Digital Offset Color

Introduction

Indigo's range of digital printing presses, based on its Digital Offset Color technology and process, offers a unique combination of high quality imaging, speed, wide color gamut, the ability to print on a wide range of substrates and to vary every printed copy.
The combination of quality, flexibility and user profitability has put Indigo into its market-leading position. There are as many Indigo digital presses installed worldwide as all the competing digital color presses put together.
This white paper describes the Indigo Digital Offset Color printing process, and its unique features. It also compares Digital Offset Color with the competing xerographic (dry toner) digital printing presses, and the conventional, non-variable offset lithography process that has traditionally dominated the worldwide printing industry.
Indigo offers a wide range of presses for a variety of applications, all based on the basic principles of its Digital Offset Color technology.

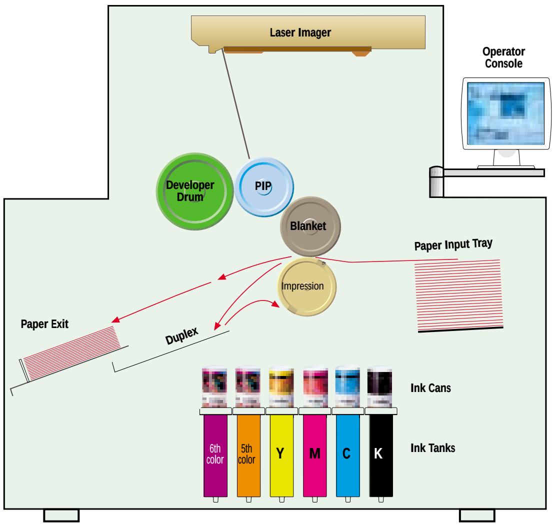


Fig. 1: Indigo printing engine

What is Digital Offset Color?

Let's break it down word by word:

1. Digital

The printed image is created directly from digital data – in other words, pages, text and images created with electronic layout and/or desktop publishing programs.
Unlike conventional printing processes, there are no intermediate pre-press processes between the digital document file and the final print. No film, no imagesetters, no plates, no platesetters, no photo-chemicals and no waste. There is also no press make-ready: no plate mounting, no registration adjustments, and no ink keys. Indigo's process is fully digital from creation to printing. And, since it is fully digital, every image can be a new one, enabling information to be completely varied as required.

2. Offset

Offset simply means that there is an intermediate cylinder that transfers the ink image from its origin on the plate cylinder to the final substrate (i.e. the paper, plastic or other material) which is to be printed.
In the printing industry, the term 'offset' is commonly used as a term for the lithographic process. Indeed modern lithographic (also called litho) presses do use an offset process. Indigo's technology also uses offset printing, based on the use of an offset cylinder covered with a renewable rubbery blanket.

The main purpose of offsetting on the press is twofold. First, it protects the surface of the printing plate from excessive wear due to friction with the substrate as it is printed. Secondly, it compensates for any unevenness of the substrate surface by enabling ink to reach the bottom of any depressions or grain. In other words, it acts as a kind of shock absorber and pressure pad, ensuring an even pressure, and therefore ink transfer, from blanket to substrate.
Offset presses can therefore print on a very wide range of substrate surfaces and thickness, and are superior to non-offset processes in this respect.
Indigo's process uses offset for the same reasons, thus making it capable of printing on a wide range of substrates.
One notable difference between conventional offset and Indigo's offset printing technology, is that Indigo's ElectroInk transfers completely from the blanket to the substrate with no ink splitting that characterizes all conventional offset printing systems. This means that a new separation, in a different color, can be created for every rotation of the press. Indigo calls this 'on-the-fly color switching'.

3. Color

As it simply sounds, Indigo's technology enables digital printing in full color. However, unlike conventional offset litho color presses, which require one complete printing unit per color, Indigo presses print multiple colors for each single pass of the substrate through the press.

In summary – Indigo combines Digital, Offset, and Color into a powerful printing process.

Indigo's Core Technologies

The three core technologies of the Indigo Digital Offset Color process are:

- ElectroInk – Indigo's liquid ink
- Thermal offset transfer technology
- On-the-fly color switching.

