Navigating the Digital Ink Jungle

With a traditional contact print technology, such as screen printing, the available ink options are pretty well understood by print providers, with solvent and UV curing inks dominating. Yes, new versions of screen inks appear regularly on the market as chemistry and manufacturing techniques improve but the applications for these inks are fairly well defined. With a relatively new and developing technology such as inkjet printing, however, the opposite is often true. It seems like everyday a new inkjet printer is launched along with a new type of ink. As with any rapidly growing business, the marketers go into overdrive, and invent products and brand names that are at best overkill and, at the worst, misleading. This has left many a print maker who is transitioning to digital in a state of confusion.

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To look at the various inkjet ink options available to graphics producers and to understand their uses, we must first understand a little about inkjet technology.

Basic Inkjet Theory

In all inkjet printers, the component that applies the ink to the media is known as the print head. In graphics inkjet printing, the print head technologies that are most commonly used are piezo and thermal inkjet (often referred to as 'bubble jet' or 'TIJ'). Both of these print-head types have arrays of very small holes (known as jets) from which droplets of ink are ejected. The size of these jets varies from manufacturer to manufacturer but most are smaller in diameter than a human hair, and the number of jets can be in the hundreds.

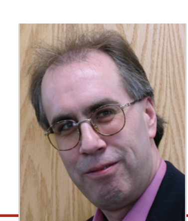
With piezo print heads, ink droplets are ejected by pulsing piezo crystals behind the print-head jets.

With thermal inkjet heads, small heating elements are used to create gas bubbles in the ink that expand to eject drops from the jets.

Both technologies are very fast with each jet capable of producing tens of thousands of droplets per second. The print heads are usually mounted on a head carriage and passed backward and forward across the media to produce an image. The number of print heads depends on how many individual colors are being used in the ink setup. Print heads are also often ganged together to increase the number of jets — the more jets, the faster the print speed.

In graphics printing, and particularly the outdoor grand format market, piezo has come to dominate due to the fact that it can work with many different ink types. Thermal inkjet is normally limited to running water-based inks.

One of the commonly held myths about inkjet is that the inks are pumped through the jets. The opposite is actually true as all print heads require a slightly negative pressure on the inks to operate efficiently. The action of firing a



By **Tony Martin**, President, Lyson Inc.

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drop from the jet simply pulls more ink into the print head from the ink supply. Many inkjet printers do have pumps in them but these are used to either transport inks from the main ink tanks to a head reservoir, or for head cleaning purposes.

Most of the inks used in graphics inkjet printing dry by evaporation, with the exception of UV curing ink. In easy-to-understand terms, an inkjet ink formulation that dries by evaporation consists mainly of a fluid that is simply there to keep the ink in a liquid state and act as a ‘carrier’ for the colorant (Figure 1). This carrier fluid evaporates as the ink dries and leaves the colorant in or on the surface of the media. When an ink is referred to as something “based” as in “water-based” or “solvent-based” then the carrier fluid is what is normally being described. The colorant is either dye or pigment, or a combination of both. Often, a second carrier fluid (or co-solvent) is used mainly to control the drying time of the ink. The presence of a second carrier fluid also controls the viscosity of the ink during manufacture. Small amounts of several other additives are present in most inks. These control or help with things such as adhesion of the ink to the media, dot gain, drop formation, corrosion of the print head, pH level, fade resistance and color brilliance. In simple terms, however, we can think of an ink as being a carrier fluid and a colorant.

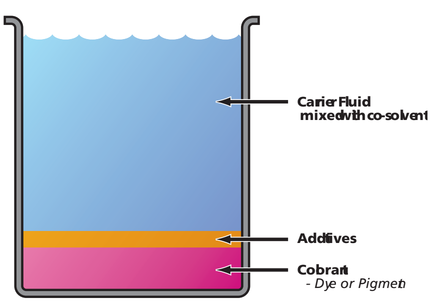

Figure 1:

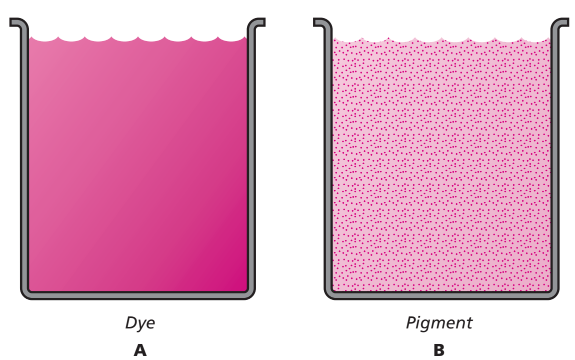

Figure 2:

