Digital Dots is an independent graphic arts research group established in 1999. The company specialises in technology evaluations for digital prepress, printing and publishing applications and has conducted technology tests since its inception. Digital Dots also provides exclusive market research, testing and evaluation services for developers and buyers and is the publisher of Spindrift, a subscriber supported journal for the graphic arts.

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Digital Dots

UV-Curable Large Format Printers

Technology Test & Guide

December 2010

A Digital Dots Special Report

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Introduction

This report presents the results of Digital Dots' research into the technologies and markets for UV-curable inkjet printers. The technology is used to produce a fast growing range of graphic products and is capturing a rising share of the large format graphics printing business. This includes sign making, posters, displays and exhibition graphics, plus an explosion of short and single copy runs of work such as art prints printed on flexible and rigid materials.

UV-curable inks were the first ink formulations that could successfully be printed direct to rigid substrates. Worldwide they have yet to overtake solvent inks for nonrigid applications, however they may one day do so. In this report we discuss the technologies, features, benefits and limitations of UV-curable printing technology, and consider various market forces driving its current and future uptake.

UV-cured inks can adhere directly to a wide range of materials and are suitable for some extremely ambitious applications. The EFI Vutek 3200GS was used to produce this impressive special event scaffold wrap.

Digital Dots has conducted independent tests to measure the maximum achievable colour gamut and resolutions of several leading devices and compared the results with high quality solvent ink-based machines printing on flexible materials. Image enhancement techniques and multipass printing make the concept of absolute dots per inch and colour gamut difficult to define, yet manufacturers use both as an indicator of output quality. Our tests are designed to provide reliable benchmarks, giving prospective buyers a reference for objective comparisons for resolution and colour gamut. The next time a manufacturer claims a "wider" colour gamut or "higher" resolution output, we can give those claims some meaning.

We present test results alongside comprehensive explanations of the technology and the criteria for purchase decisions. We explain why resolution and colour gamut are important, and we also explain their relevance for different applications and budgets.

A Bit of History

The development of direct digital output technologies has moved with remarkable speed over recent years. Digital technologies have invaded most print sectors, most obviously in commercial printing where xerographic processes have led the way, and increasingly in applications such as direct mail, book printing and on demand publishing, where inkjet technology is taking hold. As colour use rises and print run length requirements fall, along with turnaround times, digital printing technology provides new generations of print buyers with an affordable alternative. Screen printers were among the first to want digital alternatives in the early 1990s, followed by photolabs and signmakers. The technology is now proven and robust and the digital sector arguably has the most exciting future and growth potential.

The cost of prepress and of setting up the press dictates the per copy economics for all printing methods. Making the screens for the screen printing process and their reclamation for reuse can be expensive so, as in other sectors, the cost per copy falls with longer run lengths. Digital printing systems output data direct, without intermediary processes such as making plates or screens. They are extremely cost effective and competitive for short run work, such as packaging prototyping, proofing, signs and graphics, and labels. For printers running digital printing systems alongside conventional screen printing, the crossover point is generally around 150 copies, where economies of scale start to outweigh the benefits of digital processes. The market for very short run, high value work

is growing in the wake of inkjet printing innovation and software to support variable data printing.

Applications that previously were impossible to produce digitally, such as printing bespoke textiles or wall and floor coverings, can now be produced with a digital printing device. Inkjet digital printing technology can image on any surface including uneven surfaces, from cakes to ceramics. Print buyers, consumers and designers are beginning to appreciate what's possible, creating complex and visually stunning projects. The latest wide format printing technology produces superb output results on diverse materials of different weights, flexibility, thicknesses, wet and dry strengths, and finishes. This includes flexible materials supplied in rolls such as mesh and canvas, carpets and fabrics, plus papers, films, PE, polyester, PVC, transparent PVC/PA, banner, tarpaulin, textiles and vinyl. Roll fed media support "unlimited" print lengths because the printed image can be as long as the media roll. Materials for UV-cured prints also includes rigid substrates such as glass, acrylic, corrugated board, foam PVC, polyboard, polycarbonate and composite materials. New generation inkjet printers can be used to create exhibition and event displays, indoor and outdoor Point-of-Sale/Point of Purchase (PoP/PoS) signage, signage, architectural work and second surface backlit displays.

Design Execution for Retail Goes Digital

Founded in 1989 when CEO Chuck Huttinger acquired five-man firm Midwest Decal, GFX International near Chicago, Illinois, initially produced small decals. The company changed focus to Point-of-Purchase (PoP) signs and larger graphics in 1996 and now employs 170 people producing graphics and displays for every part of the retail sector. GFX has in-house manufacturing and logistics backed by a custom-developed asset management system. Its products can be seen both across the US and internationally, with a customer base that includes restaurants, specialist retailers, convenience stores, superstores and financial centres.

The arrival in the mid-1990s of large format digital printers appealed to GFX's customers who were tben interested in temporary PoP materials typically used in stores for three months or less. Although the printers available at that time were slow, GFX could see their use in prototyping and producing one-off materials.

From commodity to value-added

According to GXF's COO and senior VP Mark Taylor, "We made a decision to change our business model from commodity screen printing to a value-added service provider for retailers." From the mid- to late-90s, the company used roll-fed printers to produce output that had to be mounted and then laminated for durability, as a large part of its work was for output to rigid materials such as plastics and boards.

The first flatbed digital printer to arrive at GFX was an Inca Eagle, purchased in March 2002 after GFX staff visited Inca's headquarters in Cambridge, England. The unit was put to work producing prototype displays for in-store concepts and market testing for PoP work. "A fast food company could ask for PoP materials – window signs and menu boards – for just three stores in Indianapolis," recalls Taylor. "This technology allowed GFX to do this cost-effectively and by installing it, our company was able to grow as a whole; we were busier and some of the new digital customers fed the screen printing side of the business as well. The Eagle allowed us to cost-effectively do a lot of short-run, prototype and test market work that was not feasible in the past and we still use it today."

Growing demand for permanent in-store graphics installations with lifestyle photographic images led to the purchase in 2004 of an Inca Columbia, which was used to provide packages of graphics to suit different stores, combining the required image quality with UV durability to last two or more years. Over the next four years, the two Inca printers were used for output to PVC board, Duroplast and other rigid materials alongside a solvent-based roll-fed printer for banners, fleet graphics and wall coverings.

2008 saw the addition of an Inca Spyder 320-8 series flatbed UV-curable printer, bought to meet customer demand for increasingly fine detail in printed graphics as well as a general increase in volume. The six-colour printer adds orange and violet inks to the standard CMYK set, allowing an extended colour gamut to be printed.

Moving into litho territory

"We've printed everything from circular saw blades to short-run menu translates for major fast food chains," says Taylor, adding, "The Spyder also let us capture work that would normally be produced as short-run litho, something that we never even tried to provide. In some instances our customers told us to cut back the quality because digital was too good in comparison with the previous litho work".

In 2007, GFX had seen the launch of the Inca Onset, which at the time was a 'pie in the sky' option for them, but by 2009, as the US economy rebounded, the company compared manufacturing costs of screen print against digital for runs of under 800 sheets and considered the capabilities of a high productivity device for short-run work. "We have large customers with 8,000 locations, and cannot tell them that delivery might take as long as six weeks," says Taylor. "We felt that we could invest in a high speed Inca Onset and rationalise the move from screen printing with a new digital capability replacing short run litho."GFX opted for the higher spec Onset S70 in order to replace its screen printing operations rather than carry out the existing digital work. It is being used for press runs of up to 1000 sheets and for projects that require versioning or variable data, while the screen presses are now used only on longer runs. The company calculates that a project that would have taken 300 hours via screen printing can now be completed in just 30 hours.

GFX also think that the Onset will save wastage, as customers often over-order screen- or litho-printed items in order to keep unit costs down. Taylor comments, "We anticipate that the Onset S70 is going to give our customers more options – ordering the exact quantity needed while reducing waste and freeing up valuable warehouse real estate."

This huge diversity of applications and materials creates an equally huge diversity of opportunity for manufacturers. Consolidation in the number of suppliers occurred a couple of years ago, but the number of players in this field is once again growing along with the market. Established manufacturers are selling in substantial numbers: a mere four years since it was launched Océ recently shipped its 2000th Arizona UV flatbed printer; EFI Vutek recently announced the sale of its 100th GS3200 3.2m printer.

Why UV?

UV-curable printers are attractive for important reasons, such as the lack of VOC (volatile organic compounds) emissions and fast drying. VOCs are part of a widely occurring class of chemicals that in concentration are potentially dangerous to health and increasingly the subject of legislation. UV-curable inks contain no VOCs and are cured using ultraviolet light which emits electromagnetic radiation in the range of 200 to 380 nm. Solvent inks release 80 to 90% of their content into the atmosphere as evaporant containing pollutants which must be extracted from the working environment. UV-curable inks require no extraction systems, so investment cost is lower than that of their solvent-based equivalents. Although some UV inks emit ozone at the curing stage, it is trivial compared to the fumes solvent printers produce, so UV-curable technology can help reduce the buyer's investment cost.

Many manufacturers are developing products that use UV-curable instead of solvent inks to be both more environmentally friendly and easier to use. The output dries instantly, so UV-cured inks are suitable for high speed output. UV-curable inks adhere to both coated and uncoated rigid and flexible materials, so there is no need to mount flexible materials onto rigid bases. These factors help broaden the technology's application range and market, helping printers to improve job volumes and turnaround times often with reduced costs. Printers can also offer a

more interesting service for customers, supporting creativity and customers' ideas for imaginative promotions using print. In response, manufacturers are producing machines that provide considerable application flexibility.

So far in our research we conclude that for some flexible applications devices using solvent based inks still have the advantage. Solvent inks do not need special coatings because they are generally waterproof, extremely durable and resistant to ultraviolet light. Highly suitable for outdoor use, solvent inks when used with cast vinyls also have the edge in applications which require extreme stretching, for instance applying prints to curved surfaces such as cars. Although UV inks have been developed to provide the adhesion and flexibility for this work, they typically aren't sufficiently flexible for work that imposes extreme curvature over small areas. They generally require lamination so both substrate and laminate need behave in the same way. There are also adhesion concerns with some substrates, but pre-treatments to improve this are available. For instance HP's UV-curable Latex ink (70% water and 30% additives), needs a preheat with hot air to soften the ink and drying after imaging to fix it.

"The Spyder let us capture work that would normally be produced as short-run litho, something that we never even tried to provide." – Mark Taylor, COO and Vice President, GFX.

UV-curing engines are gaining ground in many other sectors however and manufacturers such as Polytype SA with the Virtu line which supports various print widths and media types, are configuring their machines to suit different applications. Businesses who want to get into this sector are spoilt for choice. They must consider for instance, the quality and durability of the prints, anticipated production volumes, operational and environment constraints, and customers' media requirements. What customers will pay for prints obviously depends on substrates, format, output quality, speed of turnaround, durability requirements and run length. The interplay of these factors, plus the consumables cost, capital equipment and service contract, are fundamental to the investment decision.

Market overview

We have read unsubstantiated claims that the global wide-format print sector is worth €58bn (£54.2bn) annually and that commercial printers occupy just 3.5% of the market. How accurate these figures are we don't know but it's clear that wide format printing is an opportunity, especially for commercial printers. It requires a relatively low capital expenditure to get into, so for printers used to multimillion dollar investments for conventional presses, UV-curable printers should be an attractive bet.

The primary drivers of growth in this sector are the large and energetic development base and the diverse markets for products. To some extent, this helps explain the confusion and complex technology overlap in the sector. Many established manufacturers have their roots firmly in sign-making, photolabs, and screen printing and are keen to retain long-standing customers, as the latter introduce digital technology into their print shops. Several vendors have entered the market through acquisition (EFI and HP), OEM agreements (Océ, which has a private label arrangement with Mutoh) and Agfa (with its acquisition of the Jeti portfolio to boost its existing products) or through original product development (Inca, now owned by Screen). Some of the newer players such as Agfa and Fujifilm come from the offset print sector. All anticipate interest from commercial printers who want to broaden their portfolios to capture a bigger slice of customers' overall print spend.

Size Matters

UV-curable printers range in size from desktop models (it would need to be a large and sturdy desk) supporting A3 output such as the Mimaki UJF-3042, to five metre devices such as Polytype SA's Virtu RR50. Although UV-curable

printers originated as flatbed devices, recent years have seen the introduction of a number of roll-fed designs challenging solvent-based printers for productivity and maximum format, plus some hybrid options with tables attached to roll-fed devices to support rigid media. Prospective buyers can buy machines like the Virtu RR50 which has multiple reel feeders for different media. This type of machine provides customers with more flexibility and allows manufacturers to increase their product ranges.