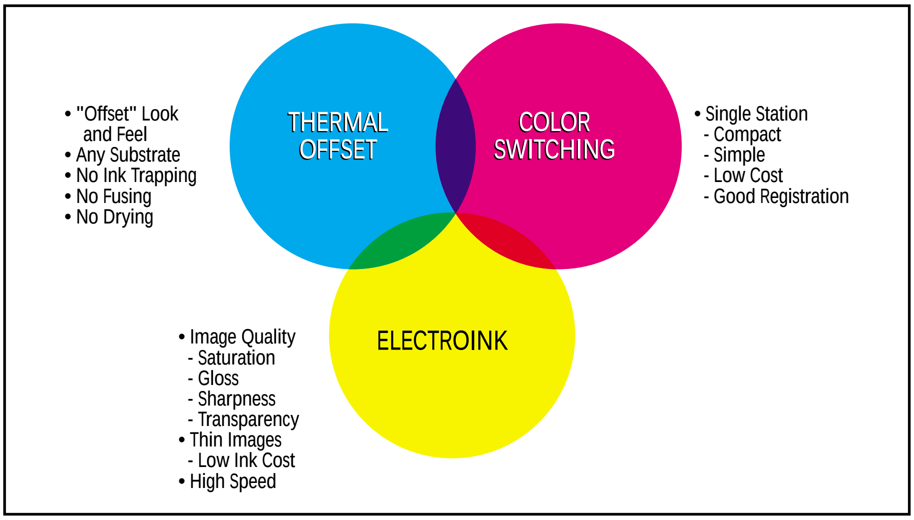


Fig. 2: Digital Offset Color Core Technologies

Digital Offset Color

ElectroInk

All of the Indigo digital presses use ElectroInk, Indigo's unique liquid ink. ElectroInk contains electrically charged ink particles, in a liquid. Like other digital printing technologies, i.e. powder toner xerography, ElectroInk enables digital printing by electrically controlling the location of the print particles. However, unlike powder toner xerography, ElectroInk enables very small particle size, down to 1-2 microns. This small particle size enables higher resolution, higher gloss, sharp image edges, and very thin image layers. In other words, ElectroInk enables printing that matches conventional offset printing quality.

In powder toner xerography, on the other hand, the particle size cannot be made too small, as particles then become airborne, and uncontrollable. Therefore, the higher the printing speed in digital printers, the larger particle sizes must become. ElectroInk, being electrically charged particles in liquid, enables controlling even the smallest particle sizes required for quality color printing (see fig. 3).

In summary, Indigo's ElectroInk enables high quality, sharp images, and high gloss color, similar to conventional offset printing, and exceeding the quality achieved by competing digital printing technologies.

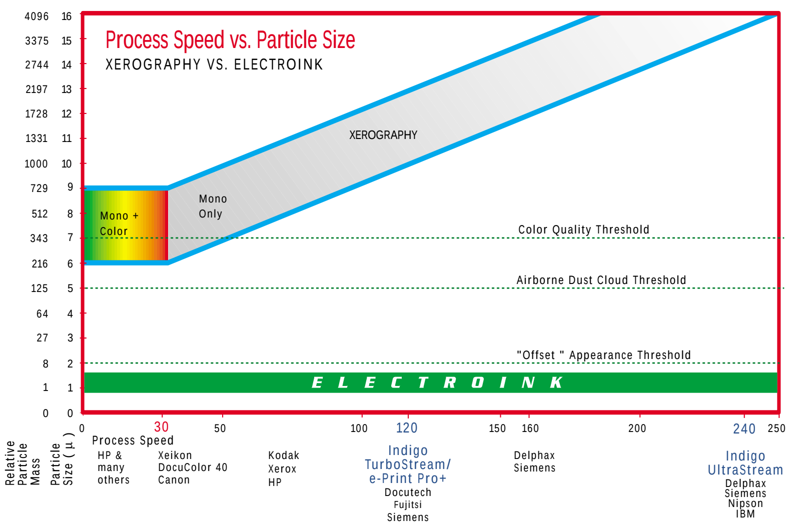


Fig. 3: Process speed vs. particle size

ElectroInk is available in an increasing range of colors, including:

- Standard process colors CMYK (cyan, magenta, yellow, black).
- IndiChrome wide-gamut six-color set. These incorporate orange and violet inks to extend the color reproduction capabilities far beyond the range possible with CMYK inks only.
- IndiChrome spot colors – mixed from a set of base inks, matching spot colors including most of the PANTONE® color range.
- Opaque White base coat for clear and self-colored substrates.
- Fluorescent inks.

