XEIKON PantherCure UV Inks
USE, PRODUCTION AND BENEFITS
Xeikon PantherCure UV Inks - Use, Production and Benefits
1 Xeikon Panther Series UV Inkjet Label Presses, a Guided Tour
   1.1 Xeikon Panther Series Printheads
   1.2 Xeikon PantherCure UV Inks
   1.3 Standard Corona, Extra Cleaning
   1.4 Screening on a Xeikon Panther Series Press
      1.4.1 Dionysos Screening Algorithm
      1.4.2 Xeikon Panther Fine Text Solution
   2 Inkjet Ink, How It is Made
   3 Xeikon PantherCure UV Inks, Strengths and Limitations
      3.1 Features and Benefits
         3.1.1 Unbeatable Durability
         3.1.2 Attractive Tactility and Uniform High Gloss
         3.1.3 Haptic Printing
         3.1.4 One-Pass Opaque White
         3.1.5 No SVHCs, Fully Compliant with RoHS, EuPIA and California Proposition 65
      3.2 Less Fit for Food
         3.2.1 The Issue
         3.2.2 What about Low-Migration Inks?
      3.3 UV Flexo and UV Inkjet: Worlds Apart
   4 Inkjet Technology, Our Expertise
About This Brochure

With a market share of 30%, inkjet is arguably less established than other digital imaging processes used for label printing. Providing a digital alternative to UV flexo and screen printing, it is a natural complement to electrophotography. While none of the production inkjet technologies offer resolutions and image qualities as high as those achieved by dry toner electrophotography, inkjet intrinsically enables faster printing. Moreover, UV inkjet in particular also has interesting esthetic and functional features: It produces an extremely smooth and high-gloss surface and enables the creation of 3D-textured effects. Not only is UV inkjet waterproof, it is also second to none when it comes to resistance to scuffing and scratching, soap, chemicals, and heat. It does not require contact between the printing head and the substrate. These properties explain why UV inkjet has gained a firm foothold in the health and beauty market and why it is the technology of choice for durable labels on household and industrial chemicals or for industrial labels on all sorts of tools and equipment. So, inkjet may be a relatively young technology, but its use in the label industry is increasing.

This brochure aims to provide you with a better insight into Xeikon PantherCure UV inks, their use, production and benefits.

The first section briefly describes the technology used in our Panther Series UV inkjet label presses. It also explains the reasons for the choices we made and how they will benefit you. The inkjet ink production process is outlined in section 2. In the third section you will find a discussion of the features and benefits of our PantherCure UV inks and of the limitations of inkjet inks and prints. And finally, in section 4, we will touch upon our expertise as a digital solutions provider.

We wish you pleasant and informative reading. Any questions? Just ask. We will be more than happy to help.
The inkjet printing process essentially comes down to a printhead ejecting droplets of ink of different colors directly onto the substrate to form the desired image. This sounds deceptively simple, but it requires the different components to work seamlessly together. And due to the nature of this technology, that is quite a challenge – a challenge the Panther Series has met successfully: It has been engineered to ensure a perfect matching of the printheads, the ink and its curing, the substrates and the screening algorithm and color profiles, enabling you to produce head-turning labels.

1.1 XEIKON PANTHER SERIES PRINTHEADS

All our Panther Series UV inkjet label presses are equipped with Kyocera printheads, piezoelectric drop-on-demand (DoD) printheads used in single-pass mode, offering the optimal combination of reliability, resolution, and print speed.

These grayscale printheads feature a native resolution of 600 dpi and an addressability of 600 x 600 dpi. Producing three different drop sizes of 3, 6 and 13 picoliters, or four gray levels, their effective resolution is 600 dpi x √4, or 1200 dpi (see Box 1). They have a maximum jetting frequency of 20 kHz at a maximum print speed of 50 m/min (164 ft/min). To guarantee constant print quality and uninterrupted printing, the heads are equipped with a temperature-controlled ink supply system and automatic cleaning and maintenance routines.

About Resolution, Addressability, and Gray Levels

Native Resolution
Resolution is a hardware specification that defines the number of discrete dots a printhead can print within a fixed area, expressed in dpi (dots per inch). Inkjet systems are characterized by their native or natural resolution, which is determined by the number of nozzles per inch in a printhead and, depending on the printhead architecture, the position of the nozzle rows relative to each other. Native resolution is sometimes expressed in npi (nozzles per inch), but mostly in dpi.

The higher the native resolution, the finer the details you can print. High native resolution also has its downside, however: The smaller the droplets, the lower their momentum, and the more likely they are to be deflected, so the more important it is to reduce the throw or jetting distance. But having a substrate pass closely to the printhead can also be an issue.

Addressability
Addressability refers to the number of dots that can be printed within a specific grid. These dots may or may not overlap.

Addressability is defined in two directions: (1) the direction perpendicular to the travel direction of the substrate and (2) the travel direction of the substrate. For inkjet systems, addressability in the direction perpendicular to the substrate’s feed direction is fixed, being determined by the number of nozzles, and is therefore equal to the native resolution. In the other direction, the number of dots can be higher. For single-pass inkjet systems, addressability is determined by the printhead’s jetting frequency, drop size and (maximum) substrate speed.
Bit Depth or Gray Levels

The bit depth determines the number of output levels or gray levels that can be printed.

Binary systems produce two gray levels. They print either “a dot” (ink is deposited) or “no dot” (no ink is deposited). Such systems are said to have a bit depth of 1 ($2^1=2$ gray levels, i.e. black or white). Systems with a bit depth of 4 bring the number of gray levels to $2^4=16$.

