

White Paper

The Xaar Guide to Digital Print for the Ceramic Sector



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→ Section 1

Introduction

With the current challenges in the ceramic sector, manufacturers are looking for ways to cut costs, maximise flexibility and gain new business. This document explores how to get the most from digital printing and which technologies are available to enable you to revolutionise your business. It will also cover the following:

- ⇒ The benefits of digital printing for ceramic tile producers
- ⇒ How ceramic tile producers can grow their business
- ⇒ Offer an understanding of the current capability and limitations of the available technology
- ⇒ Provide the latest information on how to get the best print results.

The ceramic tile industry is one of the largest scale craft industries world-wide. Various print techniques – both direct and indirect – have been used over many years to decorate tiles, mainly using traditional methods such as Screen, Flexo and Rotogravure.

Globalisation and maturing of the existing analogue print technology has created a global market limiting the differentiation primarily to price and design.

Now however, there are digital technologies available that answer the ceramic industry's need for an industrial printer that can change the dynamics of the manufacturing processes and deliver innovative new products to the market. These new solutions extend the advantages that ceramic tiles can offer over competing cladding materials, such as stone, glass or metal.

→ Section 2

Ceramic Tile Industry Trends

- More frequent design changes
- Shorter print runs
- Shorter lifecycles of products.

The ceramic tile industry is very dynamic, driven by consumer trends and retailer demands and, as such, is changing rapidly. The main market drivers as seen today are:

1. Shorter life cycle of products
2. Desire for greater product differentiation
3. Customisation & personalisation
4. Wider range of tile types, including textured tiles
5. Shorter print runs
6. Cost reduction
7. Supply chain restructuring
8. Quality.

→ Section 3

The Global Opportunity

World Production and Consumption of Ceramic Tiles

The following tables show that most of the activity in the ceramic tile sector outside of China is based within the European Union, namely Italy and Spain. The figures in 2007 reveal a strong performance for both manufacturing at 8.125 billion m² and consumption following closely behind at 7.955 billion m².

World manufacturing areas *Table: Ceramic World Review 2008*

Areas	2007 (million m ²)	% of world production	% variance 07/06
European Union	1,576	19.4	-1.5
Other Europe (incl Turkey)	423	5.2	+1.9
North America (incl Mexico)	267	3.3	-1.1
Central – South America	795	9.8	+7.1
Asia	4,778	58.8	+8.0
Africa	278	3.4	+4.5
Oceania	8	0.1	-
TOTAL	8,125	100.0	+5.2

World consumption areas *Table: Ceramic World Review 2008*

Areas	2007 (million m ²)	% of world production	% variance 07/06
European Union	1,333	16.8	+1.8
Other Europe (incl Turkey)	450	5.7	+4.2
North America (incl Mexico)	458	5.8	-9.7
Central – South America	785	9.9	+9.9
Asia	4,513	56.7	+11.2
Africa	372	4.7	+4.2
Oceania	44	0.6	+7.3
TOTAL	7,955	100.0	+7.2

→ Section 4

Why is Digital Print Being Considered?

- Reduce inventory and waste
- Shorter run lengths and cost efficient production
- Shorter lead times
- Drive for personalisation & customisation
- Non-contact technology allows for new products to be created
- Drive for higher quality.

Typically there are a number of issues that appear to be best addressed by digital print. These include:

1. Short run – labour costs of set-up and job change can make traditional printing impractical for unique projects and uneconomic for a short print run
2. Printing of textured tiles and tile edge decoration
3. High production cost of one-off tiles for sample purposes.

There is also growing discontent with the traditional supply chain as a result of:

1. Long lead-times determined by traditional processes
2. High stocks and transport costs
3. High wastage and stock write-off.

Plus, of course, traditional print does not cater for the current need for rapid change which demands “just-in-time” solutions and economic methods of handling short print runs with both acceptable production efficiencies and levels of non-productive down-time (it takes 30 minutes to change rollers on the traditional printing machines and 1.5 hours to adjust the colour). With inkjet and digital technology, changes in images and print jobs can be done quickly.

The Benefits of Digital Print

Greater differentiation and creative options through:

- ⇒ Tile edge decoration
- ⇒ Low relief decoration
- ⇒ Higher graphic variability
- ⇒ High-quality greyscale images.

