ADVANCES IN OFF-PRESS COLOR PROOFING

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Off-press color proofing has enjoyed tremendous growth in the graphic arts. It has proven to be an economical, consistent, high-quality alternative to press-proofing.

A recent advance in off-press proofing technology allows the operator to alter proofing parameters such as density, dot gain, and paper stock to more closely match the printed sheet. This new color proofing system from Kodak is based on electrophotographic technology, which is most familiar from its use in office copiers.

Color proofs are used at several stages in the printing production process. After a color original has been separated, the proof provides a quality check of the black-and-white separation films. Color correction may be required to satisfy the client. In fact, several sets of separation films and corresponding proofs may be required. In some cases, several sets of films may be proofed together. These so-called "scatter proofs" allow more cost-efficient use of large-size proofing materials.

Another common proofing stage is prior to platemaking, after plate-ready negatives or positives have been produced. These are called "final proofs" and include all page elements in-position.

A proof serves two purposes. It serves as a medium for client approval of work-in-progress, and it establishes production aim points. To perform these functions effectively, the proof should show the values in the black-and-white separation films <u>as they will appear when printed</u> with colored ink on the press sheet during a high-speed production press run.

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Given this objective, one might expect the industry to prefer traditional press proofing, as opposed to off-press proofing. But press proofing is subject to the same multiple variables that affect the performance of a production press.

Most often, the proofing press is different from the production press. The paper stock used is often different. Dot gain and color densities differ. The running speed is slower. The ink laydown order often differs. Trap is almost necessarily different.

Even more important to the growth of off-press proofing are its inherent advantages. It is a more productive and less expensive method. A proof can be produced in 20 minutes to an hour, as opposed to 2 to 3 hours with press proofing. In addition, off-press methods are more consistent, with less dependence on craft.

Worldwide, off-press proofing is growing at a rate of 5 to 10 percent annually. In Europe and Japan, many users are converting from press to off-press methods, so growth is close to 10 percent. In the U.S., where off-press methods predominate, growth tends to match the growth of color reproduction, which is about 5 to 7 percent annually.

A number of imaging technologies have been -- or could conceivably be -- applied to meet the growing demand for off-press proofs.

Diazo and photopolymer systems are by far the most widely accepted, and they produce very high-quality results.

Silver halide materials have been used for some less demanding applications -- position proofing, for example. However, a precise color match to ink pigments is difficult with photographic papers, which use dyes to render color. The color gamuts are not matched. Neither is the substrate. And the quality of dots reproduced on color photographic paper is limited.

Dry electrostatics has also been applied to produce color proofs. The size of the marking particles which form the electrostatic image are typically about 50 to 100 microns, so resolution is a limiting factor.

The same is true of ink jet and thermography. If there are significant advancements in these technologies, they could conceivably be applied to color proofing more successfully in the future.

The recently-announced KODAK SIGNATURE Color Proofing System is based on liquid electrophotographic technology. This choice of an alternative implies that existing technologies leave some room for improvement.

Existing approaches tend to emphasize one important performance characteristic -- consistency. This is, in fact, a vital requirement. There can be little or no tolerance for variability in proofs.

Color proofs are used to evaluate the results produced by dot values in the separation films. If the proofing materials and proofing process -- in other words, the "system" -- is inconsistent, then there is no reliable basis for judgment. Is the appearance of the proof affected by these specific dot values ... or by variability within the system? The second answer is unacceptable.

Existing systems provide good to very good levels of consistency. However, this performance is achieved by sacrificing flexibility. Ideally, an off-press proof will produce results that are both consistent from proof to proof and flexible to reflect variations in color densities, dot gain, and paper stock. These are among the most important of hundreds of variables that affect the appearance of the final printed product.

If our goal is to produce a proof that shows the appearance of that end-product, then we need the flexibility to show variations in color density, dot gain, and paper stock.

Recognizing this fact, some manufacturers have found ways to customize the color density of their materials to customer requests. Normally, this is done by altering the formulation of the colorants used to create the image. This allows a differentiation from shop-to-shop, but not from proof-to-proof.

A fixed degree of dot gain can be introduced by using a spacer to separate the image from the substrate. The result is optical dot gain, which simulates the effect of physical dot gain.

Physical dot gain is an actual enlargement of the dot, itself. This is caused, to varying degrees, by the absorbency of the paper or other substrate. On a production press, the impression pressure between the plate and the paper will also influence the degree of physical dot gain. Many other factors contribute.

Optical dot gain describes a perceptual effect which occurs even though the size of the dot has not changed. Because the dot is lifted off the substrate by a spacer, some reflected light will be trapped beneath it. This produces the appearance of dot gain.