According to market research firm InfoTrends, total revenues from wide-format UV-curable inkjet printing systems will grow from US $1.1 billion in 2008 to US $2.3 billion by 2013, making it the fastest-growing segment of the wide format digital printing market. These figures include hardware, ink, media and the value of service contracts. The development of inks and printheads that have made the cost of UV devices more competitive with solvent-based inkjet machines is driving this growth. UV-curable printers are also able to produce some wide-format applications, such as posters, at greater speeds than competing digital wide-format technology because of the instantly dry output UV curing provides.

The InfoTrends research suggests that the wide-format UV-curable printer market has withstood the poor economic conditions of recent years better than any of the competing technologies. This is considered to be due to high market interest, the technology's speed and production efficiency, and the environmental advantages of UV-curable inks. According to the Infotrends report, solvent-based systems revenues are expected to decline from US $3.1 billion in 2008 to US $1.7 billion by 2013, but this data is under revision. This is driven particularly by decline in the high end of the solvent market as users focus on health, safety and environmental concerns, coupled with growing competition from UV-curable technologies.

Product development and new introductions are still expected however, particularly at the low end of the market as digital production and workflows develop along with the market for on-demand signage, banners and similar products. A survey carried out in early 2010 by InfoTrends in conjunction with FESPA suggests that latex, eco-solvent and UV-curable inkjet will all grow at the expense of conventional solvent and analogue (screen printing) techniques. We believe that process digitisation and the spread of web-driven print product purchasing will further fuel market development.

A Fragmented Market

The market for this type of printing is extremely fragmented, which makes it difficult to come up with fair, representative and relevant tests. The market can be loosely categorised by format: wide such as signage, canvas printing, posters and banners, and superwide which includes advertising hoardings, backdrops, billboards and building wraps. Some applications, such as point of sale materials, vehicle wraps and exhibition graphics can straddle both categories. Each sector has different requirements for output quality, substrates, speed of

We used three test forms, a Poster 70x100 cm (above), a resolution test form (2) and also a colour characterisation test form (3).

turnaround, lightfastness, durability and finish. Roughly speaking the more gorgeous, durable and lightfast the output, the higher the price per square metre. For instance artwork prints produced for homes and offices are increasingly common and command high prices. Volumes of high value industrial print such as printing wood effects on doors and wall panels, or printing tiles and carpets are also growing. This burgeoning market for large format digital prints creates opportunities for everyone in the supply chain.

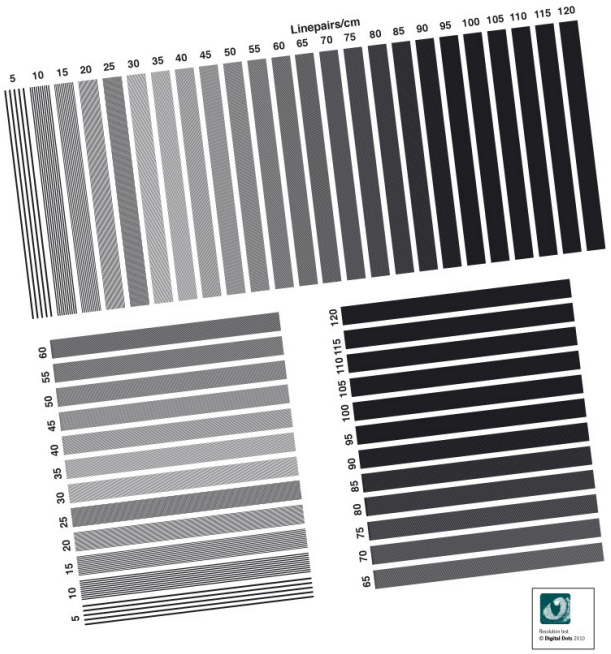
The high number machines available also reflects the desire for more efficiency and flexibility, and for less environmentally hostile technologies. The specific focus

... the more gorgeous, durable and lightfast the output, the higher the price per square metre.

of different manufacturers is however hard to pin down. All obviously want to exploit their technologies to the max and to reach as many customers as possible. Some manufacturers build application specific machines, whereas others such as market leaders Océ prefer to reach all sectors.

The Tests

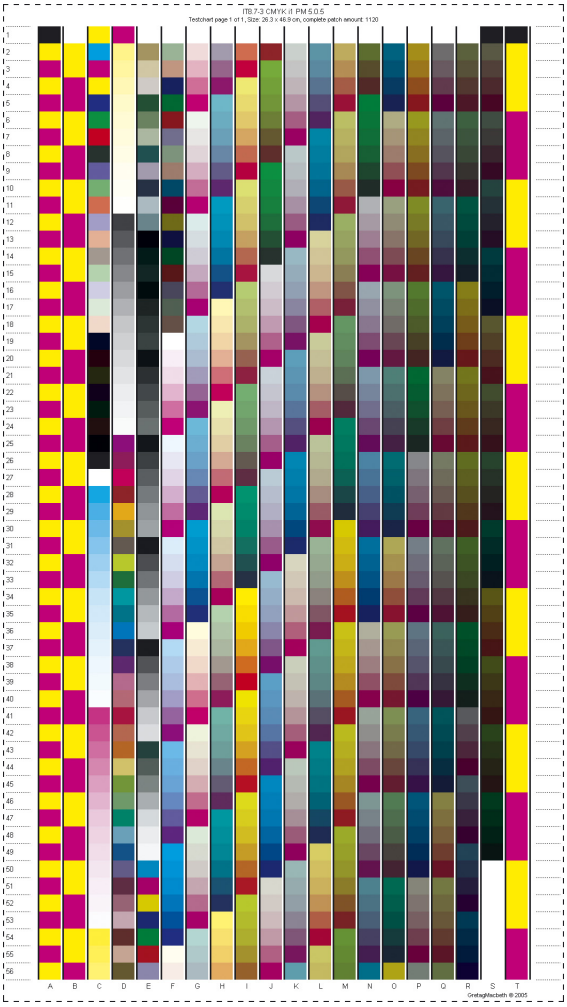
The Digital Dots tests required participants to provide output samples from supplied test files. To test colour gamut, we use a standard IT-8 CMYK profiling chart; for the resolution test, we use a specially-designed chart with line pairs at a wide range of spacings. The participants were asked to print these under optimum conditions onto the substrates of their choice. Participants were allowed to choose any combination of inks and substrates they felt would provide the best results, subject only to the condition that the materials be commercially available. We did not specify a substrate because different printheads and ink sets are optimised for different types of media, depending on the target market and applications. As we



2. The resolution test chart has line pairs at a wide range of spacings, from 5 line pairs/cm up to 120 line pairs. This can then be calculated to the equivalent resolution in dpi.

were looking for the best possible results in each instance, it was appropriate for participants to make their own substrate choices. The printed results were returned to Digital Dots for measurement and analysis in our digital colour lab.

We measure colour gamut by creating a standard CMYK ICC profile from the IT-8 chart data, using an X-Rite i1 Pro spectrophotometer and Profile Maker Pro professional profiling software. The profile was then analysed with Chromix ColorThink Pro to yield a figure for the total number of discrete colours within the gamut. We define discrete colours as those which are separated by a Delta-E (Delta E 76) value in the CIELab colour space of 1. A Delta-E of 1 is the smallest difference in colour the human eye can differentiate, although this varies slightly with individual and colour experience. Typical results for unskilled observers could be higher rather than lower, and may vary throughout different parts of the colour and tone spectrum. Whether an individual could actually distinguish all 400,000 or so colours included in, for example, the gamut of typical offset print on coated paper, as represented by the Fogra 39 characterisation data set, is not



3. We measure colour gamut by creating a standard CMYK ICC profile from an IT-8 chart, using X-Rite ProfileMaker Pro.

important: the analysis provides a consistent and repeatable metric for comparing the colour gamuts of different devices.

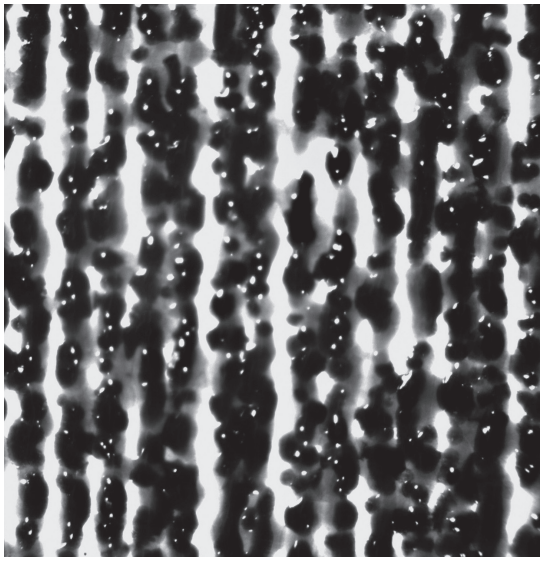
To measure resolution we viewed the prints of the line pairs chart both with a normal loupe and under a digital microscope. We wanted to determine the point at which the lines could no longer be differentiated as distinct pairs, the "true" resolving power of the system. As the spacing between the line pairs decreases, the ink dots forming each line become so close, first touching and then overlapping, that they can no longer be distinguished as separate lines. A manufacturer's stated resolution, which we refer to as the addressability of the imaging system, is used in the RIP to calculate the output bitmap data. Participants had the freedom to select the print settings in their RIP/control software. The aim was to produce the best possible results, while recognising that not all types of commercial work would require such high quality. All media choices and settings were recorded and are presented with the test results on page 33.

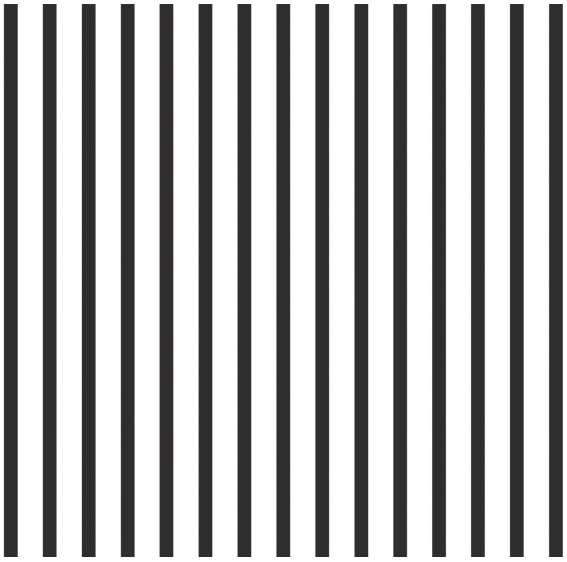
For comparison against current solvent-based technology, we had the same test files output on a selection of Epson, Mimaki and Roland solvent printers. Epson chose to output the gamut test file on an Epson Stylus Pro GS6000 Eco Solvent printer, a 1.6 metre (64-inch) roll-fed device. The GS6000 is not a high volume production machine, rather it is a short-run high quality printer which can be used for proofing. It uses an extended ink set of CMYK, light cyan, light magenta, orange and green, and so should provide a relevant reference for high-end solvent-based printing's achievable colour gamut.

Mimaki participated in the test with two UV-printers, but generously provided some output samples from its CJV30-series solvent printer. There are two ink options: SS21 a fast-drying solvent ink, and the ES3 eco-solvent ink. We present the gamut achieved for both ink types printed on glossy vinyl.

As a courtesy Roland Nordic provided some additional solvent printer output for comparison purposes. These prints were output on Roland VersaCamm VS-640 and VersaArt RS-640 printers. VersaCamm VS-640 is a 1.6 metre width roll-fed printer that uses eco-solvent inks and is available in dual four- (CMYKKYMC), six- (CMYK plus light C and light M) and eight-colour (as 6-colour plus metallic silver and white) variants. According to Roland, the VS-640 is suited to applications such as vehicle wraps, window graphics, banners, fine art posters, labels and decals and heat transfer for clothing applications. We measured samples printed with the six-colour configurations.

The VersaArt RS-640 is also a 1.6 metre roll-fed printer and uses mild solvent or aqueous dye sublimation inks. It prints in four colours only (CMYK) and is suitable for similar applications to the VersaCamm model. Our





Left: The actual resolving power for an inkjet device depends both on the size of the drop, and how it's placed. Shown is a sample from Efi Vutek GS3200 at 65 lp/cm (the image is zoomed approx 500x). *Right:* The original – the test form for resolution contains line pairs spaced increasingly closer to each other. Here the original at 65 line pairs per centimetre, and equivalent of 390 dpi. The zoom factor is approx 500x.

test samples were printed using CMYK solvent inks. We analysed these prints using the same methodology to provide a reference value, for comparing the UV-curing printers tested. Readers should note that these printers are not being suggested as alternatives to any of the UV-curing models tested here; the inclusion of these figures is solely to provide a reference for typical and high-end solvent print colour gamuts.

