basis	122.38	0.60	203.97

STARTING FORMULATIONS FOR SINGLE STATION ROD COATING OF MOTTLED WHITE OR WHITE TOP LINER

The following starting formulation recommendations are provided as preliminary recommendations for coating of a white top or mottled white linerboard using a single station Iso-Bar rod coater. Adjustment of pigment ratios, binder levels, and other formulation components must be done to optimize the formulations based on actual results obtained in commercial production. It may also be necessary to utilize additional pigments to obtain the required quality levels for rotogravure and offset printing; the need to do this will depend on the quality of the base stock and the calendering and finishing equipment available.

RECOMMENDED STARTING FORMULATION FOR ISO-BAR ROD COATER FOR PREPRINT CORRUGATED

<u>Component</u>	<u>Dry Parts</u>
No. 2 High Brightness Coating Clay	50-60
Fine Ground Calcium Carbonate (90>2 μ)	30-40
Titanium Dioxide	0-10
Latex	16
Protein	4
AZC Crosslinker	0.38
Calcium Stearate Lubricant	0.7-1.0
Acrylate Gum Thickener (only if needed for coverage)	0-0.25
Dispersant (as determined by dispersant demand curve)	0.05-0.15
Aqua Ammonia (as required for pH 8.5)	0.28 (estimated)

Prepare at 60-62% solids. Adjust solids and thickener to achieve Brookfield-100 rpm viscosity 800-1000 cPs.

The amount of titanium dioxide required (if any) will be dependent on the brightness of the base sheet delivered to the coater. Formation of the top ply is also important. As formation is improved, the optical uniformity of the base stock improves, and the amount of expensive titanium dioxide pigment required to obtain a desired final sheet brightness is minimized. In order to minimize the potential for scuffing and metal marking of the coated surface, the total amount of calcium carbonate plus titanium dioxide pigments should be kept at or below 50 parts.

RECOMMENDED STARTING FORMULATION FOR ISO-BAR ROD COATER FOR DIRECT POST PRINT CORRUGATED

<u>Component</u>	<u>Dry Parts</u>
No. 2 High Brightness Coating Clay	40-50
Fine Ground Calcium Carbonate (90>2 μ)	40-50
Titanium Dioxide	0-10
Latex	16
Protein	4
AZC Crosslinker	0.38
Calcium Stearate Lubricant	0.7-1.0
Acrylate Gum Thickener (only if needed for coverage)	0-0.25
Dispersant (as determined by dispersant demand curve)	0.05-0.15
Aqua Ammonia (as required for pH 8.5)	0.28 (estimated)

Prepare at 60-62% solids. Adjust solids and thickener to achieve Brookfield-100 rpm viscosity 800-1000 cPs.

The amount of titanium dioxide required (if any) will be dependent on the brightness of the base sheet delivered to the coater. Formation of the top ply is also important. As formation is improved, the optical uniformity of the base stock improves, and the amount of expensive titanium dioxide pigment required to obtain a desired final sheet brightness is minimized. In order to minimize the potential for scuffing and metal marking of the coated surface, the total amount of calcium carbonate plus titanium dioxide pigments should be kept at or below 50 parts.

STARTING FORMULATION RECOMMENDATIONS FOR MULTIPLE COATING OF BROWN (NATURAL KRAFT OR RECYCLED) LINERBOARD

When coating a brown (natural kraft or recycled) linerboard, it is assumed that an Iso-Bar rod coater will be used as the precoater. A Kohlerjet air knife will be used as the second coater to provide optical uniformity. For production of top quality preprint and/or folding carton grades, three coaters would be used:

- Iso-Bar rod precoater
- Kohlerjet air knife coater
- Iso-Bar rod top (finish) coater

The objective of the rod precoat is to provide some initial brightness gain and to provide holdout for the air knife coating while minimizing optical mottle.

