

Optimizing the coating process for double-coated, wood-containing papers

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Brightness, opacity, surface strength, ink density, and cracking tendency were not affected by the layout strategy for drying the precoat. Dryer capacity and economic aspects should be considered more than questions about quality in optimizing the precoating installation.

During the past few years, the paper industry's total production capacity for coated wood-containing grades, especially lightweight coated grades (LWC), has increased substantially. At the same time, competitive pressures have forced producers to strive for greater efficiency and higher quality output for all wood-containing grades. Interest in medium-weight coated (MWC) grades has grown because medium-weight coated grades offer the potential for achieving printing qualities associated with more expensive coated, wood-free grades.

Medium-weight coated grades are well-suited to heat-set web offset printing and may be suitable for sheet offset printing as well. Typical products that use MWC grades include sales promotion material, high-quality advertising, and specialty magazines.

Double coating was originally used to produce high-quality paperboard and wood-free paper grades. More recently, it has been used to enhance printing quality in wood-containing papers.

In single-coated grades, the coated layer is applied directly to a nonuniform fiber base. In double-coated grades, a precoat normally consisting of low-cost pigments is used to cover the paper surface and create a more uniform base for a top coat of high-quality components. This makes it possible to achieve a more uniform top coating layer that offers better surface quality and more uniform ink absorption in printing.

In these trials, we used a pilot coater to optimize the basic parameters in double coating and to predict the quality that can be achieved by this process.

Trial conditions and procedures

Base papers

Two base papers were used in the trials—a 44-g/m² (30-lb/3300 ft²) paper and 40-g/m² (27-lb/3300 ft²) paper. Both papers had an ash content of 6–8% and a furnish of 40–50% kraft, with the balance being stone groundwood. The roughness, or smoothness, of the base paper was 300–400 mL/min (Bendtsen). Moisture was about 3%.

Pilot coater

The trials were performed on a 1-m-wide pilot coater. The blade coating station was equipped to operate in two application modes, one using short dwell and the other using an applicator roll. In the short dwell mode, the blade was loaded with an air tube. In the applicator roll mode, the blade was mechanically loaded, and the tip angle was kept constant, independent of the blade load.

For the trials with the single coat, we used a clay coating color with a binder of styrene-butadiene (SB) latex and carboxymethyl cellulose (CMC). For the double-coat trials, we used a coarse calcium carbonate as pigment in the precoat, with SB latex and starch as binders. A mixture of fine ground calcium carbonate and some clay was used as pigment in the top coat, with SB latex, polyvinyl acetate (PVAc) latex, and CMC as binders. Table I presents detailed information of the coating colors.

The coatings were dried under a variety of conditions using a maximum of six rows of electrical dryers and four rows of gas-heated infrared dryers after the blade, followed by four gas-heated airfoils. The machine speed was varied between 1050 m/min (3450 ft/min) and 1200 m/min (3950 ft/min). The intermediate moisture was kept below 3.5%. Final moisture varied between 4.5% and 6.0%, depending on the ratio of coating to fiber.

Finishing calendering

The coated paper was supercalendered in a 12-roll supercalender at 500 m/min (1650 ft/min), under a linear pressure of 310 kN/m (1170 pli), with hardness of the filled rolls at 85 ShoreD. The paper moisture after the

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supercalender was 3.0–4.0% in the double-coated paper and 4.0–5.0 % in the single-coated paper.

Printing

Coated and supercalendered samples were printed in a production heat-set offset printing press. Four heat-set colors were printed in the sequence of black, cyan, magenta, and yellow. The machine speed was 236 m/min (775 ft/min). The pH of the dampening water was 5.0, with 12% isopropanol. The temperature in the drying hood was 160°C; the web exit temperature was approximately 130°C.

Paper testing

Coating weights were determined by the difference in ash content between coated and uncoated (or coated and precoated) paper. Coating weight was measured on-line using X-ray fluorescence, and moisture was measured on-line using infrared techniques.

Bendtsen roughness was determined according to SCAN-P21:67, Parker Print Surf smoothness was measured at 10 kg (force)/cm² (S10), and Hunter gloss values were measured at an angle of 75°. Cracking tendency was measured in accordance with a method established for heat-set offset wood-containing papers by the Finnish Pulp and Paper Research Institute.

