

Gaining control of the process for corrugated post print

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ABSTRACT: *The flexographic printing process is a complex interaction between the printed surface, printing plate, anilox roll, and ink. The introduction of laser engraved anilox rolls, photopolymer printing plates, high-quality graphics inks, along with a large range of facing liners, has made more complex decisions necessary to optimize print quality. Each of the industries supplying the flexographic printer can provide technical advice on their products, but it is not enough to consider individual product specifications alone. One must consider the entire process before making decisions on the application of the individual components to the process. Making material and equipment decisions is a process in itself. By applying the decision process, the printer may improve the quality and efficiency of production.*

KEYWORDS: *Corrugated boxes, decision making, flexography, print quality, process variables.*

In the past five years, the flexographic printing process has become more sophisticated. This is even more true in the corrugated carton post-print segment of the industry. The introduction of high-tech equipment and materials has made more complex decisions necessary. Making these decisions, rather than just applying technology, is a process in itself.

The objectives of this study are to:

1. Understand the interactions of the various elements of the flexographic printing process and identify the principles that govern the resultant print quality.
2. Apply this knowledge to form a "decision process model," which will result in the ability of the individual converter to optimize its printing process.

The flexographic printing process

The main objective of the flexographic process is to achieve a desired ink color and density on a particular substrate regardless of the size of the image element, and employing either large solid areas or individual fine halftone dots. Density is the inverse logarithmic value of reflectance. For example:

If reflectance = 100% 10% 1% 0.1%
Then density = 0.0 1.0 2.0 3.0

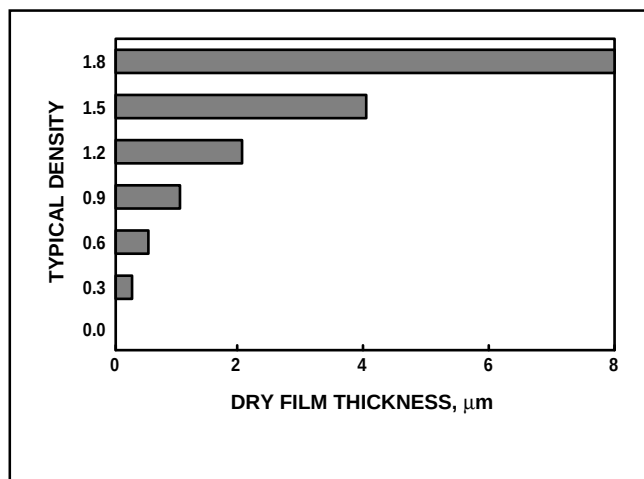
Print surface and ink interaction

The surface of the printed stock will have an effect on the visual density of the applied ink film. The typical target densities for the various stock surfaces are shown in **Table I** (1). The difference in solid ink densities for each color is determined by the reflectivity of the particular pigment used; darker colors (black, for instance) will absorb more light than lighter colors (yellow, for instance). The difference in densities for each type of stock is determined by how well the ink covers the surface of the stock; smooth, impervious surfaces cover more easily than coarse, absorbent surfaces.

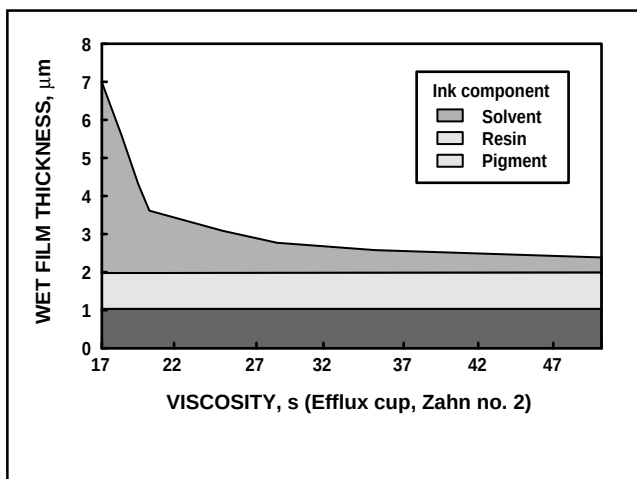
Dry-ink film thickness. There is a close correlation between ink film thickness and solid ink density. **Figure 1** shows the typical densities for various dry-ink film thicknesses on a selected substrate. Once the optimum density for a particular ink and substrate combination has been

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1. Dry ink film and density



2. Wet ink film and density



reached, any attempt to substantially increase the solid ink density will result in ink wastage. Optimum solid ink densities and printed colors should be determined prior to the press run by making a calibrated draw-down of the ink on the specific substrate to be printed and measuring with both a colorimeter and densitometer. This will minimize press startup time by ensuring that the correct materials are at hand. The press operator can then control the amount of ink applied to the stock using the same tools.

