9

Controlling digital colour printing on textiles

J R CAMPBELL, Iowa State University, USA

9.1 Introduction

The variables in digitally printing imagery to cloth using ink jet technology are so great that, if the same print design were digitally printed on a variety of different printers using the same type of ink sets and fabric, the color results would vary widely. Factors such as environmental conditions, ink properties and print head construction can cause results to vary from day to day using exactly the same printer and inks. This can be very troublesome and frustrating for print providers. The approach to getting consistent and appropriate colour requires an operator who has knowledge of fibre and fabric structure, preparatory and finishing processes and the appropriate application of ink/dyestuffs, in addition to a solid understanding of the printing technology, of colour management systems and Raster image processors (RIP)s. This chapter focuses on the multifaceted factors that users of digital textile printing technology must address in order to control the application of colour to digitally printed fabrics.

The choices of printers, software and solutions available on the market can be confusing. Users of the technology must evaluate a broad range of software and ink/dye solutions designed to support particular devices. How can the user best evaluate which components interact with each other to produce optimum results? A solid understanding of the printing technology, as well as the software and systems that run it, must be balanced with a clear picture of the role of the end output. Table 9.1 shows the printers that are currently on the market for use in digital textile printing, along with a listing of their key features. Descriptions of ink jet printing technologies are shown below.

9.1.1 Thermal drop on demand (DOD) inkjet

Thermal ink jet print heads use heat as the mechanism for forcing the ink through very small openings. The ink is heated in many small chambers by passing a current impulse through a digitally controlled heating element.

Table 9.1 Examples of digital textile printers currently on the market

Printer	Ink jet technology	Printing width	Print speed (maximum)	Inks/dyes available	Fabric handling	Resolution	Print head configuration	Intended output/use	Special Info
Displaymaker Fabrijet XII (MacDermaid Colorspan)	Thermal (Lexmark)	1.65 m	27.9 m^2/hour	Reactive or acid	Roll-to-roll web handling	600 dpi	12 heads, CMYK process and spot	Sampling, short run production	
Encad 850/880	Thermal (microburst)	60 in (1.55 m)	62 sf/hour (in 1 × 8 photo configuration)	Pigment, acid, reactive or disperse	Roll feed and take-up	600 dpi	8 heads, dual CMYK, or 8 process	Sampling, one-of-a-kind artwork, short run production	Built-in thermal dryer, 880 allows platen height adjustment
DuPont 3210 Artistri (manuf. by Vutek)	Piezo (Spectra)	3.2 m	30 m^2/hour	Pigment or acid	Roll-to-roll web handling	360 dpi	8 heads, process	Production, sampling	
DuPont 2020	Piezo (Seiko)		15–52 m^2/hour	Acid, reactive, disperse, pigment		360, 540, 720 dpi	16 heads, 8 process		
Stork Amethyst	Piezo	1.6 m	8–10 m^2/hour	Reactive or acid	Roll-to-roll web handling (requires special pretreated fabric)		8 heads, process	Production	

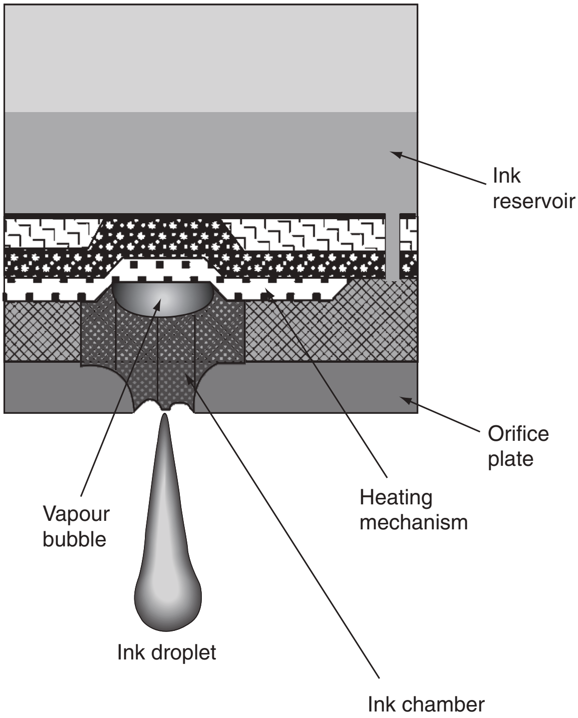
Table 9.1 (Cont.)