Inkjet systems generating a single size of drop are binary systems. Grayscale or multi-level printheads can generate ink drops of different sizes. The number of gray levels equals the number of different drop sizes the printhead can generate plus one (i.e. no drop). So, a printhead producing three different drop sizes, e.g. 3, 6, and 13 picoliters, can generate four gray levels.

**Perceived Resolution**

The big advantage of grayscale or multi-level printheads is that by varying the drop size, they achieve a higher perceived resolution than their native resolution. This perceived or effective resolution is calculated as follows:

$$\text{effective resolution} = \text{native resolution} \times \sqrt{\text{number of gray levels}}$$

Example: A printhead with a native resolution of 600 dpi and five gray levels has an effective resolution of 1341 dpi, whereas a printhead with a native resolution of 600 dpi and only two gray levels has an effective resolution of 848 dpi.

The higher the effective resolution, the higher the perceived image quality. However, what can and cannot be perceived ultimately depends on the sharpness or resolving power of the human eye, i.e. the ability to distinguish between separate dots. Figure 2 shows how this resolving power changes with the viewing distance. At normal reading distance, an effective resolution of more than 300 dpi suffices to create the illusion of a smooth image.

**Important**: Note that there is no substitute for native resolution when it comes to reproducing sharp details, such as small fonts or fine lines used in, for example, brand protection features.

1 picoliter = 10^-12 liters, i.e. one trillionth of a liter. Note that, in practice, high-speed single-pass inkjet presses mostly use only up to three different drop sizes, i.e. four gray levels, even if more sizes are available.
1.2 XEIKON PANTHERCURE UV INKS

Our Panther Series presses use PantherCure UV ink, pigment-based UV-curable inks, formulated and fine-tuned to make the most of the Kyocera printheads. These inks are available in the four process colors (cyan, magenta, yellow, black) and in white.

DuraCure

For the curing of the ink, we have developed a unique patented concept, Xeikon’s DuraCure technology. This unique curing technology takes the Xeikon Panther UV-inkjet series of digital presses to new levels of performance. Panther DuraCure curing technology is a unique technique achieving optimal gloss effects in all colours as well as ultimate durability for multiple applications across multiple sectors. Key benefits are consistent curing performance, long-term durability and the lowest possible energy consumption.

How the curing process works

Working with the Panther UV-Inkjet series of digital presses, the Panther DuraCure curing process works in a number of ways. UV ‘pinning’ of white keeps the ink from spreading and bleeding into the CMYK inks. This ensures the quality of the CMYK image is kept at the highest level: UV ‘pinning’ after the black following CMYK means DuraCure ‘freezes’ all colours across the image and maintains a uniform optimal colour brilliance and gloss. The use of LED curing with its ability to go deep into the ink layers combined with HG or mercury curing for lightly but effectively curing the surface of the UV ink offers the best of both worlds. The intelligent use of these existing technologies is what makes the difference. Combining them in an optimal way to use less energy has a positive impact on the lifetime of the curing lamps.

The combination of these curing steps results in the most durable, sustainable and effective curing solution on the market today.

Because the light bulb in the second curing step is not used at full nominal power, overall energy consumption is significantly reduced, and the operating lifetime of the light bulb extended. The system also generates less heat than a system with only a mercury vapor lamp, i.e. it can be used to cure a wide range of substrates, including heat-sensitive ones.

What About Pinning?

PantherCure UV inks are optimized for use without intermediate pinning. We only use pinning when laying a white foundation: A low-power LED UV source partially cures the white layer, which provides complete control over the four process colors in the layer printed on top of the white foundation.

Because PantherCure UV inks do not require intermediate pinning, your prints will shine with a uniform gloss, even when color densities vary, resulting in smooth images pleasing to the eye.

DuraCure technology makes use of different sources (LED and Mercury), active in different wavelengths.

The carefully selected combination of LED (long wavelengths) and mercury results in optimal curing, with the best possible visual quality (i.e. uniform gloss) for durable, longlasting labels.
UV-curable inkjet ink can be dye-based or pigment-based. Most UV-curable inks, however, are pigment-based because they are used in applications that require a high degree of lightfastness. Moreover, the UV light used for the curing could destroy the dye.

UV-curable inkjet ink is typically composed of:
- Pigments milled down below 300 nm (for white) and 150 nm (for colors), stabilized with dispersing agents to ensure good dispersion stability and a long shelf life;
- Carrier liquid, typically acrylate functions containing monomers, i.e. chemicals with a simple molecular structure that can combine with other similar molecules to form a polymer;
- A cocktail of photoinitiators (sometimes combined with synergists);
- Surfactants to control the static and dynamic surface tension of the inks, ensuring homogeneous drop formation (without the formation of satellites) and a good, fast and controlled wetting when the ink drop hits the substrate surface.
- Stabilizing agents that can capture any free radicals that might be generated when it is not wanted yet, ensuring no ink is polymerized before the UV light strikes and ensuring long shelf life. Their concentration should be well chosen to allow fast curing under UV light but prevent unwanted polymerization in the ink bottle.

Under the influence of UV light, the ink is cured (made dry), i.e. the photoinitiators capture the UV light and create free radicals. These free radicals will react with the acrylate functions of the monomer molecules to form a polymerized film (i.e. cured or dried) film. The ink is dried by crosslinking the liquid monomers to a solid polymer, there is no solvent evaporation.