Wet-ink film thickness. Figure 2 compares the wet-ink film thickness required to produce an equal color density for various dilutions or extensions of a particular ink formulation. It clearly shows that control is lost when the dilution ratio is greater than 15% and the viscosity drops below 20 seconds. Extensive dilution of the ink at the press to achieve the correct color density should be avoided.

To achieve the correct density and optimum coverage on a particular stock surface, consideration must be given to the absorbance of the stock and the viscosity of the ink. Figure 3 provides a guide to matching the solids ratio of an ink package to the surface absorbency of the stock to be printed. Absorbent surfaces generally require a high volume of low-

I. Density reference guide

Substrate	Color	Typical density
High-gloss paper and film	Black	1.75–1.85
	Cyan	1.35–1.45
	Magenta	1.30–1.40
	Yellow	1.00–1.10
Coated paper and matte film	Black	1.65–1.75
	Cyan	1.25–1.35
	Magenta	1.20–1.30
	Yellow	0.95–1.00
Uncoated paper	Black	1.40–1.50
	Cyan	1.20–1.25
	Magenta	1.15–1.20
	Yellow	0.85–0.90

viscosity ink to “wet out” the surface and achieve good coverage. Ink drying in this case is affected by absorption of the aqueous component of the ink. On the other hand, high-holdout and coated surfaces require less volume of ink containing the same amount of pigment, resulting in higher ink viscosities; ink drying is by evaporation or chemical reaction (change in pH).

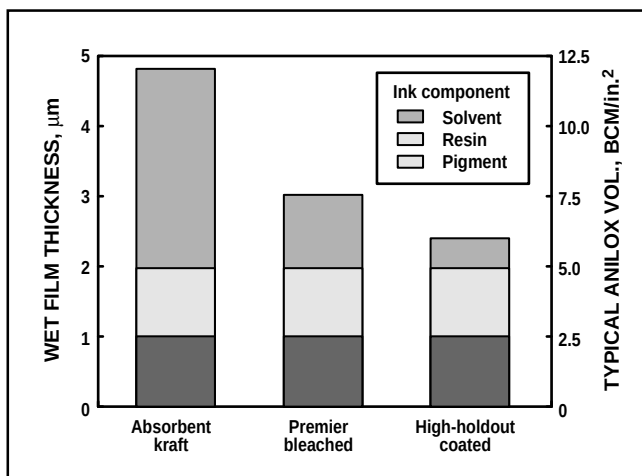
Ink transfer from anilox roll

The anilox roll has been called the heart of the flexographic process, and this analogy is true. The anilox roll is a metering “pump” that measures and delivers a volume of ink to the plate surface. The printing plate then

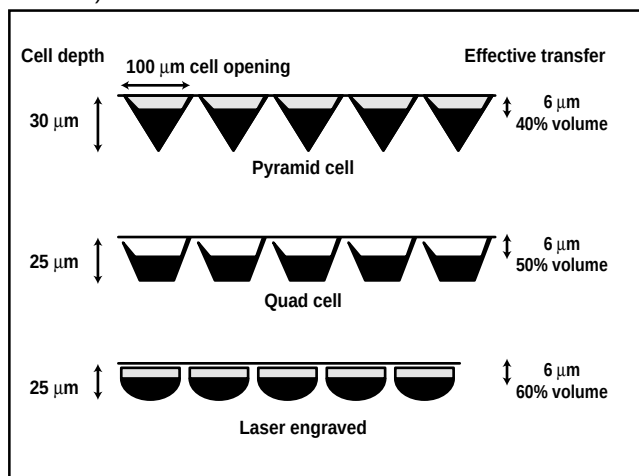
carries the ink to the stock. The efficiency of the anilox metering system is affected by the viscosity of the ink that is being pumped.