Printer	Ink jet technology	Printing width	Print speed (maximum)	Inks/dyes available	Fabric handling	Resolution	Print head configuration	Intended output/use	Special Info
Stork Amber	Piezo	1.6 m	1.8 m^2/hour (in highest quality mode)	Reactive, acid (cartridges)	Roll feed and take-up	720 dpi	7 heads, 6 process	Sampling, pre-production	
Stork/Lectra Sapphire	Piezo	1.65 m	17.6 m^2/hour (high speed mode), 4.7 m^2/hour (high quality mode)	Reactive, acid (cartridges)	Roll feed and take-up	360 × 360 dpi, 720 × 720 dpi	16 heads, 2 × 8 staggered arrangement, 8 colours	Sampling, short run production	Head height adjustment up to 7 mm, ieee 1394 port
Chromotex SPM 788-F (Zimmer)	Piezo (multi-deflection technology)	2.2 m	10–15 m^2/hour	Reactive, disperse or pigment	Roll-to-roll web handling	125 mesh resolution	8 heads, spot	Production	
Colour Booster (Hollander)	Piezo	2.23 m	22 m^2/hour in 8 colour mode at 720 × 360 dpi	Pigment, acid, reactive, disperse, disperse transfer	Roll-to-roll	360 × 360 to 2880 × 2880 dpi	16 heads, 2 × 4, 1 × 8, and any combination of concentrated and semi-diluted inks	Production	Open ink system with anti-sedimentation system, integrated TFT touch screen
Mimaki TextileJet TX1600s	Piezo	1.6 m	4.6 m^2/hour	Reactive, acid, disperse, pigment	Roll-to-roll web handling	360 × 360 dpi, 720 × 720 dpi	7 heads, 7 colour process	Proofing, short run production	

Mimaki TextileJet TX2-1600	Piezo	1.6 m	28.4 m^2/hour	Reactive, acid, disperse	Roll-to-roll friction roller	360 × 360 dpi, 720 × 720 dpi	16 heads, 2 staggered lines of 8 colours (CMYK + four colours specified)	Sample, short run production	Allows head height adjustment, ieee1394 port, anti-meandering loading device helps keep fabric aligned horizontally, optional dryer
Reggiani DReAM	Piezo (Scitex Aprion)	1.6 m	150 m^2/hour	CIBACRON® reactive (acid, pigment and disperse in development)	Rubber blanket	600 dpi	7 heads, 6 process colours + 1	Sampling, short run, medium run production	Continuous integrated washing system to keep rubber feed blanket clean, online dryer
MonnaLisa by Robustelli	Piezo (original design by Epson)	1.6 m	26–78 m^2/hour	Cenesta® reactive, acid	Endless belt drive	360, 720 dpi	24, 8 colour process	Production	
Textile Falcon by Digital Textle	Piezo variable dot (reconstruction of Mutoh's Falcon II)	2.2 m	6.9–27.9 m^2/hour	Pigment, disperse, reactive, acid	Roll-to-roll web handling	360 to 2880 dpi	8 process	Sampling, short run production	Built-in drying system, head height adjustment up to 10-mm

The heat produces a bubble of water vapour. The resulting pressure increase ejects an ink droplet on to the surface of the fabric. Temperatures of around 300 °C can be achieved, but a goal for developers using textile dyes would be to minimise the heating while maximising the droplet formation, to reduce the potential of the dye to reacting prior to its application to the cloth.

The major manufacturers of thermal DOD ink jet print heads are Hewlett Packard, Canon, Lexmark and Xerox. In the total ink jet market, 85% of all inkjet heads produced are thermal (Ujiie, 2003). This is due primarily to the fact that the technology is inexpensive. Most thermal ink jet printers (sometimes also referred to as 'bubble jet') use water-based inks and are good for low-volume printing. High resolution is attained by using a small drop size. The performance of thermal print heads over their lifespan is an exponentially decreasing curve. Their consistency is also somewhat variable because, as the inks are heated up to nearly vapour level for creating the ink droplet, some of the colourant or binder is often deposited on the print head resistor (Tincher, 2003). Figure 9.1 illustrates the structure of a thermal ink jet head.