Reduced costs and improved operating efficiencies through:

- ⇒ No printing consumables needed (such as rollers etc)
- ⇒ Shorter print times, no set-up time
- ⇒ Cost-effective short production runs.

The economic viability of small batch production and the cost & time involved in ceramic tile printing will be transformed by the adoption of digital print techniques. It could end up being as viable to print one tile as economically as one hundred thousand, thus enabling sample tiles to be provided to the distribution network and printed in very small batches as they are ordered by the consumer, cutting down on storage, stock, distribution costs and wastage.

→ Section 5

Commercial Applications

A number of innovative manufacturers have chosen to use Xaar's latest TF Technology™ and XaarDOT (Drop Optimisation Technology). Printers already available today are:

Cretaprint 'CretaPrinter'



Cretaprint, of Spain, has been developing decoration solutions for tile manufacturers worldwide for the past 10 years. Specialising in the provision of ceramic decoration solutions, Cretaprint developed this inkjet decoration system in collaboration with Xennia Technology, responding to the changing market dynamics. The CretaPrinter is modular in design so that ceramics manufacturers can configure a solution that best fits their production requirements. CretaPrinter can produce a different and random pattern on each tile it prints, mimicking the patterns of natural marble and other materials. The unique and Xaar-patented recirculating printhead and ink supply allows for the use of high viscosity materials such as ceramic pigments. Patterns are printed in greyscale (see section 7) to produce clear, high resolution images. Its modular design allows tile manufacturers to print widths of between 280mm and 1120mm and to print at speeds of up to 35m/min with a combination of up to 6 colours.

Cretaprint is working with the principal tile manufacturers in Spain and Italy. More than 1,000,000 square metres have been produced with very good productivity results.

Newtech 'KeraMagic'



Newtech SRL, Italy, is a specialist manufacturer of machinery for the ceramics industry. The four-colour digital KeraMagic machine, specifically developed to print durable, high-quality, high-resolution images directly onto tiles quickly and reliably, was launched at the Tecnargilla show in October 2008. The KeraMagic answers the ceramics industry's need for an industrial strength inkjet printer that can handle a variety of fluids with ease to cost-effectively produce short run volumes of bespoke tiles. Two models, both using the Xaar 1001 are available: the 350mm width KeraMagic 350 and the 700mm width KeraMagic 700. Both machines print up to 25m/min at 360dpi and eight levels of greyscale to produce impressive clarity. Compared with analogue devices with short image repeat lengths, the KeraMagic software can handle much larger repeat images. An image length of up to 20m allows replication of natural materials with no visible repeat pattern, providing new and lucrative creative opportunities and premium pricing.

Other developments

Technoferrari will be commercialising printers in the first quarter of 2009. Other manufacturers using other inkjet printheads include Ferro's KERAjet printer, Systems's ROTODIGIT and ROTOPLOTTER and the range of Gamma 60 & 70 printers from DURST Phototechnik AG. These systems use Xaar-based licensee and non-Xaar-based Drop-on-Demand inkjet technology and offer the benefits of non-contact print.

Section 6

The Question of the Ink

Traditional ceramic ink sets come in a limited range of colours and are based on inorganic pigments or soluble salts in oil or solvent. Wet glazes are rolled on, then the tile is printed and then it is fired. Final images on the tiles are only visible after firing, making colour management very challenging.

Quality is now becoming more and more important as consumers demand higher quality images on tiles, for example marble or wood grain effects. These designs and effects are being driven by innovative new digital ink products.

Ceramic inks have to be adapted for optimum performance in inkjet printers and there are a few traditional ink companies who have seen the potential of digital ceramic tile printing and are manufacturing inks to suit this market. Examples are:

