TECHNICAL GUIDE

INK

Second Edition

FESPA
profit for purpose

It's all about the ink

Ink has been around since at least 2300 BC, so we know it's a mature and well-developed technology. The ink business generates a lot of money for a lot of companies. Since 2011 when global ink revenues were around $20 billion, 2018 revenues are estimated to be over $35 billion and rising. The offset sector, for which the greatest range of inks is available, accounts for about 44% of global sales. Gravure still accounts for around a third. Digital printing ink and toner consumption are in the minority.

Gutenberg developed the first dedicated printing ink when he invented his printing press in around 1452. Previously inks were concocted for writing on parchment and vellum, so Gutenberg needed something new to work on a press. His initial recipe was oil based with soot, varnish and egg white, but the addition of turpentine and walnut oil to soot produced a superior ink that would stick to a surface without blurring. It wasn't until the early 19th century when the first specialty ink company, Lorilleux, was founded in France and the first ink making process was patented, that printers stopped making their own inks.

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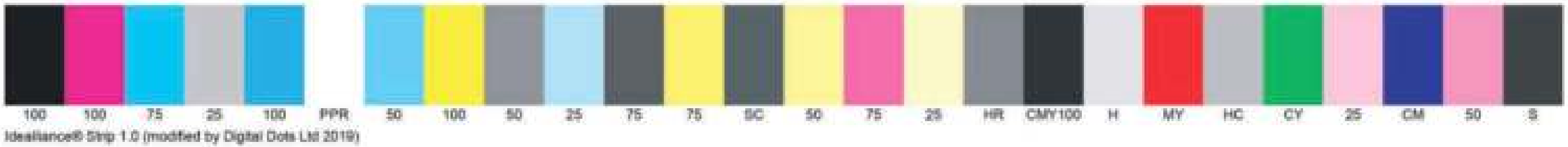
Four colour wet process inks were introduced in the early 20th century at about the time of the invention of the first litho press and just before rotogravure printing technology was introduced around 1910. In the 1930s letterpress became popular and the first pigmented flexo inks were developed. Throughout history the pace of developments in printing methods has driven ink innovation and it continues to accelerate with new digital printing methods and application demands. These drivers combine with the need to comply with environmental regulation and together they push ink innovations that support new business opportunities. The environment is now a key concern for the chemicals industry.

Ink formulations can contribute to product performance as well as appearance.

What is ink?

Ink is a chemical recipe designed to optimise various behavioural characteristics, such as surface tension, colour appearance, curing speed viscosity, adhesion, or high lamination bond strength as is required in packaging. Ink manufacturers succeed on the basis of knowledge, experience, research and development, their understanding of ink chemistry and the strength of their patent portfolios. Most are chemical companies specialised in developing and producing inks specifically for different printing methods, substrates and applications. There is a huge range of ink products for use in offset lithography, gravure, flexography, letterpress, screen and digital printing, including inkjet and toner devices, but inks generally fall into four classes: liquid, aqueous, paste and powders. Developers can be active in any or all classes, leveraging their knowledge of colour science, rheology and dispersion technologies. Rheology governs how liquid inks flow and dispersion technology ensures that the right chemical agents are present in the ink, for instance, to prevent pigment particles clumping together and adversely affecting colour brilliance. Performance has to be optimised for the substrate category: rough papers will need more ink to achieve good quality than smooth ones, for instance.



A colour bar is used to check colour density and also to validate that the print run is compliant to the specified printing standard.

Ink chemistry is a necessarily complex business because an ink recipe's composition affects how it gets dried and how quickly, performance on press, interactions with substrates and laminates, its appearance when dry, how it behaves in use and environmental interaction. The chemistry delivers varying levels of durability, deinkability, lightfastness and behaviour for food packaging, synthetic and natural textiles such as polyester, silk, linen, cotton, flooring, furniture, décor, wallpaper and so on. Ink formulation, how inks work with different printing technologies and interact with different media, requires constant research and development and patenting to protect intellectual property. Inks are increasingly subject to stringent labelling requirements relating to health and safety, storage, use and restrictions on their disposal.

The mixing of colorants and other ingredients to produce the required performance is a sophisticated science. And for printing companies awareness of how different ink recipes work in different situations is vital to investment decisions.