The conditioned paper was dried for 1.5 s at 300°C. The sample was immediately folded in the machine direction in a laboratory calender at a linear pressure of 4.6 kN/m (26.3 pli). Tensile strength in the folded paper was measured according to SCAN-P38:80.

Wet pick was determined by comparison with a dry sample. The surface of the coated sample was moisturized and printed in Prufbau with Huber's picking ink. A dry sample was printed with the same disk. The ink density of both samples was measured, and the wet pick value was calculated. A lower value represents better water resistance.

The visual impression and uniformity of the heat-set printed samples was determined by comparing different samples to one another visually. Opacity and brightness were determined according to SCAN methods. Machine-direction surface strength (IGT) was determined according to ISO 3762.

Effect of single coating, precoating, and top coating weights on paper properties

Double coating vs. single coating

A single-coated, 40-g/m² base paper was compared with two other papers: (a) an identical base paper double-coated with the same total coating weight and (b) a heavier base paper (44 g/m²) double-coated with a heavier total coating weight. The coating components used for double coating were of lower cost than those used for single coating. The properties of all three papers are listed in Table II. Results can be summarized as follows.

When the total coating weight is the same, the double-coated paper maintained a smooth surface after printing, while the single-coated paper became rougher as a result of fiber swelling. The printed gloss is superior in the double-coated paper. When the coating weight of the double-coated paper was increased, the double coat provided a higher overall quality both before and after printing.

Other comparisons showed that fiber coverage and

I. Coating formulations

Formulation	Parts	Solids contents, %	Viscosity, cp
Single-coated		60.5	1200–1400
SPS* clay	100		
80% < 2 µm			
85.5% brightness			
SB latex	10		
Med.-viscosity CMC	0.8		
Insolubilizer	0.5		
Optical brightener	0.5		
Double-coated		61–64	200–900
Ground CaCO ₃	100		
60% < 2 µm			
SB latex	6		
Starch	6		
Insolubilizer	0.4		
Top coat		62	1350–1550
CaCO ₃	70		
90% < 2 µm			
95% brightness			
1 Brazilian clay	30		
87% brightness			
SB latex	6		
PVAc latex	6		
Med.-viscosity CMC	1		
Insolubilizer	0.6		
Optical brightener	0.5		
Stearate	0.5		

*SPS is one of the most common lightweight coating pigments in Europe and is supplied by English China Clay, England.

II. Quality comparison between single- and double-coated papers

	Single-coated	Double-coated	Double-coated
Basis weight, g/m ²	40	40	44
Coating weight, g/m ²			
Top side	11.9	6	8
Bottom side	...	6	8
Before printing			
Brightness, %	74	74	75
Opacity, %	94	93	95
Smoothness,* mL/min	17	12	11
Paper gloss, %	59	62	66
After printing			
Smoothness,* mL/min	22	10	10
Smoothness,* mL/min (for printing area)	25	12	12
Printed gloss (four-color)	82	85	87

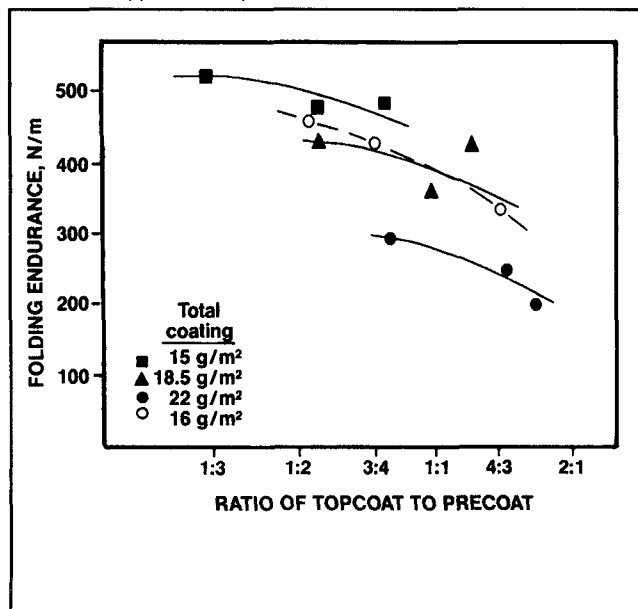
*Bendtsen.