Of course, this phenomenon occurs to some extent whenever we reproduce an image directly onto paper. Normal multiple reflections and refraction produce an optical dot gain of 10 to 12 percent. Adding a spacer typically increases that by about 8 percent, producing a total apparent gain of about 20 percent. Note, however, that the amount of dot gain that can be represented is fixed at about 20 percent.

The paper stock or substrate cannot be varied, either, since existing products are designed to use a single substrate or, at best, a very limited selection of substrates.

Another important factor relating to the appearance of the printed product is the color of the ink used to print it. Many of today's proofing systems use colorants which are not spectrophotometrically matched to printing inks. As a result, there is the potential for metameric color matches (apparent matches which may appear mismatched under some other lighting conditions).

In addition, optical brighteners are sometimes used to counteract the apparent high d-min caused by the use of several layers of photopolymers. These brighteners create a brilliance that is unmatched in the printing process.

There are other limitations shared by diazo and photopolymer proofing systems. Consistency of results depends to a degree on the operator's performance. Proofing with these systems is a multi-step, labor-intensive process that is not particularly user-friendly. Finally, with some systems, the operating environment must be controlled within certain parameters of humidity and temperature.

In a historical perspective, the systems in use today represent significant advancements in proofing technology. Still, the limitations are real.

Electrophotography offers inherent advantages which address all of these limitations, along with some potential disadvantages that have been effectively overcome in the design of the KODAK SIGNATURE Color Proofing System.

Before we discuss those points, let's review how electrophotography works with KODAK SIGNATURE products. Basically, it is a four-step process.

First, a photoconductive -- or "PC" -- film is made sensitive to light when it receives a uniform electric charge across its surface.

Wherever the PC film is exposed to light, the charge migrates away from the surface. Electrophotography is similar to silver halide photography in that the effect of exposure by light can be amplified, and that effect varies based on exposure level.

At the toning stage, charged marking particles within a liquid toning ink are attracted to the opposing electrical charge in the image area. Finally, the marking particles are semi-fused to the PC film.

A 30-by-40-inch piece of photoconductive film is imaged during four passes through the KODAK SIGNATURE Toning Console. A cyan, magenta, yellow, or black separation film is registered with the same piece of photoconductive film for each pass.

The system is controlled by a sophisticated microcomputer which leads the operator through each step.

After all separation films are exposed onto the photoconductive film, the composite image is transferred to the appropriate paper stock in a separate laminating unit. Virtually any coated paper stock can be used to receive the image, which helps replicate the results of an actual press run using the same type of paper. The color and gloss characteristics of the paper can be evaluated in the proof.

The laminating process takes about 2 minutes, after which the PC film is peeled off and discarded. Three to four proofs can be produced in an hour, which is comparable to the most productive methods currently available.

The heart of the system is the KODAK SIGNATURE Toning Console, where imaging of color proofs takes place.

The PC film is loaded on a platen. The film is lifted by a mechanical arm to allow the operator to position one of the separation films on the platen using register pins.

When the operator presses a button on the control panel, the platen begins its automatic transport and a uniform charge is applied at the first station. Next, the image is exposed by a slit aperture exposing system.

A pre-wet station conditions the PC film for development. The toning ink is applied, after which excess liquid is skived. After rinsing and drying, the platen is transported back to the home position.

At this point, the mechanical arm lifts the imaged PC film to allow the operator to remove one separation and position the next. These steps are repeated four times to complete the imaging process.

During the drying stage of each cycle, the image is semi-fused to the PC film, so the film can be handled normally without damaging the image. Finally, the image will be transferred to a coated paper stock in the laminating unit.

The ability to create a proof on virtually any coated paper stock is a major advantage. Another advantage is that electrophotography lends itself to automation. In fact, automation is necessary to deal with any variability in the process. In the KODAK SIGNATURE Toning Console, sophisticated on-board electronics automate, monitor, and control each stage of charging, exposing, and toning the PC film. Several sensors inside the console gather information during the process.

There are electrostatic volt meters -- "electrometers" -- which monitor the charge on the film as a function of time. The electrometers provide a direct measurement of the latent image. This ability to evaluate the latent image is beyond the capabilities of silver halide technology.

Using electrometer readings and computer control, the voltage applied to the development electrode can be varied to provide any compensations required by the latent image to achieve the desired aim density.

There is also a light intensity monitor to let the process control computer know if the light is losing its intensity due to age.

An on-line densitometer measures the actual densities produced during each pass through the console to further maintain absolute consistency.

All of this data interacts with algorithms in the process control computer. Stored there are mathematical models of the film characteristics, the toning ink characteristics, and the process characteristics.

The process control computer sends instructions to the charging station prescribing the voltage required for the proper surface charge to the film. It instructs the exposure system as to how wide the slit aperture should be for proper exposure. It tells the toning station how much voltage should be applied to the development electrode. All of these instructions are based on the monitored results during each cycle.