Fountain roll and doctor blade in ink metering. We must remember that high ink viscosities and high press speeds tend to leave more ink on the surface of the anilox roll, thereby transferring more ink to the plate surface. The effectiveness of the wiper roll as a metering device is determined by the hardness of the wiper roll and the hydraulic pressure generated in the wiper roll/anilox nip. This hydraulic pressure is caused by the inability of the ink to flow away from the nip due to ink viscosity and press speed. Therefore,

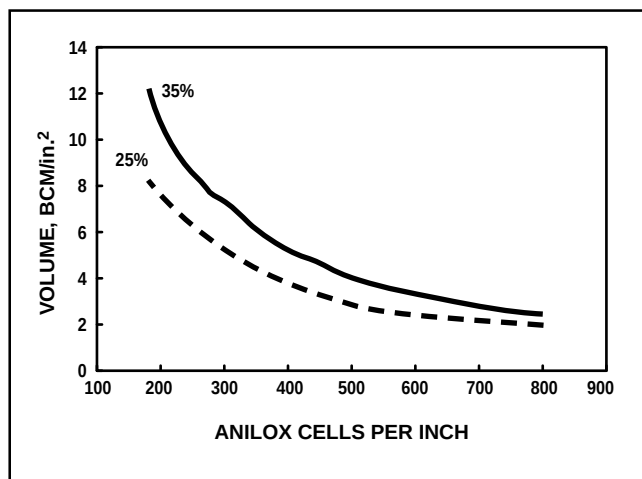
3. Stock type and wet film



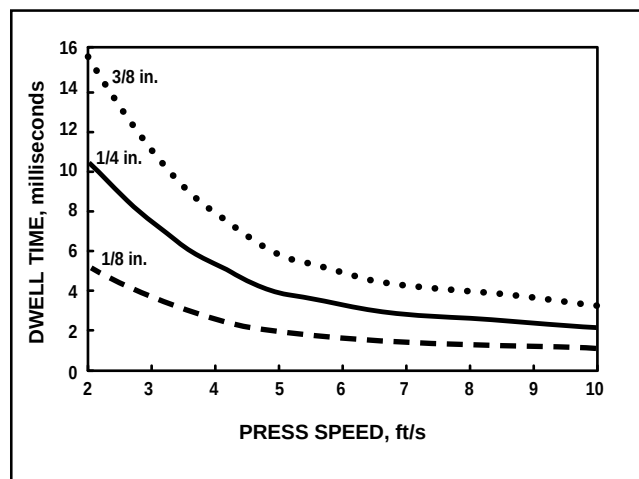
4. Anilox cell depth vs. effective transfer volume (200 cells/in., 7 BCM/in.²)



5. Anilox cell volumes for optimum depth:opening ratios



6. Typical nip dwell times for 8-in.-diam. anilox rolls



with fountain roll metering, close control of press speed and ink viscosity is essential to control the wet-ink film transfer to the printing plate and the resultant solid ink density on the stock. Constant measurement and maintenance of the ink viscosity on the press is essential to control print quality.

For absolute control of ink metering at the anilox roll, a doctor blade to remove the excess ink on the surface of the anilox is essential, but even with doctor blades ink viscosity plays an important role in determining how much ink is transferred to the stock. Plastic, fiberglass, and steel doctor blades will be affected differently by changes in ink viscosity and press speed, but the effect on

ink transfer is minimal compared to variations given by wiper roll metering.

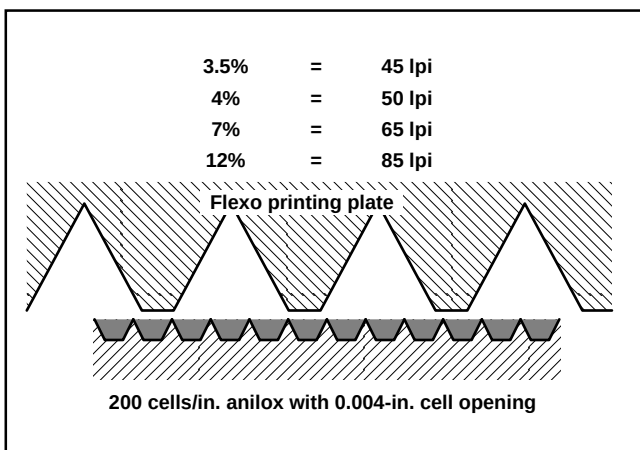
Effective transfer volume. During contact with the plate in the nip, some of the ink in the anilox cell is transferred to the plate surface. The ratio of the total cell volume to the ink transfer volume could be called the "volumetric efficiency" of the cell. This efficiency ratio is determined by the rate at which the ink will flow out of the cell. Anilox cell shape, ink viscosity, surface tensions, and press speed will affect the volumetric efficiency of the cell. **Figure 4** shows some typical anilox cell cross-sections related to their effective transfer volumes.