- ⇒ **Fritta SL /Chimigraf** – Fritta have been in operation since 1973 and have operations globally. They specialise in the manufacture of water-, solvent- and UV-based inks for flexography, rotogravure and screen printing. Fritta have entered into collaboration with Chimigraf, to produce high quality ceramic inkjet inks. The company conducts an intensive R&D programme focused on developing market leading inks and coatings for the graphic arts and industrial markets, including ceramics, decoratives and textiles. www.fritta.com / www.chimigraf.com
- ⇒ **Colorobbia** – The Colorobbia Ceramic Colour Company is one of the major world players in the development and production of materials and technologies for the ceramic sector. With headquarters in Italy and production facilities worldwide, Colorobbia specialises in the production and distribution of material and technologies for the traditional and advanced industrial ceramics industries. www.colorobbia.com
- ⇒ **Esmalglass-Itaca Group** - Esmalglass-Itaca Group offers global solutions within the world of ceramics. It is a large international group with a clear priority, to present the best products along with the technical assistance, technological innovation and design, indispensable needs for the customers to advance in the market successfully. The group has production facilities worldwide with presence in 7 countries with 11 centres and they employ over nine hundred members of staff worldwide. To find out more please visit www.esmalglass-itaca.com

→ Section 7

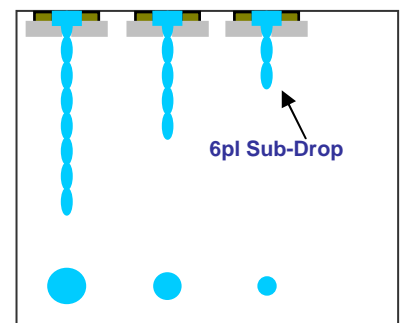
Xaar Variable Drop Technology and XaarDOT™ (Drop Optimisation Technology)

Up to now inkjet ceramic tile printers have overcome the issue of quality through the use of low density inks. The approach has been to print with relatively large drops - still small, but large in inkjet terms. This works well for light areas because distance between the drops is minimised, so producing smooth tints. However, it does not work so well in the dark areas, as the higher density is harder to achieve. This can be improved by using high-density inks, but this loses detail in highlight areas. Using Xaar Variable Drop Technology (greyscale) printheads can achieve the smoothness required in light areas and the density required in the dark areas, providing the right ink is used.

Variable Drop Technology

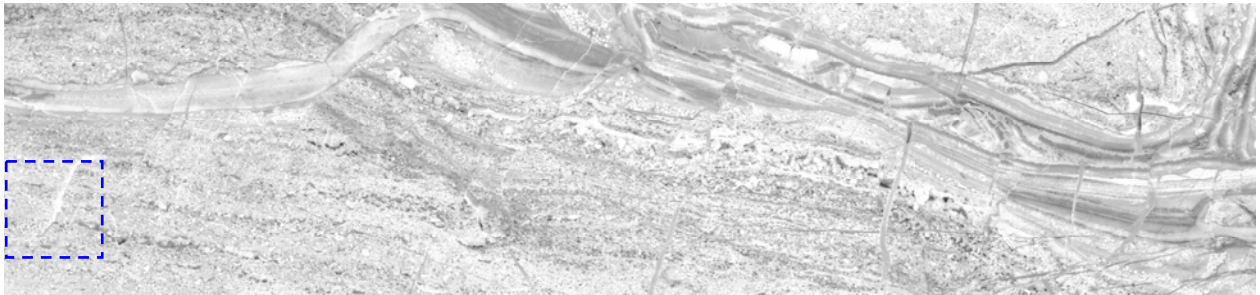
Greyscale technology allows variable-sized drops of ink to be placed directly on the tile.

There are several advantages of variable drop size. The natural npi of the printhead enables pin-sharp patterns are achievable using the smaller drop sizes; and drop size selection allows you to print on tile types of different absorbency and into different glazes.

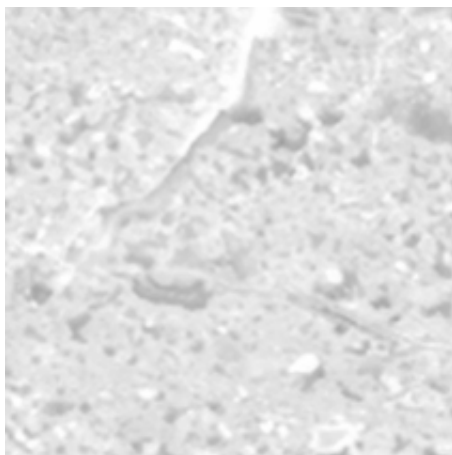


This is achieved by very rapidly firing small droplets of ink which coalesce as they leave the nozzles. In the Xaar 1001, there are 1000 nozzles in two rows of 500, giving a "native resolution" of 360 npi. Each droplet or sub-drop is 6pl (as illustrated in the diagram) and the Xaar 1001 has seven final drop sizes from 6 to 42pl. The smallest drop size determines the viewed resolution and therefore determines the quality of the end result. 6pl equates to an effective printed resolution of about 1000 dpi. This is especially important for assessing the lowest achievable smooth tint for the light areas.