Industry commentary

UV-curable ink technology has been in use in the commercial printing market since the 1970s, particularly in screen printing. On exposure to the correct intensity of UV light, the inks cure almost instantly from liquid to a hard, resilient and pliable film. UV-curable inks have lacked sufficient flexibility, causing cracking and flaking on some surfaces and although ink chemistry is improving, there have been problems with some materials with poor adhesion and a crazy paving effect on flexible media. This can be fixed with lower curing times so that although the surface may not be fully dry, it doesn't craze. This, coupled with the flexibility of digital printing with its near-zero makeready and the ability to vary the content of every print, has led to a dramatic level of technological development in, and market uptake of, UV-curable industrial digital printing. The instant drying means faster production is possible than with alternative wide-format digital printing technologies, while the ability to print directly onto rigid substrates does away with mounting and laminating processes, again making production both faster and cheaper. The lack of VOCs and harmful emissions, a detrimental component of solvent inks, is an environmental benefit of increasing importance to users, as health and safety concerns continue to move up the agenda. The emergence of viable web-driven applications, such as on-demand posters, banners and backdrops, is increasing the range of markets for this technology, from corporate signage in the retail sector, through to posters and banners for consumers.

Printheads

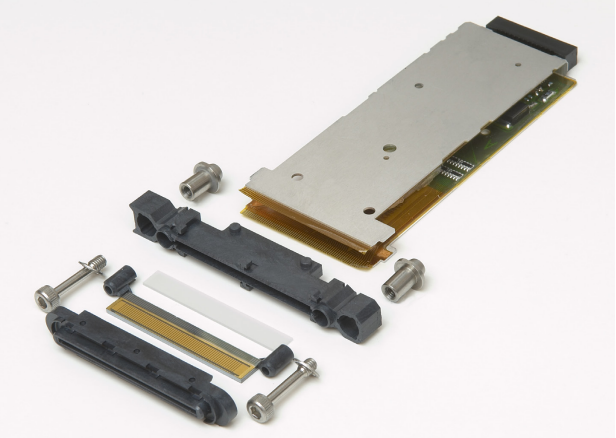
Printhead technology controls how ink is delivered to a substrate, and varies according to the purpose for which it is designed. There are two kinds of inkjet printhead: continuous flow and drop on demand. In a continuous flow printhead, pressure waves cause ink droplets to diverge from the ink flow. The droplets pass through an electric field which directs the droplets either to the substrate or back to the inkflow. This technology can

lay down drops extremely quickly and because the ink is continuously flowing through the nozzles, the risk of clogging is minimal. This makes the continuous flow inkjet very suitable for high speed applications but until recently it has not been considered precise enough for top quality work. Continuous flow technology is improving however and is now being used in machines such as the Kodak Prosper digital colour press, for high quality commercial printing.

Drop on demand printheads only eject an ink droplet when required. They use either piezo electric or thermal energy for drop emission. A thermal head heats the ink to form a bubble which is then ejected from the nozzle to the substrate. Piezo electric heads use electric energy to force the drops out of the nozzle and is more common for high quality applications such as digital proofing. Thermal technology, widely used in office applications and consumer printers, is increasingly used for quality work. In wide format only HP offers a thermal printhead technology used in wide-scan heads to jet latex ink. Canon uses a variant of its bubble-jet thermal technology in its iPF series of wide format printers.

These technologies can be configured as either binary or greyscale printheads. A binary head such as those in Grapo's Manta uses a single bit per pixel, so it either prints a droplet or it doesn't. Greyscale heads print variable droplet sizes ranging from 6 to 42 picolitres and because of this can create an impression of higher resolution. It is important to know what the minimum and maximum droplet size is for a particular head as this can influence the printer's coverage and ability to render fine details. An eight level greyscale head uses three bits of data per pixel (2x2x2=8) and a sixteen level head four (2x2x2x2=16) to address multiple grey levels. Small dots can be used for highlights and fine details and larger ones for shadows and flat tints. Varying the droplet sizes in some respects creates an effect similar to that of stochastic screening in analogue printing: improving the appearance of highlights and shadows, and reducing ink usage. Heads that only print very small binary droplets generally achieve full coverage with multiple passes of the printhead over the substrate, so greyscale heads can be less productive. Theoretically with variable drop technology, which uses a smaller droplet size, there should be no need for light cyan and light magenta inks however these inks are still used in many machines with variable drop heads.

The combination of small droplets combined with precise drop placement makes possible sharper images and smoother tonal transitions; larger droplets print denser and more uniform solids. A number of machines are



HP Scitex's X2 print head is designed for extremely high throughputs. It can be assembled into multiple head modules for output resolutions of up to 800dpi, according to HP.

available offering variable dot technology including market leader Océ's Arizona VariaDot with 6 to 42 pl droplets, Agfa's Anapurna printing 8 to 24 picolitre (pl) drops (depending on the model) and Mutoh's Zephyr 65 which prints 8 to 40 pl drops. Variable sized dots can produce outstanding quality results, which is why our resolution and colour gamut test results must be considered in context.

Printheads, one to eight per colour, can move across the substrate or be fixed, with the substrate moving past the heads as they lay down inks. Printers can be configured with either single pass or multipass (scanning) heads, printing to either roll or sheet fed substrates. A device's speed is limited only by the speed with which the substrate can be moved through the machine, so devices with a fixed configuration can be extremely productive. Multipass heads however, which move back and forth across the

substrate, can disguise problems such as banding caused by nozzle blockages, misfirings or mechanical failings in the head. Engines of this type may not be ideal for work that has a lot of small text and fine lineart. Printers can also be configured with fewer heads in a multipass configuration, reducing the cost of the machine and productivity.

The native resolution of printheads used in large format flatbed devices, as defined by the distance between the nozzles, ranges from around 50 to over 300 dpi. This spacing determines the head's addressability so manufacturers try to improve output appearance, particularly for applications for close-range viewing. Typically they slightly offset the printheads' position on each printing pass to give higher addressable resolutions in one direction, while the spacing of rows of drops in the direction of printhead travel can in theory be made as narrow as mechanical tolerances and productivity demands will allow. This is why you will often see asymmetric resolutions such as 600x300 dpi quoted.

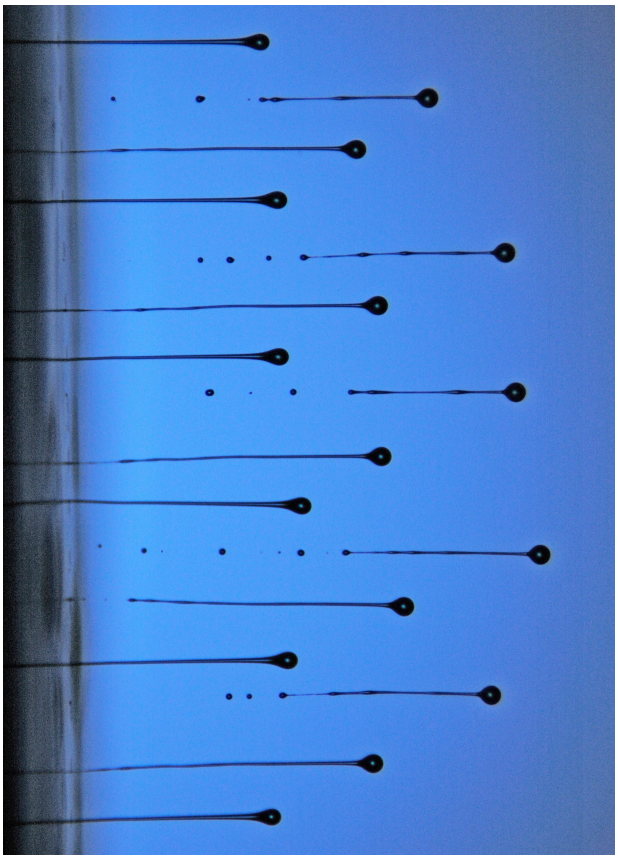
Inks

Inkjet printing systems are extremely versatile and can extend the traditional printers' ink set beyond CMYK. The addition of light cyan, light magenta, grey, green, blue, and white inks dramatically expands the printed colour gamut, making it easier to match brand and custom colours.

To be jetted through an inkjet head, ink has to be highly fluid. Inks must be optimised for the heads and maintain the correct viscosity to jet properly. But jettability is only part of it. The surface tension of the ink must also be compatible with that of the substrate, so that their interaction maximises adhesion. Once printed these inks must perform well on the substrate so besides adhesion, curing characteristics, stability, colour consistency and durability must all be factored into the recipe. Developers achieve optimum compatibility through the ink formulation and substrate surface treatments, which is why companies such as Agfa and HP make inks for several different product lines including wide format and high speed web printing. Manufacturers also buy in inks to blend different components and optimise performance. There are two broad categories of ink used for large format inkjet printing: solvent and UV-curable inks.

Solvent Inks

Solvent inks contain VOCs which readily vaporise. They are soluble and use pigment colorants with large particles. They do not fade as readily as dye based inks which have smaller particles and a wider colour gamut, but are vulnerable to light and ozone. Solvent inks are inexpensive to use and stick fast to almost any sort of surface, from uncoated flexible vinyls to sticky decals, but they produce toxic fumes when dried and used solvent inks require special disposal. These inks fall into several classes: the



This image called "Tailes From the Nozzle Bank" was taken during a series of experiments at the Cambridge University Engineering Department's Inkjet Research Centre. It shows ink drops emerging from a bank of inkjet nozzles. The image is about 2.3 mm across, the drop heads are 50 microns across and the tails are less than 10 microns wide (10 times thinner than a human hair). Image reproduced courtesy of Steve Hoath, Cambridge University.

most durable hard solvent inks, through mild to so called eco solvent or low solvent inks, formulated for use in enclosed spaces with no need for special ventilation.

Developers continue to look at alternatives however. For instance, Vutek introduced its BioVu bio ink based on corn and sold by Mutoh as MuBio a few years ago, and Mutoh recently launched Bio-Lactite. It sounds like a yoghurt, but Mutoh claims this ink can lower running costs and is backwards compatible with installed devices.

UV-curable Inks

UV-curable inks have a different chemistry altogether: light rather than heat turns liquid ink into a solid that sticks to a substrate. The quality, flexibility, durability, light-fastness and cost of UV-cured prints is a function of the inks, substrate and curing technology as well as the viewing environment. UV-curable inks sit on top of the substrate and solvent ones penetrate it, so the two have fundamentally different characteristics. The dried layer of solvent ink keys with the substrate to provide a durable bond, so the higher the percentage of solvent in the formulation, the greater the bond with the material's surface.

UV-curable inks contain colorant particles, usually pigments, suspended in a fluid with various other components. The composition determines the ink's behaviour while liquid and properties when cured. Exposure to UV light activates photo-initiators in the inks which fragment into reactive materials to start the process of polymerisation, locking the colorant particles into place in a solid matrix. Photo-initiators are usually free radicals, highly reactive molecules which trigger the assembly of monomers so that they combine in the ink to form polymers. But free radicals can also combine with oxygen in a process called oxygen inhibition which can potentially reduce cure effectiveness.

The curing process must also be carefully controlled because UV curing is cumulative. The amount of energy provided for curing and the depth to which it penetrates the ink film have a critical effect on the properties of the finished print in terms of stretch and adhesion. Undercuring can lead to skinning, in which a cured layer forms over partially-cured or uncured ink, reducing the ink's adhesiveness and lifting it from the substrate, while overcuring can make the ink brittle, leading to cracking and even flaking away from the substrate. Cationic inks, discussed later, offer a possible solution.

Free-radical inks only cure and bond to the media in the presence of UV-light, so curing stops when the UV exposure finishes, which can lead to partial curing and problems with adhesion across layers. Also UV-curable inks are laid down in a thinner layer and because of their chemistry can be quite brittle. The cumulative result of curing may also result in further brittleness and ink flaking.

The vacuums in flatbeds must be strong enough for heavyweight substrates. Here the Polytype Virtu RS35.

Compared to solvents, UV-curable inks are not as durable or as suitable for applications where heavy surface abrasion is likely. Although UV-curable and solvent inks use similar pigments, solvent inks meld deep into the substrate making the prints generally less likely to fade, more durable and less prone to scratching. However the lower the amount of solvent, for instance in an eco-solvent formulation, the less the bonding and adhesion potential.

UV-curable inks sit on the substrate surface rather than penetrating it. This can make them unsuitable for printing on really shiny surfaces where there is no key such as glass. UV-curable inks also have variable opacity, from transpar-

ent to translucent to allow light to permeate the ink and cure it, and this can also impede curing on reflective surfaces. Such problems can be overcome through the use of primer or bonding agent.

Although there are no VOCs to worry about with UV-curable inks, there are potential operator problems with UV light exposure and sensitisation to uncured inks. Sufficient skin exposure to UV light causes symptoms akin to sunburn, but irritation of the eye can also occur from looking at unshielded UV sources and may build up over time. UV-curable inks are not volatile so handling issues are related to direct contact with uncured inks, which can lead to skin irritation. Uncured or partially-cured inks may also have an odour and UV-curable inks are perishable with a limited shelf life, so ink stocks must be rotated.