ElectroInk is supplied as a concentrated paste that is loaded into the press in tubular cartridges in a 'clean hands' operation. Inside the press it is fed into ink supply tanks and diluted with oil, to form a fluid mixture of carrier liquid and colorant particles ready for printing.

Thermal Offset

Known as Thermal Offset, the Indigo process uses a blanket heated to approximately 100°c. This causes the specially shaped pigment-carrying particles within the Indigo ElectroInk to melt and blend into a smooth liquid plastic. The blanket heat is not high enough, nor is the dwell time long enough, to heat the paper or other substrates as they contact the blanket.
When it contacts the cooler substrate, the ElectroInk immediately solidifies, strongly adheres and transfers to the substrate. The print is effectively dry as soon as it leaves the press, eliminating any risk of ink ‘set-off’ marking other copies. Print finishing can be performed immediately. This is a major benefit over conventional lithography which requires either assisted drying systems, or a ‘natural’ drying time of several hours, before any print finishing processes can be applied.
In summary, Indigo’s offset technology enables the "look and feel" of conventional offset printing, the ability to print on virtually a limitless substrate range, and the capability of immediate drying, which enables duplex printing or finishing with no need to wait.

Color Switching

Indigo’s Digital Offset Color printing technology enables printing of all color separations on a single station. After one color separation has been created and printed, the next one (a different color) is created and printed on the same station. This is possible since the blanket completely transfers the previous image, and none of the image stays on the blanket.
Single station printing has several advantages, which includes compactness, lower cost of hardware, and better mechanical accuracy, which translates, for example, to better registration.

Quick Guide to the Indigo Digital Offset Color Printing Process

The Printing Cycle

The Indigo printing engine basically performs the following operations sequentially:

1. Electrostatic charging of the electrophotographic Photo Imaging Plate (PIP) which is mounted on the imaging cylinder.
2. Exposure of the PIP by a scanned array of laser diodes. These lasers are controlled by the raster image processor which converts instructions from a digital file into 'on/off' instructions for the lasers.
3. Inking of the PIP and removal of ink from non-image areas by the highly charged developer roller.
4. Removal of excess liquids and ink particles from the non-image areas on the PIP surface and removal of loosely adhered ink particles from the image areas.
5. Removal and recirculation of most of the excess carrier liquid from the image and non-image areas of the PIP surface.
6. Transfer of the inked image to the blanket cylinder.
7. Removal of any residual ink and electrical charge from the PIP.
8. Heating of the inked image carried by the blanket.
9. Transfer of the heated inked image to the substrate held by the impression cylinder.

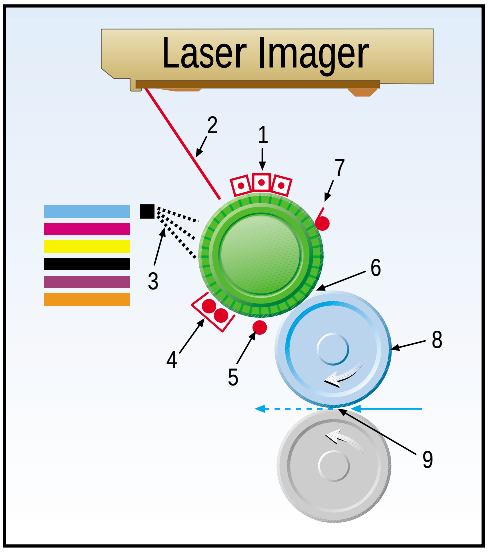


Fig. 4: The printing cycle

These operations repeat themselves for every color separation in the image. They are now discussed in more detail starting with charging of the PIP.