RECOMMENDED STARTING FORMULATION FOR ISO-BAR ROD PRECOAT FOR FLEXO DIRECT PRINT LINER

<u>Component</u>		<u>Dry Parts</u>
No. 2 Coating Clay		15
Medium Ground Calcium Carbonate (60>2 μ)		75
Calcined Clay		10
Latex		14
Protein		4
Acrylate Gum Thickener (only if needed for coverage)		0.25
AZC Crosslinker		0.9
Dispersant (as determined by dispersant demand curve)	0.1	
Aqua Ammonia (as required for pH 8.5)		0.28 (estimated)

Prepare at 60% solids. Adjust pH to 8.5

The level of binder may need to be adjusted based on the surface strength of the linerboard base sheet. The ratio of clay to calcium carbonate may need to be adjusted based on actual experience during commercial operation.

RECOMMENDED STARTING FORMULATION FOR ISO-BAR ROD PRECOATING FOR FLEXO PREPRINT LINER

<u>Component</u>		<u>Dry Parts</u>
No. 2 Coating Clay		60
Medium Ground Calcium Carbonate (60>2 μ)		40
Latex		16
Protein		4
Calcium Stearate Lubricant		1
Acrylate Gum Thickener (only if needed for coverage)		0.25
AZC Crosslinker		0.9
Dispersant (as determined by dispersant demand curve)	0.1	
Aqua Ammonia (as required for pH 8.5)		0.28 (estimated)

Prepare at 60% solids. Adjust pH to 8.5

The level of binder may need to be adjusted based on the surface strength of the linerboard base sheet. The ratio of clay to calcium carbonate may need to be adjusted based on actual experience during commercial operation.

RECOMMENDED STARTING FORMULATION FOR KOHLERJET AIR KNIFE COATING FOR DIRECT PRINT LINER

<u>Component</u>	<u>Dry Parts</u>
Coating Clay	15
Fine Ground Calcium Carbonate (90>2μ)	75
Titanium Dioxide	10
Latex	12
Protein	6
Calcium Stearate Lubricant	1
Acrylate Gum Thickener (only if needed for coverage)	0.3
AZC Crosslinker	1.6
Dispersant (as determined by dispersant demand curve)	0.1
Aqua Ammonia (as required for pH 8.5)	0.42 (estimated)

Prepare at 48% solids. Adjust pH to 8.5

The ratio of clay to calcium carbonate to titanium dioxide and binder level may need to be adjusted based on actual experience.

RECOMMENDED STARTING KOHLERJET AIR KNIFE COATING FORMULATION FOR PREPRINT LINER

<u>Component</u>	<u>Dry Parts</u>
No. 1 Coating Clay	60
Fine Ground Calcium Carbonate (90>2μ)	25
Titanium Dioxide	15
Latex	12
Protein	8
Calcium Stearate Lubricant	1
Acrylate Gum Thickener (only if needed for coverage)	0.3
AZC Crosslinker	1.8
Dispersant (as determined by dispersant demand curve)	0.1
Aqua Ammonia (as required for pH 8.5)	0.56 (estimated)

Prepare at 48% solids. Adjust pH to 8.5

The ratio of clay to calcium carbonate to titanium dioxide and binder level may need to be adjusted based on actual experience.

RECOMMENDED STARTING ISO-BAR TOP COATING FORMULATION FOR PREPRINT LINER

<u>Component</u>	<u>Dry Parts</u>
No. 1 Coating Clay	60
Fine Ground Calcium Carbonate (90>2 μ)	25
Titanium Dioxide	15
Latex	16
Protein	4
Acrylate Gum Thickener (only if needed for coverage)	0.3
AZC Crosslinker	0.9
Dispersant (as determined by dispersant demand curve)	0.1
Aqua Ammonia (as required for pH 8.5)	0.28 (estimated)

Prepare at 60% solids. Adjust pH to 8.5

The ratio of clay to calcium carbonate to titanium dioxide and binder level may need to be adjusted based on actual experience.