

Methods of cylinder engraving for gravure printing

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ABSTRACT: *The first step in gravure printing is engraving a cylinder for use by the printing press. The three most common methods of engraving are electromechanical, direct transfer, and carbon tissue. Each method offers advantages for different types of inks and substrates.*

KEYWORDS: *Cylinders, engraving, gravure printing, methods engineering.*

Due to the simplicity of the process, gravure printing is one of the most widely used methods for the production of medium to long print runs where uniform color is required. Gravure produces high-quality multicolor printing on a variety of materials including film, foil, coated paper, and paperboard. There are four components to a gravure press: an engraved cylinder, an ink fountain, a doctor blade, and an impression roller. This article deals with the methods used to produce the first component—the engraved cylinder.

How cylinders print

A gravure cylinder consists of a steel tube with a plate welded at both ends and a shaft protruding from the ends which is used as a bearing surface in the press. A thin skin of copper, 0.010–0.030 in. thick, is electroplated over the steel and ground to the finished diameter of the cylinder. Each color of

the artwork or design is separated in high contrast, or gray tones, with each color on a separate film. These film separations often require extensive hand retouching and drawing. The films are used to create small depressions, or cells, which are engraved into the surface of the cylinder to form the print design. Prior to engraving, a screen ruling is calculated which determines the number of cells per inch and the size of the cells that are required to produce the final print desired. The type of ink to be used, the amount of detail in the design, and the substrate to be printed, among other factors, determine the screen ruling of the cylinder. Once engraved, the surface of the cylinder is flooded with ink and wiped free with a metal squeegee called a doctor blade. When the substrate (the material being printed) is pressed against the cylinder, the ink left in the cells is transferred to the substrate, and the print is made.

The copper between the cell walls is the only support for the doctor blade in the engraved areas. Without it, the doctor blade could dip into the wide depression and scoop out portions of the ink, as illustrated in Fig. 1. This could cause an uneven laydown of ink, making the center of the printed area light. To protect the soft copper from abrasive inks and the pressure of the doctor blade, a thin layer of chrome is electroplated over the copper. When a design becomes obsolete, the engraving can be removed from the copper, electroplated with new copper, and re-engraved with a new pattern. Although a cylinder can be re-engraved indefinitely, many designs remain on a cylinder for 10–15 years, producing millions of impressions.

Engraving methods

There are three main methods of engraving gravure cylinders in use today. The majority of cylinders are engraved electromechanically. However, particular designs, colors, or substrates may require the use of the older direct transfer or carbon tissue methods. In terms of printability, the main difference in the three engraving processes is the size and shape of the cells formed on the cylinders. In carbon tissues, different values of color are achieved by different depths for each cell (called variable depth). Different thicknesses of ink are applied by the cylinder to print different shades of color. There is very little substrate showing between each dot in the print. Direct transfer changes the size of the dots but not the depth to print differ-

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ent tones (called variable area). All the cells are the same depth, so ink is transferred to the substrate in a uniform thickness but with a different amount of substrate appearing around each dot. Electromechanical engraving changes both the size of the dot and the depth, so it uses both variable area and variable depth to form the print. Electromechanically produced cells are inverted pyramids, whereas other engraving methods form boxlike shapes. The three engraving methods are illustrated in Fig. 2.