What's in it?

All inks comprise a carrier, either liquid or paste, plus colorants. The carrier, or binder, is the vehicle which delivers colorants to a substrate. Inks are mixtures of binders, colourants, solvents and additives. They can include well over fifty compounds including fluorescents, solubilisers, surfactants and particulate matter, like metal particles, to give inks their particular characteristics and flow properties. The binder can be mineral or increasingly vegetable oil or water; water based inks are the fastest growing variety of ink.

The ink's viscosity, meaning its stickiness and fluidity, determines its flow properties and suitability for different printing methods. Flexography requires low viscosity inks to achieve good quality, as does gravure printing whereas offset inks have relatively high viscosity. In screen printing where there is a huge array of process options and applications, the ink's viscosity must be tuned to the size of the screen mesh and ink layer thickness.

Binders may also include thinning agents such as water or solvents, which can sometimes make up the bulk of the ink but can then in part be recycled. For instance toluene, a solvent used in gravure printing to dissolve the binding substances around pigment particles, can be mostly recycled. Some manufacturers have replaced petroleum based ingredients with vegetable based or renewable ones to reduce solvent use.

Pigments are insoluable solid particles held in a suspension, so they can separate from the binder. Pigments can make up from 5% to 30% of an ink's volume, depending on the colour tone of the ink. A pigment particle can be made up of millions of molecules only a small proportion of which actually end up on the substrate surface to respond to light. Pigmented inks are generally more colourfast and resistant to water than dye based inks, but they can be more expensive and have inconsistent in colour rendering. They have a smaller colour gamut than dye based equivalents.

Dyes are dissolved molecular organic compounds. The molecules interact with other ingredients in the ink, so dyes are potentially more able to benefit from additives to the carrier fluid such as Optical Brightening Agents (OBAs) and other colour enhancing additives. Most inkjet printers use dye based inks. However these inks are not waterproof and have a relatively low UV resistance, so prints with dye-based inks should be laminated for outdoor use. They can tend to be cheaper, stronger and of denser colour than pigmented inks, but they can also sink into a substrate or slither about on a coated surface, which makes them difficult to control.

Additives influence an ink's flow behaviour, drying and abrasion resistance, among other things all of which are important considerations for applications such as packaging and signage printing, and for printing matte coated substrates. Ink viscosity affects performance on press and in printed appearance. Solvents and hot air blowers are used for rapid drying of highly viscous inks, for instance in some screen printing applications, especially for thick ink layers. Ink manufacturers have developed special surface coatings for substrates to improve ink performance and control its behaviour.

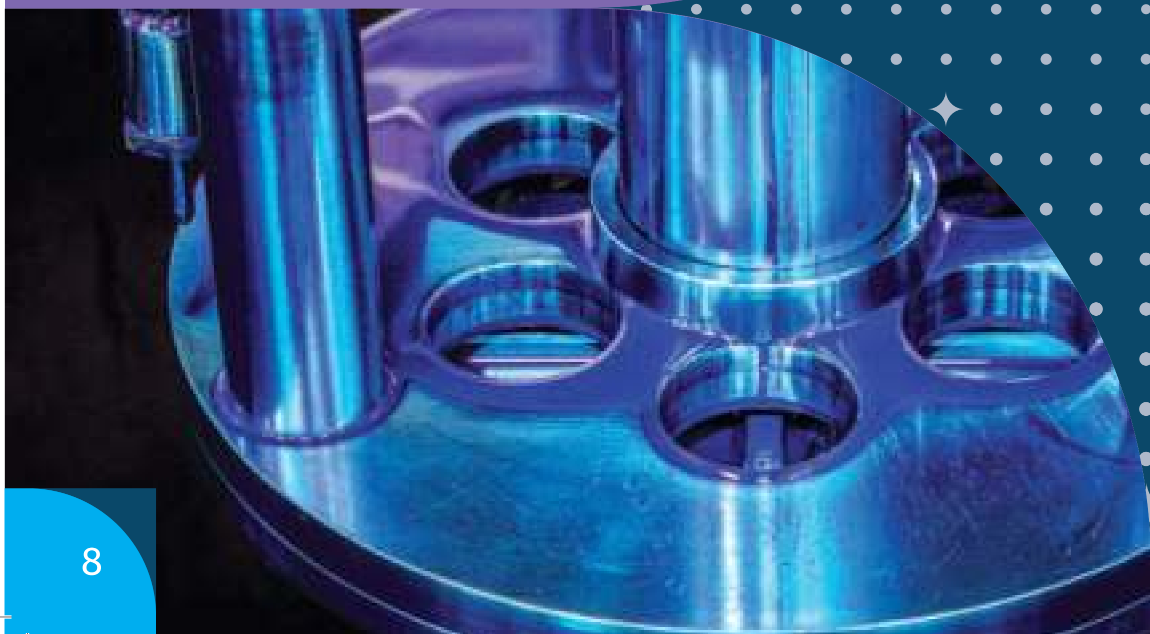
Solvents are Volatile Organic Compounds (VOCs) containing heavy metals and nonrenewable oils, but with low boiling points so they evaporate at relatively low temperatures. VOCs for ink recipes are selected according to their properties such as boiling point, flash point (the temperature at which the solvent produces enough vapour to ignite), odour, safety, toxicity and explosion limit. Commonly used VOCs in printing inks are glycol ethers, ethanol, ethyl acetate and water to which alcohol has been added. Water is used as a carrier solvent for some types of gravure packaging printing and in inkjet inks such as latex ink used in wide format digital printing.