III. Impact of top coat-to-precoat ratio, total coating weight, and application method on printing properties

Ratio of top coat to pre-coat	Gloss, %	Parker print surf	Wet pick, %	Visual impression*
Applicator roll precoat, 22 g/m² total				
0.84	58.4	1.23	0.73	21
1.38	61.2	1.14	0.64	22
1.62	66.6	1.08	0.38	14
Applicator roll precoat, 18.5 g/m² total				
0.55	56.3	1.26	1.22	21
0.91	56.5	1.26	0.85	20.5
1.14	56.5	1.26	0.85	15
Short dwell precoat, 16 g/m² total				
0.58	56.0	1.28	1.41	14
0.76	53.5	1.45	1.33	8.5
1.36	59.9	1.00	0.51	4

*Low numbers indicate more uniformity.

1. The impact of the ratio of the top coat to precoat on the cracking tendency (Open symbols indicate the short dwell, and filled symbols indicate the applicator roll.)



smoothness can be improved beyond single-coated results even when the total coating weight on a double-coated sheet is less than the coating weight on a single-coated sheet of the same basestock. Material costs for the double-coated sheet can be lower, since low-cost pigments can be used in the precoat, and quality can be optimized in the top coat. Moreover, the printing ink stays mainly in the top layer of the double-coated sheet, resulting in a lower ink demand, less fiber swelling, and milder drying requirements on the press. In a full-scale installation, these benefits would have to be weighed against some loss in paper strength from multiple wetting and drying (loss of stretch) and possible losses in production efficiency as a result of having four coating stations instead of two.

The impact of the ratio of top coating to the precoat

Top coats were applied in weights ranging from 5.0 to 13.5 g/m² in combination with precoat weights ranging from 6.5 to 12 g/m². Paper qualities were evaluated throughout these ranges. Some of the results are presented in Table III.

The final properties of the double-coated paper were determined mainly by the top coat. The precoat layer provides a uniform base for the top coating. At a constant total coating weight, properties such as gloss and smoothness improved when the top coating was increased, but these improvements were not seen at lower total coating weights. Wet pick tendency diminished with increased top coating weight, and the visual impression and surface uniformity of the sheet improved when the weight ratio of top coating to precoat was increased. All these improvements have to be weighed against the higher price of components in the top coating. In a full-scale commercial installation, the amount of top coating that could be used probably would be limited by drying capacity or the need to maintain the target coating profiles.

Cracking tendency, measured as tensile strength after folding, increased at higher ratios of top coating to precoat weight (especially at higher total coat weights), as shown in Fig. 1. Still, the most important factor that affected cracking tendency was the total amount of coating. Since MWC grades had high ratios of coating to fiber, the cracking tendency would have to be monitored closely during full-scale production of these grades.

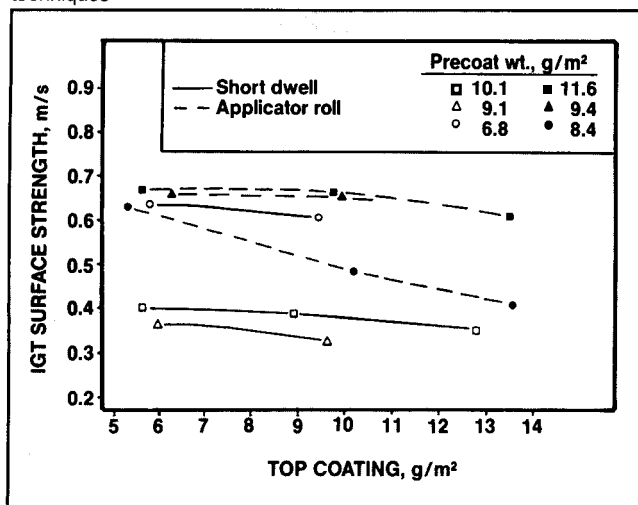
The weight of the top coating had a relatively slight influence on the IGT surface strength of the double-coated paper, as shown in Fig. 2. The weight and method of applying the precoat had more influence. In particular, the use of a short dwell coater at low precoat levels yielded a relatively high surface strength. Apparently, these factors enabled the top coat to penetrate the precoat and anchor directly to the fiber layer.

Precoating and top coating weights both influenced the brightness of the double-coated sheet, as shown in Fig. 3. Precoating weights above 9.5 g/m² yielded higher brightness. As top coating weights increased, brightness increased too, but improvements in brightness diminished above 10 g/m². High brightness was best achieved when a top coating weight of about 10 g/m² was applied over a somewhat heavier precoat.