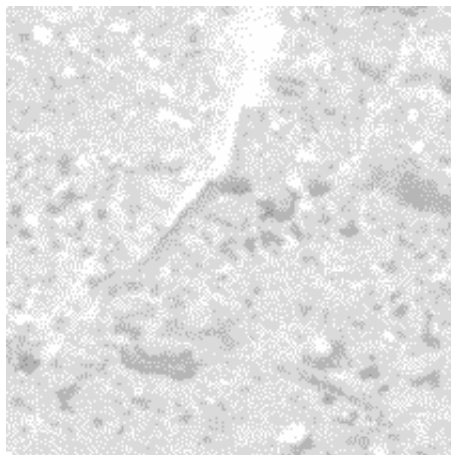
The improvement in the quality of the print over that achievable with binary printheads, where the drop size is always the same, is significant – in number terms the native 360 npi resolution appears as an “effective resolution” of around 1000 dpi to the human eye and is best illustrated as shown below (middle image).



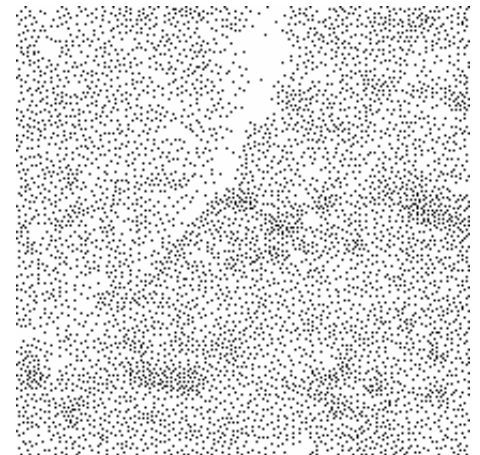
Images below are 4 x magnification of detailed area above



Original Artwork



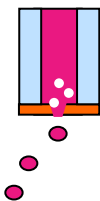
XaarDOT 8 Levels (8)



Binary (2)

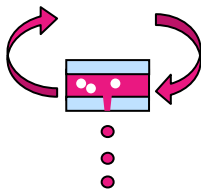
End-shooter versus Side-shooter Inkjet Technology

‘End Shooter’ printheads fire the ink drop out of their nozzle at the end of a long narrow channel. The potential ‘Achilles heel’ with all end shooter designs is that nozzles can fail, either by particulate blocking or because air bubbles form. A failure then requires a wipe/purge maintenance routine to re-prime the nozzles.



However, Xaar's Hybrid Side-Shooter™ printhead technology achieves variable drop formation – fast and reliably. Two acoustic waves moving through the channel meet in the middle and cause pressure changes which fire a drop out of the side of the channel i.e. downwards through the inkjet nozzle. With HSS™ the ink flows right past the back of the nozzle. Due to the TF Technology™ air or particles are moved away from the nozzles, keeping the channel primed and operational.

Any nozzles that are lost due to a knock or impact will quickly self-recover.



The HSS™ multi-pulse greyscale approach produces multiple 6pl sub-drops which combine to give a range of drop sizes that go on to form the image on the tile. Each inkjet drop is dynamically varied by changing the number of sub-drops combined to make up the final drop volume to give a print result that typically contains up to 7 different drop sizes producing a wide range of tones, and hence high print quality.

One of the important benefits of this multi-pulse variable drop formation is that it minimises satellites. Satellites are small drops created from the tails of the ejection process. Smaller sub-drops create smaller tails and so smaller and less satellites. This gives a very clean and precise print result.

Long printhead lifetime and high native resolution have been available for a long time within Xaar's piezoelectric drop-on-demand technology. The combination of shear mode and shared wall patented technologies (see <http://www.xaar.com/our-technology.aspx> for more explanation) has allowed Xaar and our licensees to produce printheads that deliver industrial-strength life.