According to the European Printing Inks Federation, there are over one million different ink formulations used in Europe alone. This includes special recipes for applications such as banknote and security printing, printing on CDs, and textile printing. Formulations for different applications also vary according to the printing method, such as UV flexo printing and screen printing, or for different substrates such as kraft, plastics or glass and ceramics. Conductive inks are used for printed circuit boards and photovoltaics. Ink developers also provide pigments to third parties, for formulating bespoke recipes.

A vat of pure yellow inkjet ink

Substrates

As well as the printing method, the physical and chemical properties of a substrate determine ink formulation requirements. In all sectors of conventional printing this relationship is well understood and the media compatibility of inkjet inks is increasingly mature. However most inks for digital printing are still specific to the media and the printing method. Some solvent, eco-solvent, UV-curable and latex inks work across media and some applications but the lines are vague, so check ink and media compatibility and test wherever possible.



Ink characteristics

Within the four categories of ink used in printing, inks are characterised by features such as transparency, flow properties and drying, gloss, behaviour on press, and light and abrasion resistance. How well the ink works with substrates, its adhesion and stability are also important, for instance having good sweat and moisture resistance in shampoo packaging. Ink systems combine inks and specialist coatings for particular applications such as cigarette carton printing, where low residual odour and low migration properties are preferred. Antimigration inks also block migration of dyes in food packaging and block food migration into the substrate.

Elasticity is a major requirement for vehicle wrapping, where inks must be stretchable without compromising colour appearance or breaking away from the substrate. Some highly creative applications in the sign and display business can benefit from a cracking ink that produces crackled effects. Inks may also have to have thermoforming properties, for instance for use in three dimensional printing.

Rotary screen printing on textile materials require high levels of light-fastness and rub resistance.

Ink performance

For printers and their customers how the ink performs matters a great deal. Inks are formulated for specific sectors of the printing industry, so newspaper inks are designed to print on newsprint, UV inks for packaging and label printing, screen inks for screen printing and so on. Screen printing works with a huge range of substrates and applications, so there are many diverse requirements for these inks. They must meet the needs of commercial screen printing for sign and display, screen process printing, industrial screen printing for cups, toys and promotional materials, and special processes such as textiles, or printed circuit boards. Uneven and difficult surfaces such as leather and porcelain which are printed using pad printing technology, as well as digitally, also make their own demands on inks. Optically variable or colour-shifting ink is increasingly used in security printing so that a colour can appear to be different from different viewing angles.

In the €50 note the 50 appears pink or green depending on the viewing angle.