Effects of different application methods

Short dwell and applicator roll techniques were used on

2. The impact of top coating weight on IGT surface strength at different weights of precoat applied by short dwell and applicator roll techniques



both the precoat and top coating trials so that both methods could be evaluated for their impact on paper properties. In the short dwell coater, water and color do not penetrate as well into the base paper, and this coater is expected to run better, with fewer web breaks.

Precoating trials

When used for precoating, the short dwell coater did not allow the binder to penetrate well enough into the base paper to give adequate surface strength. At a low precoating of 6.8 g/m², however, the top coat binder was able to penetrate through the precoat into the fiber layer, resulting in improved surface strength, as shown earlier in Fig. 2.

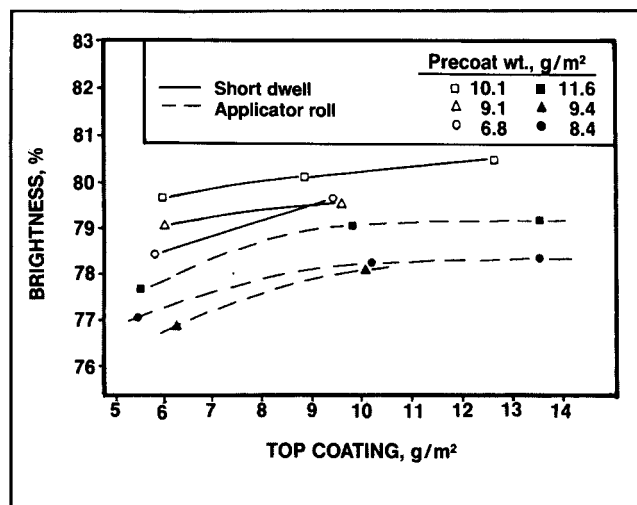
Brightness was improved when the short dwell mode was used for the precoat (Fig. 3), perhaps because the coating pigment did not penetrate as deeply into the base paper. (Brightness is normally reduced by a loss of light-scattering surface and by improved bonding from increased penetration.) The surface uniformity and, to some extent, paper gloss and smoothness were better with the short dwell application, probably as a result of improved holdout (Table III).

The roll applicator wetted the base paper surface in the applicator roll nip, causing considerable fiber swelling before the blade but relatively little fiber swelling after the blade. The pressure penetration in the applicator roll system improved the anchoring of the coating layer to the base paper, but it also caused some of the coating pigment to penetrate into the base paper, with a loss of brightness. The cross-direction profile was more uniform than with the short dwell coater. Since surface strength depended on penetration of the coating color and binder into the fiber layer of the base paper, the applicator roll provided better surface strength and somewhat lower cracking tendency (Fig. 1), when used for the precoat.

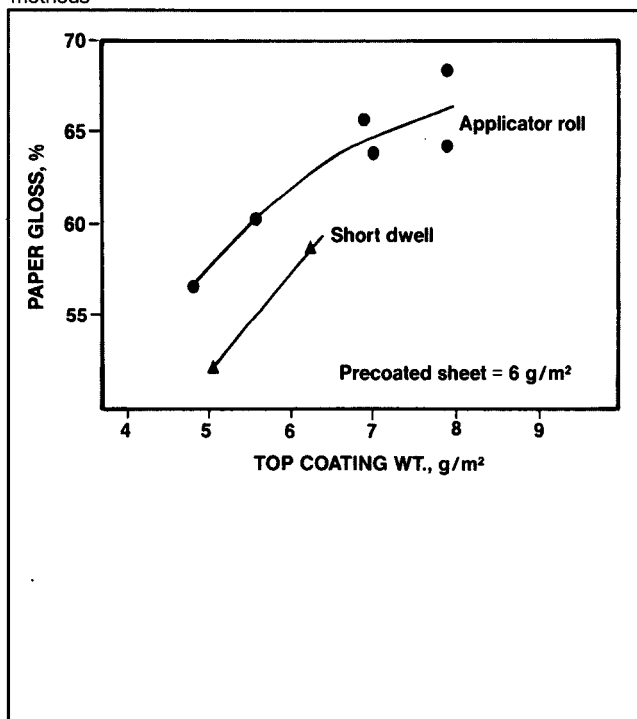
Top coating trials

When used for the top coat, the roll applicator provided a better gloss than the short dwell coater, as shown in Fig. 4. Consequently, the applicator roll would be a good choice

3. The impact of top coating weight on brightness at different weights of precoat applied by short dwell and applicator roll techniques