Printhead and Drop Formation Option Technology

There are a variety of printheads available in the marketplace that offer effectively 3 different drop configurations or 3 different modes of operation. Xaar provides a selection of printheads that offers companies the flexibility to choose the right printhead for the application. XaarDOT™ (Xaar Drop Optimisation Technology) encompasses a range of drop formation options, each with specific features.

XaarDOT™ is incredibly flexible in giving tile manufacturers the choice of what drop size or sizes and consequently the DPI to use for a job. The choice really is yours:

Drop Formation Options

XaarDOT Name	Drop formation method	Mode of Operation
Fixed Drop	Binary	Fixed drop size for all jobs.
Selectable Drop	Multi-pulse Binary	Selectable drop size on a per job basis. All drops are the same size throughout the job.
Variable Drop	Multi-pulse Greyscale	Drops are dynamically varied within a job. the maximum number of greylevels selected on a per job basis

1. Fixed Drop (Binary)

Typically Binary printheads are used for larger drop applications. Drop size ranges from 35-80 picolitre(pl) and produce a lower quality image which is directly related to drop size. These printheads are less sensitive to mechanical artefacts and more forgiving of the print environment.

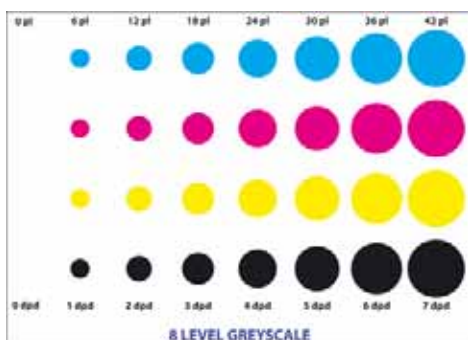
2. Selectable Drop (Multi-pulse binary)

Selectable drop printheads form drops by multi-pulsing, which allow drop size (which directly effects actual resolution) to be selected per job. Varying the drop size provides the flexibility to print on a number of substrates maintaining maximum theoretical throughput. You can therefore also use this approach to tune the drop size to best match the absorbency of the tiles.

3. Variable Drop (Multi-pulse greyscale)

With piezoelectric greyscale printing there are basically two approaches to producing different size drops from the inkjet nozzle: either extend the drop growth time to make a bigger drop (6-24pl) or alternatively apply high frequency multi-pulses to grow a drop. Xaar takes the multi-pulse approach, which provides, for example, a 6-42pl drop size range giving a smaller drop of 6 pl and then working upwards in 6 pl linear increments.

Xaar's greyscale printheads can generate up to 15 different drop sizes by combining multiple small sub-droplets (e.g. 6pl), fired in quick succession, into the same printed dot. This allows the 360 dpi actual resolution to give results equivalent to an effective dpi of 1000 (sometimes called 'apparent resolution'), but using far fewer nozzles, and this gives results that more closely match the perception of the human eye. The 1000 dpi 'apparent resolution' is directly related to the 6pl sub-drop size and not the native pitch of the nozzles. Variable drop formation technology is crucial to successful commercial level 'single-pass' inkjet printing.

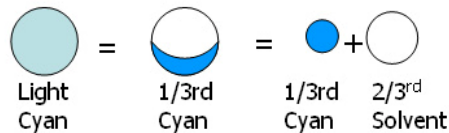


Variable Drop: Quality & Production Benefits

The benefits of variable drop printing are:

- 1) High quality combined with high productivity: image quality is improved even at low native nozzle pitches. For example 360 dpi appears like 1000+ dpi from a binary printhead ('apparent resolution') when using 8 greyscale levels at normal viewing distances.
- 2) Image resolution and quality required by industrial print markets
 - Smooth gradation and tonal range: Smoother screening with linear drop volume increments
 - Sharp text and lines produced by the range of drop sizes
 - Larger (40+pl) drops to ensure excellent image saturation and coverage
 - Allows fine tuning to accommodate tile surface absorbency characteristics.
- 3) Fast drying: the minimum amount of fluid is used when using multiple drop sizes. This minimises excess solvent or carrier which in turn means minimal drying time and cuts solvent use.
- 4) 8-level greyscale (0-7 dpd) is equivalent to 8 densities of CMYK.