UV-curable inks are not typical of inkjet; they are also used in offset and flexo printing. However, UV-curable inkjet inks do have six times lower viscosity than UV offset or UV flexo inks, which has several consequences for substrate interaction and migration (see pages 18 and 20). It also limits the choice of possible raw materials.
1.3 STANDARD CORONA, EXTRA CLEANING

Another crucial aspect determining the quality of your prints is the interaction of the ink with the substrate, more specifically adhesion and colorant penetration. How well does the printed image stick to the substrate and does the substrate absorb any of the colorant? Adhesion should obviously be maximized. Colorant penetration, however, must be minimized for several reasons: First, it has a negative impact on color depth, dot shape, and size. Second, it has an adverse impact on curing performance. And finally, it increases your costs, as you would need more ink to achieve the same color depth.

We therefore recommend using a primer and/or special corona-preconditioned UV inkjet label stock, as this will optimize the adhesion and your color gamut and make a world of difference to the color vibrancy, uniformity, and sharpness of your prints.

When printing on synthetic label stock, you will benefit from the corona, which is fitted as standard in all our Panther Series presses, enabling you to print on as wide a range of synthetic substrates as possible, without hassle.

Moreover, our UV inkjet presses include a cleaning roll to remove any dust particles that might otherwise block the nozzles or stick to the ink layer. The result: impeccable prints.

1.4 SCREENING ON A XEIKON PANTHER SERIES PRESS

1.4.1 Dionysos Screening Algorithm

The printheads in our Panther Series UV inkjet presses produce three different drop sizes, offering four gray levels. However, this is not enough to print continuous tone images, as the commonly accepted industry standard for high-quality reproduction of continuous tone images, offering sufficiently smooth gradations between any process color and white, is 256 gray levels (256 gray levels are indeed sufficient, as the human eye cannot distinguish more than 200 shades).

Xeikon inkjet presses therefore use the proprietary Dionysos screening algorithm, an FM screen, which has been specially developed to make the most of the presses’ 600 dpi printheads, producing images that are pleasing to the eye. The screening algorithm generates a bitmap instructing the printheads to produce one of three possible drop sizes, i.e. 3, 6, and 13 picoliters (see Box 2).
**Why Screening?**

**General Principles**

Inkjet systems, like most digital printing systems, cannot print continuous tone images, as they can only deposit dots with a limited number of gray levels (see Box 1). This is why for printing purposes, the RIP converts continuous tone images to a bitmap, i.e. a pattern of dots containing the right number of gray levels per process color. This re-sampled bitmap is printed.

The process used for this conversion is screening or halftoning, which basically transforms a continuous tone image into a series of halftone dots placed in a pattern. For a continuous tone color image, all colors are broken down into the four process colors (CMYK), after which the screening process is applied to each one. Screening relies on the limitations of the human eye, i.e. it cannot easily distinguish small dots that are closely spaced (see also Box 1). The goal is to find a dot size and pattern such that, at normal reading distance, the human eye is being tricked into seeing these dots as a continuous tone.

**AM versus FM Screening**

There are several different types of screening, but we will limit our discussion to two of them: Amplitude Modified (AM) screening and Frequency Modulated (FM) screening.

AM screening is the “conventional” halftoning process, which arranges dots of different sizes in a grid, i.e. lines of equidistant dots. These screens are characterized by their screen ruling or line frequency, i.e. the distance between the lines, which is measured in lines per inch (lpi). To prevent image distortion caused by interference between screens, the screens of the different colors are rotated over a certain angle relative to each other, which results in the typical rosette pattern. The size of the dots is varied according to the tonal values that need to be represented, hence the name “amplitude modified.” Smaller dots are used for the lighter tones, while larger overlapping ones represent darker areas.

An FM screen, or stochastic screen, uses dots of the same size and places them in a pseudo random pattern, which may vary from one type of FM screen to another. FM screens change the number of dots according to the desired tonal value, hence the name “frequency modulated.” Darker tones are represented with more dots, lighter tones with fewer dots. Depending on the type of FM screen, the shape of the dots may differ, and the halftone dots may be woven together in worm-like shapes.

**Inkjet Mostly Uses FM Screening**

When printing a halftone screen, the press will “build” each halftone dot of multiple device dots, the size of which is determined by the printhead’s resolution and gray levels (see Box 1).

AM screens are less suitable for inkjet printing systems. Because it is difficult to control the exact landing spot and size of an ink drop on the substrate (1 pt microtext cannot be printed), it is difficult to accurately build up the rigid geometric pattern of AM halftone dots using multiple ink drops, as these screen dots, by definition, should have a defined shape and size at a precise location in the grid. Also, the staggered nozzle arrays in the printhead may induce a pattern of their own, interfering with that of the AM screen. FM screens with their randomized halftone dots are much more forgiving.

*Note: At lower speeds, dot positioning accuracy can be better controlled, opening the way for AM screening. But these low speeds are not used for high-end label printing.*

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2 Truly random patterns might actually produce unwanted ones, so FM algorithms are specially developed to avoid this.
1.4.2 Xeikon Panther Fine Text Solution

Small fonts and fine lines used, for example, in brand protection features remain a challenge for inkjet presses: They may appear blurred, even with a native resolution of 600 dpi. This is due to the nature of inkjet technology: The diameter of the ink drop as it leaves the nozzle does not correspond to the diameter of the wetted surface of the dot generated by this ink drop. As the drop touches the substrate, it spreads, doubling or tripling in size. This spreading is influenced by the surface energy, the viscosity of the ink, the drop speed, and the absorption characteristics of the substrate. On a paper substrate, for example, a drop diameter of approximately 10 µm generated by a theoretical ink drop of 0.5 picoliters, at a resolution of 1200 dpi, becomes about 15-20 µm. However, no commercially available inkjet label press can jet drops as small as 0.5 picoliters. For UV-curable inkjet presses the smallest possible drop has a volume of 3 picoliters, which corresponds to a drop diameter of approximately 18 µm and a dot diameter on the substrate of 50-65 µm.