> The amount of energy provided for curing and the depth to which it penetrates the ink film have a critical effect on the properties of the finished print in terms of stretch and adhesion.

The quality and durability of UV-curable inks have increased of late and their cost has fallen as manufacturers scale up production. These inks are becoming more robust with better lightfastness and abrasion resistance. UV-cured prints offer good durability and lightfastness, though it's still unclear whether they are equivalent to solvent levels in this respect. Lightfastness is a key criterion for many of those looking to buy UV-cured print. Durability is another key factor in printing device selection for certain types of work and in what people will pay for the prints. So UV inks are being designed to use more light-stable pigments and have greater strength. How long colours remain stable outdoors and the substrate's influence on a print's lifespan are factors that we continue to investigate.

Cationic Inks

Advances have been made recently with an alternative to free-radical UV-curable inks. Cationic inks use cationic monomers and a photoinitiator to create polymers. They require longer exposure to less intense UV light but this can yield more durable results. Cationic inks such as GerberCAT Cationic UV inks which cure contiguously, can use a less intense UV-cure frequency, requiring less energy to cure and generating less heat in the printer. These inks are therefore suited to applications printing onto fragile substrates. Cationic ink curing only has to be initiated and continues until it is complete, which requires less energy. But oxygen can inhibit polymerisation so these inks must be carefully stored. For this same reason free-radical inks generally function better for applications where large droplet sizes are preferred.

The promise of cationic ink is better performance because the ink cures completely: once the curing reaction starts it continues until no more curing can take place, which can improve adhesion and aid durability, lightfastness, resistance to pollution and the effects of weather. However controlling cationic inks so that they don't start curing before they are supposed to is tricky. These inks can also be sensitive to substrate surface chemicals which may interfere with curing and prevent full adhesion, and cationic inks are prone to absorbing ambient moisture. They also need to be kept clear of the printheads to prevent accidental curing of areas outside the print parameters, and cleaning cycles require vigilance to ensure there are no stray droplets. All of this can prevent the photoiniators from reacting, so the inks fail to cure. Cationic inks are obviously more expensive than free-radical inks because of their chemistry and the nascent state of their market.

For all of these reasons there is only one machine in the display market using cationic inks. Konica Minolta introduced a head and cationic ink technology at drupa 2008 and supplies heads to various manufacturers including

Gerber for the Solara Ion. Gerber shipped its first Solara Ion machine in 2008.

UV-curable vs Solvent Inks

UV-curable printing has a number of benefits over other wide-format digital printing technologies, most of which use solvent-based inks. Perhaps the principal benefit for companies selling these prints is their fast drying and application flexibility. Curing may actually continue for a number of hours after exposure to the UV source, but this process requires no time- and energy-consuming drying stage, and no additional drying equipment, saving floor-space and capital investment. Altogether this makes for both faster and cheaper production, and a faster return on investment (ROI) for the printer.

Another strength is the technology's ability to print directly onto a very wide range of substrates, from rigid display board materials and roll-based flexible media including

UV-curable ink has strong environmental advantages too, as it contains no VOCs so no extraction system is required to remove them from the working environment.

vinyls, self-adhesive, woven banner materials, paper, film and textiles, to exotic materials such as wood, metal, glass and ceramics. As well as making possible new and novel types of production, this saves the time, manpower and the costs associated with mounting and laminating roll-fed output onto its final substrate, again speeding production, reducing its costs and hastening ROI.

UV-curable ink has strong environmental advantages too, as it contains no VOCs so no extraction system is required to remove them from the working environment. This can save both capital and ongoing energy costs and because nothing evaporates from UV inks as they cure, less ink is required: pretty much everything that the printhead ejects remains on the substrate. Because UV-cured inks sit on top of the substrate and don't soak in, there is lower and more predictable ink usage and easier de-inking. These inks can be used on porous materials as long as the printer has a trough to remove excess ink and prevent it splashing back onto the printheads. Compared to solvent alternatives, free-radical UV-curable inks do not tend to dry in printheads or cause nozzle blockage, but it is possible for shiny substrates such as glass to reflect UV light causing partial curing in the nozzles. Most solvent machines regularly pass or spit ink through the heads in order to keep them clear. This is not required with UV-curable inks.

Cures for All Ills

For UV inks to cure completely the UV energy must fully reach the inks. White ink is commonly used as a background colour or base for the other colours to enhance colour quality. It is used for under-, over- and spot printing but because white reflects light it must be cured for longer. Equally black inks are more difficult to cure because black absorbs light. Both inks need longer UV curing to achieve full adhesion, but longer cure times risk overcuring, leading to crazing and cracking.

Most machines on the market use UV lamps most commonly irradiating at 245 to 405nm. These lamps generate a lot of heat, which in mid to high performance systems usually requires a cooling system to dissipate. Even so, much of the heat can reach the substrate in multiple-pass printing, potentially causing problems with heat-sensitive materials such as thin films. The lamps are also expensive which adds to a device's cost, and typically have to be replaced every 1000 to 1200 working hours. Their output can change with age and they can lose intensity before they fail, undermining cure effectiveness. Mercury arc lamps also need to warm up which takes time and energy and their use can also form ozone, a respiratory irritant.

LED Curing

LEDs (Light Emitting Diodes) offer an alternative to mercury arc lamps. They start up immediately and have no

movable parts such as shutters, so they are more reliable. There is also no risk of bulbs breaking or ozone emission. LEDs require less than half the energy of conventional lamps, generate less heat and can last over ten times as long. LEDs radiate no infra-red heat so the printing device

There are several combination of hybrid roll-fed and flatbed inkjet printers. Here the Mimaki JFX-Plus, a flatbed printer with roll feeding as an options. Other hybrid systems combines roll-feeding with an optional attachable table.

can print onto a wider range of substrates. LED output power is also predictable and consistent throughout a diode's life. For printers and their customers this can mean more reliable and consistent output.

LED arrays for UV-curable inks are designed to emit UV light over very specific narrow wavelength ranges, so the relationship between inks and LED energy must be carefully tuned. For instance the Agfa Anapurna 2500 LED lamps emit UV-light at a wavelength of 395 nm. The long wave-length means that the ink curing goes deep into the ink layer, aiding adhesion. UV-curable inks respond to these wavelengths and cure at much lower power levels and temperatures. However the inks must be formulated to respond to the specific spectral outputs of the LEDs, which puts additional demands on the ink formulation. Also the current technology cannot provide the level of UV exposure necessary to cure these inks at high speed.

Mimaki, Screen UK, Roland DG, Sun LLC and INX Digital and Agfa have all introduced machines that use LEDs for UV curing and we have tested the Mimaki JFX-1631 as part of this project.

Costs

UV-curable inks currently cost more than solvent inks, but as there is no need to extract fumes the overall investment is lower which compensates for higher ink prices. Also UV inks dry instantaneously so the print engines can be more productive, and improved colour accuracy can reduce the frequency of reprints. UV-curable machines can print onto a large array of materials, flexible and rigid, so there is no need to fix and overlaminate prints onto rigid substrates. This saves a production step and increases production capacity.

For many applications such as signage, less UV-curable ink is needed than is the case with solvent inks. According to Agfa it takes 12-14 millilitres of solvent ink to cover a surface area of one square metre, whereas the same area printed with a UV-curable ink only needs 8-10 millilitres. The Océ Arizona Series UV-curable printers for example, consume less than 8 ml of ink per square metre. Reduced overall consumables cost for a job enhances either profitability or competitiveness, depending on the printer's preference.

Controlling the ink droplet size also influences consumables usage as well as output quality. Variable ink drop sizes and the use of light inks (light cyan, light magenta, light yellow, grey etc) provide ways to boost the apparent resolution, with less ink. Light inks can be printed in between the dots of the primary colours, for example, thus allowing smoother tonal gradations than would otherwise be achievable with fixed dot sizes and relatively coarse resolutions. The smaller the droplet, the greater the pigment concentration will be, so ink consumption can be lower without compromising the print quality. Precise droplet control can help improve quality, enhancing the value of the job while using ink more efficiently. So saying, beware claims about ink savings, such as one supplier's contention that their droplet control yields a 35% saving. Savings are subjective and not easy to prove or replicate.

Another important factor influencing costs is how a print job is specified in the front end system. Some print jobs

are over-specified with for instance, too high a resolution for the viewing distance. If a job is over specified, it will take longer, use more consumables and cost more than it should. Customers may like the quality, but they're unlikely to be pleased with the price. Conversely if the print is under-specified and output quality disappoints, customers may take future business elsewhere. One way or another, the printer is exposed to unnecessary business risk.

Substrates & Formats

Substrates must be rated to work with the ink used in a given device and they must be available in the right format, whether the device is single sheet or roll-fed, simplex or duplex. Wide format UV-curing printers are available in many widths but the entry level is generally considered

The Inca Onset's material handling system is designed to provide flexibility and the versatility to print onto a wide range of media.

to be 1.6m (54"), for example the Agfa Anapurna M range, Mimaki's UJV-160 and the TeckSmart UV 1600. Other common sizes are 2.5m such as the Océ Arizona 550 GT, 3.2m such as EFI Vutek's GS3200 and five metres such as Polytype SA's RR50. The overall sizes of these machines depends on whether they are flatbed or hybrid machines with optional roll-feed attachments.

When considering materials the machine must be able to support the roll weight, and the vacuums in flatbeds must be strong enough for heavyweight substrates such as plywood. Substrate flexibility and stability are obviously important for applications such as vehicle wraps which require considerable elasticity (200% and more) and must be able to withstand extremes of weather and light exposure. Laminates, applied prior to wrapping must have the same stretch characteristics as the substrate. Some substrates, such as thin films, rigid plastics and thin aluminium can distort or warp when exposed to extreme light and heat. The preferred substrate may also need pretreatment to ensure that inks adhere properly.

Quality & Finish

Inkjet technology is capable of delivering exceptionally high quality output, but it isn't always perfect. Apart from colour accuracy and tonal rendition, the most serious concern for users and print buyers is mottling and banding. Both can occur as a result of malfunctioning or nozzles blocked with air, dust or dried ink, or because of media misfeed: if the substrate moves too slowly, excess inking occurs and if it moves too fast for the heads, a white line will result.

Developers have various ways of overcoming such problems. HP uses a special software algorithm to compensate for missing nozzles, so that the engine can keep printing without compromising print quality. Roland with Intelligent Pass Control and Mutoh with its Intelligent Interweaving have developed special algorithms, that use a range of criteria such as viewing distance, purpose and content as specified in the set up, to determine how best to achieve the final quality expectation. They allow operators to select the print mode best suited to a customer's needs. The technique can achieve very bright, sharp, detailed images quickly without using excess ink. The objective is to get acceptable quality for a given viewing distance, using the right amount of ink and at an appropriate and predictable printing speed.

Mutoh's algorithm is particularly impressive. The printer lays down the ink in optimised variable frequency waveforms instead of the more commonly used straight lines. The technique can substantially reduce, and sometimes eliminate, mottling and banding defects and

Mutoh claims it can even disguise the effects of misfiring or defunct nozzles because the wave curves can overlap. Mutoh is working on print weave patterns for specific devices to yet further optimise their performance, and this technology is now standard on the majority of Mutoh wide-format piezo inkjet printers. Mutoh also supplies solvent machines on an OEM basis, for instance to Xerox and Océ, so the technique is being used in a growing range of applications and market sectors.

The options for the finish on large format prints are growing almost daily. From a simple matte or glossy finish it is now possible to control the degrees of gloss, with controlled curing.

The options for the finish on large format prints are growing almost daily. From a simple matte or glossy finish it is now possible to control the degrees of gloss, with controlled curing.

Flatbed printers need a large bed to feed and receive substrates. They, and many hybrid machines, use vacuums to aid stability and some have zoned vacuum areas. If the media doesn't precisely fit the zoned area on a flatbed machine, areas not covered are masked off. The process adds time to output processes and to a machine's cost but it is necessary for many applications that use flexible media.

Quality is not just a matter of inks and software sophistication. Sturdiness in the frame and printhead, the mechanics of the material transport all help minimise vibration for accurate droplet placement and therefore quality. Roll to roll printers have spindles on the front and back of the machine to manage media, and it's important that these are strong enough to hold the rolls and that they can maintain a straight and steady tension.

Productivity

In all areas of the graphic arts, prepress digital productivity innovation has brought down the per copy cost of print. Process automation continues to drive efficiency and productivity, especially on large machines such as the Inca Onset S70. Different print modes affect output quality: fastest for draft or production, slowest for high quality.