The difference between a dye and a pigment can be explained pretty easily also. A dye is a colorant that is dissolved fully into the carrier fluid and the resultant ink is a true solution (Figure 2a). Once dissolved into the carrier fluid, a dye should never separate or settle out, unless you have poorly made ink, of course! An analogy for a dye ink is when you dilute a concentrated juice drink with water and, once stirred, it never separates again no matter how long you leave it. A pigment on the other hand is a very fine powder of solid colorant particles that are suspended or dispersed through out the carrier fluid (Figure 2b). A crude analogy for a pigment ink is a sandy-colored river or sea water: if you look closely, you can see sand particles dispersed throughout the water. The secret in making a good pigment ink is to keep the pigment suspended in the carrier fluid for a long period of time, particularly at the low viscosities required for inkjet printers. Pigments have a natural tendency to settle out much as sandy water, where the sand will fall to the bed once the water has stopped being agitated. In a well-made pigment ink, little or no settling out of the pigment should occur. Unless directed so by the manufacturer, it is not a good idea to shake an ink bottle or cartridge before use. Shaking can introduce air bubbles into the ink or re-disperse large lumps of settled out pigment, which in turn can lead to blocked jets.

The main difference between an inkjet ink and a screen printing ink is the viscosity. Inkjet inks have to be very thin to operate successfully in most print heads and are sometimes only three or four times thicker than water. Screen inks, on the other hand, are more like a paste. The real challenge facing ink chemists is to develop inkjet inks that have the same performance as screen inks but at a much lower viscosity.

The Golden Rule of Inkjet

The golden rule of inkjet is:

When any inkjet ink dries by evaporation then the dried ink must be able to be re-dissolved by the liquid form of the same ink.

Sounds pretty simple, however, this rule is vitally important if an inkjet printer is to function reliably.

Most photo quality inkjet devices use print heads that have hundreds of jets, and liquid ink is always present at the orifice of these jets. It doesn’t take a genius to realize if you use an ink that dries by evaporation, there is a very good chance the ink will dry up and clog these jets. The challenge that always faces the printer designer and the ink and media developer is to make a machine that has fast-drying output yet doesn’t clog.

The easiest way to remove a clog of dried ink from the single jet on a print head (Figure 3) is to use liquid ink to re-dissolve the dried ink. A separate washing system that bathes the head in an “ink-dissolving” solution adds considerably to the complexity of the printer. It is simpler to stick to the golden rule and depend on the ink to unclog itself.

One commonly held misconception is that when a jet or jets clog (evidenced by lines or banding in the print) then the cause is an impurity or lump in the ink. In 99.9 percent of the cases, a clogged jet is caused by dried ink or by an air bubble in the ink. Air in the channel behind the jet on a print head is a sure way of stopping the jet from firing correctly. Air in the channel acts like a shock absorber to the firing action.

Another common untruth is that pigment inks clog jets worse than dye-based inks. The perception is that, because pigment inks contain solid particles, these little particles can somehow gang up to form a blockage of the jet. When you consider that an average pigment particle size is under 0.1 micron and the common jet sizes today are between 20 –25 microns, it would take several hundred of the little devils to join together and block the jet! Only a pigment ink that is poorly made or formulated could block the jet.

Water-Based Inks

The first wide-format graphics inkjet printers from companies such as Encad (now Kodak) and Hewlett Packard were all based on thermal inkjet technology and used water-based inks. Early inks all used dyes as a colorant but water-based pigment inks were quite quickly developed to address the signage market.

Today, there are literally dozens of water-based wide-format printer models from several manufacturers using both piezo and thermal print heads. Water-based inkjet printers are the most commonly used machine types in graphics printing. Water based printers are, however, generally limited to producing prints for indoor display. Yes, outdoor graphics can be produced using special media or by applying a protective laminate, but these methods tend to add considerably to the finished cost of the print. The reasons for this are pretty obvious if we consider the golden rule. It is pretty difficult to make a water-based ink that can be re-dissolved by itself and yet make the finished print water proof.