This issue is exacerbated by the nature of the RIP technology: The RIP converts an input design file to a bitmap with dots, which has to be screened before it can be printed (see above).

By RIP'ping at 1200 dpi and using our proprietary Dionysos screening algorithm, we have managed to resolve the issue of blurry fine lines.

The effect of the Xeikon Panther fine text solution

WITHOUT Xeikon Panther fine text solution

WITH Xeikon Panther fine text solution
Inkjet Ink
How It is Made

Flexo inks and inkjet inks differ mainly in their viscosity. In order to ensure reliable high-frequency jetting, inkjet inks must have a low viscosity, which for UV-curable inkjet inks is about six times lower than that of commonly used UV-curable flexo inks. Moreover, inkjet pigment particles should remain equally dispersed as the ink passes through the printhead, and never block any nozzles. How does this impact the ink manufacturing process?

Although the major manufacturing steps for flexo inks and inkjet inks are similar, there are also some important differences, which we will illustrate by focusing on the manufacturing process of pigment-based inks used in flexo and DoD inkjet systems (see 8).

### Step 1 - Dispersion

Creating stable pigment dispersion is arguably one of the most important steps in pigment-based ink production. The last thing you want to happen is the pigment particles settling to the bottom of the ink recipient, or worse, coagulating and blocking a nozzle.

### Preparing the mill base (pre-mixing)

The mill base is composed of pigments, dispersing and wetting agents, and carrier fluid. UV-curable inkjet inks use reactive monomers as a carrier, while the mill base of UV flexo inks contains a mixture of reactive monomers and oligomers. The wetting and dispersion agents are chosen carefully to ensure optimal interaction between the solid pigment particles and the carrier so as to achieve homogeneous and stable dispersion. The mill base is thoroughly mixed to ensure proper wetting of the pigment by the carrier before proceeding to the milling step.

### Milling

See Figure 8

The mixture prepared in the previous step is milled down to a homogeneous mixture. As the pigment particles for the different inks are roughly the same size, similar milling equipment is used. The big difference, however, is the milling time. Flexo inks are milled down to particle sizes smaller than 1 µm, but the presence of the occasional micron-sized particle is not a problem. Inkjet ink pigment particles, however, should all be smaller than 1 µm to prevent nozzle clogging. The milling process for inkjet inks therefore takes approximately three to five times as long as it does for flexo inks (and offset inks for that matter).
Step 2 – Finetuning and Mixing

The composition of the ink is finetuned and mixed. During this step extra monomers (types and functionality depending on the substrate) and photoinitiators (types depending on the curing system, print speed, etcetera) are added. The ingredients are measured out and mixed under controlled conditions to ensure the ink composition is identical from batch to batch.

Filtering

Filtering is a critical step in the production of inkjet inks, and a costly one at that. While the flexo printing process is quite forgiving when it comes to particle size distribution, inkjet printing is not. One oversized particle of barely a µm is enough to clog a nozzle. Filtration ensures the ink is absolutely free from any oversized particles.

Degassing

Some UV-curable inkjet inks are degassed before they are packaged. Entrapped air bubbles lower the compressibility of the ink. The pressure pulse generated in the ink chamber of a piezoelectric DoD inkjet system will then fail to eject the ink from the nozzle. While several solutions exist to remove dissolved air from the ink during the printing process, degassing as the penultimate production step helps to minimize entrapped air. However, these inks should not be completely degassed either, as some dissolved oxygen helps to maintain ink stability during transport and storage.

Step 3 – Packaging

The packaging process is similar for both types of ink. Flexo inks are packaged in buckets and containers whereas inkjet inks are stored in specially developed bottles. The packaging material should be compatible with the ink, especially if the ink is reactive. The anti-contamination and UV protection properties of the packaging ensure the inks maintain their quality throughout their shelf life.

CONCLUSION

Inkjet ink production requires extra steps and takes much longer than flexo ink production.

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4 1 micron = 1 µm = 10⁻⁶ m = 0.001 mm, 1 nm = 10⁻⁹ m = 10⁻⁶ mm, or 1 mm = 1,000 µm = 1,000,000 nm

5 1 µm is the general upper limit. Particle sizes depend on printhead architecture, native resolution, and color.
Our PantherCure UV inks are tweaked and fine-tuned to ensure our presses perform their very best, delivering prints that will make your print buyers come back time and again. These inks offer plenty of esthetic and functional features and benefits, making them suitable for a whole host of label applications in health and beauty, chemicals, and the durables industry. But, in all fairness, while UV-curable inkjet inks have a lot of benefits, they also have limitations in food applications.

### 3.1 FEATURES AND BENEFITS

#### 3.1.1 Unbeatable Durability

**Scratch and Scuff Resistance**

The lower the surface energy of a material, the higher its scratch and scuff resistance. Layers of well-cured UV-curable inkjet ink generally have a low surface energy, which is why UV-curable inkjet prints score better than any other digital prints, and PantherCure UV prints are no exception.

To evaluate the hardness of a coating or ink layer, the industry often makes use of Pencil Hardness measurements (sometimes referred to as the Wolff-Wilborn test) in order to determine the scratch hardness of a particular layer. This test makes use of the different hardness values of graphite pencils to evaluate a layer’s hardness.