Measuring the output speed of digital printing machines is notoriously subjective. Printing at the lowest resolution to meet the lowest possible quality expectation, will be superquick, and the same machine printing at the highest possible quality level will of course output much more slowly. Manufacturers may offer different models with the same output speed but for different prices. Different models may for instance have variable or fixed drop sizes or fewer printheads, so although both print at the same rate, they output different quality levels.

Applications and markets

Thanks to the ability of UV-cured ink to adhere directly to a wide range of materials, UV-curable printers are capable of handling an exceptionally broad range applications, including:

- Billboards/hoardings
- Scaffold and building wraps
- Banners, backdrops and signage
- Point of Sale or Purchase (PoS or PoP) and hospitality industry displays, folded and flat
- Posters, both reflective and back-lit
- Window and other retail graphics
- Gaming machine panels and other product decoration
- Packaging prototyping and short-run/custom production
- Novelty promotional items – printing on wood, metal, glass, ceramics and other non-standard substrates

- Wall coverings
- Home and commercial decors
- Industrial
- Labels, stickers, decals

The Long-term, Large-format Digital Printer

Kleinhempel in Hamburg specialises in producing very large format work typically of 100 square metres or more for outdoor installations. This includes backlit posters, billboards and building wraps, in addition to permanent indoor decoration, theming or branding for retail, commercial and municipal spaces. Projects undertaken have included wrapping the Weltzeituhr, a 150m high spire at the Alexanderplatz in Berlin, producing and installing a 17,300 m² building wrap at the Dubai World Trade Centre and a branded motorway bridge wrap for Nissan.

Establishing the business in 1936 as a photographic studio in the Hamburger Kunsthalle fine art museum, founder Ralph Kleinhempel originally made 35 mm colour transparencies of the paintings to sell to museum visitors, along with separations for printed reproductions. Kleinhempel's son Christopher, who apprenticed as a photographer at the Reger studio in Munich, took over the business in 1984 and added a large photographic studio and lab which in its heyday employed nine photographers and produced a lot of large format photographic print.

Today, the company has an impressive arsenal of nine large format digital printers in production, including three 3m and three 5m width EFI Vutek machines, two HP DesignJet Z6100 42" inkjets and an HP Scitex latex printer. Some 40 employees work across two shifts to produce a range of products on paper, canvas, textile, mesh or backlit films.

Digital direction

Kleinhempel's involvement with large format digital print is no recent fad, however. It dates back to 1992 when Kleinhempel was the first company in Europe to install a Vutek 1600. This five metre machine printed eight colour solvent inks with eight 'airbrush' printheads and was ideal for printing for backlit display panels in sizes up to 5x10 metres, so expanding the range of work Kleinhempel could tackle.

In 1998 Kleinhempel installed a Vutek 5300 5m width solvent-based printer. This printer was generally acknowledged to offer the best image quality on the market and was a platform for Vutek's global success. In 2004 Kleinhempel made substantial improvements to its production workflow through centralisation of various

departments: photo studio, prepress, inkjet printing, post-production shipping and service, consolidating everything into one building. But by the end of the decade the tough economic environment coupled with continuing customer demand for speed of turnaround with no loss of quality meant that Kleinhempel was again shopping for a better and faster superwide printer.

"We are consistently under pressure to deliver more posters at better quality and increasingly quickly," comments Christopher Kleinhempel. Believing that building existing customer loyalty is more important than chasing new business, Kleinhempel was less focused on company growth than on achieving better and faster output with an overall shorter production cycle. As a result, the company took the decision in 2010 to invest in an EFI Vutek GS5000r, a five metre width UV-curable roll-fed printer, buying the display unit from EFI's Fespa 2010 stand in Munich in June. "We did think about a Durst five metre UV-curable printer," comments Kleinhempel,

"but bought Vutek again because we have had a really good experience with the company, and the price was better."

Better, faster

Compared to Kleinhempel's older UV-curable Vutek printers still in production – a QS3200r roll-fed machine and a QS200 hybrid – the GS5000r offers superior image quality through its use of greyscale printheads. For each printed pixel a greyscale head fires from one

to seven droplets to simulate different grey levels for each ink. There is also a choice of resolutions, either 600 dpi using 24 pl droplets or 1000 dpi via 12 pl droplets, to achieve near-photographic image quality with text claimed to be readable down to four point.

Enhanced productivity complements these quality improvements. Each printhead nozzle has a higher firing frequency and the GS5000r uses more recent UV lamp technologies to cure the ink faster. Ink options of CMYK plus CMYK light or double CMYK allow for a potential productivity of up to 288 m^2/hour. However, Kleinhempel's production manager Christian Marx says that to meet customers' expectations and his own company's quality standards, an average production speed of around 60 m^2/hour is more typical.

Printing reliability is also expected to be improved with the GS5000r. The design features two printheads instead of the three found in earlier models, but with no reduction in expected lifespan. The greyscale nozzles and improved UV-curable inks have led to less clogging in the printheads. A more robust frame design and various other component upgrades should also help with long-term reliability.

From Christopher Kleinhempel's perspective, the new printer is not a textbook exercise in calculating return on investment, it's there to continue to improve service to existing customers. "By lowering production costs with a faster and better printer like the GS5000r, we gain an edge in a tough market," he says.

As noted earlier, UV-cured print does not yet suit applications requiring extreme localised flexibility, such as vehicle wraps. It has an equivalent lifespan to solvent for some outdoor applications, although solvent based over-laminated output may be preferred for long term exposure. However UV-curable inks work very successfully on many textiles, such as canvas, industrial nylon and cotton. But for existing screen printing firms, the advantages of digital print for short-run and variable data production are already apparent; the higher production rates of UV-curable printers should appeal to those interested in higher volumes. Commercial offset printers looking to expand their service portfolios will note that solvent-based print is already in decline in the west and be more likely to opt for the still-developing UV-curable technology, particularly if they want the versatility of printing direct to rigid and flexible substrates on the same engine. All-digital shops used to the office environment suitability of toner-based presses are far more likely to choose the less industrial UV-curable option when establishing a large format capability.

Test Commentary

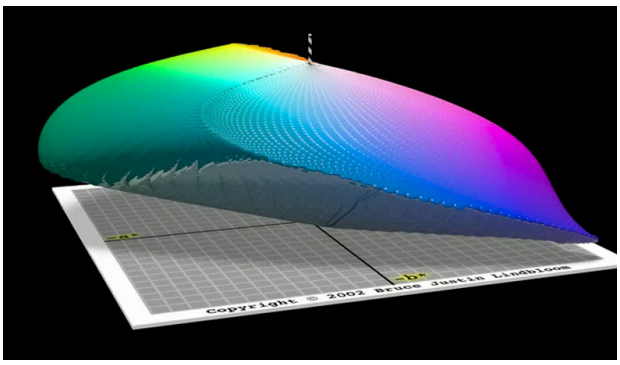
Our tests aimed to quantify two key parameters of UV-curable large-format printer output: colour gamut and resolution.

Colour gamut

The vast majority of output from large format UV printers is used in a commercial context, to promote, advertise and often physically showcase consumer goods. Vivid, eye-catching colour is an effective way to do this and it's desir-

able that colour gamut from UV-cured prints matches that achieved with other printing processes, especially for consistency across campaign and marketing materials. It is also necessary to be able to match corporate or brand colours to produce consistent colour across output locations. These factors can make the difference between winning work or not, so they must be taken into account when evaluating competing technologies.

In screen and offset printing, maintaining brand consistency is typically achieved through the use of spot or special colours. However digital printers in this sector are not designed to add the occasional fifth (or sixth) colour in a separate print stage as is the case with a conventional analogue press. Manufacturers of digital machines instead



The number of single visible colours for humans is about 2.4 millions, according to colour scientist Bruce Lindbloom.

seek to increase the available colour gamut using high pigmentation versions of CMYK inks. Alternatively they offer configurations that support additional primary colour inks, including for instance orange, green or blue, to substantially expand the available colour range.

Colour gamut is a function of ink and substrate. Because UV-curable inks form a film on top of the substrate rather than penetrating it, the substrate has less influence over colour appearance than it does in solvent-based printing. The principal parameters affecting colour gamut are the spectral purity of the pigments used and the transparency of each ink, plus the whiteness and gloss of the substrate. The inks are overprinted so it's crucial that pigment particles in the lower layers show through as transparently as possible, when the ink is cured. Pigments from the automotive sector are often used in UV-cured inks as these offer the colour density, covering power and light-stability required. In some ink formulations, particularly those developed from screen-printing UV-curable inks, the order in which colours are laid down matters; in others the print order is not critical. UV-curable inks for digital devices, such as those tested as part of this project, are generally tuned or optimised to suit the specific printheads and curing lamps in each printer.

Resolution

Resolution is a thorny topic. In inkjet printer design and marketing both manufacturers and buyers want to see the highest numbers, but figures without context are misleading and make direct comparison of product specifications difficult or even meaningless.

For most graphic arts professionals, higher resolution generally means better image quality. But the viewing distance comes into play for large format applications. The prints are viewed at different distances in different applications so there may not be the same need for high resolution. Screen printing can be as low as 25 lpi for example, something which most commercial printers, publishers and print buyers would consider as totally unacceptable. On the other hand, some large format output applications actually assume using and viewing the printed matter close up, for instance in point of sale applications or labels, which requires the appearance of high resolution.

The advantage of new generation inkjet printers over conventional methods is their ability to print multiple passes and to vary dot sizes. This enhances the appearance and can also disguise quality fluctuations across the format, to ensure consistency across the printed surface. But the native resolution of the print head is only part of the story.

In most cases, how well continuous-tone images can be reproduced is more important. The more photographic the results, the higher the value of the prints. Manufacturers improve appearance using software as well as hardware, with sophisticated colour management and screening

algorithms. They can get impressive results, despite printing at relatively low resolutions. Sometimes it's important to print for example legible 4-point text, which needs high resolution and high precision in drop placement.

We measure achieved resolution in a single colour (black) by printing line pairs with increasingly narrow gaps between them, and viewing them under a digital microscope. The method is similar to that of testing lenses and other optical components and provides a test of actual resolving power rather than dot addressability, an important distinction.

Dot addressability refers to the array of grid positions at which a RIP may choose to place or not place a dot when rendering an image, text or line art. The print head must then be able to place droplets to reproduce the digital bitmap version of the image on the substrate.

To enhance image appearance and tonal range, output can be controlled to use more than one bit when addressing the placement of ink droplets. Three bit output means (2x2x2) eight grey levels per colour channel, and four bit output (2x2x2x2) offers 16 tone levels for a given ink.

Multipass printing (scanning) can create the appearance of higher resolution and quality. The size of the droplet is also crucial: there's no point to reproducing a very fine line (or screen dot) using a droplet size that is larger than the line itself.

Scanning technology is one of the reasons why manufacturers' quoted resolutions can be several times higher than the values measured in our tests, which measure the achieved, true resolving power. The results of the resolving power test are most directly relevant in the context of line art and text reproduction, and to a lesser degree to screened photos.

For most buyers of digital print, the critical factor is perceived resolution rather than a printing device's ability to resolve line pairs on the page. The former can be shaped through clever colour management and screening, dot placement and manipulation. However a clear and unambiguous way of measuring and describing resolution in large format inkjet output makes fair the comparison of different devices. We believe the resolution test provides a first stepping-stone towards a clearer understanding of the significance of stated resolution for these devices.

The Screen Printer Turned Large Format Digital Specialist

Boyall Graphics based in Northampton, UK, has a background in conventional screen printing. Jeff Boyall and Wayne Cayton started the business in 1975 in a converted garage, manually producing artwork which was then exposed using a photographic enlarger in a darkroom. Since then, the company has grown to employ 20 staff and since the acquisition of a Polytype Virtu RS 35 3.5 metre UV-curable printer its screen printing equipment now sits almost completely idle.

Boyall's biggest early customer, which it retains to this day, was Coca Cola, for which it produces the backlit

Boyall Graphics printed these glass panels on a Polytype SA Virtu RS35 printer.

panels that go into drink vending machines. This involves printing onto clear polycarbonate panels with a white backing, requiring extreme care. Accuracy to within 0.25mm both in registration and dimensional fit is imperative, as is consistency in the density of the white underlayer and most importantly the integrity of the Coca Cola red when illuminated. Working in conventional screen print meant pre-printing and stocking panels for

Coca Cola, ready for despatch as and when required. With more than 50 different stock designs just for the UK, this meant warehousing up to 250,000 panels. Producing a new design could take two to three weeks.

Printing UV-curable inks onto glass is one of the most challenging applications on the market. The curing is hampered by the lack of key on the surface and by the way in which UV inks dry.