1. PIP charging

A clean, bare PIP segment rotates under a corona wire called the Scorotron. The Scorotron unit generates electrical charges which flow towards the PIP surface and cover it with a uniform static charge.

2. PIP exposure

As the PIP cylinder continues to rotate, it passes the imaging unit where up to 12 laser beams expose the image area, dissipating (neutralizing) the charge in those areas. When the exposed PIP rotates toward the next station it is actually carrying a 'latent image' in the form of an invisible electrostatic charge pattern that replicates the image to be printed.

3. Image development

Next, the ElectroInk is applied to the PIP. The ink is pumped along flexible pipes to the area between the PIP and developer cylinders at the top of the press. At the appropriate timing in the imaging sequence, the ink is injected as a smooth and uniform 'curtain' along the length of the gap between the cylinders. The injected ink fills a narrow gap between the cylinders.

As the Developer roller and the PIP carry different voltages, strong electrostatic forces are created between the two rotating cylinders. Those forces attract the charged ink particles to the low charged image areas, while repelling the ink particles from the highly charged non-image areas. The ink that is repelled from the non-image areas migrates toward the developer roller and is carried into a catch tray that returns it to the ink tank.

4. Metering station

Next, the PIP rotates through the metering station in which two small electrically charged rollers (wetting roller and reverse roller) rotate in opposite direction to the PIP cylinder. The reverse roller, that is precisely mounted in very close proximity to the PIP surface, exerts a combination of electrodynamic and hydrodynamic forces that remove excess liquids and ink particles from the non-image areas on the PIP surface. It also removes loosely adhered ink particles from the image areas thus rendering it a sharp and coherent appearance.
Ink removed from the PIP at this stage is recovered in a catch tray and sent to a separator, from where the oil is filtered and re-used.

5. Image compacting station

Next, the PIP plate rotates under a squeegee - an electrically charged rubber roller which exerts mechanical pressure and electrical forces to remove and recirculate most of the excess carrier liquid from the non-image areas. It also removes excess carrier liquid from the image areas, thus concentrating the ink particles and rendering them a more cohesive and rigid structure.
The excess carrier liquid is recycled via a catch tray to the separator. At this stage the image is ready for transfer to the blanket. The non-image areas on the PIP surface are clean from any residual ink particles, the image is sharp and rigid, and all the excess carrier liquid which is not needed anymore was removed and recycled.

6. First transfer

The PIP then rotates into contact with the electrically charged blanket on the transfer cylinder, and the ink layer is electrically transferred to the blanket.

7. Cleaning station

Finally, the PIP rotates past a cleaning station which removes any residual ink and discharges the residual voltage.
At this point this part of the plate surface has made a complete rotation and is ready to be recharged ready for the next image.

8. Second transfer

Meanwhile, on the rotating and heated blanket, the ElectroInk is being heated, which causes the particles to partially melt and blend together, forming a hot adhesive liquid plastic. As the ink comes into contact with the substrate, which is significantly below the melting temperature of the particles, the ink solidifies, sticks to it, and ‘peels’ off completely from the blanket, ensuring 100% transfer from blanket to substrate. The blanket is therefore clean and ready to accept the next impression as it rotates past the PIP cylinder.
As mentioned before, Indigo presses print multiple colors from the same ‘offset’ blanket. The cycle repeats itself for each color separation and the only difference between the cycles is in the ink that is injected and the image data corresponding to the printed color separation.

Some detail changes

This imaging and ElectroInk application process is essentially the same for all Indigo presses, although there are detail differences between models.

In 'Series 1' products from Indigo, the development stage is exactly as described above.

In 'Series 2' products (UltraStream 2000 and the products based on UltraStream), the development stage is based on an enhanced technology, called BID (Binary Ink Development). BID does not call for 'spraying' the ink on the PIP, but applying it from a development roller to the PIP. It also does not use the same developer station for all colors, but a different one for each color. BID enables higher speed development - for higher speed products (see fig. 5).