Pencils of different hardness values are pushed into the sample and the coating hardness is identified by the trace generated. The value scale ranges from 6B – the softest – to 9H – the hardest. The value indicates the hardest pencil that does not scratch the surface. Typically films such as polyester and polycarbonate fall in the range of B to 4H.

Scratch and Scuff resistance also relies on good adhesion of the ink. Table below illustrates adhesion of PantherCure UV inks on different substrates.

<table>
<thead>
<tr>
<th>Xeikon PantherCure performance</th>
<th>Pencil hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PantherCure UV ink</td>
<td>HB</td>
</tr>
<tr>
<td>HB</td>
<td></td>
</tr>
<tr>
<td>HB</td>
<td></td>
</tr>
<tr>
<td>HB</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Xeikon PantherCure performance</th>
<th>Adhesion on</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xylocron Butadiene Styrene</td>
<td>Very good</td>
<td></td>
</tr>
<tr>
<td>Poly Carbonate</td>
<td>Very good</td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>Very good</td>
<td></td>
</tr>
<tr>
<td>PET, PE, PP (1)</td>
<td>Very good</td>
<td></td>
</tr>
</tbody>
</table>

**Pencil hardness scale**

<table>
<thead>
<tr>
<th>6B 5B 4B 3B 2B B HB F H 2H 3H 4H 5H 6H 7H 8H 9H</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFTER</td>
</tr>
<tr>
<td>HARDER</td>
</tr>
</tbody>
</table>

(1) Tests on PET, PE and PP performed on treated surface
Lifelong Legibility

Due to the choice of very specific high-performance pigments, PantherCure UV inks score remarkably well in terms of lightfastness. Lightfastness is a measure of how well a printed image resists discoloration or fading as a result of exposure to light over time. It is typically determined using the Blue Wool Scale, which measures the colorfastness to natural daylight of a color by comparing it against a blue wool standard, hence the name. Originally developed to compare the fastness properties of textile dyes, it is expressed on a scale of 1-8, where 1 is the lowest value. A rating of 6 means “very good lightfastness”. Several independent tests have shown that all current Xeikon PantherCure UV process colors meet or exceed rating 6. Your prints will remain their vibrant selves for a very long time indeed.

<table>
<thead>
<tr>
<th>Xeikon PantherCure Performance</th>
<th>Indicative Explanation of Blue Wool Scale Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>PantherCure UV ink</td>
<td>Blue Wool Scale</td>
</tr>
<tr>
<td>8</td>
<td>8 hours</td>
</tr>
<tr>
<td>6</td>
<td>20 hours</td>
</tr>
<tr>
<td>6</td>
<td>40 hours</td>
</tr>
<tr>
<td>6</td>
<td>80 hours</td>
</tr>
<tr>
<td>8</td>
<td>160 hours</td>
</tr>
</tbody>
</table>

Measured on White PVC substrate (Metamark MD5) Xenon Test Chamber, dry conditions, black panel temperature 63°C (condition estimated as 1 year under fluorescent light)

Heat, Water and Chemical Resistance

UV-curable inkjet inks are heat-resistant: The polymers formed after complete curing of the ink have a high melting point. Labels printed with PantherCure UV inks can withstand high temperatures without breaking a sweat. The ink will not melt, and your labels will not become sticky.

UV-curable inkjet prints are also notoriously water-resistant because water has no chemical affinity for the cured ink film. So, you can leave your PantherCure UV prints in the shower, safe in the knowledge that all the colors will stay put.

And finally, cross-linked systems, like UV-curable inkjet inks, are generally quite resistant to chemicals. With PantherCure UV ink, there is no risk of any crucial safety information becoming illegible due to spills.

<table>
<thead>
<tr>
<th>Xeikon PantherCure Performance</th>
<th>Chemical resistance against</th>
</tr>
</thead>
<tbody>
<tr>
<td>PantherCure UV ink</td>
<td>UV offset</td>
</tr>
<tr>
<td>Ethanol</td>
<td>3</td>
</tr>
<tr>
<td>Acid</td>
<td>5</td>
</tr>
<tr>
<td>Alkali</td>
<td>5</td>
</tr>
<tr>
<td>MEK (methyleneiketon)</td>
<td>3</td>
</tr>
<tr>
<td>Salt solution</td>
<td>5</td>
</tr>
<tr>
<td>Liquid soap</td>
<td>5</td>
</tr>
<tr>
<td>Oil</td>
<td>5</td>
</tr>
</tbody>
</table>

Ink has been coated on PET-film with 6micron bar coater, printed samples were rubbed 10 times with cotton-tipped buds. Result shows visual judgment where 1 means poor result, 5 is excellent.

Lightfastness

Due to the choice of very specific high-performance pigments, PantherCure UV inks score remarkably well in terms of lightfastness. Lightfastness is a measure of how well a printed image resists discoloration or fading as a result of exposure to light over time. It is typically determined using the Blue Wool Scale, which measures the colorfastness to natural daylight of a color by comparing it against a blue wool standard, hence the name. Originally developed to compare the fastness properties of textile dyes, it is expressed on a scale of 1-8, where 1 is the lowest value. A rating of 6 means “very good lightfastness”. Several independent tests have shown that all current Xeikon PantherCure UV process colors meet or exceed rating 6. Your prints will remain their vibrant selves for a very long time indeed.