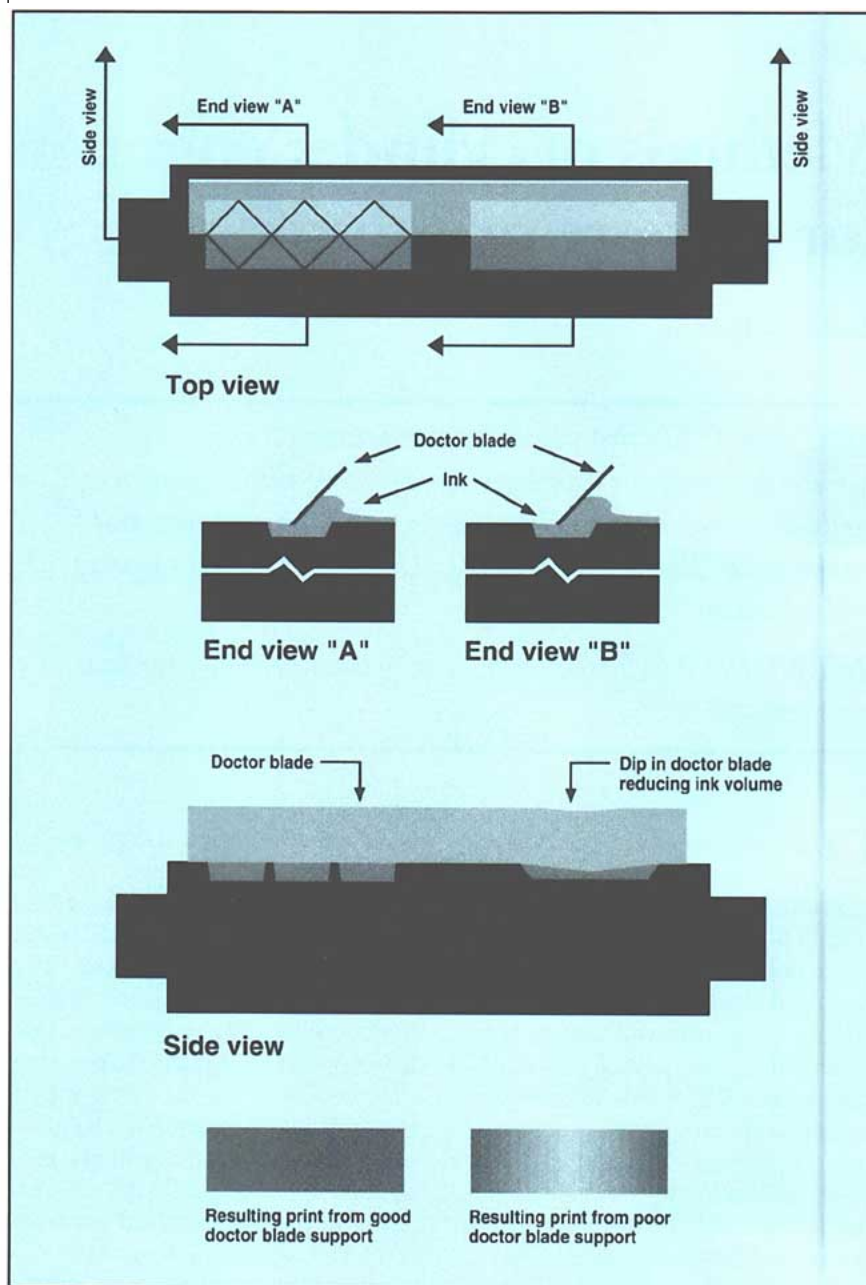
Electromechanical engraving

Electromechanical engraving, also called electronic engraving, is the newest and most widely used of the three engraving methods, as well as the most environmentally friendly. No acids or solvents are used for engraving or to develop and clean resists (protective coatings that inhibit or slow the penetration of acid used in the other methods). Instead, cells are carved into the cylinder by an oscillating diamond that intermittently comes into contact with the rotating cylinder, as shown in Fig. 3. As the copper is displaced from each cell, a suction hose draws the copper away, storing it for convenient removal and reclaiming.

Lighter areas of the design are achieved by driving the oscillating diamond to a shallow depth, leaving cells which are small in height and width (engraving tone cells). Darker areas, or full tones, are made by driving the diamond to the maximum depth allowed by the screen ruling in use, creating large cells in height and width. All cells are centered on a grid defined by the screen ruling in use. Full tone cells will be neatly nested beside each other with a minimum of wall left between them. Lighter tone cells will be spaced far apart with a lot of space between each cell, as shown in Fig. 2.