Digital benefits

Boyall made an initial foray into digital printing in 2001 with the acquisition of a Vutek 3360 solvent-based roll-fed printer. This brought low stock holding, speed, flexibility, quality and the ability to support customisation, so the company was keen to bring these benefits to its work on vending machine fronts too. The firm spent eight years monitoring the market, considering machines from Inca and NUR (prior to its acquisition by Hewlett Packard at the end of 2007) and Durst, but these were not considered suitable because they lacked the colour gamut or production throughput capability of the eventual choice, a Polytype SA Virtu RS35, installed in 2008.

This 3.5m width machine is a true hybrid, offering flatbed imaging for rigid media up to 1.25x3.5 metres and rollfed up to 3.5m, in which the beam carrying the printheads is advanced across the smaller dimension in the manner of a true flatbed device. For imaging on longer rigid substrates, additional input and output tables are available which Boyall also installed. Roll-fed imaging operates in the usual manner, with the media being continuously advanced; this mode is used extensively by Boyall for double-sided banner and fabric printing.

The machine can be configured as either 6-colour (CMYK plus light C and M) or CMYK plus white. Much of Boyall's work is illuminating print requiring CMYK plus white, seldom requiring the 6-colour capability. Company founder Brandon Boyall comments, "the Virtu was best suited to our needs out of all the machines tested. It was the only machine that surpassed our minimum requirements for speed, quality, versatility and upgradability. With our major customers invited to share in the testing and evaluation process, our final decision had their full support, and continues to impress now that it's in full swing."

Stewart Bell of distributer DPI, admits that at €450,000 the Virtu RS 35 isn't a cheap machine, but says, "You get what you pay for. The machine is so well-built and so reliable that Boyall haven't taken out a service contract. Other than routine maintenance on filters and printheads, we've only had to go in twice in two years." It's also very economical on ink, using only 40 or 50

One of the most innovative applications we have come across is printing panels for use in a kitchen!

litres per month. The unit installed at Boyall has 36 printheads, but there is also a 48-print head version available and a choice of 80 or 30 pl drop sizes. Boyall chose the 30pl heads for their superior resolution.

Clear advantage

Boyall has recently moved into decorative print on substrates such as glass. The Virtu can print onto glass after applying a primer and once cured, this provides a particularly resistant finish, even without any kind of post-imaging treatment. A recent project included decorating worktops, splash-backs and table tops, canvases and signage for a teaching kitchen installation at a college of higher education. According to Brandon Boyall, the customer was amazed at the quality and range of products that could be printed.

The move to digital has completely transformed Boyall's business model, from being an established screen printer

to being a specialist large format digital print company whose screen print frames are now rarely used. Plans for the future include developing the existing customer base as well as continuing to develop totally new areas such as the direct to glass printing.

Brandon Boyall comments, "The Virtu's versatility allows us to buck the current trend of being sucked into the same old digital print market by encouraging niche and new products that other machines struggle or can't cope with."

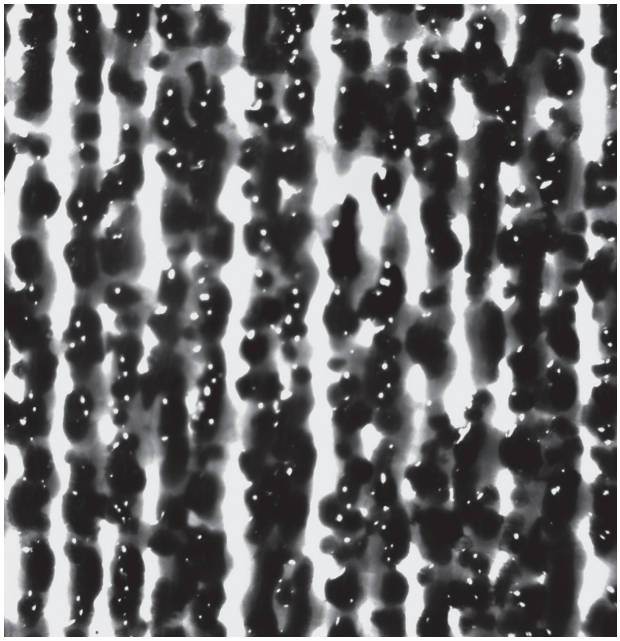
The Tested Printers

EFI Vutek GS3200

Introduced at International Sign Expo in April 2009, the Vutek GS3200 is a 3.2 metre width roll-to-roll printer that can also be adapted to image rigid media up to 50 mm thick. The company says this conversion process can be carried out in as little as a minute, potentially enabling the GS3200 to replace multiple machines. EFI claims that the printer functions equally well in either mode, making it a true hybrid. The company has sold around 100 units since shipping began in 2009.

Maximum output speed for the GS3200 is quoted as 223 m^2/hr for roll media with flatbed productivity at 44 1.2x2.4m boards an hour, including manual loading and unloading time. EFI has introduced MediaMaster, a sheet-feeding system for loading and unloading rigid media sheets to and from the GS3200. This doesn't increase the sheet-fed rate, but makes it possible to sustain it indefinitely, with manual reloading and removal of finished stacks. Planned developments in this area will eventually increase flatbed throughput and will benefit all installed GS3200s, since the feeding systems will be field upgrades. The printer can also print simultaneously on two 1.524m (60") rolls.

This device uses twenty Seiko printheads, offering a choice of 12 or 24 pl drop size per job and a native print head resolution of 360 dpi. Offset multi-pass printing and the appropriate choice of drop size give what EFI calls "true" 600 and 1000 dpi resolution. The firm says the latter yields photo quality imaging suitable for fine art applications



In the resolution test the Efi Vutek GS3200 showed distinct line pairs up to 65 lp/cm in the horizontal direction and at up to 35 lp/cm in the vertical one. These equate to 390 and 210 dpi respectively. Here the 65 lp sample at 500x enlargement, as seen through the digital microscope.

and high quality point of purchase or sale (PoP or PoS) and similar work, in addition to output for viewing at greater distances.

The GS3200 is technically a ten-colour machine. EFI offers standard CMYK, light C, light M, light Y and light K and white inks of its own manufacture, eschewing additional primary colours. Earlier experiments with this in previous printers met with little market acceptance and required wasteful purging sequences to switch between standard and expanded gamut sets. The company also designs and manufactures its own shuttered mercury vapour UV lamps for ink curing on the GS3200.

The ten-colour arrangement allows for considerable flexibility in how the white inks are used: overprint,

Efi Vutek GS3200 is a 3.2 metre width roll-to-roll printer that can also be adapted to image rigid media up to 50mm thick.

underprint, spot, underspot, fill and overspot, but with varying performance hits according to how many layers are printed. This is because the arrangement of printheads has the two white ink heads at the far ends of the printhead, which means that in white under- or overprint applications, only one half or one third of the length of each of the two white printheads can be used per pass, depending on how many layers are being printed.

An overall white pre-coat followed by four- or eight-colour CMYK, for example, requires two layers (whites first, then colours) and therefore halves productivity. A three-layer printing process: two layers of white for increased opacity on heavily coloured substrates plus CMYK, or two layers of CMYK with white between them for day/night backlit or window graphics, for example, will reduce productivity by two thirds. However, spot colour white in conjunction with either 8-colour or Fast-5 (see below) doesn't reduce performance at all.

In addition to the 8-colour plus white printing using the standard and light CMYK inks, it is possible to use a doubled-up standard CMYK set plus white. The latter is dubbed the Fast-5 option and it yields maximum productivity because twice as much of each ink can be laid down in each pass. EFI also points out that some competing models require the user to decide at the time of ordering whether they want to print pre- or post-print white, while the GS3200 (and earlier models) can do both.

EFI's Fiery XF RIP drives the GS3200. There are no options for different finishes, although there is some control over the overall level of curing applied to vary the degree of gloss. EFI reports that different geographical markets have different preferences for the glossiness of finish and that these preferences change over time. There is also an option to weave or overlap printed bands with a degree of added noise in the print control signal, which reduces the appearance of banding which can occur as a result of directional reflectance properties in the cured ink. EFI's technique can increase an 8-pass printing mode to 10 or 12 passes, with concomitant reductions in throughput.

EFI submitted test samples produced using the eight-colour (CMYK plus light versions) ink set in the 1000 dpi mode on Avery M2 pressure-sensitive vinyl with the light smoothing option selected. Our gamut test indicated a total of around 416,000 colours.

In the resolution test, which was printed on the same Avery vinyl and with the same resolution and smoothing settings as the colour gamut chart, distinct line pairs could be seen at up to 65 line pairs in the horizontal direction and at up to 35 line pairs in the vertical one. These equate to 390 and 210 dpi respectively.

HP Scitex FB7500

The HP Scitex FB7500 was launched in 2008 and is designed for industrial printing environments. This UV-

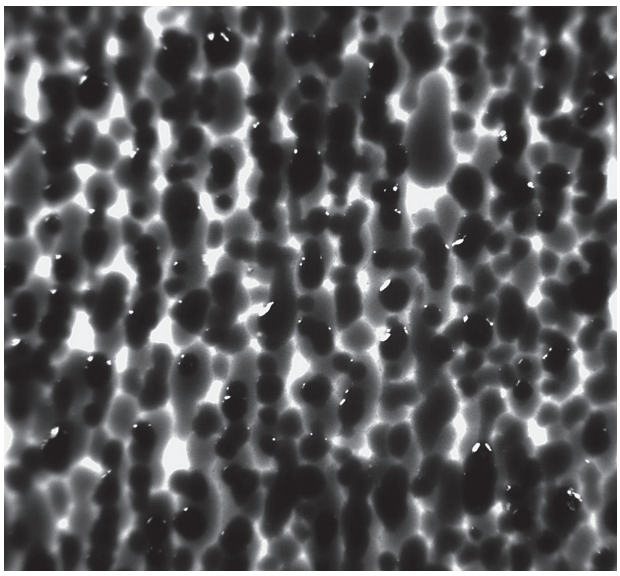
The HP Scitex FB7500 is designed for industrial printing environment. It prints up to 3.2x1.65m media up to 25mm thickness.

curable flatbed printer is suitable for PoP/PoS applications, exhibition graphics, signage, backlit displays and posters, printing up to 3.2x1.65m media up to 25 mm thickness with three-quarter loading. It uses 312 HP Scitex X2 MEMS printheads, 52 for each of the six colours. Each head has 128 nozzles producing a native resolution of 100 dpi. The addressable resolution for the FB7500 is 1200 dpi. The ink droplet size is 42 pl (picolitres) and the maximum output speed is 500 m^2/hr depending on print mode. In Best Quality Mode the speed is 90 m^2/hr.

Printing with up to six colours, CMYK plus light cyan and light magenta, minimises graininess and optimises grey balance and it's possible to fit another two printheads. The HP Scitex FB221 UV Inks are designed specifically for the FB7500 and are claimed to be water- and abrasion resistant, with at least two years durability. The curing system uses cold mirror shuttered mercury arc lamps to minimise IR radiation. The FB7500 has what HP call "three-quarter automation", which means that the operator loads the substrate onto a feed table, which then automatically registers the sheet and loads it to the print table. Printed sheets are then automatically unloaded to a stacker.

The FB7500 has a 6-zoned vacuum table driven by a patented VCU (vacuum carrying unit) solution, and is the first industrial machine to come with Print Care maintenance. This includes a maintenance scheduler and wizards, remote assistance, backup and restore. HP suggests one of two RIP systems, either the Caldera Grand RIP+ or the ONYX ProductionHouse.

HP Scitex submitted test samples produced using the 1000x1000 dpi mode on matte coated paper. Our gamut test indicated a gamut of around 594,000 colours. In the resolution test, printed at the same resolution and on the same matte paper as the colour gamut chart, distinct line pairs could be seen at up to 65 line pairs in the vertical direction (at the correct orientation of the test chart). The limit in the horizontal direction was 50 line pairs. These figures are equivalent to 369 and 299 dpi respectively.



In the resolution test the HP Scitex FB7500 showed distinct line pairs up to 50 line pairs in the horizontal and 65 in the vertical direction. This equates to 299x369 dpi. Here the 65 lp sample at 500x enlargement, as seen through the digital microscope.

Inca Onset S20

Inca's Onset S20 was launched at Fespa 2009 and is intended to fill the gap between Inca's top-of-the-range

Onset and the lower mid-range Turbo Plus UV-curable flatbeds. Dubbed the 'Baby Onset', the S20 shares its faster sibling's 3.2x1.6 metre bed but is rated for up to 250 m^2/hr, depending on print mode and finish choices. It is designed to suit print shops with an output requirement of around 2500 square metres over two eight-hour shifts.