Hence, water-based inks are usually printed onto coated media for outdoor use. The coating encapsulates the inks to protect the colorant from water. Even so, these media are usually only for short-term outdoor use and so lamination is required for long-term protection. In the inkjet industry, a great deal of development work is going on at the moment to try to make water-based inks water proof and capable of being printed onto uncoated media and cured by some method after printing. These ideas are in their infancy. For now, it is best to say that water-based inks are best used on coated media.

A major debate over the years has been the *dye vs. pigment* argument with water-based inks. The recent increase in the use of pigment inks in photo quality inkjet printers — and the marketing frenzy that has continued since their introduction by some printer manufacturers — has left the average inkjet user somewhat confused and, in many cases, frankly disappointed. There are two commonly held misconceptions about the dye vs. pigment argument. First, pigment inks are always more light stable than dye-based inks. Second, pigments now match dyes in terms of color quality.

It is true to say generally pigments are more fade resistant than dyes, particularly for outdoor exposure where the intensity and type of light is very different from artificial illumination. For indoor display, however, the gap is closer than you might imagine. All reputable ink makers conduct extensive internal fade testing of their products and there are several third party testing institutes that can be hired to predict an image's useful display life. One of the most well known and respected test centers, Wilhelm Imaging Research, conducts accelerated indoor display life testing on many different inkjet ink/media combinations. They have published results that show some dye-based products last as long as an estimated 120 years while the leading pigment-based ink set on certain media lasts only 34 years. These facts are always conveniently ignored by the marketing giants of our industry.

It is also worth noting that a lot of the top-end fine art reproduction houses use Iris inkjet printers to produce gicleé prints renowned for their longevity. All Iris printers use dye-based inks.

The reason why dye-based inks tend to produce more brilliant color than pigment inks can be explained in Figure 4. The way we see colors of a printed image is by the light reflected off the surface of the print. The particles in a dried pigment ink have a very rough surface, so the light reflected off the print tends to scatter in all directions (Figure 4a). A dried dye ink has a smoother surface, so it reflects the light back more uniformly (Figure 4b).

The latest pigment preparation technology has improved color quality by grinding the particles to the smallest possible size and by using resins to coat the particles, which smoothes out their rough surface. One major printer manufacturer produces marketing material that implies their pigment inks contain particles that are perfect round little spheres. I can assure you that these particles still look like a load of little uneven meteorites when viewed under a powerful microscope!

It is a simple fact, however, that dye inks do produce visually brighter and deeper colors than pigment inks, and that some very long lasting dye inks are available. In the photographic world, this presents an interesting dilemma. Photographers who are used to the color quality delivered by traditional silver halide photo papers are often not able to achieve the same results using inkjet. This is because traditional color photo chemistry always uses dyes and they are comparing this to pigment inkjet prints. This fact is now being recognized with many of the lat-

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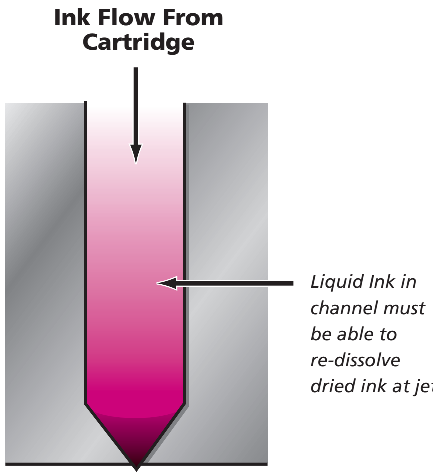
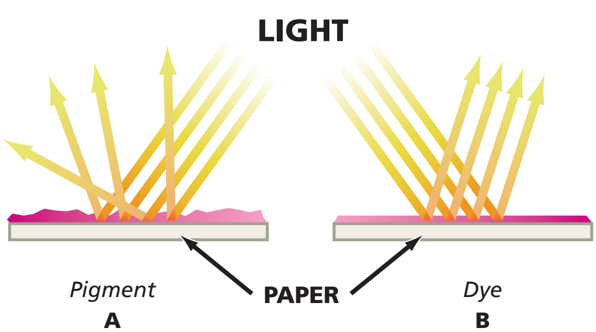


Figure 3:



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est water-based photo printer offerings from Canon and Hewlett Packard using dye-based ink technology.