There are two methods used to tell the engraver what size cell to engrave in each location. The most common is to use a scanner that reads the film separation and assigns a gray level to each area. It then assigns one of 256 shades of gray to be engraved. For

1. Effect of cell walls on doctor blade support

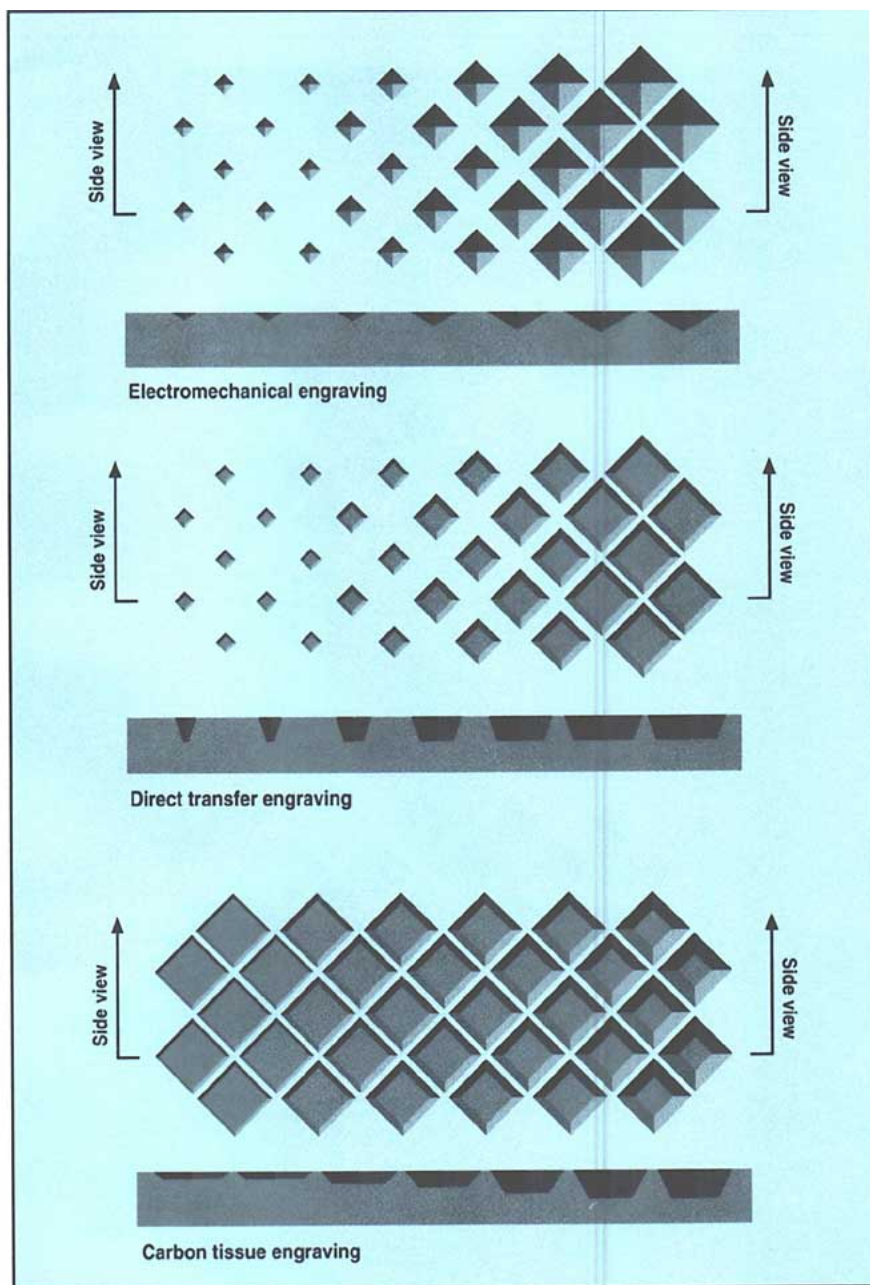


light tones, it sends a signal to the diamond to engrave a tone cell. If it sees a mid tone, it signals to engrave a medium size cell. The other method used to determine cell size is to supply the signals in pure digital form from a high-end color separation computer workstation. No film is involved. This method bypasses errors and inaccuracies that can occur in the scanner setup.