Perhaps the most important behavioural expectation for productive and cost effective print, is that the transfer process doesn't interfere with the rest of the printing process and that it meets the application requirements. The ink transfer mechanism and how ink is expected to be dried or fixed to the substrate will determine the ink's structure and recipe. The ink splitting process affects the ink's design, so how printing processes create the ink film must be taken into account when determining performance objectives. Inks used in direct ink film transfer such as with hot embossing or thermotransfer will have different requirements to other processes. How the ink is pressed through a screen in screen printing, or gets jetted onto the substrate in inkjet printing affects performance and so shapes an ink's chemical composition and drying properties. Drying is commonly by physical absorption or evaporation, but inks also dry chemically by way of oxidation or radiation curing, or by solidification as is the case with hot melt inks used in high speed inkjet marking.

Adhesion requirements depend on the demands of the application. Ink mechanically adheres by sinking into pores or fibres in the substrate surface, which generally requires pressure. Ink may sink into the surface by capillary action, which is how inkjet printing works, or ink is bonded by the chemical and physical effects of the ink and substrate.

There are many special colour ink formulations such as they metallic RGB screen inks from Merck for printing on black surfaces.

An ink's flow properties determine its suitability for different print processes. Inks can range from being very thin and watery to almost dry and powdery as is the case with electrophotography. Their recipes vary according to the required appearance in print, from simple black text through to metallics and pearlescent inks. Inks used for food packaging must have low odour and low migration properties. Other factors shaping ink design are toxicity and emissions controls.

Ink considerations

From an investment perspective, there are numerous factors to consider to meet the business's needs. They include the ink's productivity, cost, colour gamut, drying performance and speed of cure, VOC emissions and energy consumption. Other considerations are the need for primers and coatings for a given substrate, gloss and chromatic performance, resistance to edge chipping and colour concentration. Multiple presses using different print processes must have colour matching compatibility with other inks and ink recipes across devices and processes. Legislative constraints may require facilities adaptations for compliance, and possibly requirements for risk labelling in textiles and soft signage.

ISO standards

One way to improve quality control is to request that supplied inks conform to the ISO 2846 series of standards. This series describes requirements for the colour and transparency of printing ink sets for four-colour printing for sheetfed/heatset web, coldset/newspaper, gravure, screen and flexo inks, but does not cover digital inks. The standard is a useful guide for conventional print processes, and is necessary for compliance to the ISO 12647 series for print process quality control. However even ISO 2846 compliant inks should be tested for colour and transparency characteristics under specific printing conditions. Be sure to run tests on the full range of media to be printed and print methods.

Graphics professionals have two major questions to resolve when it comes to ink: performance and cost. The cost of ink is highly subjective. Inks are designed to work with multiple processes to maximise income streams for their developers and manufacturers. Ink prices are very much subject to supply and demand and volumes purchased. Inks sold in the greatest volumes such as for commercial offset or conventional screen printing cost less per kilo than small amounts of exotic inks that only work with a particular inkjet printhead. Investments should take into account the supplier's business model, for instance click charges, contracts based on annual consumption or buy as needed.

Categories of inks

Solvent inks are any ink that is not water based. They are durable and vibrant, and suitable for outdoor use. They contain varying amounts of solvents and the type and character of solvent components influences ink performance. Solvent inks are UV light, water and scratch resistant and when printed they partially dissolve the substrate and bond with it. The intensity of this etching process depends on the amount and properties of solvents in the ink. Materials printed with solvent inks are durable but potentially difficult to deink, so these prints are not always environmentally friendly. They dry rapidly in air but in some printing systems are dried with heat applied at different stages of production: pre-, during and post printing, depending on the printing system. Solvent inks are hazardous, so ventilation equipment is required to extract fugitive fumes. Solvents are widely used in gravure printing for publication and packaging printing, and wide format digital printing for applications such as vehicle wrapping, signage, and indeed any application that requires speed, colour quality and quick drying.

Eco-solvent inks are less risky, with similar properties to solvent inks but slower drying. They are durable with excellent light, water and scratch resistance and are suitable for indoor and outdoor use. They contain lower amounts of VOCs than solvent inks, so they are only somewhat hazardous to health and can be used in an office environment, although the prints have a strong odour.

UV inks contain liquid monomers used to adjust their processing viscosity, and oligomers which work with monomers to form the binder. When the monomers and polymers are exposed to UV light they react and form three dimensional crosslinked polymers. Photo-initiators in the ink are agents which decompose during UV exposure and trigger polymerisation in a chain reaction, to create a cross-linked structure. The pigments and other additives in UV-curing ink are not dissimilar from those used in conventional printing inks.