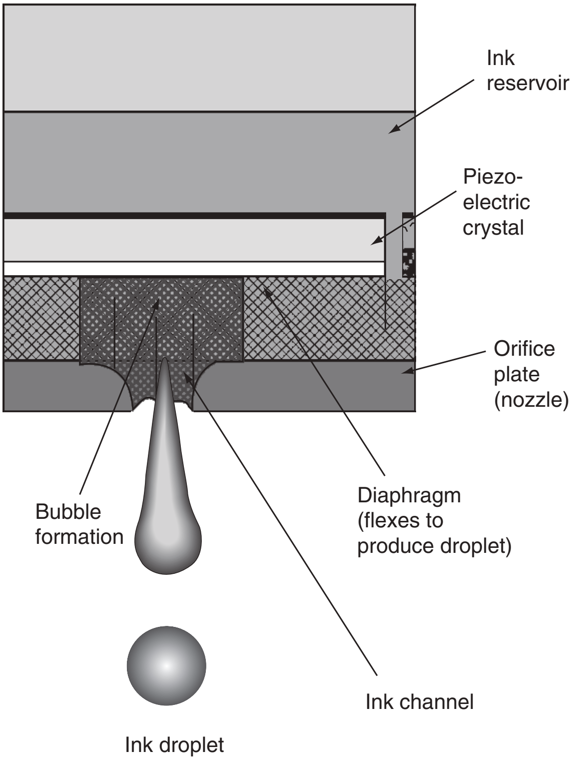
9.1 Illustration of a thermal ink jet head through the droplet cycle.

The use of DOD thermal heads in digital textile printing can have both advantages and disadvantages. Encad, a Kodak company, originally introduced the Encad 1500TX wide format printer for textiles in the USA in 1998. This printer, as well as Colorspan's Fabrijet printer, were two of the earliest printers released in the USA, both employing thermal ink jet technology. The relatively inexpensive cost of the thermal heads allowed Encad to create separate ink cartridges for each colour printed and to have them fed by bulk ink tanks that could be refilled while the printer was printing. This meant that, if one colour failed or clogged the cartridge, then that specific cartridge could be removed and replaced without impacting any of the other print heads. A disadvantage of thermal ink jet technology is that it requires the ink to be heated to nearly boiling temperatures to cause the ink droplets to be released from the print head to the fabric surface. Because many fabric dyes use heat and moisture as the primary catalyst for reacting with the fibre, if the user wanted to print dyes that could bond with the fibre for permanent washable colour, thermal ink jet printing raised issues. When the dye was heated in the thermal ink jet head, it was losing some or all of its binding power prior to touching the cloth. As a result, ink developers who were producing dye-based inks for fabric had to modify the dyes to be more resistant to lower level heat so that they could be successfully run through the thermal print heads and still bond to the fabric.

9.1.2 Piezoelectric DOD inkjet

Piezo print heads work by the following principle: droplets of ink are mechanically ejected from a nozzle in the ink chamber, when an electrical current impulse activates a piezo crystal. This crystal has the special property of changing its form when an electric voltage is applied, which causes the chamber to be compressed and the ink to be squeezed through the small openings in a manner similar to an oil can. Since the process is a mechanical one, it can be very precisely controlled. Figure 9.2 illustrates a piezo print head configuration.

The major manufacturers of piezo DOD heads are Epson (90% of all Piezo heads), Brother, Spectra, Aprion, Trident, Konica and Xaar. Advantages to piezo technology are that the heads are more reliable and have a longer lifespan than thermal heads. They are good for high-volume printing and are able to produce the smallest droplet sizes in the printer world (Epson, June 18, 2004: http://www.epson.de/eng/about/piezo/). Piezo heads are slightly more capable of using a wider variety of inks and pigments, because the head can be created entirely out of inert ceramic materials. Also, the inks do not have to be modified to withstand the temperatures that thermal heads require. The performance of DOD piezo



9.2 Piezoelectric print head.

heads over time is mostly level with a rapid drop-off. The main disadvantage of piezo technology is its cost. Another disadvantage is that piezo print heads are susceptible to entrapped air, which can lead to misfiring nozzles requiring multiple head cleanings (Baydo & Groscup, 2001). The print heads are permanently mounted into printers and are not easy to replace if they do fail. Piezo DOD printers are typically higher priced than the thermal DOD printers.

9.1.3 Multi or binary continuous inkjet head (CIJ)

In the continuous process, a constant stream of droplets is generated by a pump and a piezo crystal. The droplets pass through an electric field and become charged. A second electric field transmits a digitally controlled signal to the droplet stream with the result that individual charged droplets are deflected and strike the fabric surface at specific locations. Around 100 000 droplets per second leave the ink chamber, although with very high performance printers up to 625 000 drops/second can be ejected (BASF, 2004).