<table>
<thead>
<tr>
<th>Indicative Explanation of Blue Wool Scale Values</th>
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<tbody>
<tr>
<td>Blue Wool Scale rating</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
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<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

Measured on White PVC substrate (Metamark MD5) Xenon Test Chamber, dry conditions, black panel temperature 63°C (condition estimated as 1 year under fluorescent light)
3.1.2 Attractive Tactility and Uniform High Gloss

UV-curable inkjet ink produces a single full density layer with an average thickness of 6 µm, offering medium to high texture. Also, the viscosity of UV-curable inkjet ink is such that the ink flows spontaneously, creating an extremely smooth surface with a high gloss. With our PantherCure UV inks you can achieve highly tactile, 3D-textured effect prints. Moreover, because our inks do not require intermediate pinning, and thanks to our unique curing process, your prints will shine with an extremely uniform high gloss that makes solid colors pop.

3.1.3 Haptic Printing

Making use of the 3D-textured effect, the high tactility that can be achieved with PantherCure UV inks, Xeikon developed a specific solution for printers looking to enhance and increase their range of labels. Recent research showed that consumers are more likely to touch a product when it attracts visual attention, and if they touch the product, they are even more likely to purchase it. Adding tactile elements to a product’s packaging will definitely contribute to the overall brand image of a product.

It is the unique combination of the Xeikon X-800 workflow and the PantherCure UV ink that can generate a tactile layer, responsible for a so called “haptic effect” in print. (Some would refer to 2.5D printing as an application that bridges the gap between 2D and 3D printing.)

Printers can easily create designer labels with enhanced tactility, textures and a luxury feel. By generating a double white PantherCure UV inkjet layer, the haptic printing process not only boosts and expands the range of possible applications for high-end label markets, it helps make significant time savings by avoiding any modifications to the prepress files. The haptic design (structure’s shape and form) is created by the designer and stored as separate layer within the pdf file, on the X-800 this layer will be ripped separately and sent to the White station on the Panther. While printing, the software will make sure that the white layer (and thus all patterns / effects that are within the design of the white layer) is printed twice by the white inkjet head, resulting in a thick – tactile – white ink layer. Thickness of the tactile layer is between 12 and 15 micron.
3.1.4 One-Pass Opaque White

A white foundation is typically applied to achieve that much sought after “no label look” with transparent substrates, or to prevent the metallic surface shining through the print when using metallized labels. The more opaque the white layer, the better it masks the color of the underlying surface. Inkjet technology is at a disadvantage when it comes to producing highly opaque colors. For UV-curable inks used in single-pass high-frequency jetting systems, like the Panther Series, the pigment particle size should be small enough to prevent nozzle clogging. The smaller the pigment size, the less opaque the ink. Also, the required viscosity of the inks does limit the maximum possible pigment concentration. The lower the concentration, the less opaque the ink. Nevertheless, when printing at the maximum print speed of 50 m/min (164 ft/min), our PantherCure UV white ink achieves an opacity that is more than adequate for most applications (basic white). Printing in “high white mode”, i.e. at half the maximum speed, yields a superior opacity, with one layer only, in one pass.

<table>
<thead>
<tr>
<th>PantherCure White ink</th>
<th>Optical Density</th>
<th>Y</th>
<th>L*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Jet Mode (basic white)</td>
<td>0.16</td>
<td>69</td>
<td>87</td>
</tr>
<tr>
<td>Double Jet Mode (high white)</td>
<td>0.09</td>
<td>81</td>
<td>92</td>
</tr>
</tbody>
</table>

Indicative Explanation of the opacity values

| Optical Density | The opacity of an ink layer represents the amount of light that is incident on the layer divided by the amount of light that is transmitted. In print optical density (OD) is often used to present opacity, where OD represents opacity expressed as a logarithm to base 10. |
| Y reflective method | A spectrometer is used to measure the amount of light reflected, resulting in the Y reflective value. The opacity of the white patch is calculated as follows: Opacity (%) = (Y black / Y white) x 100 |
| L* method | A spectrometer is used to measure the L* values, quantifying the lightness of a patch. The opacity of the white patch is calculated as follows: Opacity (%) = (L* black / L* white) x 100 |

3.1.5 No SVHCs, Fully Compliant with RoHS, EuPIA and California Proposition 65

PantherCure UV inks are fully REACH compliant, i.e. all the raw materials are registered, and no substances are used that are subject to authorization or restriction. More importantly, they contain no substances mentioned in the Candidate List of Substances of Very High Concern (SVHC). This list is updated twice a year, and we closely monitor the preparatory work on these updates so that we can anticipate any changes and evaluate their impact on our ink formulations.

PantherCure UV inks are also fully compliant with the European RoHS Directive and several other similar regulations, such as the Chinese RoHS, on the use of the heavy metals cadmium, lead, mercury, and hexavalent chromium and the presence of other hazardous substances, such as polybrominated biphenyls (PBBs), diphenyl ethers (PBDEs), chlorine and bromine levels, and several phthalates.

PantherCure UV inks are fully compliant with the EuPIA Exclusion policy for printing inks and are fully compliant with California Proposition 65.

Certain countries may apply other import restrictions for specific ink components, in which case we will make the necessary applications.

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6 REACH stands for Registration, Evaluation, Authorization, and Restriction of Chemicals and is a regulation of the European Union, requiring all substances produced or imported in Europe to be registered with the European Chemicals Agency (ECHA). Together with ECHA’s scientific committees, authorities assess whether the risks of substances can be managed. They can ban hazardous substances if their risks are unmanageable. They can also decide to restrict use or make it subject to prior authorization.

7 SVHC are substances that may have serious and often irreversible effects on human health and the environment. If a substance is identified as an SVHC, it will be added to the Candidate List for possible inclusion in the Authorization List. In terms of REACH compliance, SVHC refers specifically to those substances that meet the hazard categories mentioned and that have been placed by the European Commission on the Candidate List of substances considered for authorization.