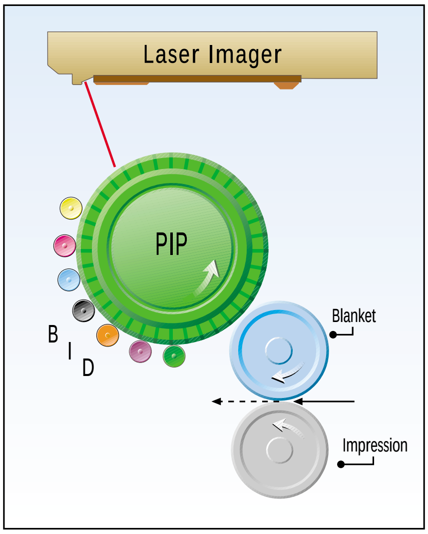


Fig. 5: Series 2 printing engine

Another detail change is the second transfer. The sheet-fed models for commercial printing use the 'multi-shot' imaging sequence. These models are the e-Print Pro+ (and the earlier E-Print models), TurboStream and UltraStream models.

In "multi-shot", one color separation is created at a time on the PIP, then transferred to the blanket and onto the substrate, as described above. The substrate stays on the impression cylinder for several rotations as it receives each separation, printed separately one after the other. As the final separation is printed, the substrate is delivered for duplexing or to the output tray.

Indigo's web-fed products employ a 'One-Shot Color' process, as it is not possible to wrap the material around the impression cylinder for multiple passes. In this case, the PIP cylinder rotates several times, transferring a succession of separations and building them up on the blanket, before they are transferred to the substrate all in the same impression pass.

After describing the technology and the process, let's touch on the advantages which stem from them.

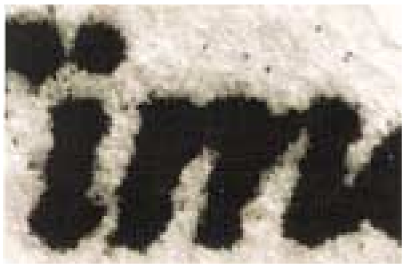
Digital Offset Color Advantages

Quality Characteristics

1. Edge sharpness and definition

Viewed at high magnification, it is easy to see that ElectroInk forms much sharper images than xerographic dry toners, and it is even superior to offset lithographic dots.
The sharpness of ElectroInk is particularly noticeable at the edges of halftone dots, or fine type characters. Also noticeable is the contamination-free background of ElectroInk images. This is due first to the small size of the ink particles and second to the way the ElectroInk particles are transformed when they are on the press.
As mentioned, several mechanical and electrostatic processes take place on the Photo Imaging Plate cylinder, which have the effect of concentrating the ink particles and giving image areas a clean, sharp edge.
Also, when the ink is transferred to the heated blanket, because the ink particles melt and blend, the strong surface tension of the liquid ink facilitates the formation of a sharp, clean edge.
When transferred from the blanket to the final printing substrate (paper or plastic), the heated liquid plastic cools down to form a thin colored plastic layer on the substrate surface. When printing on paper, the cooled ElectroInk does not soak (or 'wick') into the

ElectroInk



Xerography (Powder Toner)

Fig. 6: ElectroInk vs. Xerographic toners

paper fibers. Thus, printed dots, linework and text, stay sharp and well defined on the surface of the paper.
Like ElectroInk, xerographic dry toners don't penetrate the paper either, but they do suffer from large particle size and stray toner particles scattered outside the image edges, leading to poor edge definition no matter what substrate is used. (see fig. 6)

2. Dot gain and color consistency

Dot gain - the tendency for printed dots and lines to spread out and enlarge as the ink image passes through the pressure of transfer - is consistent and predictable on Indigo Digital Offset Color presses. Indigo presses have built-in dot gain compensation which corrects the exposed dot size so that it prints to the desired size. In addition, Indigo presses automatically adjust the optical density (i.e. appearance in terms of lightness or darkness) and dot size so that they always appear the same, copy after copy.
With a conventional offset lithographic press, there are wider fluctuations during a run caused by factors that include: fluctuating ink and water temperature; water/ink balance and their tendency to emulsify; plate and blanket wear; and atmospheric humidity altering the absorbency of the paper. Neither automatic nor manual adjustment can completely iron these out, because there is always a time lag between the problem appearing and the adjustment taking effect, during which many copies are printed.
With Indigo presses there are fewer operating variables, and the optical density of the printed image can be electronically set by the operator within a wide operational range.