For the engraver who must engrave the same design on different cylinders printing different substrates, electronic

engraving has a distinct advantage. Different substrates produce differing amounts of dot gain (growth of dot size when the ink is transferred to the substrate). Some high-quality papers with a very smooth surface and low absorbency have minimal dot gain. Coarse, highly absorbent papers like those used for decorative laminates have an extremely large amount of dot gain. The gain can be so extreme that normal continuous tone engravings (those containing gray tones as well as black and

2. The three engraving methods



white) for low absorbent substrates will print nearly black everywhere except in the lightest tones on absorbent substrates.

The electronic engraver can alter the signal determining the size of cells by passing the signal through a gamma curve and assigning a different output signal that is to be sent to the oscillating diamond to achieve that specific gray level.

Imagine a line screen with a largest cell 255 μm in width and smallest cell zero width (i.e., no cell). If we were to

engrave 256 shades of gray starting at no cell, which represents white, to the full size cell of 255 μm , which represents black, each cell would be 1 μm larger than the previous cell. If we use a straight lined gamma curve, when the scanner sees a gray level of zero (white) on the film separation, the gamma curve will tell the engraver to engrave a 0 μm cell or no cell. When the scanner sees a gray level of 100, it will engrave a 100 μm cell or a light mid tone. A gray level of 255 on the

film positive (black) would engrave a 255 μm cell, which prints as black. If we used a gamma curve that was bowed downward, when the scanner saw a gray value of 100, then the engraver would engrave a 50 μm cell. The resulting print from this engraving would be lighter in the tones and mid tones. A gamma curve that bows upward darkens the tones and mid tones. In this case, when the scanner sees a gray value of 100, the engraver engraves a 150 μm cell. The effect of these gamma curves on the engraving is shown in Fig. 4.

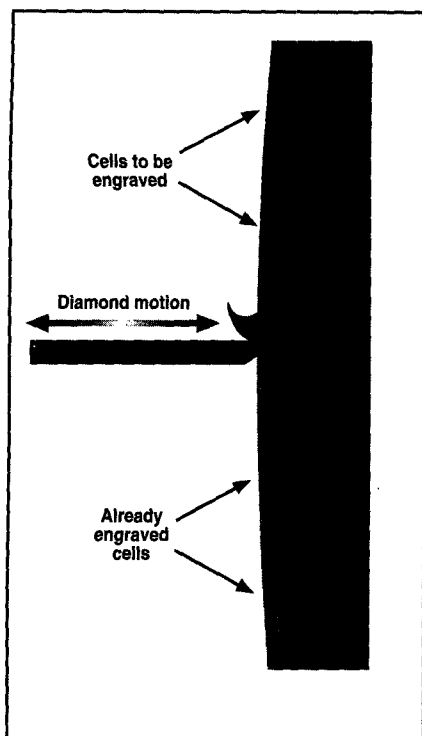
Using gamma curves in this fashion can be helpful when a design is to print on both smooth and rough substrates for coordinating products. The film separation does not have to be re-separated with different levels of gray required for the two substrates. Different gamma curves can be used with the same separation to engrave cylinders that will print on substrates with different dot gain and produce images that will look alike. Figures 5, 6, and 7 show the same engravings illustrated in Fig. 4 but with the resulting dot gain of a smooth, low absorbent substrate and a highly absorbent substrate. Notice how the dot gain of the light gamma curve engraving printed on absorbent substrate, shown in Fig. 5, nearly matches the tone ranges of the dark gamma curve engraving printed on low absorbent substrate shown in Fig. 7.

Direct transfer

In direct transfer, the cells that are engraved into the cylinder are chemically etched into the cylinder with the acid ferric chloride. A cylinder that has been ground to the final size is coated with a photo resist which is sensitive to ultraviolet light. Wherever the UV light strikes the resist, the resist hardens. During the developing process, the unhardened resist is dissolved, leaving bare copper. The hardened resist remains on the cylinder to protect the copper from the ferric chloride.