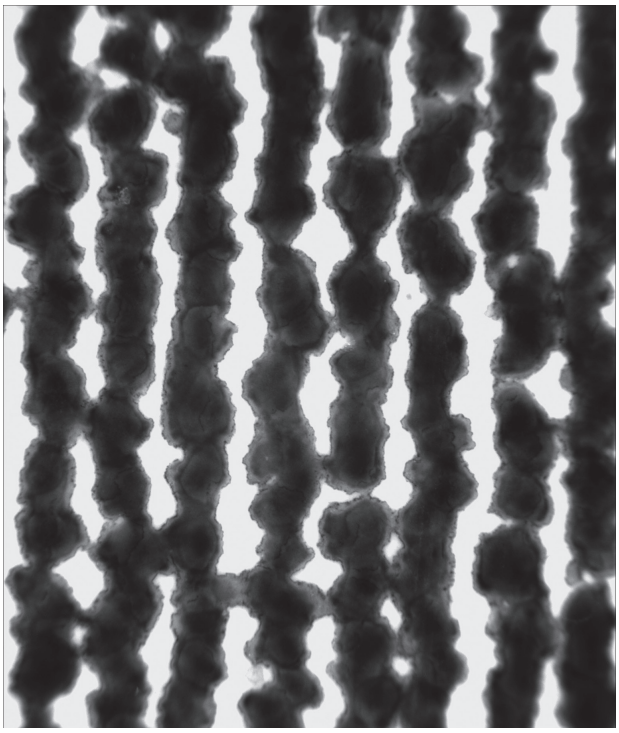
The S20 uses Fujifilm Dimatix Spectra printheads in a full-width array with 26 heads per colour. These have a native resolution of 50 dpi and are tuned to emit a 27 picolitre (pl) droplet. Multi-pass printing with a small offset on each pass provides an addressable resolution range of between 600 and 1000 dpi. The operator can choose bi- or unidirectional printing modes to suit different applicat-ions. Inca supplies either the Wasatch SoftRIP or Colorgate RIP software.

There is a choice of four- or six-colour configurations though to date Inca has sold only six-colour versions. The latter uses Fujifilm Sericol UV-curable CMYK, plus light cyan and light magenta, two white ink channels, or orange and violet inks. White can be printed under or over the CMYK inks, or with them as a fifth colour. Under- and over-print options require a separate printing pass which at worst would halve productivity. It might however be possible to print the solid white using a faster mode than is required for the CMYK; fifth colour white entails no performance loss.

Two water-cooled mercury vapour lamps are used for curing, one at either side of the printhead to support bi-directional printing. The operator can control the output of these lamps, allowing a range of different finishes to be achieved, from matte to satin to full gloss, by apply-ing different amounts of curing. There is a slight trade-off between fine detail and the depth of colour saturation, however the gloss mode involves less curing and can lead to some visual crumbling at fine edges.

That said, Inca claims that its technology lays the ink down flatter than rival designs using the same printheads, producing a less topographic appearance and therefore lower diffraction of light from the cured ink surface, to give a wider colour gamut. This technique is also claimed to yield better density from less ink.

Although the ink set with orange and violet could be expected to yield the widest gamut because of the addit-ional primary colours, Inca chose to submit a gamut test chart produced using the CMYK plus light inks option. This, it says, is a more typical configuration and helps achieve a more nearly photographic quality with improved tonal transitions in skin tones.



In the resolution test the Inca Onset S20 showed distinct line pairs up to 30 lp/cm in the horizontal direction and at up to 40 lp/cm in the vertical one. These equate to 180 and 240 dpi re-spectively. Here the 40 lp sample at 500x enlargement, as seen through the digital microscope.

To exploit the full gamut offered by the orange and violet inks requires an RGB workflow in order to avoid losing the extra colours that fall outside CMYK colour gamuts, which are not as large as RGB ones. According to Inca, RGB workflows are not widely understood amongst its customer base and therefore uptake of this variant of the S20 has been low. There has been better uptake in the US where the orange helps match the brand colours of stores such as Home Depot. The violet ink is also claimed to

Inca's Onset S20 has a 3.2 x 1.6 metre bed and is rated for up to 250 square metres per hour, depending on print mode and finish choices.

help produce better results with certain deep blues. The company was not able to supply a reference ICC profile for the CMYKOV ink set, suggesting that promoting the extended gamut configuration of the S20 has not been a top priority.

Media handling options on the S20 include support for rigid substrates up to 50 mm thick when working fully in manual mode, but it's likely that some automation would be added for busy production shops wanting to get the most out of the machine. The partial automation option, which includes a pre-loading table and automatic sheet unloading, limits media thickness to 10 mm.

Inca wouldn't divulge how many S20s have been sold, saying only that around 30 per cent of sales were in the UK, with North America next, followed by continental Europe. This reflects both the geographical distribution of screen printers, who are the major customers for Inca devices, and perhaps the marketing strengths of worldwide distributor Fujifilm Sericol in the various territories.

For the colour gamut test, Inca printed the IT-8 CMYK target on Buchanan Westland Silk 250/245 paper in 16-pass gloss mode with addressability set to 400x739 dpi. Analysis of the ICC profile for the S20 yielded approximately 453,000 colours.

In the resolution test, also printed on Buchanan Westland Silk 250/245 with the same RIP settings, the Onset S20 showed a clear image of distinct lines at spacings of up to 40 line pairs in the vertical direction (at the correct orientation of the test chart). The limit in the horizontal direction was 30 line pairs. These figures are equivalent to 240 and 180 dpi respectively.

Mimaki JFX-1631

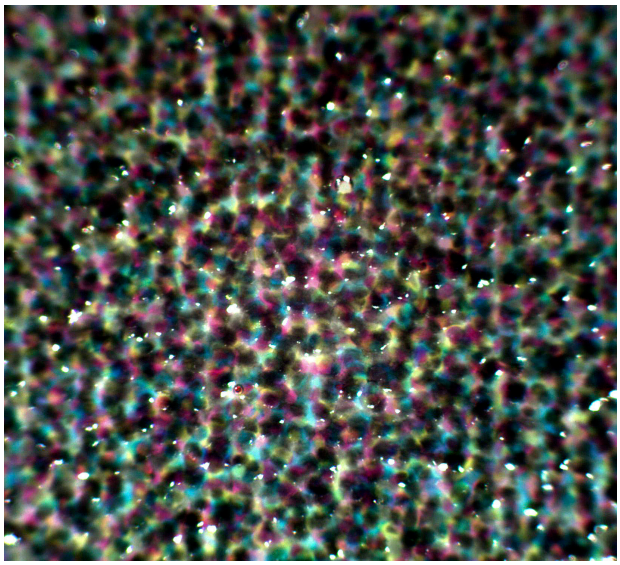
The Mimaki JFX-1631 was launched in 2009 and the JFX-1610plus and JFX-1631plus in October 2010. This printer series comprises 1.6m wide flatbed printers for UV-cured inks. The JFX-1631 can be used for a wide array of applications like PoP displays and panels, packaging on transparent materials, and can print onto rigid media such as metal, hard plastic and glass.

This printer prints on up to 3,100x1,602mm media (JFX-1631plus) or 1602x1500mm (JFX-1615plus). When using

Above: The Mimaki JFX-1631plus was launched in October 2010 and can print 1.6x1.5m media up to 50mm thickness. *Below:* The Mimaki UJF-3042 is marketed as the "Compact UV LED flatbed printer", and can image up to 30x42cm.

the post-curing unit for high speed printing and curing, the maximum print size is reduced by 150mm (front), 250 mm (back) and 400mm (total).

The printer series accepts media up to 50mm thick using in all eight drop-on demand piezoelectric printheads. The addressable resolution is 1200x1200 dpi using variable dot



In the resolution test the Mimaki JFX-1631 showed distinct line pairs up to 90 lp/cm in the horizontal direction and at up to 90 lp/cm in the vertical one. These equate to 540 and 540 dpi respectively. Here the 90 lp sample at 500x enlargement, as seen through the digital microscope. Ideally this test should have been printed in black for clarity, instead of CMYK.

size technology (seven different dot sizes, of which the smallest is 6 pl). The JFX-1631's maximum print speed is 13 m^2/hr in CMYK only (23.6 m^2/h for the JFX plus Series), depending on the media.

Mimaki bundles the RasterLink Pro 5 RIP with support for 16-bit rendering for smooth gradations. There are two choices of ink: the LF-200 flexible UV ink in CMYK plus White, and the LH-100 hard UV ink in CMYK, White and Clear varnish. The LF-200 ink has 200% elasticity, while the LH-100 hard ink has high scratch- and chemical resistance. The white ink is typically used to enhance image quality and contrast on transparent materials, or as a base on dark or coloured substrates. The ink is cured using LEDs with low or no emission of infrared light, reducing heat and so enabling printing on heat sensitive materials like acrylic and styrene. The low heat emissions also mean lower power consumption. The UV LEDs have an estimated lifetime of up to 10,000 hours and use 50% less energy compared to conventional metal halide lamps.

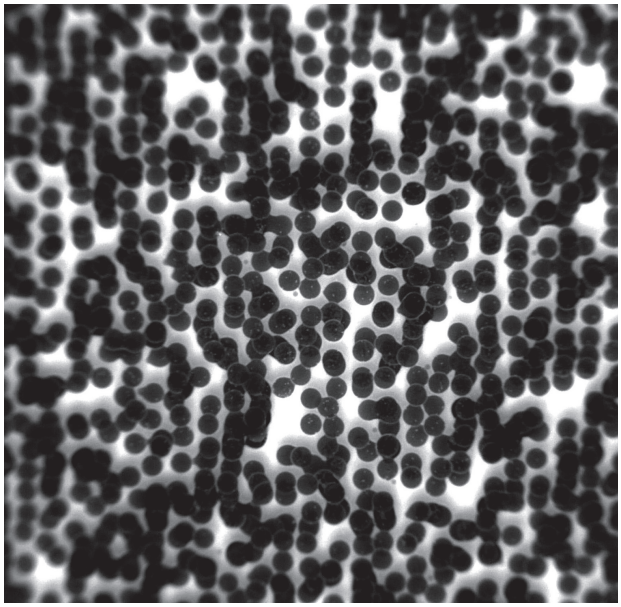
The head positioning mechanism uses high resolution linear scaling for fine step accuracy of dot placement. This results in fewer banding artifacts and makes possibile the printing of legible 3pt characters. An optional roll unit is available which enables printing the full size of the flatbed.

Mimaki submitted test samples for the JFX-1631, produced using the 1200x1200 dpi mode on glossy vinyl. Our gamut test indicated a total gamut of around 547,000 colours. In the resolution test, which was printed with the same resolution and glossy vinyl as the colour gamut chart, distinct line pairs could be seen at up to 90 line pairs in both the horizontal and vertical direction. This equates to a resolving power of 540x540 dpi.

Mimaki UJF-3042

The new Mimaki UJF-3042, launched in 2010, is marketed as the "Compact UV LED flatbed printer", since it's an A3 printer (printing up to 30x42 cm on media up to 36.4x46.3 cm). It shares many of the JFX plus series' features, like using drop-on-demand piezoelectric printheads, a maximum media thickness of 50 mm as well as using UV LEDs for curing. However it is designed for use with the LH-100 hard UV-ink.

Since it's a relatively small printer, and priced accordingly, it can obviously be an entry model for companies who want to print personalised promo items, cards, nameplates, novelties, electronics covers et cetera. This printer can print white ink under- or over simultaneously without slowing down the print speed, which is about four minutes for an A3 print. The maximum addressable resolution is 1440x1200 dpi, and the RasterLink Pro 5 RIP is normally bundled with the machine. A vacuum system is



In the resolution test the Mimaki UJF-3042 showed distinct line pairs up to 100 lp/cm in the horizontal direction and at up to 90 lp/cm in the vertical one. These equate to 600 and 540 dpi respectively. Here the 100 lp sample at 500x enlargement, as seen through the digital microscope. This is on the edge, with line pairs clearly starting to collapse.

incorporated in the table to keep the object/jig steady and flat. The UJF-3042 has low power consumption (max. 0.5 KVA) and uses a standard plug with 220V electricity.

Mimaki submitted test samples for the UJF-3042 produced using the 1440x1200 dpi mode on glossy vinyl. Our gamut test indicated a total gamut of around 452,000 colours. In the resolution test, which was printed with the same resolution and glossy vinyl as the colour gamut chart, distinct line pairs could be seen at up to 100 line pairs in the horizontal direction, and 90 line pairs in the vertical direction. This equates to 600x540 dpi.

Océ Arizona 550 GT

Launched in 2010, the Arizona 550 GT is the latest and fastest printer in the highly successful Arizona series. It's a flatbed printer for UV-curable inks, with a roll media option for flexible substrates. With the possibility to print on both rigid and flexible media, the system is suitable for a wide range of applications, such as PoP, banners, exhibition graphics, displays et cetera.