Once set, a proprietary closed loop mechanism, called Color Adjust, regulates and monitors the print density and the dot size in real time throughout the job run. Just as importantly, Color Adjust will remember the adjustments for repeat runs in future, meaning that a repeat job will be identical to the original – this is difficult to achieve with lithography which depends to a great extent on operator skill.

ElectroInk   Offset

Fig. 7: Dot shape - ElectroInk vs. Offset

3. Image gloss

Many people believe that the key to the quality of offset litho printing is its glossy appearance. This isn't quite true – what matters is the uniformity of the gloss. For instance, many magazines and company brochures have varnished front covers to give a high quality feel, but either gloss or matt varnishes may be used. The uniformity of the finish is the key issue rather than just its surface gloss.

ElectroInk gives a highly uniform finish complementing that of the underlying substrate – whether the substrate is a high gloss coated paper or a rough matt paper.

This characteristic is a very important feature of the Indigo process. It is very different from xerographic dry toner printers and copiers, which produce images having the same gloss irrespective of the paper they are printed on, and thus suffer from variable gloss levels between shadow areas (i.e. solid toner coverage) and highlight areas (with little or no toner coverage).

ElectroInk images match the gloss of the underlying printing substrate, from rough to dull to high gloss, just like conventional offset prints. Paper stocks have a typical surface roughness ranging from about 1 to 10 microns in height. The ElectroInk layer is only about one micron thick, and therefore it follows the 'hills and valleys' of the substrate surface texture, rather than filling them in. The result is that there are no large variations in gloss between the inked image areas and the bare paper substrate. (see fig. 8)

Even the finest xerographic color toner is limited to a particle size no lower than 7 to 9 microns, otherwise it is too fine to be controllable and forms a powder cloud or dust. Since powder toner particles are so large, they create thick images – which cannot replicate the surface roughness of the paper. Powder toner images therefore have their own unique gloss – which contrasts with the gloss of the paper. This gloss non-uniformity is perceived as poor quality printing.

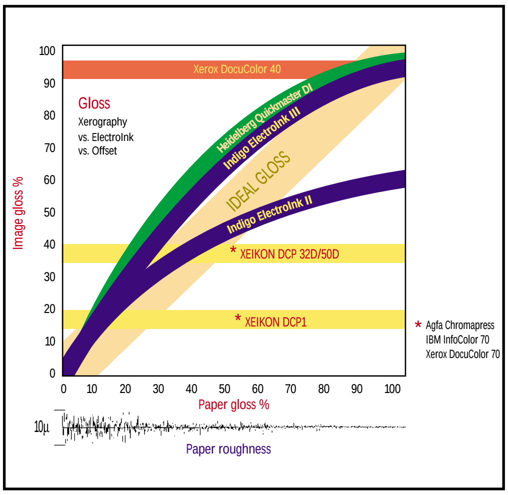


Fig. 8: Image gloss as a function of paper gloss

It is possible to plot the gloss characteristics of the various digital and lithographic processes on a graph which demonstrates that ElectroInk has practically ideal reflective characteristics, nearly matching the paper gloss for all but the very smoothest coated surfaces.
ElectroInk is superior to lithographic inks for medium gloss papers, but litho is marginally superior for ultra-glossy grades.
Xerographic toners plot as straight horizontal lines on the graph, indicating they have their own gloss no matter what the substrate.

4. Color space
ElectroInk can be used to print according to the main international color standards. These standards are all based on the four 'process' ink colors - cyan, magenta, yellow and black (CMYK).
Lithography uses different ink formulations for each standard, but ElectroInk uses one color set for all the standards and then meets their specific needs by electronically varying the thickness (and therefore color density) of the printed ink. This is a unique ability of ElectroInk, and is due to its specific formulation and the electrical nature of the ink.
In addition to printing in the four process colors, IndiChrome ElectroInk inks expand the color gamut beyond what can be achieved with CMYK alone. IndiChrome enables both 6-color process printing and spot color matching.