Direct transfer is a high contrast method of engraving. If the print is to render various shades of color, the film used to expose the resist onto the cyl-

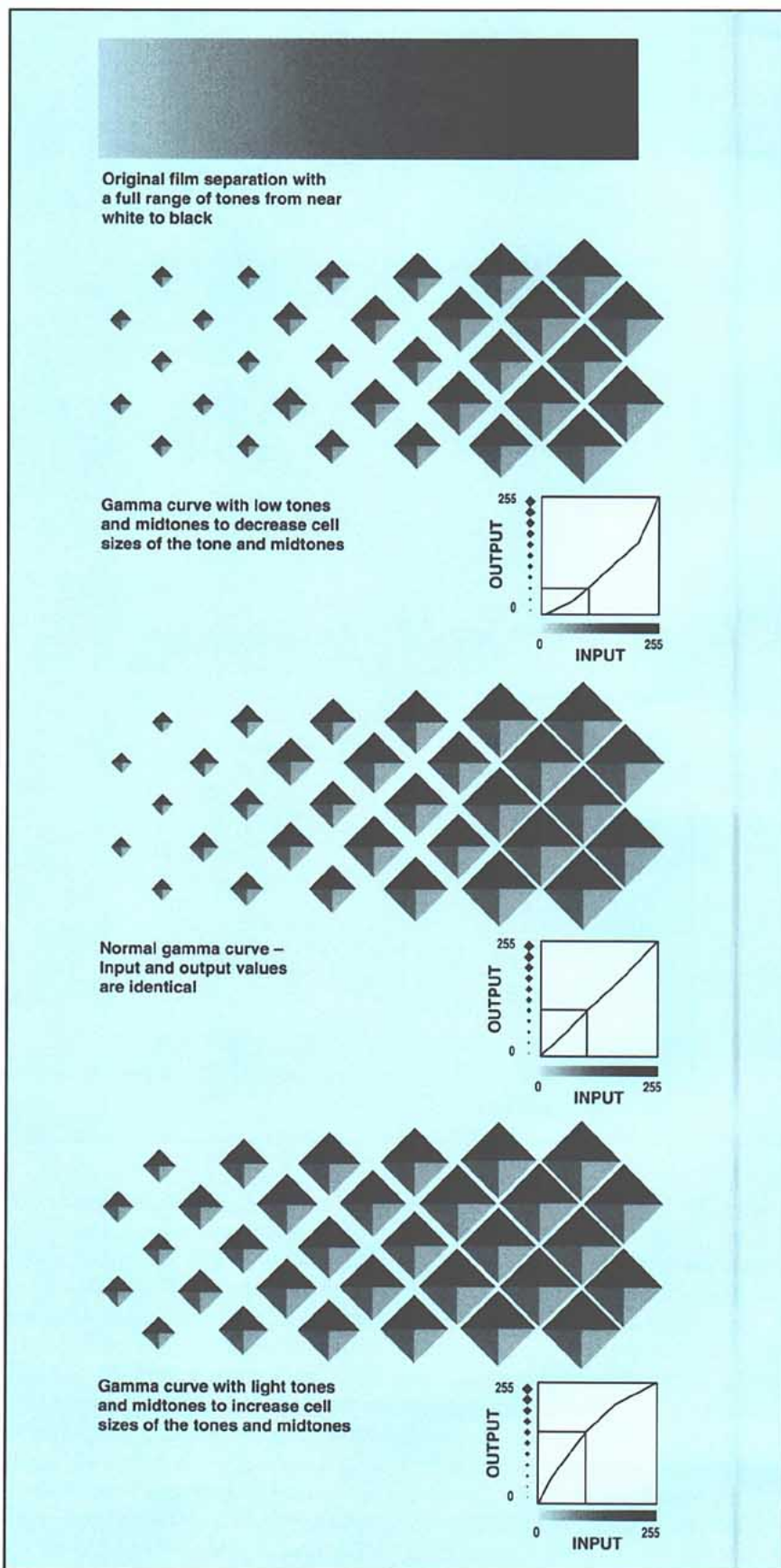
3. Electromechanically engraving a cell



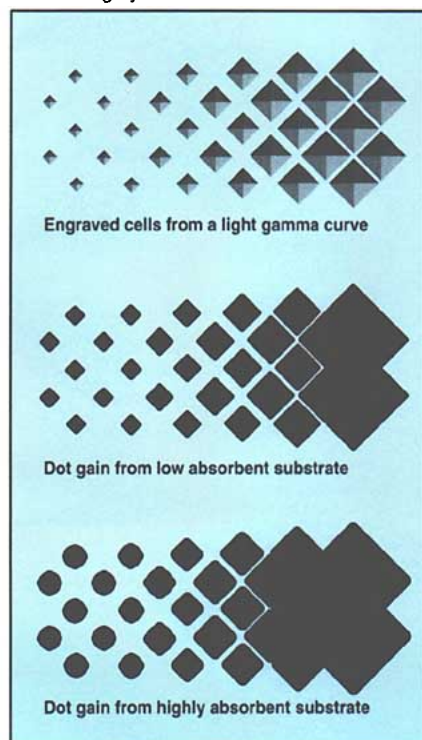
inder must have varying size cells—from full-size cells to the smallest allowed by the surface imperfections of the substrate. Because the cells are etched into the copper, they must be black on the film, and the wall between the cells must be clear. After the cylinder is exposed and developed, it is inspected for defects caused by dirt or lint caught between the film and the resist during exposure. Any defects are painted out with an asphalt material that is impervious to the acid. The cylinder is then dipped into