CIJ is the most complex print head technology. Of the three main print head types, CIJ is the least adapted to process colour printing. It is expensive to manufacture and maintain, but clogging is minimised. With CIJ, users must also deal with recycling or disposing of the unused ink. CIJ is well suited for high-speed applications. Major manufactures are Scitex, Stork, Domino and Toxot. The Stork Amethyst is the most popular CIJ printer that is currently being marketed for textile applications.

9.1.4 Initial questions of colour management software

Once the basic structures and limitations of the hardware are understood, the user of digital textile printing technology must consider the role and impact of design and printing software. Colour management software for these systems must answer three key questions. Firstly, what is the colour gamut (range of printable colours) of the system, taking into account the printer, inks and fabric to be used? Secondly, are the desired colours inside the printer's colour gamut? Thirdly, how can the system produce all of the colours that are within the colour gamut for the desired fibre type and fabric construction (Gordon, 2001)?

The digital textile printing (DTP) user must initially do some market research to determine which colours are attainable within the limits of specific printers and ink sets. This information can be gathered by contacting a representative from the ink and printer suppliers. If a printer is incapable of producing a desired colour due to its structural set-up (for example, CMYK only vs. CMYK + MedM, MedC, LightM, LightC), no amount of colour management can make it possible. It is also very important to understand that there are some colours that can be displayed on an RGB monitor that are not printable using a CMYK device, and vice versa (CMYK representing the cyan, magenta, yellow and black inks used in process colour printing). A brief discussion of the different colour systems will be addressed later in this chapter.

Many of the early printers that were introduced to the digital textile printing market were simply modified versions of graphics printing systems using a standard CMYK process colour set-up. These systems were initially not very well received by large-scale textile mills because the colour gamut obtainable in CMYK is considerably smaller than the gamut of spot colour inks used in conventional rotary screen printing of textiles. If sampling and strike-off printing was to truly take hold, these new printers would have to become able to more closely match the spot colour prints that were standard for textiles.

9.2 Characteristics and variables of digital ink jet printing (DIJP)

After the major decisions have been made regarding hardware and software, the user of DTP technology must be able to conceptualise the printing issues that distinguish this technology from traditional textile printing processes. This section will expand on the physical and user-orientated issues of the technology.

DIJP does not require rollers or screens. It is a non-contact printing process; the print heads never touch the fabric, they merely drop the ink droplets on to the surface. As such, it is inherently different from almost every other type of large format textile printing. By its very nature, it allows for the possibility to design without a repeat. DIJP enables artists/designers to be more creative and provides for greater experimentation with colour (up to 24-bit process colour possibility) and composition with much less cost. A designer can realise an idea on cloth in a very short period of time and, if the design is not successful, the design process can be returned to immediately, modifications made and a reprint made for the results to be witnessed. From a textile printing production point of view, DIJP decreases machine downtime in-between designs. This has an important and profitable impact for companies producing strike-offs and samples. DIJP has the potential to lower the costs of short production runs and to produce them with a faster cycle time, thus allowing manufacturers to be more responsive to the marketplace. This technology also virtually eliminates dye waste and, as such, is more environmentally friendly. Another key feature of DIJP is that it eliminates major colour registration problems that are always an issue with roller or rotary-based screen printing. It also enhances the opportunities for personalisation and customisation, allowing artists and designers to interface directly with the end consumer to address their personal preferences and interests. Due to many of these capabilities, DIJP holds the potential to tip the balance of textile print manufacturing back to more industrialised, higher labour cost countries, while reducing the inventory costs that are currently incurred by housing the multitudes of screens and inks. Given that DIJP holds all of this conceptual potential, let us look more closely at the factors that must be accounted for in the day-to-day production of consistent and effective fabric prints.

As we have already addressed the print head technology, the physical and use-orientated variables to be discussed below will be printing width/fabric handling, print speed and features, print resolution, drop size, ink types/characteristics, fibre type, fabric structure, pretreatment, dye/ink penetration, environment, post-treatment and continued care. Each of these variables will impact on both colour matching and colour permanence. The integration of raster image processing (RIP) software, colour profiling and management issues will be discussed in section 9.5.