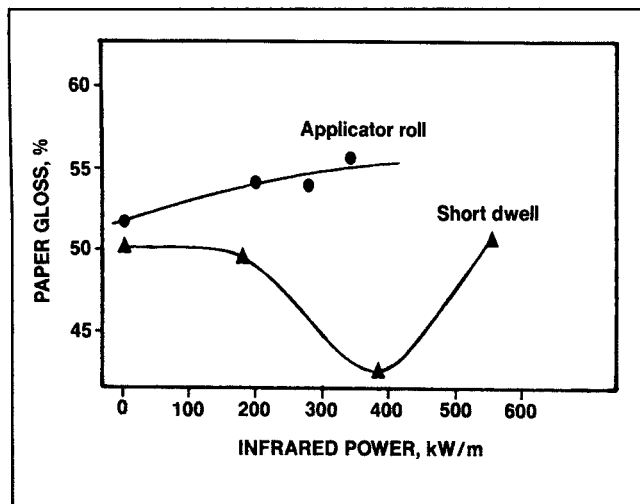


4. The impact of top coating weight on gloss for different coating methods

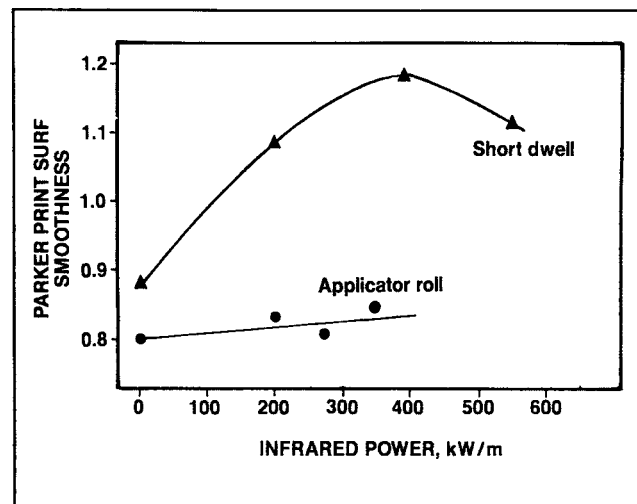


for a coating station for the top coat of MWC grades. The pressure and longer dwell time in the applicator roll system seems to fill nonuniformities in the precoated sheet before doctoring, thereby improving the final gloss and smoothness. Pre-swelling of the precoated surface before metering may also aid this improvement, although not as dramatically as with uncoated basesheet. Higher coating weights were achieved more easily with the help of the applicator roll, too. On the other hand, the applicator roll coater provided approximately 0.5 fewer units of brightness, evidently because of the loss of light-scattering surface.

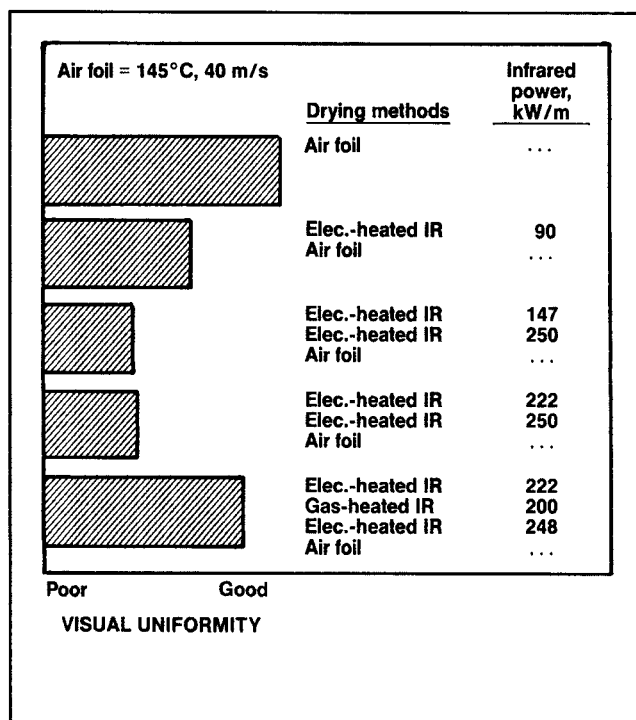
5. The impact of infrared drying on gloss for different precoating methods



6. The impact of infrared drying on smoothness for different precoating methods



7. The impact of infrared in top coating on visual mottling



We expected that the roll applicator would provide better surface strength than the short dwell system by anchoring the top coating layer more effectively to the precoat, but this was not the case in these trials. Surface strength seemed independent of the method of applying the top coat. It seemed more affected by the relationship between the fiber layer and coating layer than by the relationship between the precoat and the top coat.