The maximum print area is 1.26x2.51 metre edge to edge printing (full bleed) for rigid media (maximum media size 1.25x2.5 metre), and with a maximum print width of 2.19 metre for roll media (media width max 2.2 metre). The maximum speed is 61 m^2/hr depending on print mode and substrate in CMYK, and 14.1 m^2/hr when printing CMYK plus White. The Arizona 550 GT use two piezoelectric printheads per colour, each with 636 nozzles. Océ prefers not to talk about resolution achieved in dpi, rather that the Océ VariaDot Technology offers near photographic quality. Sometimes this is compared to an addressable resolution of 1440 dpi. The ink droplets can be varied in sized from 6 up to 42 pl.

Océ use CMYK only for their colour imagers, arguing that with the VariaDot Technology there is no need for any Light Cyan or Magenta to ensure smooth gradations. Another benefit of the VariDot Technology is its low ink

In the resolution test the Océ Arizona 550 GT showed distinct line pairs up to 75 lp/cm in the horizontal direction and at up to 100 lp/cm in the vertical one. These equate to 450 and 600 dpi respectively. Here the 100 lp sample at 500x enlargement, as seen through the digital microscope.

consumption: 8 ml per square metre on average, which can be up to 50% less than when using a more conventional six colour configuration.

The Océ Arizona is the latest and fastest printer in the Arizona series, with a print area of 1.26x2.5m.

The White Ink Option can be installed at the factory or later at the customer site. The UV-curable inks don't contain any VOCs, so the printer can be installed in a room with normal ventilation (five to ten air changes per hour). The curing is achieved through high intensity UV mercury vapour lamps, where Océ control the heat so that heat sensitive substrates can be used. There are two ink options, the original IJC255 inks, and the newer IJC256 inks mainly for outdoor media and applications. Océ use their ONYX ProductionHouse RIP in the Océ Edition for the 550 GT.

Océ submitted test samples for the Arizona 550 GT produced using a variable drop size of 6-30 pl on matte poster paper. Our gamut test indicated a total gamut of around 550,000 colours. In the resolution test, which was printed on the same matte poster paper as the colour gamut chart, distinct line pairs could be seen at up to 75 line pairs in the horizontal direction, and 100 line pairs in the vertical direction. Océ prefer not to specify an addressable resolution in dpi, preferring to refer to the 6-30 pl variable drop size but the achieved result equates to a resolving power of 450x600 dpi.

Polytype SA Virtu RS35

Polytype SA describes the Virtu RS35 UV-printer as a hybrid machine, meaning that the operator can easily switch between flatbed and roll fed modes. The Virtu RS35 prints on substrates up to 3.5 metres wide and 95 mm thick. It's an industrial print production machine, printing up to 300 m^2/hr, depending on substrate and print mode.

This printer's design and features make it suitable for a huge range of applications, such as printing on glass, large format posters, wooden board, fabric, metal, ceramic tiles, plastic, and even carpets. The Virtu RS35 can be equipped with either 36 or 48 piezo drop-on-demand printheads, each with 128 nozzles per head. The different print modes

The Polytype SA Virtu RS35 is a hybrid UV-printer able to print up to 3.5 m wide media, and up to 95 mm thickness.

then use either a 30 pl or 80 pl droplet size. The stated resolution is up to 1200 dpi. Six colours are used, CMYK and Light Cyan and Light Magenta, plus White. The ink is pigmented UV-curable solvent free and cured by water cooled UV lamps. While being VOC free, the printer still is equipped with a fume extractor and safety casing for increased comfort and safety for the operator.

Adding to the Virtu RS35's strong features, Polytype SA has introduced a linear motor system, used in the print table to reduce vibrations and improve dot placement. The print frame is concussion-free in order to handle delicate material with extra care. Polytype SA offers the Virtu RIP as a bundle, but the RS35 works with most high end front ends on the market, including the Caldera and ONYX RIPs.

Polytype SA submitted test samples for the Virtu produced using the 1200x1200 dpi mode on glossy vinyl. Our gamut test indicated a total gamut of around 426,000 colours. In the resolution test, printed with the same resolution and glossy vinyl as the colour gamut chart, the output was done in CMYK and with some kind of screening so it was impossible to accurately distinguish the narrower line pairs to determine the resolving power.

Price Comparison

Make/Model	Price (€)
EFI Vutek GS3200	Undisclosed
HP Scitex FB7500	Undisclosed
Inca Onset S20	777,000
Mimaki JFX-1631	115,000
Mimaki UJF-3042	25,000
Océ Arizona 550 GT	Undisclosed
Polytype SA Virtu	300,000

Comparison of Stated Addressable Resolution Versus Achieved Resolving Power

The native resolution of the printhead, the addressed resolution by the front end, and the actual resolving power on the substrate are all important. In our view the actual resolving power is the most important of all because it reflects the whole system's performance and the precision with which ink droplets are placed onto the substrate.

Make/Model	Max Resolution (dpi)	Resolving Power (dpi)
EFI Vutek GS3200	1000x1000	210x390
HP Scitex FB7500	508x500	369x299
Inca Onset S20	400x739	180x240
Mimaki JFX-1631	1200x1200	540x540
Mimaki UJF-3042	1440x1200	600x540
Océ Arizona 550 GT	Variable drop size; 6-30 pl*	450x600
Polytype SA Virtu	1200x1200	Unestablished

* Océ do not claim a specific resolution, preferring instead to make this statement.

Comparison of Colour Gamut Test Results

Here for comparison are the numbers of colours contained in the gamuts of tested devices, in black, and of various popular colour spaces, calculated via the same method, shown in green.

Device	Ink and Stock	Number of Colours
Offset printing	CMYK on glossy coated paper **	402,000
EFI Vutek GS3200	UV-cured ink, CMYKlclmlylk* on glossy vinyl	416,000
Polytype SA Virtu RS35	UV-cured ink, CMYKlclm*, on glossy vinyl	426,000
Mimaki UJF-3042	UV-cured ink CMYK on glossy vinyl	547,000
Inca Onset S20	UV-cured ink, CYMKlclm on semigloss coated paper	453,000
Roland VersaArt RS-640	solvent based ink, CMYK ***	503,000
Mimaki JFX-1631	UV-cured LH100 ink, CMYK on glossy vinyl	547,000
Roland VersaCamm VS-640	solvent ink, CMYKlclm on glossy vinyl ***	548,000
Océ Arizona 550 GT	UV-cured ink, CMYK on matte coated poster paper	550,000
Mimaki CJV30	SS21 solvent based ink, CMYK on glossy vinyl ***	556,000
Mimaki CJV30	ES3 solvent based ink, CMYK, on glossy vinyl ***	577,000
HP Scitex FB7500	UV-cured pigmented ink, CMYKlclm*, on glossy vinyl	594,000
Epson Stylus Pro GS-6000	solvent based ink, CMYKlclmOG on glossy paper ***	658,000
Wide-gamut printers	dye based ink, 8+ colours on glossy photo paper ****	~800,000
sRGB working space		832,000
Adobe RGB (1998) working space		1,200,000

* lc, lm = Light Cyan, Light Magenta

**Represented by the FOGRA 39 characterisation data set. This gamut is for reference only.

*** The solvent based printers are included for reference only. The main focus of the test is printers using UV-curable ink.

**** The dye-based printers are included for reference only. The main focus of the test is printers using UV-curable ink.

Conclusions

According to this data all the UV-curable inkjet printers tested here can reproduce more colours than a standard high quality offset CMYK press, and often by a wide margin. This should ensure that given correct colour management throughout, reliable colour matching can be achieved between their output and offset-printed materials that might be produced simultaneously. When there is no need to constrain the colours to an offset gamut, the image quality of most of the UV-curable printers tested surpasses standard offset's gamut!

Based on these findings it would appear that UV-curable printers do not yet quite match the colour gamut of solvent-based alternatives. This conclusion is based on a sample of the available engines provided by manufacturers willing and brave enough to submit test results for the project. The differences in gamuts are at least not as dramatic has sometimes been suggested. If more vendors accept and use our suggested method of defining both a numeric value, and a unit (ΔE1) for the achieved colour gamut on a certain substrate, we hopefully will be able to reduce the somewhat confusing and unclear references to a "large colour gamut" or "wider gamut than ever" in technical documentation and brochures. We also hope that the way we test achieved resolving power is accepted as a good alternative or complement to today's use of stated addressable resolution in dpi, or possible droplet size. All three are actually useful when determining the suitability of a certain device for a specific application.

Next Steps & Future Developments

The sheer range of possibilities with UV-curable inks and related technologies creates a wealth of opportunities for screen printers, commercial printers and entrepreneurs. There are two powerful forces at work driving this market: web to print and variable data technology, which are becoming intimately intertwined. The web is already a popular channel for print ordering and as consumers become more aware of their output options, this channel will grow exponentially. Variable data output requires more powerful RIPs and higher speed data delivery to drive engines at rated speed. In both cases software must combine ease of use for print buyers, with the necessary features to support PDF workflows and fully exploit the output devices.

Variable data processing using for instance the PDF/VT data format and an APPE 2.5 RIP can now occur at speeds that easily keep up with the printing engine. Few manufacturers have yet to fully exploit the technology and wide format RIP developers have only recently started to pay attention it. HP's SmartStream Designer plug-in for Adobe CS InDesign, EFI and smaller developers such as ixPressia an offline and devce independent package, are in the vanguard for wide format variable data output using object nesting so that static elements in variable data PDFs are only processed once.

These are some of the areas we continue to explore. We are also looking into colour managed workflows for wide format output, materials and data formats such as PDF. Standards such as ISO 12647 for process control are becoming increasingly relevant for the large format sector.

We are developing additional tests for this project and expect to publish further results and technology evaluations in 2011. We are also encouraging manufacturers to submit more machines for testing.

The new tests address density, white metrics, contrast, ability to reproduce tone scale nuances, tone, small text and fine line rendition, brand colour matching, colour management on different substrates and will evaluate the tonal range of devices.

Acknowledgements

Digital Dots has a long history of technology testing, but in the many years of this work no other project has proved so difficult to execute and complete as the test of UV-curing printers. The technology and its applications are hugely diverse, and the range of machines available is equally broad. This makes for a tricky testing environment but it's great news for buyers. This project would not have been possible without the support of the following organisations. They have courageously submitted test results for evaluation and provided invaluable feedback for our work.

We would also like to express our appreciation and gratitude for Sophie Matthews-Paul's invaluable support and expert advice. Sophie is truly this sector's Queen!

EFI Inc.

EFI is a world leader in customer-focused digital printing innovation. EFI's award-winning solutions, integrated from creation to print, deliver increased performance, cost savings and productivity. The company's robust product portfolio includes Fiery digital colour print servers; Vutek superwide digital inkjet printers, UV and solvent inks; Rastek UV wide-format inkjet printers; Jetrion industrial inkjet printing systems; print production workflow and management information software; and corporate printing solutions.

www.efi.com

HP Inc.

"Third party reports providing clarity on important product features and technologies such as color gamut and printing resolution of both HP high-end units as well as other players in the industry are important tools for our customers and prospects. These documents also structure discussion among influencers and journalists when looking at the various technologies across suppliers". François Martin, Marketing Director, HP Graphics Solutions Business, EMEA

www.hp.com

Inca Digital

Inca Digital Printers, part of the Dainippon Screen Group, is one of the world's leading pioneers and manufacturers of flat-bed inkjet printing technology. The Eagle and Columbia printers set the early standards in flatbed printing inkjet technology. Today the groundbreaking Onset Series, as well as the Spyder range, ensure that Inca's products remain at the

forefront of productivity, quality and reliability. Fujifilm Sericol manufactures and develops the UV inks used in Inca machines and sells the flatbed printers around the world. Our facility in Cambridge, UK, incorporates R&D, customer support, machine assembly and commissioning, a dedicated training facility and clean rooms for printhead assembly and refurbishment. Around a third of staff are involved in R&D and significant investment here helps us maintain our position at the forefront of machine productivity, innovation, quality and reliability.

www.incadigital.com

Mimaki Europe BV

Mimaki is a leading manufacturer of wide-format inkjet printers and cutting machines for the sign/graphics, textile/apparel and industrial markets. Mimaki Europe B.V. is a fully owned subsidiary of Mimaki and was established in Amsterdam in 2004. It provides sales and services support through resellers in each European country, including Russia and North Africa.

www.mimakieurope.com

Océ BV

Océ's award-winning Océ Arizona series is a family of flatbed printing systems first introduced in 2006. The company, which recently announced its 2000th installation, is the market leader in the sector. Dutch-based Océ's wider offering includes office printing and copying systems, high speed digital production printers and wide format printing systems for both technical documentation and color display graphics. In 2010 Océ joined the Canon Group of companies with headquarters in Tokyo, Japan, to create a global leader in the printing industry.

www.oce.com

Polytype SA

Polytype has long experience in the printing industry and is produces the only true hybrid machine on the market. The Virtu printer has all the features required for roll-to-roll, flatbed and oversized output. This is made possible by the company's specialist technology.

www.polytype.com