9.2.1 Printing width/fabric handling

The maximum printing width of wide format ink jet printers for textiles ranges from 36 inches (91 cm) to as much as 126 inches (320 cm). The user should purchase a printer based on maximum print width needs. The greatest variable in fabric width lies with how the different printers handle the fabric. Since many of the early printers that were introduced to the digital textile printing (DTP) market were modified graphics printers that were used for printing paper, these printers required the fabric to be paper backed for stability and then fed through the printer in the same way that a roll of wide photo paper would be handled. This added cost to digitally printed fabrics. All of the Encad printers that can be used for textile printing require paper backing, but this also allows for printing of many other media types on the printer as well. Other issues with paper-backing will be discussed further in the section on pre-treatment.

The first digital textile printer in the USA to handle the fabric without paper backing was MacDermaid Colorspan's FabriJet XII. This printer came equipped with a component that the company called an 'edge tracker' that would automatically track the edge of the fabric and clip the print image so that ink waste and mess was avoided. As part of the fabric handling system, the FabriJet employed web handling with a web tension range from 500 gm to 5000 gm. If the width of the fabric on the supply roll got smaller, the take-up roll would get larger to balance the tension. Since the FabriJet didn't require paper backing, it had to have an open platen so that excess ink would fall through sheer fabrics and be handled by an ink blotter. The FabriJet also had a component called the 'selvage edge handler' that would allow fabric with fringed selvage to be printed without causing the print head to be dragged across the fringe yarns. These features proved to be far more efficient for textile-specific printing needs than those of the more standardised printers, and they are the key features that continue to be implemented and improved with the more recent printers released to the market for fabric printing.

9.2.2 Print speed and features

There are five key features relating to print speed that have an impact on the quality and quantity of ink application to cloth.

Printing speed

Printing speed is controlled primarily by the mechanism by which the print heads are mounted on to a carriage and the system for traversing the carriage back and forth across the width of the fabric. Since digital data and ink are constantly being sent to the print heads there must be a flexible chain-like mechanism that can travel part of the distance across the platen. The heads will most probably be positioned on the carriage so that they are staggered along the length of the fabric. This allows for multiple colours to be applied during the same print pass.

Print head movement (uni- or bi-direction printing)

Printing speed will be greatly affected by whether the printer is capable of bi-directional printing, meaning that it prints ink both as it travels across the fabric and as it returns. These settings can often be adjusted on the printer to improve or reduce the quality or ink lay down, based on the user's needs.

Printing passage (print pass)

To allow for the quantity of ink necessary to create the proper hue and saturation on the fabric surface, many printers are required to have multiple print passes of the same ink drop arrangement over the same area of fabric. Most graphic photo paper applications require a maximum of four-pass settings, while it is quite common to see textile settings of six-pass or more in order to lay down enough ink to get the proper colours on these much more absorptive media. Companies that have developed software packages for digital textile printing have often designed 'double-strike' settings that cause the printer to lay down twice as much ink as it would have done in a normal six-pass mode.

Ink placement

The mechanism for creating the precise droplet formation and placement on the fabric surface is a function of both the print head construction and the speed at which the carriage is moving. Software interpolation governs the pattern that the ink droplets will be arranged in, based on the structure and capability of the print heads.

Head height

To allow for the printing of thicker or textured fabrics such as pile weaves, some printers are able to adjust the height of the print heads or platen. For an extremely thick fabric, it is not recommended to use the fastest print speed settings.

9.2.3 Resolution

How the raster image processing (RIP) software handles resolution is very important, but it is the printer technology that governs the geometric resolution (300 dots per inch (dpi), 600 dpi) vs. the perceptual resolution. A good RIP package will allow full control of dot gain adjustment and an ability to control half-toning. All of these adjustments will be heavily influenced or limited by the structure of the fabric that is being printed.

There is some debate about the necessity of resolutions above 600 dpi in the use of digital textile printing. Higher resolution does allow for smaller drop size, and thus enables more accurate tonal control for images with large ranging gradient fills, but it is not clear that the finer detail in a photographic image will be attained, due mostly to the structure of fabrics (discussed in 9.2.7).

9.2.4 Drop size and formation

A smaller drop size (perhaps 10 picolitres vs. 40 picolitres) should allow the print to capture fine details, reduce graininess and integrate finer tonal curves. The cleaner the droplet of ink, the less likely the occurrence of satellite drops, which can reduce the clarity of the image. The drop pattern is controlled by the firing of the print head and is affected by the viscosity of the ink.