the acid while it rotates so that the acid has constant contact with the entire surface of the cylinder. The etching of the cells into the copper is a timed chemical reaction. When the required depth is achieved, the cylinder is removed from the acid and rinsed with water to stop the etching process. After the resist is removed, the cylinder is complete. The resulting cell shapes vary in height and width, but all are the same depth. The results of this process are shown in Fig. 2.

The engraving process takes from 5 min to 15 min, depending on the depth required. This is a quick process com-

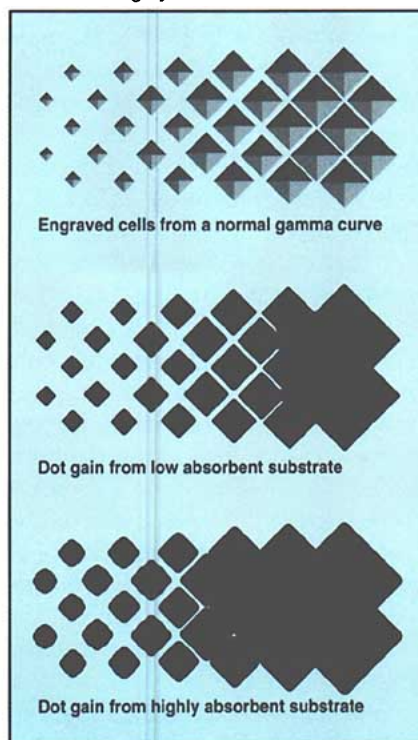
4. Effect of gamma curves on engraving



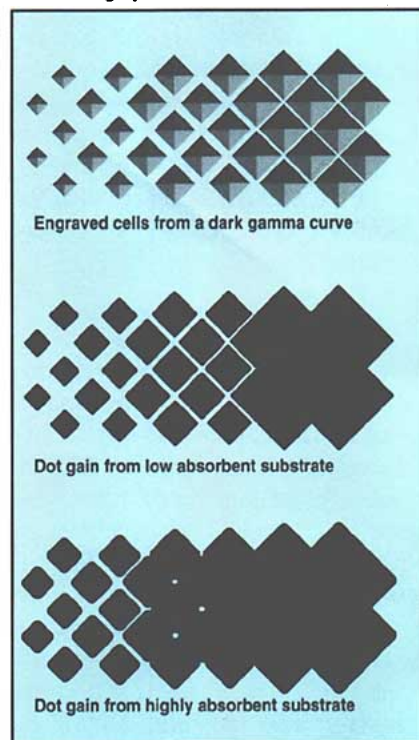
5. Light gamma curve engraving printed on low and highly absorbent substrates