Deep anilox cells have a lower volumetric efficiency than shallow cells; therefore, high-volume anilox rolls are not suitable for high-viscosity inks. This combination tends to cause ineffective scavenging of the cell during ink replenishment, resulting in dry ink buildup in the cell bottom and more down-time for press cleaning.

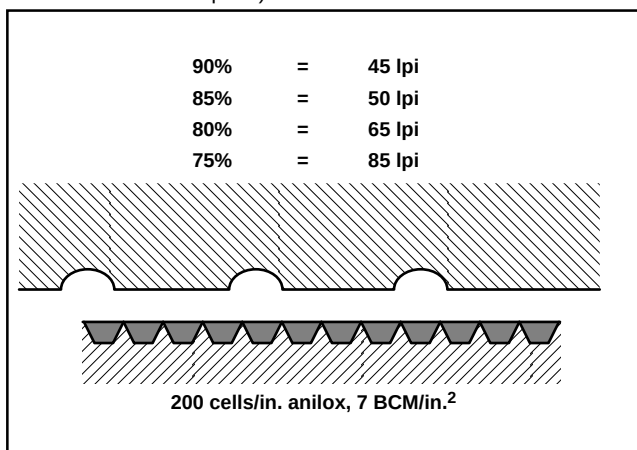
Anilox roll configuration

The anilox roll surface coating will affect the amount of ink released from the anilox cells. The surface energy of chromium, sprayed ceramic, and laser engraved ceramic differ from each other. This difference is sometimes compensated for

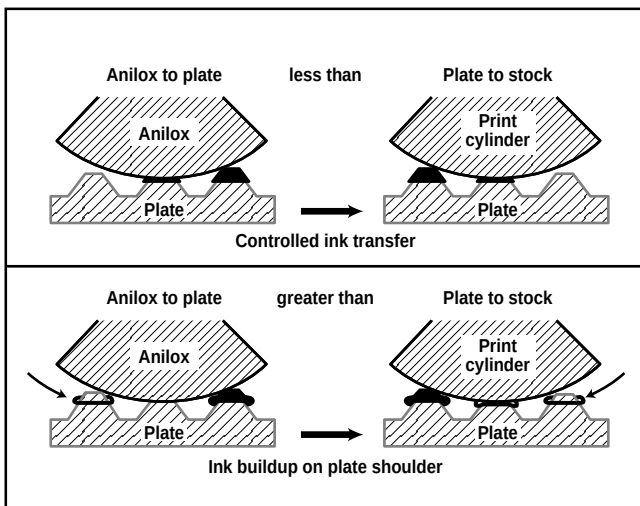
7. Anilox and plate relationships for highlight dots



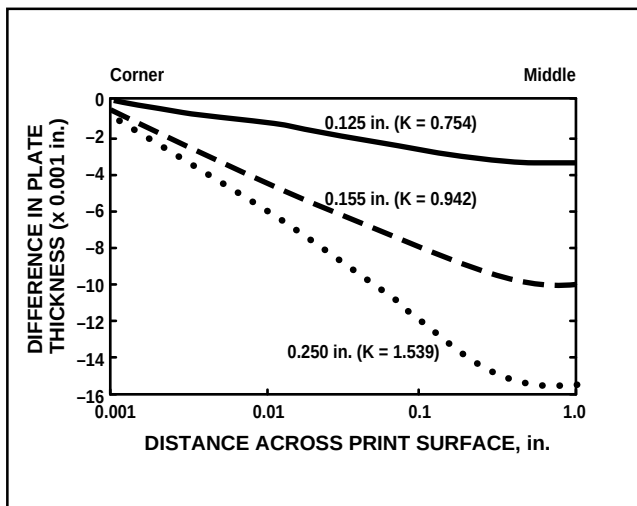
8. Anilox and plate relationships for shadow tones (volume of cell = volume of reverse in plate)



9. Impression control



10. Plate cupping (image reduction = $100\% \times K/\text{repeat length}$)



by quoting an “equivalent volume” for cell volumes of ceramic anilox rolls.