9.2.5 Ink types and characteristics

Ink factors that will affect usability include (i) the molecular size of the colourant, (ii) the colour gamut attainable with the dye class, (iii) the stability of the ink to resist precipitation so that it can have a longer shelf-life, (iv) viscosity, (v) the ink's ability to be de-gassed so bubbles won't form in the print head, and (vi) the ink's colourfastness (washfastness, lightfastness, crocking). Inks to be used for DTP will vary based on fibre type, pre-treatment, finishing and end-use. For sampling or printing fabrics that don't require washfastness, pigment inks can be used. Pigmented inks require a binder to hold the colourant to the fabric. In ink jet printing, the binder must be applied either in the ink, by separate nozzle, or by pre-treating the fabric with a receptive binder. For more production orientated fabrics, or one-of-a-kind pieces, washfastness is likely to be more desirable, and so it would be appropriate to use the dye class that is most suited to the fibre type. To determine which ink type will have the best performance on the major fibre types see Table 9. 2. Reactive dyes are used for cellulosic fibre fabrics, such as cotton. As their name suggests, the dye reacts with the cellulose to form covalent chemical bonds. To complete the chemical reaction, alkali, moisture and heat are required. For ink jet printing, the alkali must be applied to the fabric in a pre-treatment process because the alkalis will interfere with the dye's effective drop formation and with the nozzle components on the print head (Ervine *et al.*, 1999). Acid dyes are used to print the protein fibres (wool, silk) and polyamide. These dyes typically need a pre-treatment on the fabric to prevent the dye from wicking through capillary action across the surface of the fabric (Ervine *et al.*, 1999). This is especially the case in the use of silk fibre fabrics. Disperse dyes can also be used to print synthetic fibre fabrics (predominantly polyester). The disperse dyes can be printed on to paper or directly on to the surface of the fabric. These dye sublimate into the surface of the fabric, so high levels of heat are required to make the dye permanent in the fabric.

9.2.6 Fibre type

There are additional factors related to fibre type that will affect the way the ink is bound to the fabric. For instance, the absorbency, wicking properties, surface structure and length of the fibre will affect how the colourant is applied. Silk, cotton and wool are very absorptive fibres, which means that any water-based ink or dye will soak quite readily into the surface of the fabric. Most synthetic fibres are not nearly as absorptive, so they will require lesser amounts of ink to be applied to the surface of the fabric. Nylon, polyester and silk have good wicking properties, and so are more likely to require a pre-treatment that will reduce the wicking of the ink as it is dropped to the surface of the fabric. Wool has a very scaly and rough fibre surface compared to silk and the synthetic fibres, which adds to its bulkiness and absorption. This means that wool will probably require far more ink to attain the same colour than nylon or silk might. The length of the fibre contributes to the quality of the yarn and thus to the smoothness of the fabric. In DTP, the smoother the fabric, the more accurate and detailed the image can be printed.

9.2.7 Fabric structure

The fabric structure will also impact the clarity and colour richness of a digitally printed image. Wicking can also be enhanced or subdued, based on the fabric structure. Weaves with long floats like satin tend towards higher levels of wicking, plain weave fabrics or knit minimise it. If the fabric structure is very bulky or uses a great deal of yarn, as is the case with knitted fabric, they will be more absorptive and require greater amounts of ink/dye

Table 9.2 Best performance of ink on fibre type

Inks/ fabrics	Cotton	Linen	Nylon	Polyester	Silk	Viscose rayon	Wool
Acid			✗		✗	✗	✗
Dye-based/UV	✗	✗	✗	✗	✗	✗	✗
Disperse				✗			
Pigment	✗	✗	✗	✗		✗	
Reactive	✗	✗			✗	✗	✗

to be printed. The denser the weave or surface structure, the more likely that there will be an increase in surface tension, which might be undesirable if the user is working with a low absorption fibre, because the dye will take longer to soak into the surface of the fabric. Some fabric structures will also tend to increase capillary attraction. The fibres and yarns adjacent to where the ink drop has fallen will be more likely to wick some of the colourant in their direction.

9.2.8 Pre-treatment

The pre-treatment needed for the fabric will depend on the ink to be used (dye-based, reactive, acid, disperse, pigment). Many who are interested in entering the field ask, 'is pre-treatment truly a requirement?' The answer is most likely yes if we want to achieve the right colour, improve the performance of the ink, and maximise the fibre's chemical reaction with the ink (Locastro, 2001).