Drying optimization

Several studies have been made to find the best drying processes for wood-containing papers. Among other findings, these studies have determined that drying strategies affect print mottling of LWC papers¹. More recently, drying strategies for double-coated, wood-containing papers have been studied also².

Precoat drying trials

In precoat drying trials, paper gloss and smoothness were strongly affected by infrared drying only when the precoat was formulated with a binder of low-viscosity starch and applied with a short dwell coater. Gloss and smoothness seemed unaffected by the precoat drying strategy when the precoat was formulated with a binder of medium-viscosity starch or when the precoat was applied with an applicator roll.

Figures 5 and 6 present the impact of infrared drying power on gloss and smoothness. When the precoat was formulated with a binder of low-viscosity starch and applied with a short dwell applicator, increases in infrared power up to 400 kW/m caused gloss and smoothness to decrease in the double-coated and supercalendered products. Beyond that point, however, gloss and smoothness began to increase with further increases in infrared power. Base paper absorption was strongest at the transition level of 400 kW/m. Paper gloss under these conditions also was affected by the temperature and air velocity in the airfoils. A low evaporation rate in the first two airfoils after the blade yielded up to 7 more units of gloss than more intense airfoil drying conditions. This same phenomenon was not noticed with starches of higher viscosity, which generally exhibited less sensitivity to the choice of drying strategy. The visual impression and uniformity (determined using dye stains to indicate mottle)

¹Engstrom, G., Strom, G., and Norrdahl, P., Tappi J. 70(12): 45(1987).

²Tani, P. and Sunde, H., Influence of precoat drying on MWC paper quality, PTS-Streicherei-Symposium 1989, Munich, 1989.

of the double-coated final product in printing were not sensitive to the choice of precoat drying strategy or to changes in starch viscosity.

When the precoat was applied with an applicator roll, neither paper gloss nor printing gloss were much affected by changes in the precoat drying strategy. Nor was paper smoothness affected by changes in drying strategy. The reason is that with an applicator roll, most of the fiber swelling associated with precoating occurs before the metering blade, resulting in a more uniform coating layer that is less sensitive to changes in drying after the blade. Even so, the applicator roll precoat yielded a slightly more mottled appearance in the final double-coated product when subjected to more intense airfoil drying conditions or higher infrared power levels. Higher basis weight and top coating weight explain the higher gloss and smoothness of sheets precoat with the roll applicator, as indicated in Figs. 5 and 6.

Brightness, opacity, IGT surface strength, ink density, and cracking tendency were not affected by the choice of drying strategy. Overall, the drying strategy trials indicate that changes in precoat drying strategy do not have much influence on the quality of wood-containing, web-offset, MWC grades. Therefore, in optimizing a precoat drying layout, the dryer capacity and the economic aspects of the installation should be given more consideration than questions about quality.

Top coating trials

In drying trials for the top coating, the visual impression of samples colored with Croda ink were evaluated after the top coat was dried in different ways. The increased use of infrared after the blade yielded more mottling, up to a power level of 500 kW/m, as shown in Fig. 7. Beyond this level, the increased use of infrared yielded a more uniform surface. High evaporation rates in airfoils yielded more mottling, too, as shown in Fig. 8. More detailed studies on top coat drying will be performed in the near future.

Coating machine concepts

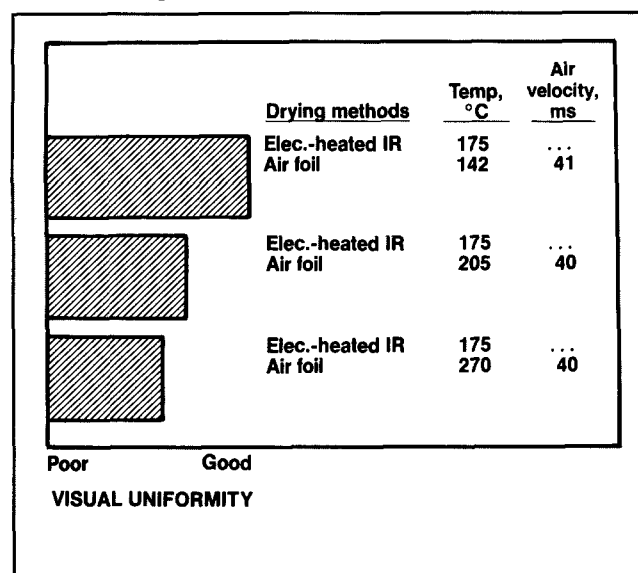
The production of MWC grades with four blade coating stations can be approached in three different ways:

1. Off-machine coater with four blade stations
2. On-machine coater with two blade stations and an off-machine coater with two blade stations
3. Two off-machine coaters with two blade stations each.