- 5) Eliminates the need for Light Cyan, Light Magenta and Light Black (Grey): a full size drop of light ink can effectively be replaced with a smaller full-strength drop. The resolution (determined by the smallest drop size) is enhanced as the smallest drop is now effectively 30-40% of the original drop size.



- 6) Increased 'value' per nozzle: There are a fixed number of nozzles in a printhead. Typically more nozzles are required if you use small drops. So, the reality is that you get a much higher value per nozzle – each nozzle effectively behaves as multiple nozzles e.g. 7 if 7dpd – again, same cost per nozzle but effectively 7x the number of nozzles per inch to get the same coverage. This could be up to 15 times.

All these benefits combine to produce better image quality without the overhead and cost of multiple nozzles. Variable drop capability combined with reliability and printhead lifetime are all important to reach the levels of productivity required for industrial markets such as the ceramic tile industry.

→ Section 8

The Xaar 1001 Printhead

- Unrivalled reliability
- Outstanding print performance
- Patented TF Technology™.

The 1001 printhead has been developed specifically for use in industries such as ceramics, packaging, textiles, and printed electronics where the demands are for high throughput single pass printing with high quality print or materials deposition; reliability and efficiency of operation; long life and the ability to handle difficult fluids such as white or metallic inks.

The printhead is designed for use in production line environments with a number of unique features for easy installation including simple electrical and ink supply connections and a patented “Self –Alignment System”. The printhead also has a nozzle guard to protect the nozzle plate.

The technologies employed are Xaar’s variable drop (Greyscale) technology which allows the deposition of variable size drops of ink and TF Technology™ which assists in print quality and delivers particularly high reliability and ease of use.



Xaar 1001

TF Technology™

The way the Xaar 1001 operates is a significant departure from the traditional design of a piezoelectric printhead. All previous printhead designs regardless of manufacturer have ink entering at the back of the channels which then carry the ink to the nozzle at the front of the channel.

Xaar's TF Technology™ provides ink re-circulation at the nozzle and when combined with the side shooter architecture is a significant step forward towards running inkjet systems reliably for a full shift with minimal maintenance. Printheads with all channels (nozzles) working to their full potential is essential in single pass production printing.

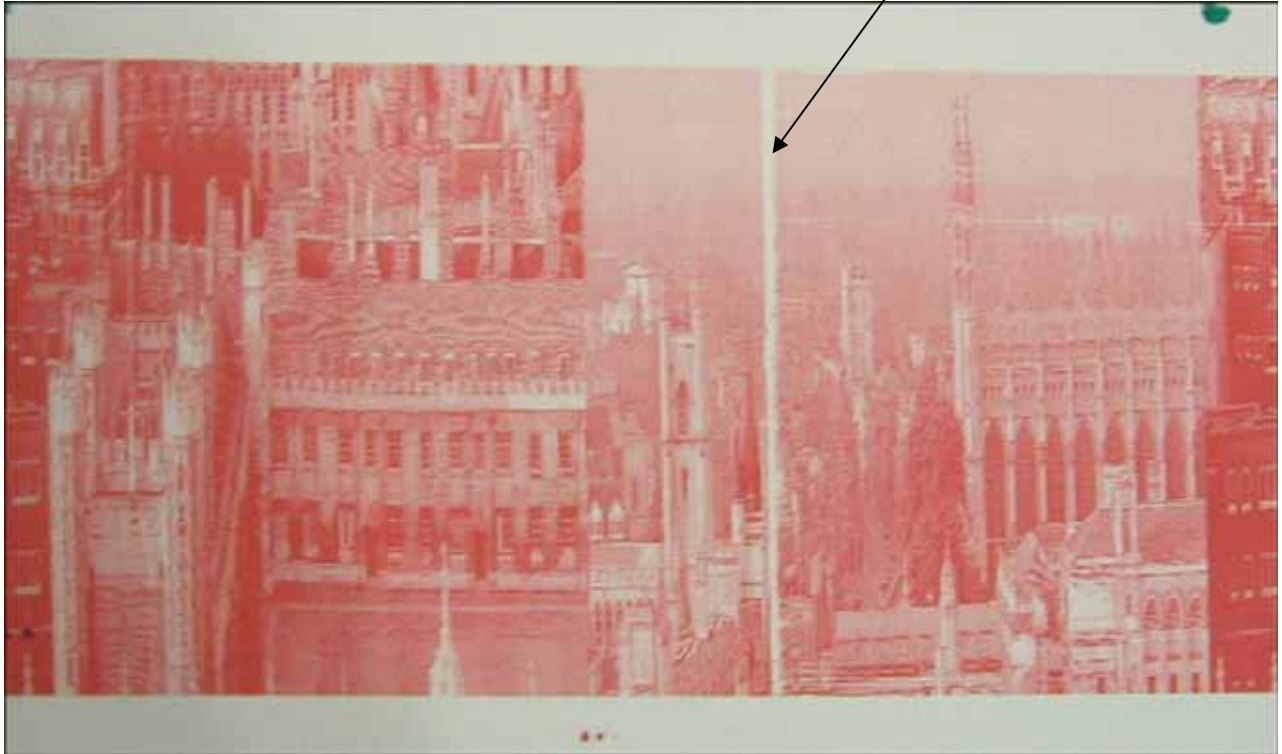
With the Xaar 1001 printhead design the ink passes through the channels and washes past the back of the nozzles that are now positioned in the side of the channel rather than at the end, and returns through an ink recirculation system where it can be filtered for the removal of air bubbles and contaminants such as dust particles. This creates a through-flow of ink that delivers very high reliability.