One type of pre-treatment that is unique to digitally printed fabrics is paper-backing. Is paper-backing needed? This depends on the printer and fabric. Because of their weight and stability, some fabrics can be run through printers that don't support roll-to-roll web handling, but generally for these printers the paper-backing provides more peace of mind. An advantage to paper-backing is that, if the fabric being printed is of an open weave or is very light weight, some of the printed dye would actually soak through the back of the fabric. If there were no paper backing to absorb that excess ink, the ink would be deposited on the platen or stage of the printer, creating a potential for discolouration across the back of the fabric. A working disadvantage to paper-backing is that it may be quite difficult to keep some fabrics on grain during the paper lamination process. A sheer fabric that is printed as sample curtain fabric cannot afford to be off grain when it is presented to a buyer.

9.2.9 Environment

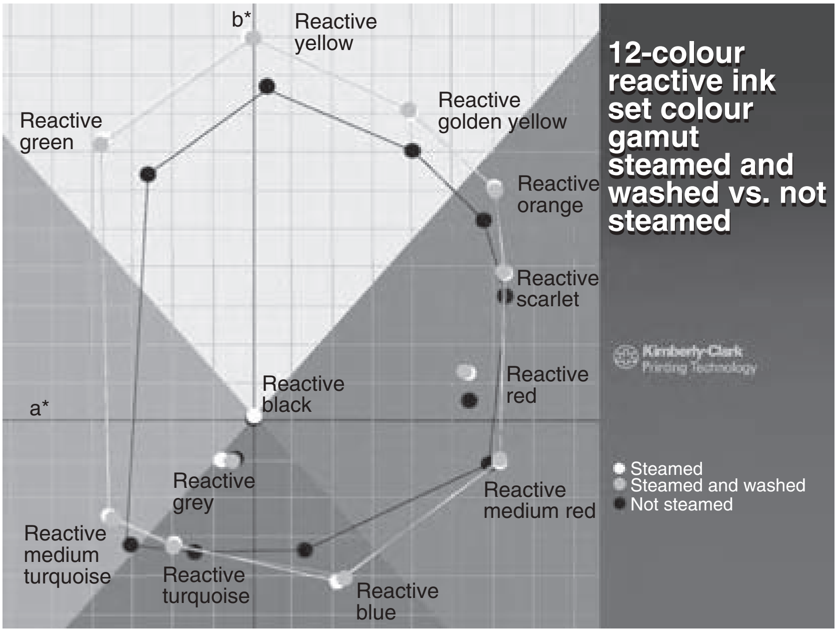
To maximise the efficiency of the printer, fabric and dyes, the environment in which the printing occurs should be controlled as much as possible. Reactive dyes require a much more humid environment to reduce clogging and maintain high levels of bonding to the fabric. This is not the case at all with pigments. Typically, the printer components run more efficiently in drier atmospheric conditions. Pay close attention to the suggested operating conditions for the inks, fabric and printer used. Maintaining more consistent environmental conditions will help to ensure more accurate and uniform printing.

9.2.10 Substrate post-treatment

So when is post-processing a requirement? This depends on the pre-treatment, the ink being used and the purpose of the output. Reactive and acid dyes require steaming for the dyes to bond to the fibre; disperse dyes require heat for sublimation. The two strongest reasons for post-treatment are to increase the colour gamut (many of the dyes display a wider gamut after steaming) and to improve colourfastness to light, crocking or washing. Figure 9.3 (see also colour section) shows experiments conducted at Kimberly–Clark with a 12-colour reactive ink set showing enhanced colour gamut space provided by steaming and washing.

Where is post-processing done? Steaming and some fixation processes may be done on premises in either a low or high-pressure steamer. High-pressure steamers undoubtedly provide superior control and consistency from print to print, but are often quite expensive for digital textile artists or small production firms. To attain consistent colour in large batches, washing should most likely be done in finishing mills with conventional machines. Table 9.3 shows the most likely combinations of pre- and post-treatment needs for digital textile printing.

Managing colour matching and consistency of digitally printed fabrics is greatly complicated by the post-processing requirements. Because acid, reactive and disperse dyes change colour and expand their gamut after steaming, colour profiling can most likely not occur until after this phase. In addition, some of the colours that have ‘popped’, or become enhanced, through steaming may be lost again during the rinsing process. If a fabric is going to be used in an end product, then rinsing is also a necessity to wash



9.3 Experiments conducted at Kimberly-Clark with a 12-colour reactive ink set showing enhanced colour gamut space provided by steaming and washing.