Oil-Based Inks

The next major step in graphics inkjet development was the introduction of machines running oil-based pigment inks. These inks use a very slow drying carrier fluid (such as Isopar) that is usually derived from a mineral oil source, hence the term "oil-based." The benefit of this approach is that the printer is very easy to use and maintain as the print head jets are very unlikely to clog with dried ink. The downside is that special coated media is required that quickly absorbs the oil-based carrier fluid onto the media base leaving the colorant on the surface. These types of media are obviously more expensive to manufacture than uncoated products and so print production costs tend to be higher with oil-based printers. There are many oil-based inkjet printers being used in the market although there are few machine manufacturers introducing new models. The graphics industry has now moved on to the more economical and versatile solvent and UV curing ink-based printers.

Solvent-Based Inks

In the late 1990s, inkjet printers began appearing on the market that really addressed the needs of sign and screen printers — the ability to print onto uncoated, non-absorbent materials with aggressive inks that had a long outdoor life without lamination. The early pioneers of this technology such as Idanit (now Scitex Vision), VUTEk and Rastergraphics (now Océ) paved the way to the point today where there are dozens of printer manufacturers around the globe offering solvent-based models from 36" to over 15' feet in width and with print speeds in excess of several hundred square feet per hour. Solvent inkjet has become the dominant method for producing digital prints in the industrial graphics market. Media manufacturers have embraced the solvent technology and produced a wide range of low cost substrates for solvent inkjet including self adhesive vinyls, scrim banners and even textiles.

The make up of solvent-based inks is very easy to understand. A solvent or mixture of solvents is used as the carrier fluid and pigment as the colorant. A resin is added to the ink, as well as a "glossing" agent. Basically, when a solvent-based ink dries and the carrier fluid evaporates, we are left with pigment particles "glued" to the surface of the media by the resin. The glossing agent is present to maintain a gloss surface and help with abrasion resistance. The performance of solvent-based inks and media has reached a point where prints can be made that have as much as a five year outdoor life without lamination. Media is a key element to the life of a print. Even the best ink will not last on a media that breaks down in a relatively short time outdoors — a pretty obvious concept, however, one that is often overlooked by print providers. Although solvent inks adhere very well to vinyl, they must be over coated when used in high abrasion and chemical exposure applications such as vehicle graphics.

The term "solvent" is open to interpretation and, unfortunately, is misused by many in the inkjet industry. If you look up the word "solvent" in an encyclopedia you will find something along the lines of "a substance, normally a liquid, in which other materials dissolve to form a solution." This describes pretty well any liquid including water. In the inkjet industry, "solvent" is used generically to describe any ink that is not water-based!

On top of this, we have terminology used to describe ink products such as "soft," "mild," "safe" and "green" on one hand; and "hard," "real," "true" and "strong" on the other. How can a liquid be described as soft or hard? No wonder people are confused. One of the more intriguing terms used is "eco" solvent ink. To most people, "eco" infers ecological. These inks generally contain glycol esters or glycol ether esters, which are both derived from mineral oil — hardly a renewable resource or an ecologically sound process!

Perhaps, the terms "mild" and "aggressive" might be best suited to describe the two groups into which solvent inks fall. A mild solvent ink (i.e., "soft" or "eco") generally uses very slow drying liquids as the carrier fluid. Printers that use these inks have several heaters fitted to aid with drying. The faster the machine prints, the more heat is required. One of the main benefits for using these slow-drying carrier fluids is that they make it easier to design and manufacture a reliable printer. As mentioned earlier, there is a constant trade off for printer developers between producing a machine with fast drying output and producing one that doesn't suffer from dried out inkjet heads. Using mild solvents simplifies the design process.

Aggressive solvent inks (i.e., "hard" or "true"), on the other hand, are generally faster drying and need fewer heaters on the system. Because of this lower heat requirement, media that are prone to "cockle" under heat, such as some types of self adhesive vinyl, can be used more successfully than on a mild solvent ink system. Aggressive solvents also have the added benefit of softening up the media surface, which helps the bonding of the pigments. Hence, aggressive solvents tend to be more scratch and weather resistant, and work on a wider range of materials. The types of resins and additives that can be used with aggressive solvents also make it easier to produce an ink that is glossy when dry so colors appear to have more "pop."