To ensure an efficient ink volume transfer, experimental research has found (2) that the depth:opening ratio of the anilox cell is an important factor when selecting the correct configuration of an anilox roll. A 40–50% depth:opening ratio is suitable only for low-viscosity inks. For medium-viscosity inks, a 35% depth:opening ratio is preferred, and for high-viscosity inks 25% is recommended. **Figure 5** relates the anilox cell volume to a corresponding cell count for 35% and 25% depth:opening ratios.

Why ink resolubility is important. During the printing process,

as the plate runs through the nip with the anilox, each anilox cell is in contact with the plate surface for only a fraction of a second (nip dwell time). The anilox–plate nip footprint length is dependent on both the anilox and plate diameters and the impression between the two surfaces. **Figure 6** gives some typical values of nip dwell times for various press speeds. For example, on a typical press with a 60-in. repeat length running at 60 sheets/min (5 ft/s), with an anilox impression of 0.005 in., the anilox–plate nip footprint would be approximately 0.25 in. and the nip dwell time would be 4.2 milliseconds. During this nip dwell time, the ink in the anilox cell must redissolve the

ink film left on the plate after the last impression cycle before fresh ink can be deposited. Resolubility of the ink package must be maintained to minimize ink buildup on the plate and subsequent machine down-time for cleaning. Measurement and maintenance of ink pH at the press is essential to maintain the resolubility of some ink systems. Maintaining the resolubility of the ink will reduce the need for excessive impression to increase the anilox contact time in an attempt to promote better ink transfer.

Anilox cell density. The smallest element of art that can be printed will be determined by the cells/inch (cpi) density on the anilox roll. If the

II. Typical values for corrugated post-print applications

<i>Plate thickness, in.</i>	<i>Distortion cupping, in.</i>	<i>Minimum impression, in.</i>	<i>Elastic modulus, psi</i>	<i>Min. nip pressure, psi</i>	<i>Max. nip pressure, psi</i>
0.250	0.016	0.020	130	2.08	8.32
0.155	0.008	0.010	130	2.09	8.38
0.125	0.004	0.005	130	1.30	5.20

III. The process model for corrugated post print

<i>Quality desired</i>	<i>Board type</i>	<i>Liner</i>		<i>Ink viscosity</i>	<i>Anilox</i>		<i>Plate caliper, in.</i>	<i>Quality results</i>
		<i>Weight</i>	<i>Quality</i>		<i>Vol., BCM</i>	<i>Cells/in., cpi</i>		
High graphics 4-pt. text 85 lpi	Micro flute	Heavy weight	High-holdout coated	35 s High color content	3.5–5	440	0.125	High graphics 4-pt. text 85 lpi
Med. graphics 6-pt. text 65 lpi	E-flute	Medium weight	Bleach white	30 s High color content	5–7	360	0.155	Med. graphics 6-pt. text 65 lpi
Low graphics 8-pt. text 45 lpi	B-flute	Light-weight	Mottle white	25 s Low color content	7–9	220	0.175	Low graphics 8-pt. text 45 lpi
Brown box 10-pt. text Solids	C-flute	Light-weight	Kraft	20 s Low color content	10–12	180	0.250	Brown box 10-pt. text Solids

smallest print element on the printing plate is spanned by the opening in the anilox cell, then control of the ink delivery to this portion of the plate is diminished. For example, if an attempt were made to print a 6-point Times text using a 200-cpi anilox, the 0.004-in. opening in the cell would bridge the small openings in the bowls of the “a,” “e,” and “d,” and any reverse type, causing the type to fill in and print solid. If screen tones are to be printed, a 4:1 ratio should be maintained between the anilox cells/inch value and the lines per inch of the screen to be printed. **Figure 7** shows the relationship between a 0.004-in. highlight dot on the printing plate and a 0.004-in.

opening in a 200-cpi anilox roll. **Figure 8** shows the relationship in the shadow tones. When a 4:1 ratio between anilox cells/inch and screen lines per inch is used, then 4–85% tonal range can be printed in control. A higher ratio will increase the controllable tone range; a lower ratio will decrease it.