8 The most recent version of the Candidate List can be found at https://echa.europa.eu/candidate-list-table

3.2 LESS FIT FOR FOOD

While inkjet, particularly UV inkjet, is gaining traction in the label industry, we do not recommend using it for food packaging applications. At Xeikon we know that, as far as migration – the transfer of substances from the packaging to the food – is concerned, dry toner electrophotography has a great advantage over all other digital printing technologies. This is why we advise you to opt for one of our range of dry toner presses for your food packaging applications. What exactly is the issue with UV inkjet, and why are low-migration inks no silver bullet?

3.2.1 The Issue

Migration
Substances used in printing inks can contaminate the food inside the packaging, even without direct contact. The transfer of these ink components or “migrants” from the printed layer can occur via (1) penetration of the migrants through certain packaging material, (2) set-off transfer to the reverse packaging side, (3) gas-phase migration, and (4) condensation extraction.

Figure 10

Migration depends on several factors, one of the most important being the size of the migrating molecule: The smaller or lighter the molecule, the higher its mobility, and therefore the higher its tendency to migrate/evaporate.

Penetration migration:
Penetration of migrants through the substrate to the reverse side of the print.

Set-off migration:
The unintentional transfer of ink components from the outer printed surface to the food contact surface on a reel, in a stack or during storage (e.g. stack of printed paper cups, boards or folding cartons). This type of migration is less of an issue for self-adhesive labels.

Gas-phase migration:
Migration due to evaporation of volatile components under room temperature conditions or during heating (e.g. when microwaving, cooking, or boiling products in their packaging).
UV-Curable Inkjet versus UV Flexo and UV Offset

In contrast to UV flexo and UV offset inks, it is impossible to formulate UV-curable inkjet inks in such a way that they too are food-compliant. To ensure sufficiently low viscosity, the molecules used in UV-curable inkjet inks are much smaller than those in UV flexo and UV offset inks, for which low viscosity is not a requirement. Moreover, there are several reasons why it is almost impossible to guarantee 100% curing: The UV not reaching all the photoinitiator molecules because the layer is too thick; the pigments absorbing UV light, which interferes with curing; older lamps producing insufficient UV light; oxygen inhibition, etcetera. Also, radical and non-radical chemical polymerization reactions are very difficult to carry to completion: As the molecules grow, their mobility decreases. As a result, the reaction slows down to the point where the mobility of the molecules is insufficient for them to cross-link, despite there still being unreacted monomers and radicals left. As a result of all this, there are potential migrants present: Unreacted monomers, excess photoinitiator, and photoinitiator fragments. When printing on a porous substrate, the problem is exacerbated: The molecules absorbed by the substrate cannot be cured, as the UV light cannot penetrate deep enough.

Functional Barriers

But surely you can apply a functional barrier? Yes and no. While such barriers can, in some cases, reduce the issue of penetration migration and, where appropriate, gas-phase and condensation migration, the smell of the uncured ink remains the same. Moreover, contamination due to set-off migration can still occur, even in the presence of a functional or near-perfect barrier. Note that European legislation stipulates that packaging should never alter the composition, smell or odor of the food.

Migration Limits

How much migration is acceptable? There is no international standard that regulates migration limits, nor are there uniform regulations on printing inks. Countries worldwide have their own regulations.

With a view to limiting the risk, legislators have defined migration thresholds or limits. Based on toxicological evaluations, the EU authorities, for instance, have compiled positive lists of “evaluated substances” that are part of the existing packaging regulations. These lists provide acceptable migration thresholds for individual substances, i.e. specific migration limits (SMLs). The SML is the maximum permitted amount of a given substance that can be released from a material (packaging material and/or printed layer) into food. In the EU, printing inks as such are generally not explicitly regulated, but many evaluated substances are used in printing inks and therefore must comply with the SML determined by the EU. Non-evaluated substances for which no toxicological data are available should not be detectable. A generally accepted definition of “detectable” is “below 10 parts per billion”.

Switzerland is one of the few countries that have issued specific restrictions on the components used in inks for food packaging applications. The Swiss Ordinance on Materials and Articles in Contact with Food explicitly imposes thresholds for substances in food packaging inks. Annex 10 of the Ordinance includes a list of permitted substances that have been toxicologically evaluated and for which an SML has been established (part A), as well as permitted but non-evaluated substances for which the default SML has been set at 10 ppb (part B). This Ordinance has gained international recognition.

As a rule, you should demonstrate through migration testing that your application complies with the relevant requirements: For any of the substances present, the statutory SML must not be exceeded, nor must the overall migration limit (OML), which is the maximum permitted quantity of non-volatile substances, i.e. the sum of all the substances that can migrate to the food. In the EU, the OML is set at 10 mg/dm² of food contact material. In the US, FDA regulations apply.

Note: All ingredients in Xeikon PantherCure UV inks are mentioned in the Swiss Ordinance on Printing Inks. This ink formulation is a deliberate choice to ensure our Panther technology is ready to be used in food applications as soon as curing technology can be improved or further optimized, e.g. by the use of nitrogen (see further).
3.2.2 What about Low-Migration Inks?

Several inkjet inks are being marketed as low-migration inks. In principle, low-migration inks have been specifically formulated and tested for use in food packaging printing. They are made from materials that, under normal or foreseeable conditions, and when correctly used in the application in question (including very stringent control and evaluation of curing conditions), do not migrate into the food or beverage product at levels above the currently accepted limits when printed on a limited set of substrates. After all, low-migration inks on thin PE or paper substrates will still pose a risk of components migrating through the substrate. However, different ink manufacturers may use different definitions and it is worth reading the small print.