In summary, both mild and aggressive inkjet systems work well and can produce excellent prints that are suitable for long-term outdoor display. Aggressive solvent inks have the added benefits of being less media-dependent, better adhering, more weather resistant and brighter in colors. While running costs with both ink types are remarkably similar when purchased in cartridge form, aggressive solvent machines tend to use around 10 percent more ink because increased head maintenance cycles are required. However, most now come with bulk ink delivery systems as standard or as an option. This reduces running costs considerably versus cartridge-fed mild solvent machines. It remains to be seen if the mild solvent machine vendors introduce bulk ink at a cost to compete. A factor sometimes overlooked when selecting an ink is its resistance to other solvents. Finished prints often come into contact with pretty severe chemicals, particularly in cleaning agents. Standard Windex or specialty vinyl cleaning products can quickly remove some mild and less expensive aggressive solvent-based inks. Check with your ink supplier if this is a concern.

Solvents have come in for a lot of bad press in recent years. For some people, the very mention of the word conjures up images of spotty-faced, spaced-out youths hanging around on street corners sniffing glue! The fact is there are no golden rules to solvents, and that there are equally as many safe aggressive solvents as there are toxic mild solvents. There are also many commonly held myths around solvents, such as "if it doesn't smell, then it's safe" or "the more aggressive a solvent, the more poisonous it is." For instance, dipropylene glycol mono-methyl ether is a commonly used material in many low-odor mild solvent-based inks and has an exposure limit set by the US Occupational Safety and Health Agency (OSHA) at a relatively low 100 parts per million in the work place, where as some of the lactates used by several aggressive ink manufacturers are actually food additives, are easily metabolized and have no exposure limits set.

The thing to do before using any ink is to request a material safety data sheet (MSDS) from the supplier. By law, they have to provide this. A well-written MSDS provides specific information about exposure limits and ventilation/extraction requirements. It should also list the components in the ink, along with the Chemical Abstracts Service (CAS) registry number for each item. A quick search on the web using the CAS number will provide you with a wealth of health and safety information. Good resources are also the OSHA and the US Environmental Protection Agency (EPA) Web sites at www.osha.gov and www.epa.org.

Unfortunately, a loop hole in the regulations exists that allows a manufacturer to state something along the lines of "proprietary organic solvent" on an MSDS if the ink is supplied in a sealed cartridge format. Even so, the MSDS should still contain exposure information. If not, request a written statement on the safe use of the ink from the manufacturer. Failing this, contact your local OSHA or EPA office for advice. In any case, once you are aware of the safe exposure limits for the ink you are using, then don't ignore this. If the recommendation is to use in a well-ventilated area or extract the vapors, then do it. The effects on health to exposure to the more noxious solvents such as ketones are not always immediately apparent, whereas long-term exposure can result in damage to health or the body becoming sensitized where symptoms such as nausea, headaches and skin rashes occur. The fact is there are many safe, solvent-based inks available and, as long as health and safety guidelines are followed, they can be used happily with no personal risk.

The VOC Debate

There has been much talk recently about Volatile Organic Compounds (VOCs) and the government's commitment to reducing VOC emissions. Solvents that are derived from living things (carbon containing materials) can all emit VOCs, and this includes 99 percent of the solvents used in both mild and aggressive solvent-based inks! Don't be fooled by claims that solvent-based inks are VOC free or don't emit VOCs. True, some slow evaporating solvents only emit VOCs slowly at room temperature but when force dried by a system's heater unit, as many VOCs are put into the atmosphere

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as with a fast drying aggressive solvent. Don't panic, however. It would take an awful lot of solvent-based printers in an organization to reach a VOC emission level that required regulatory reporting or intervention. The term VOC is very generic. If you are concerned about the effect your printing is having on the environment, then there are many solvent-based inks available containing solvents whose fumes are biodegradable. Many of the lactate family of solvents are recognized by the EPA as environmentally preferable chemistry and are made from renewable resource materials. The World Wide Web is a good resource for information on this.

UV Curing Inks

The latest ink technology is ultraviolet (UV) curing. The make up of a UV curing ink is very similar to a solvent-based ink, and pigments, additives and resins are used in much the same way, with one distinct difference. The carrier fluid is a substance that is liquid in its normal state but cross links or "cures" when exposed to high levels of UV light. Some versions of UV curing ink contain small amounts of solvent, but we can think of a UV curing ink as containing 100 percent solids when cured.