This technology brings a wealth of benefits to the printhead. The fact that the ink is continuously recirculated allows the ink temperature to be accurately controlled across the head and as ink viscosity is dependent on temperature and viscosity determines drop size the technology brings about an improvement in print density consistency and hence print quality.

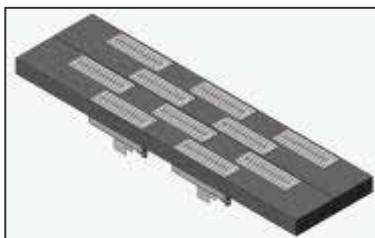
The continual recirculation of the ink allows both higher viscosity inks to be used than have previously been possible and heavier pigment loadings as found in metallic inks remain in suspension.

With traditional printheads a slight mechanical knock to the head, as may happen on a production line, would cause other printheads to ingest air through the nozzles, de-prime, and stop printing. The through-flow of the ink within the Xaar 1001 enables it to self-recover, leaving only a thin strip of the media unprinted, meaning only one print (or tile) will be lost and there is no need to stop the whole production line. This is a critically important property of the printhead allowing it to be used in production lines, where continuity of production is paramount.

Print sample illustrating
self-recovery – line
dropped due to impact



Self Alignment Feature and Scalable Integration



The printheads have patented location features, one positioned at each end. These have been developed to facilitate quick, easy and accurate printhead installation and replacement. With the use of these features, a printhead to printhead alignment accuracy of $\frac{1}{3}$ rd of a pixel can be achieved.

Print bars can be built by the integration of a number of overlapping printheads to give the desired print width and can be used for the following:

- Add colours
- Increase speed - laying down half the print with each of two print bars doubles the output
- Increase npi - by off-setting the heads by half a pixel to give twice the native resolution across the print.

→ Section 9

Summary

More and more manufacturers printing tiles with traditional methods are demanding inkjet printing solutions. Inkjet printing is moving into a new era with the introduction of the Xaar 1001 TF Technology™ printhead. The printhead is robust and can run for hours in production without maintenance, depending on design and quantity printed. This is a major benefit as it enables digital to integrate into a manufacturing line alongside traditional printing methods. One of the perceived downsides of digital inkjet printing is the higher cost of ink, however this should be considered in the wider context embracing the benefits of material savings, time and inventory waste. Today, there is also less chromatic variability and lower colour intensity. But, manufacturers are confident that the benefits outweigh the downsides, so we are looking forward to some exciting changes in the ceramic sector.

Quick Comparison Table – Digital Print versus Traditional Print

Digital	Traditional
Short print runs	Long print runs
No printing consumables needed	Rollers etc needed which increase costs
Variable design	Fixed design
Short lead times	Longer lead times
Tile edge decoration	Decoration only up to tile edge
Low stocks	High stocks
Lower distribution costs	High distribution costs
Low wastage	High stock write-offs
Image changes can be done on the fly	Long down-times for image change and colour adjustments
Wider range of colours with digital inks	Traditional ceramic ink sets come in a limited range of colours



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