6. Normal gamma curve engraving printed on low and highly absorbent substrates



7. Dark gamma curve engraving printed on low and highly absorbent substrates



pared to the other two engraving methods discussed in this article. However, the labor-intensive steps that must occur before engraving the cylinder can add from 1 h to 6 h to the process.

There are several benefits to direct transfer engraving. Any combination of line screen and engraved depth can be achieved. This is very important when engraving cylinders for decorative laminate printing where pearlescent inks and metallics will be used. These inks contain relatively large particle sizes that pose two problems. First, a large number of these particles need to be applied to the substrate to achieve the desired effect. Second, because the particles themselves are large, they have a tendency to become packed into the cells, reducing the effective ink volume of the engraving. The solution is to use coarse screen rulings and deep engravings. This will produce wide, deep cells that will lay down a large volume of ink and minimize the packing of ink particles. Normal engravings for standard colors range in the 120–150 line screen engraved to depths of 36–40 μm . For

pearlescent and metallic inks, 85–100 line screen engraved to a depth of 80–100 μm may be necessary. This amount of ink volume cannot be achieved with electronic engraving.

For single value engravings where many different shades are not needed, direct transfer engraving can provide tremendous laydown of ink with minimal loss of detail. Although all cells must be centered on a grid pattern determined by the screen ruling, partial cells of any shape can be achieved. This is unlike electromechanical engraving. If a partial cell is required to better define an edge, an electromechanically produced dot will be in the standard diamond shape, smaller in size and centered on the grid of the screen ruling. Examples of direct transfer and electromechanical engraving are shown in Fig. 8.

For these reasons, direct transfer engraving is usually the best choice when fine detail and large ink laydown are needed. Also, when multiple shades of a color and a heavy laydown of ink are required, direct transfer is usually the best engraving method.

In order to show lighter values of a color, smaller dots are used to lay down a smaller amount of ink. The smaller cells that will produce the lighter values of color must be in the standard diamond shape and on the grid centers of the screen ruling. This is also true for electromechanical engraving, but for any given screen ruling, direct transfer acid etched engraving can yield the deepest engraving with the heaviest laydown of ink. In any given screen ruling, a chemically engraved cell can easily have double to triple the cell volume of an electronic cell.

Direct transfer has some disadvantages. The most serious is the environmental problem. Many acids, solvents, and related pollutants must be disposed after engraving. Some engravers have found this issue too costly and have discontinued using direct transfer. Unlike electromechanical engraving, if the tone values are not correct on the films, there is no way of altering them during the engraving process. The film must be re-separated. In some cases, this could require several weeks to complete. Because a photographic process is used to

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expose the image onto the cylinder, there are usually some imperfections in the engraving. These must be corrected before going to the press. Missing cells are carved into the cylinder by hand with the aid of a magnifying glass. Areas that do not start etching immediately upon contact of the acid are shallower than the rest of the cylinder. These areas are spot re-etched.

Carbon tissue

This is the oldest of the three engraving methods and is the least reliable and repeatable. This method uses a gelatin relief resist that, when exposed to different amounts of light, produces membranes of varying thickness. Thicker membranes, which are formed where a lot of light has struck the tissue, slow the advance of the chemical etchant ferric chloride. In these areas, there will be shallow cells that will print a light tone. Areas that have received very little light will have thin membranes. The acid will pass through these areas quickly and will engrave deep cells that will print full strength color. The resulting cell shapes are the same height and width, but vary in depth, as illustrated in Fig. 2.