There are many benefits to using UV curing inks. Primarily, they can print on many materials that are difficult or impossible to print on with water- or solvent-based inks. If you take a material such as styrene or foam core and try to print on it with a solvent-based ink, for instance, then you will probably find that the ink would either absorb into the substrate or bleed all over the place and the print quality would be unacceptable. With a UV curing printer, a UV light source is usually attached to the print head carriage so that the inks are cured instantly after printing, before this absorption or bleeding can take place. Most of the UV printers that have recently appeared on the market are of the flat bed type and are designed for printing onto rigid materials although many models are dual purpose and can accept flexible roll media as well. The introduction of UV curing inks has really opened up the range of materials that can be used and increased the number of applications for inkjet. UV curing is not the be all and end all, however, and has some limitations and problems that need to be understood when selecting an ink type.

UV cured inks tend to be more brittle than dried solvent-based inks particularly when made to the low viscosities that are required for inkjet. They can crack or break away when used in applications where the substrate needs to be very flexible or stretched, such as with vehicle wraps. New UV chemistry has improved this recently, but it can still be a problem. The color quality of UV curing inks tends to not be as good as with solvent-based inks. This is due mainly to the inks being cured before they "wet" out on the surface of the media and so they are rougher and have a more matte appearance. Over coating with a lacquer is often needed to get the same "pop" as with a good solvent-based ink. UV curing inks tend to have a shorter shelf life in their liquid state as the curing process can start to occur in the bottle after a certain length of time. Avoid storage at high temperatures, as this can induce the curing process. Currently, most UV curing inks have a shelf life of around nine months to a year after manufacture compared to solvent-based inks at around double this figure. Most UV curing inks are thicker than can be used through an inkjet head at room temperature, so the machine manufacturers use heaters in the print head to lower the viscosity of the ink just prior to printing. Bearing in mind that heat can initiate the curing process, care has to be taken not to leave head heaters on when not printing. Once a print head has been cured, it can't be cleaned and has to be replaced.

In terms of health and safety issues, there are very different concerns with UV curing inks than with solvent-based inks. Little or no VOCs are given off from UV curing inks. The main concern here is the emission of ozone that many UV light sources create. Ozone is a very corrosive gas that must be vented. Shield the UV light source well and avoid looking at it directly (eye damage can occur). Avoid physical contact with uncured inks as many contain initiators that are irritants and bad skin rashes can result. As with solvents, it is important to understand the health and safety precautions when using UV curing ink. As long as guidelines are followed, they can be used safely and with good results.

Best Inks for Applications

There is no doubt that the range of ink options available today for use in inkjet printers has increased the number of applications that can be covered by digital printing. There is also, however, no doubt that certain ink types and equipment are better for certain applications than others. Here's a list of the main applications along with the best ink types to use for each.

Photographic prints for indoor display	Water-based dye, water-based pigment
Fine art prints for long-term indoor display	Water-based pigment, water-based dye
General exhibition graphics for indoor use	All ink types (water-based with lamination)
General point-of-sale graphics for indoor use	All ink types (water-based with lamination)
Indoor signage	All ink types (water-based with lamination)
Indoor back light displays	Water-based dye, water-based pigment, Solvent-based pigment.
General outdoor signage	Solvent-based pigment, UV curing, water-based pigment (with lamination), oil based.
Outdoor banners	Solvent based pigment, UV curing, water based pigment (with lamination), oil based.
Outdoor back light displays	Solvent based pigment, water based pigment (with lamination), UV curing, oil based.
Vehicle wraps and graphics	Solvent based pigment, UV curing, water based pigment, oil based (all need over coat ing for protection).
Uncoated rigid materials	UV curing, solvent based pigment (substrate dependent).

Obviously, there are many crossovers on the list and some inks can be used for many applications. When I have mentioned more than one ink type, the best is listed first, while the other inks will still provide acceptable results. Some may argue that there are some omissions from this list. A solvent based ink, for instance, can be used to produce a pretty good photographic print for indoor display but it will not have the quality or detail of a water based ink print on coated media.

The Future

The development of inkjet inks is moving on at a furious pace to meet the demands of the graphics printing industry. Improvements in chemistry will expand the performance of all ink types and enable many new applications to be encompassed by inkjet. White inks are now becoming a reality that will allow printing onto non-white or clear substrates. Look out for water-based inks that can print onto non-coated media and improvements in UV curing ink performance along with safer solvent-based products.

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