Using these principles, a suitable anilox cell density and volume can be determined. The anilox roll configuration, in most cases, may become a fixed part of the decision process; therefore, care must be taken when choosing anilox volume and line count.

Why impression control is important to ink transfer. To ensure

a continuous flow of ink from the anilox roll to the stock surface, the anilox–plate impression must be less than the plate–stock impression. If the anilox–plate impression were to be greater than the plate–stock impression, then ink deposited on the shoulders of the print characters would not be removed during the stock impression; this would cause ink to build on the shoulders of the characters, forming a hard edge or halo effect. **Figure 9** illustrates that when the correct impressions are set, the ink deposited during the inking cycle will be removed during the print cycle and the plates will remain clean for a longer period. Special stepped plates may be supplied

and mounted alongside the printed images to assist the press operator in setting the correct impressions.

Ink transfer from plate to stock

The minimum amount of impression that can be used, either anilox to plate or plate to stock, is governed by the accuracy of the plate surface. Distortion of the plate print surface is generated by wrapping the accurately formed flat printing plate around the print cylinder. As the image is stretched, the plate becomes thinner. This distortion-related deformation has a greater effect on the center of the print elements, causing cupping of the print surface (3). Also, greater image distortion factors will result in more surface cupping. Typical values of distortion-related cupping are shown in **Fig. 10**, where a 2-in. solid area on a typical printing plate was measured after being mounted on a 36-in.-circumference cylinder. On a 0.25-in. plate, the fine type can be as much as 0.010 in. higher than the center of a large solid print area, resulting in over-impressing the fine type to print the solid. Because distortion cupping is the product of the image distortion factor and the plate thickness, reducing the plate thickness by a factor of two reduces the cupping by a factor of four.

The amount of impression pressure between the printing plate and stock will affect the way the ink is transferred from the plate to the stock and also the quality of the printed image. The minimum amount of impression pressure that can be used will be determined by the thickness and hardness of the printing plate system used. **Table II** gives values that are typical for corrugated post-print applications.

The use of thinner plates not only increases the quality of the image on the plate, it also reduces the need for excessive impression to overcome the plate thickness distortion and reduces the forces generated in the impression nip. The advantages of using thinner plates are:

- Better control of ink transfer
- Less distortion of the finer printing elements
- Reduced plate wear
- Reduced press wear.

Making up the difference with foam. When thinner plates are used for corrugated post-print applications, closed-cell foam must be used to reduce the effective modulus of the plate mounting system to prevent board crush. The thickness of the foam used depends on the thickness tolerance of the board to be printed. For example, on high-quality E-flute board only 0.020 in. of foam may be required, but on C-flute a minimum of 0.060 in. may be necessary. Other materials are also used to build up the difference between the thinner plate gauge and the total press undercut, but one must consider that each thickness of material used has a thickness tolerance, and this all adds to the total inaccuracy of the plate surface.

Conclusions

There are so many factors that govern the flexographic printing process that it is impossible for the press operator to control the end product if he or she is not given the tools to measure each of the variables. These tools are essential to operator education and process control:

- Efflux cup viscometer for measuring ink viscosity
- Simple pH meters for controlling the resolubility of the inks
- Densitometers for controlling the film of ink that is printed
- Gauges on each print station to measure and control anilox-plate-stock impressions
- Printable standard targets that can highlight a print problem, allowing adjustments to be made before the quality becomes unacceptable to the customer.

The decision process

To achieve good print quality over a range of printed mediums—from C-flute brown box, solid colors, through B-flute mottled white, fine-line graphics, to E-flute high-holdout process printing—one must first appreciate that this full range of products cannot easily be produced on the same printing machinery. It is becoming more common for converters to specialize in a fairly narrow range of products that are suited to their particular flexographic presses.

To understand the limitations of a particular printing system, I have provided the process model for corrugated post print (**Table III**), which places the individual components of the process in their respective relative positions. Using this table, starting at the left-hand column at the desired quality level and stepping through the process variables that control the quality, one may arrive at the right-hand column, hopefully at the same quality level. However, each time a step is made to a higher level in the next column after the quality of the board and liner has been selected, it becomes twice as hard to achieve the quality, and the chances of the press operator maintaining the level of quality are halved. The table may also be used as a guide to deciding on the next level of equipment update, for example, choosing the correct anilox configuration and selecting the inks to match. ■

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