Incidentally, this same computer is the source of step-by-step commands which prompt the operator through the production cycle. It includes self-diagnostic capabilities and service testing functions.

Besides guaranteeing consistency, electronic process control is the key to a principal feature of the KODAK SIGNATURE System -- which is independent control of density and dot gain for each of the four process colors. This is made possible because electrophotography allows us to change exposure and density independently.

This is impossible with silver halide technology. If we look at a familiar characteristic curve, we see that density is a function of exposure, and exposure alone. More or less exposure yields more or less density.

In electrophotography, there is another handle to turn which will control density ... namely, the voltage difference between the image area and the development electrode -- or the "delta voltage." This delta voltage controls how many marking particles are attracted to the surface of the PC film, which, in turn, determines density.

We can vary color density by controlling exposure and/or this delta parameter. On the other hand, dot gain is controlled solely by varying the exposure. Increasing the exposure will increase the spread of the dot -- will increase its physical size. So physical dot gain can be shown precisely by controlling exposure.

Then, any necessary adjustments can be made by the process control computer to make sure that color densities meet their aim points independently. If exposure is increased to show more dot gain, then the delta voltage can be decreased to maintain the same density values.

We believe that control of dot gain and density will be perceived by the printing trade as a major breakthrough, allowing proofs to reflect press conditions with unprecedented accuracy.

With all practitioners of the graphic arts, the requirements for image quality are high. Image quality is often considered a disadvantage of electrophotography. The marking particles used in dry toners and office copiers range from 20 to 30 microns in diameter. This is unacceptable in printing and publishing. Using a 150-line screen, a 5 percent highlight dot is about 20 to 30 microns in diameter. Consider the difficulty of reproducing that dot using marking particles the same size -- that are irregularly shaped.

By contrast, marking particles in KODAK SIGNATURE Toning Inks are only about one micron in diameter. The size of these particles is the key to graphic arts quality.

However, their size also makes it difficult to manage and contain these ultra-fine particles. Best results are achieved by dispersing them in a liquid. The dispersant, itself, must be nonconductive and, therefore, nonaqueous. These necessary characteristics limit the choices of dispersant materials. Our choice was an aliphatic hydrocarbon-type liquid.

Remember, we are speaking of a dispersion of particles, as opposed to a solution. And dispersions can settle. These proprietary liquid toning inks are highly resistant to settling. They do not agglomerate as readily as other toning inks. In the event that settling does occur, they are readily redispersable.

The pigments used as colorants in KODAK SIGNATURE Toning Inks are the same pigments used in S.W.O.P. inks. This provides a close match between the proof and the printed sheet. It also eliminates the possibility of metameric matches, since the pigments are spectrophotometrically identical.

Another challenge was to create a formulation for the toning inks which would enable the particles to hold their electrical charge indefinitely when suspended in a liquid solvent. Experimental concentrated toning inks have been stored for a period of two years without any loss of charge.

A critical design parameter we set for ourselves was to transfer 100 percent of the image from the PC film to the substrate during lamination. Office copiers and other electrophotographic systems leave a ghost image on the photoconductive material. This adds an element of inconsistency that we chose to design out of our system by allowing 100 percent transfer to the substrate.

In office copiers and other electrophotographic systems, the photoconductive material is reused. We chose a single-use approach with a disposable material in the interests of consistency.

A unique advantage is that the same photoconductive film material can be used for negative or positive imaging. Negative or positive modes can be assigned with the push of a button that simply reverses the electrical charge applied to the film. There's no need for users to stock two types of materials -- negative- and positive-working materials. This feature is the result of proprietary Kodak technology.

Until it is charged, the PC film is not sensitive to light, so it can be handled safely under normal roomlight conditions. Within this white-light environment, room temperature can vary from 55 to 85 degrees Fahrenheit and humidity can range from 15 to 55 percent. Even broader ranges of acceptable humidity will be offered in the future.

With most sensitized materials, convenient handling and a comfortable working environment entail trade-offs in photographic sensitivity. With electrophotographic materials, exposure is achieved at photographic speeds. Electrophotographic and silver halide materials are close in sensitivity, while diazo and photopolymer materials are orders of magnitude slower.

Its photographic speed is one of many characteristics which make electrophotography a strong candidate as the technology-of-choice for future imaging systems -- including direct digital proofing systems.

We at Kodak believe there will be a continuing need for full-size contact/optical proofs. But we also see a growing need for intermediate one- or two-page digital proofs.

Further advancements in KODAK SIGNATURE Products and electrophotographic technology could result in a family of optical and digital off-press proofs. All would offer a high-fidelity match to each other and to the press sheet.

It also seems likely that the impressive benefits this technology brings to the graphic arts may find application in other image-related information systems of the future.

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