Two films are generally used for carbon tissue engraving. The first film will be the continuous tone positive that will allow varying amounts of light to filter through to the tissue, thus creating the membranes of varying thickness. A second film that is a high contrast screen is used to burn in the cell walls to 100% exposure. This will ensure that the tissue is its maximum thickness at the cell wall and that the wall will not be etched during the engraving process.

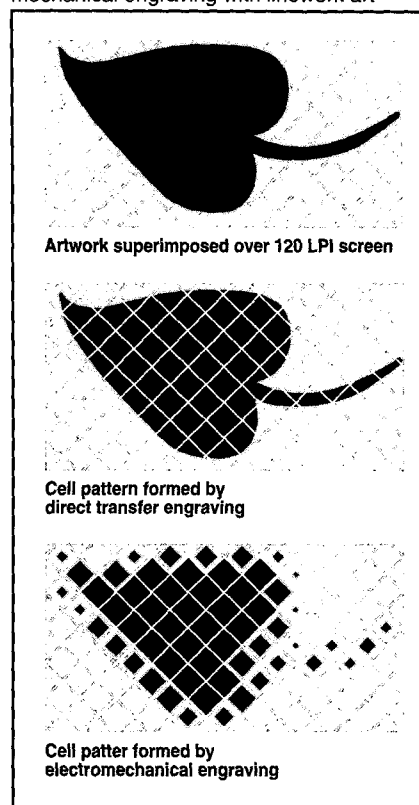
The engraving process is a critical step because the final contrast of the print can be altered by the water content of the acid (the Baumé). The more water contained in the acid (low Baumé), the faster the acid breaks through the thick-membraned areas. The thin-membraned areas are less affected by the Baumé of the acid. When the acid contains more water, the overall difference in depth between the tone areas and the solid

color areas will be minimal and the resulting print will be low contrast. When less water is used in the acid (high Baumé), the acid is slow in breaking through the thick-membraned areas, producing a larger difference between the depth of the tone cells and the solid color cells and a higher contrast print.

If the continuous tone film did not contain the perfect range of tones (the difference between the lightest and darkest areas of the positive), the contrast could be controlled during the engraving. This might be considered a benefit, but the ability to change the contrast can work against you as well as for you. The carbon tissue engraving process is affected by room temperature, humidity, Baumé of the acid, and length of time in the acid, as well as the fact that the cylinder has to be engraved in two halves on separate days. This usually results in two halves of a cylinder with two different contrasts. Finishing the cylinder (balancing the two halves) can take several weeks of meticulous hand-staging and re-etching.

Despite the many drawbacks to carbon tissue engraving, there are some good points. All the tone and solid cells are the same size. When printing light tones, it is very important not to have the smallest dot smaller than the surface imperfections of the substrate. If there are dots smaller than surface imperfections, some cells may not deposit their ink because they will not touch the substrate. This is usually referred to as salty print. The substrates typically used for laminates have a very rough surface, usually requiring a large tone cell to minimize salty print. As the size of a tone cell is increased while the solid cell is not, the range of tones of a particular screen ruling is decreased. This usually has a detrimental effect to the look of a design. Since carbon tissue engravings have the same size tone cells as the solid cells, they usually have minimal salty print and a wide range of tones. An engraving in which all cells are the maximum size allowed by the screen ruling usually will give the smoothest set of tones. The individual dots are hard to see with the naked eye when there is little substrate left showing between the dots. The eye will see the color change from

8. Cell patterns of direct transfer and electro-mechanical engraving with linework art



dark to light, but not the dots change from large to small.

If fine line screens could be utilized, the ability to see dots would not be an issue. However, the substrate used for laminates has a relatively large dot gain during printing. Some papers can almost double the size of a dot. Couple this problem with a rough surface that requires a large dot anyway, and the overall fidelity of the print is marginal at best. Because carbon tissue applies a thin layer of ink to a full-size cell, there is very little dot gain in the mid and light tones. Even if the dot grew in size, the visual tone created in the print is not determined by the size of the dot but by the amount of ink deposited in the areas. Therefore, carbon tissue engraving has very good fidelity of print in the light and mid tones on rough surfaces. ■

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