There are essentially three strategies to achieve as low a migration risk as possible:

1. Elimination of all the factors that interfere with curing e.g. removing any oxygen by degassing the ink prior to use and by applying nitrogen or other inert gas in the curing area. As explained above, however, 100% curing can never be achieved, even in optimized conditions. There is always a risk of migration.

2. Intelligent ink formulation by including molecules with multiple reactive groups to reduce the risk of there being unreacted monomers left after curing. Unfortunately, most of these molecules increase the viscosity of the ink, which makes them unsuitable for use in high-frequency jetting systems. So far, only one molecule has proved fit for purpose: VEEA, or 2-vinylxyloxyethoxyethylacrylate, which features two reactive groups and low viscosity. A lot of the UV-curable inks for high-speed single-pass inkjet printing use this component, as do Xeikon PantherCure UV inks.

3. Polymeric photoinitiators to prevent migration of individual photoinitiator fragments. These heigh molecular weight components increase the viscosity significantly at low amounts and are hence a complex and expensive option.

Important: Following any of these strategies is, however, not sufficient for the ink to qualify as a low-migration ink. As explained above: You will always have to demonstrate compliance of the application by conducting migration tests. Also, you will have to ensure that the level of quality of the curing is sufficient and remains constant during production.

Are low-migration inks the future for inkjet in food packaging applications? Water-based inkjet inks, particularly latex inks 13, offer interesting prospects. UV-curable latex systems 14 do not contain small molecules, which is a plus, but they do contain photoinitiators, fragments of which could migrate. EB-curable 15 latex inks would probably be the better option, especially since they do not contain any photoinitiators and the penetration depth of the radical-generating electrons is greater than that of UV light, ensuring a more thorough curing on absorbing substrates. However, these inks will never outperform dry toner when it comes to food safety. So, for food applications, dry toner is the option of choice.
### 3.3 Flexo and UV Inkjet: Worlds Apart

<table>
<thead>
<tr>
<th>Property</th>
<th>Inkjet</th>
<th>Flexo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity</td>
<td>Low (needed for jetting)</td>
<td>high</td>
</tr>
<tr>
<td>Molecular weight of ingredients (carrier liquid, monomers, photoinitiators, …)</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Reactive functionality in one molecule</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Pigment concentration</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Layer thickness/material usage for same optical density</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Use for food packaging on absorbing substrates</td>
<td>Not recommended if part of the ink cannot be cured by light because of quick absorption</td>
<td>More critical compared to film, but less absorption due to higher viscosity of ink and fast printing speed</td>
</tr>
<tr>
<td>Use for food packaging on filmic substrates</td>
<td>Not recommended if too high amount of low molecular weight compounds present after curing</td>
<td>OK if curing conditions are very well maintained and checked</td>
</tr>
</tbody>
</table>
Inkjet Technology
Our Expertise

Our roots are in dry toner electrophotography, with expertise stretching back 30 years. In the last few years, however, we have also invested in inkjet technology, as we are convinced that there is no one-size-fits-all solution for digital label production, or for digital print production in general for that matter. Today, our R&D focus and efforts are equally divided between dry toner electrophotography and inkjet, with two separate competence centers set up.

Dry toner electrophotography or inkjet? The technology that fits best depends on the application. Wine labels do not necessarily have to be chemical-resistant, whereas for industrial and health & beauty labels it is a must. Pharmaceutical labels require extra fine print and food labels should be food-safe.

Figure 11  Comparing digital label printing technologies

As each technology has its own merits, you should ideally combine several, or all of them, in order to be able to make the most of their respective advantages and features. The good news is: As a digital solutions provider, we can advise you on the best technology for each application, but we can also provide you with industry-leading solutions in both dry toner and UV inkjet. And even better, we have developed a digital front-end that can control different press technologies, supporting customized and integrated workflows, thereby offering you a fully integrated production set-up.
Aiming to provide you with the best solution for your applications, we also want you to get the best possible performance from our inkjet presses.

Our Inkjet Competence Center therefore focuses on all the different aspects of inkjet technology. For example, we do research into pigment dispersion and evaluate UV-curable as well as water-based inks. We also study the behavior of inks in the printheads, i.e. the impact of various formulations on the wave form, open time, drop formation, the stability of the jetting process, as well as the interaction of the ink droplets with the substrate, curing, drying, etcetera. And finally, we work on digital primer and varnish solutions.

To ensure we keep abreast of the latest developments and emerging technologies, and to stimulate knowledge creation and innovation, we have invested in a team of highly-skilled researchers and engineers, supported by state-of-the-art equipment.
Xeikon is an innovator in digital printing technology. The company designs, develops and delivers web-fed digital color presses for label and packaging applications, document printing, as well as commercial printing. These presses utilize LED-array-based dry toner electrophotography, open workflow software and application-specific toners. Xeikon also manufactures basysPrint computer-to-plate (CtP) solutions for the commercial printing market. These proven CtP systems combine the latest exposure techniques with cost-efficient UV plate technology, high imaging quality and flexibility. For the flexographic market, Xeikon offers digital platemaking systems under the ThermoFlexX brand name. ThermoFlexX systems provide high resolution plate exposure including screening, color management, as well as workflow management. All the Xeikon solutions are designed with the overarching principles of profitability, quality, flexibility and sustainability in mind. With these guiding principles and a deep, intimate knowledge of its customers, Xeikon continues to be one of the industry’s leading innovators of products and solutions.

For more information, visit www.xeikon.com