UV inks cure under UV light and have a completely different structure compared to conventional inks. They are commonly used in conventional and inkjet printing processes to print non-absorbent materials such as plastics and metals, but increasingly they are used in labelling and sign and display applications, conventional and digital, printing on a growing range of substrates.

UV curing is achieved using UV light from mercury arc lamps or Light Emitting Diodes (LEDs). LED curing technology requires less than half the energy of conventional lamps, so they generate less heat and can last over ten times as long. LEDs radiate no infra-red heat, so the printing device can print onto a wider range of substrates including very delicate ones without the risk of distortion. LED output power is predictable and consistent throughout a diode's life, however LEDs are slower to cure the inks and the depth of cure is not as great as with mercury arc lamps. UV- curable inks for LED curing respond to specific wavelengths and cure at much lower power levels and temperatures. LED arrays for UV-curable inks are designed to emit UV light over very specific wavelength ranges, so the relationship between inks and LED energy must be carefully tuned. The inks must respond to the specific spectral outputs of the LEDs and this puts additional demands on the ink formulation.

These inks have advantages compared to solvent based inks in that they are almost solvent free, dry quickly so they can be finished without gassing off. There is no dried ink in the press which makes for cleaner running and UV-curing inks have high mechanical stability and chemical resistance. But they can be expensive as can the curing equipment, and care must be taken to protect operators from exposure to UV light.

UV-curable inks print on most substrates and like solvent inks they have high UV, water and scratch resistance and are suitable for indoor and outdoor use. They are flexible and dry immediately and are used in some screen and offset printing applications, and extensively in wide format digital printing. Solvent UV inks are a blend of solvents and UV- curing ink, reducing the amount of solvent but in other respects they are similar to solvent inks.

Latex inks are water based and are claimed to have equivalent performance to solvent inks. These inks are an aqueous polymer dispersion with the ink dried virtually immediately using heat, which limits the substrates they can be used with. Latex inks are used for all sorts of print including flexible applications, such as vehicle wrapping. They pose no health risk and are durable.

Dye-sublimation inks are water based inks, with water evaporated using heat to sublimate ink into the substrate surface. These inks are used in textile printing for lightfast and washable prints and mainly used to print flags, soft signage, interior décor and fashion. They are durable with a high colour brightness, and therefore suitable for outdoor applications,. The inks are nonhazardous, but print media can shrink or distort during printing, so they are only suitable for a limited range of substrates.

Overprint varnishes are basically inks without colorants. They are used to provide a protective and enhancing layer over the printed image and can be applied inline wet on wet, or off-line wet on dry. As with ink, there is a bewildering array of coating options and their recipes are determined according to performance requirements and the technology used to coat the print.

Flexo printing technologies such as Kodak Miraclon's Flexcel exploit printing forme and ink characteristics to print top quality output. ©Kodak

Emerging developments

Ink technology is constantly changing in line with innovations in printing methods. However legislation is an important driver, with regulations such as the European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation intended to improve protection of the environment and human health. Take up has been slow since it was introduced in 2006, but it is gradually eliminating harmful substances from the list of ingredients ink makers can use.

Environmental impact mitigation is rising up the agenda for everyone, with the European Union leading the way in terms of regulation. For ink, the three main environmental concerns are the use of heavy metals, such as lead, zinc, cadmium, nickel and copper; VOCs; and non-renewable oils included in mineral oils. Environmental concerns, as well as technological advances are driving a trend towards using vegetable oils based on rapeseed, soybean, palm oil and rice bran, for instance, rather than non-renewable petroleum based oils.

There is considerable activity in the area of digital inkjet printing as manufacturers strive to optimise the relationship between printheads inks and substrates to improve performance and quality, and reduce environment impact. Some aqueous inks contain reactive molecules for greater adhesion, durability, resistance and performance on press to provide an alternative to UV curing inks. Low temperature flexible inks for instance save energy and are coming onto the market. Water is being used more widely to produce dispersion inks that are non-toxic, low migration and odour free.

Ink is only a small part of print media production, but its role is crucial. Whatever the printing and whatever the application, there is an ink to do the job.

Further Reading

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The Dorking Business Park
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