5. Instantaneous image drying
Because ElectroInk solidifies as soon as it transfers to the substrate, the finished print emerges dry from the Indigo printing press. Further image hardness is acquired in the first few hours post printing.
Indigo-printed material can withstand considerable handling activities immediately, unlike conventional offset lithography, not equipped with assisted drying, that requires a drying period of several hours before further processes, such as cutting or folding, can be performed.
Print drying is considered by GATF (The Graphic Arts Technical Foundation) as the number one problem of conventional lithographic printing, responsible for many image artifacts and defects, as well as print operation issues.
Conventional litho inks depend on a process known as 'oxidation drying' which mainly relies on absorption and evaporation of the solvent carrier. There are accelerated drying techniques available, usually involving heat or irradiation, but these require additional capital investment, use more energy and create hydrocarbon emission and corresponding pollution problems.
When heat is used it can also dry out the paper, driving out moisture. As the paper stack paper cools down, there is a danger that the edges will re-absorb water from the atmosphere and swell slightly. The middle of the stack, which is not exposed to the air, will not absorb water, so the edges will distort and take on a characteristic wavy formation causing problems at the finishing stage or if sheets have to be turned and printed on the reverse.
Another form of drying used with conventional offset lithography involves specially formulated photopolymer inks which solidify on exposure to ultra-violet lamps on the press. However, the UV inks are relatively expensive, and they are unpleasant to work with: un-solidified ink can often trigger allergic skin reactions for press operators, while the lamps generate ozone gas, another health hazard which has to be extracted and vented outside.
These problems contrast sharply with ElectroInk which solidifies on contact with the substrate without further treatment and is emission-free. Also because it has a relatively

low fusing temperature of about 100˚c - unlike the high temperatures in excess of 150˚c (300˚f) required for dry-powder xerography - the printing substrate is not heated, damaged or distorted.

6. Light fastness

The encapsulation of the pigment sub-particles within the ElectroInk plastic resin helps to preserve the chemical properties of the pigments against oxidation and relative humidity effects, especially under strong ultra-violet daylight conditions. This means that color durability of printed images, either in the form of fading or deepening, is superior compared to conventional offset printing.

Laboratory tests show that typical light fastness levels of ElectroInk images on a representative selection of substrates is 5 for Magenta, 5-7 for Cyan, 4-6 for Yellow and 4-6 for Black.

Substrate Compatibility

1. Variety

Indigo's Digital Offset Color process is compatible with a wider variety of substrate types, surfaces and thickness than any other digital printing process. These include paper, card stock, plastic, film and metals.

Only one formulation of ElectroInk is needed to print on any stock that the press can handle. This means that Indigo press users can rapidly switch between substrates without having to worry about changing inks.

Some surfaces need a simple treatment so that the image binds to the surface better, and can withstand subsequent handling and conversion processes. Indigo has developed surface treatments called Sapphire for paper substrates and Topaz for plastic films. These treatments are quite simple to apply.

With conventional offset printing, different inks for papers and non-absorbing plastic films are required – the latter usually need UV polymerizable inks. When printing on paper stocks with different absorbencies, it may be necessary to adjust the viscosity of the ink by means of thinning or thickening agents, or even use specially formulated inks.

Particularly absorbent papers can also increase offset ink consumption by up to about 50% which contrasts with ElectroInk where consumption has no dependence on the substrate properties.

Dry-powder xerography is heavily dependent upon the electrostatic properties of the paper substrate, and small changes in the environmental relative humidity may result in noticeable variations in print quality. The high fusing temperature needed for xerography puts serious limitations on the choice of coated paper stock or plastic films that can be printed.

2. Lamination and over-varnishing

Stock printed with ElectroInk is compatible with standard coating processes such as lamination or varnishing.

Lamination of thin plastic films over the printed stock can be done in the conventional way, using a variety of solvent-borne, water-based, UV-based or solvent-free adhesives.

A varnish coating, either UV or water-based, can also be used and ElectroInk plastic resin withstands a large variety of chemical solvents. No significant image degradation occurs when using most of the standard coating materials.