Four-station, off-machine coater

A four-station, off-machine coater is ideal for producing double-coated MWC grades efficiently. The off-machine approach is also ideal for situations in which uncoated and coated grades have to be produced. On the other hand, it may be unnecessarily complicated to produce single-coated grades in this way. This four-station, off-machine approach relies upon a good coater runnability and a base paper with minimal defects. Even though breaks at the coater won't affect the paper machine, the efficiency of the coater would be jeopardized by breaks.

8. The impact of the evaporation rate in the first air foil in top coating on visual mottling



Two station on-machine coater and two station off-machine coater

The use of an on-machine coater with two blade stations and a separate off-machine coater with two stations provides more flexibility than a four-station, off-machine coater, particularly in producing single-coated grades. At the same time, labor requirements remain low. Yet this approach presents the challenges associated with on-machine coating.

Good runnability and minimal web defects are a necessity for high efficiency, since a break at a precoat station will affect the entire paper machine. Since web defects in the precoat paper can be isolated and eliminated at the rereeler before top coating, the risk of breaks at the off-machine coater is relatively low. This on- and off-machine coating approach makes it possible to produce both single-coated and double-coated grades with minimum difficulty. The production of uncoated grades, however, becomes more complicated than approaches involving no on-machine coating.

Two off-machine coaters

The use of two off-machine coaters is the preferred approach when runnability is critical. Web defects can be isolated and eliminated at the rereeler after the paper machine and after precoat. The top coating process in particular can be expected to exhibit improved runnability using this approach. Breaks at either coater have no effect on the efficiency of the paper machine or the other coater.

This approach offers maximum flexibility for the production of uncoated, single-coated, and double-coated grades. Investment and labor requirements are higher than with other approaches. Moreover, paper losses during trouble-free runs will be greater than what they would be with a more integrated approach. If flexibility and runnability are important, however, this approach may be justified. It is particularly well suited to the production of low-strength grades that are sensitive to good runnability.

Conclusions

Compared to single coating, double coating offers quality benefits that become even more apparent after printing. Double coating also makes it possible to reduce the total cost of coating components in some cases.

Gloss and paper smoothness can be improved at a constant total coating weight by increasing the coating weight of the top coat, particularly in working with higher total coating weights. The best brightness will be achieved at a top coat weight of not more than 10 g/m² and a precoat weight above 9.5 g/m².

Using a roll applicator for the precoat provides better surface strength and cracking resistance. The use of a short dwell coater for the precoat achieves higher brightness and somewhat better gloss, smoothness, and paper surface uniformity. Runnability and coater efficiency also will be better with short dwell precoat.

When the precoat is applied with an applicator roll, gloss and smoothness are almost unaffected by the precoat drying strategy. When the precoat is applied with a short dwell coater, paper gloss can be affected by the infrared power levels and by the temperature and air velocity in the airfoils, but the visual impression and uniformity of the paper in printing is still not sensitive to drying strategies. Higher starch viscosities also reduce the sensitivity to drying strategies, with low-viscosity starches being noticeably more sensitive. The precoat drying strategy does not have a great influence on the quality of wood-containing, web-offset MWC grades. Therefore, drying capacity and economical considerations can take priority over quality concerns when precoat drying is chosen for a MWC grade. Quality considerations should be more important when a top coat drying strategy is selected.

The use of a roll applicator for the top coat provides better gloss than a short dwell coater. A roll applicator also eliminates potential problems in achieving high coating weights with a short dwell coater.

A production line with two off-machine coaters is the most desirable approach for MWC, based on flexibility and runnability. Due to the high investment cost for this approach, other approaches must also be considered. The range of paper grades to be produced will be a determining factor in selecting one approach over another. □

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Basis weight: g/m² = 1.48 × lb/3300 ft²

Temperature: °C = 5/9 (°F - 32)