Table 9.3 Pre- and post-treatment options for digital textile printing inks

Inks/ process	Pre- treatment	Steaming	Thermal fixation	Washing	Colour- fastness
Acid	Yes	Yes	No	Yes	Yes
Disperse	Yes	Yes*	Yes	Yes*	Yes
Dye-based UV	Yes	No	No	No	No
Pigment	Yes	No	Yes	No	Yes
Reactive	Yes	Yes	No	Yes	Yes

Note: Some companies, such as Jacquard® Ink Jet have developed a modified post-treatment process for disperse dyes, in which they can be steamed in the same manner that reactive and acid dye printed fabrics would be. This allows users with the equipment to process natural fiber fabrics to also include some synthetics in their repertoire without re-tooling or purchasing more equipment.

off any excess dye that has not been fixed during steaming. In this case, colour matching and profiling will have to occur after the fabric has been both steamed and rinsed.

9.2.11 Continued care of digitally printed cloth

As the digital textile printing industry becomes more developed in the production arena, there will be a need for more focused attention on the continued care issues with digitally printed fabrics. Although the overall performances of the acid, reactive and disperse dyes are thought to be similar to what they would be with traditionally printed fabrics, there are differences that could impact on their longevity. The nature of ink jet printing technology is such that very little ink is used per square metre of the fabric. Ink drops will predominantly soak only into the outer surface of the fabric after it has been printed, especially in tightly woven or pile fabrics. The dyes often do not penetrate the fabric completely. This means that digitally printed fabrics are more susceptible to colour loss from the wear of rubbing over time than they might be from washing. Laundering and storage issues of digitally printed fabrics need to be further explored to inform the design and development stages of printing. Washing conditions and agents are related to consumer preference; colourfastness problems may be minimised by consumers' appropriate selections of washing conditions and agents. Therefore, in order to provide consumers with appropriate care information, it is necessary to examine how different washing conditions or agents affect colourfastness in the laundering of digitally printed fabrics.

9.3 Design potential and limitations of digital textile printing

This section will elaborate on the design issues and potentials/limitations of the technology for digitally printing to fabric. These issues are ultimately tied to the successful and consistent application of colour due to the designer's role in conceptualising the end product. The following are issues that have been determined to have an impact on the design approach: (i) the use of repeat designs versus non-repeating image creation, (ii) the use of photo-realistic imagery, (iii) the potential for greater variations in size and scale, (iv) the possibility for creating more producible engineered digital three-dimensional forms, (v) limits of file size with contemporary software and hardware and transportability of files to the digital printer (Parsons & Campell, 2004; Ujiie, 2003).

9.3.1 Use of repeat designs vs. non-repeating image creation

Using traditional textile printing processes, the physical size of a print design is limited to the size of the screen or roller. With direct digital textile printing, it is possible to develop large-scale print designs in which the elements of the print design are never repeated.

9.3.2 Use of photo-realistic imagery

In creating digitally printable imagery for textiles, the designer can incorporate the use of high-resolution images to push the limits of photo-realistic printing. The use of high-resolution images is only technically limited by the ease of use with currently available hardware and software and the current (and yet constantly changing) storage and transport media for dealing with large file sizes (Parsons & Campbell, 2004).

Photo-realism opens the possibility for the use of multi-layered imagery, ghosting effects, an unlimited use of color, extreme tonal images, surface/texture simulation, digitally created effects, and a number of possibilities that are not cost effective or even possible to produce through traditional printing methods.

9.3.3 Variations in size and scale

Digital printing allows the designer to quickly print out the same image at different scales to test the visual impact, or to add variation to a textile collection without having to design multiple images. This is a function that would require a great deal of time and money, if it were done through traditional printing techniques. Designers can also use digital capture technology to obtain high resolution images of the microscopic world and transform them easily into huge scale prints, with little loss of visual quality.

9.3.4 Engineered digital three-dimensional forms

Apparel, furniture and/or sculptural pieces can be designed for digital textile printing in which the imagery is continuous around the form. Through the integrated use of textile and apparel design software, printable designs can be tailored directly to pattern pieces for a garment. By engineering the textile print designs into each garment pattern shape, print designs can become more personalised and body specific. The image-filled pattern pieces are all that are printed to the fabric, leaving all areas of the fabric that are not used in the garment unprinted, thus saving ink. These pieces can simply be cut out and sewn together to create a finished garment (Parsons & Campbell, 2004).

9.3.5 File size and transportability limitations

Usability of the software and hardware involved in DTP is determined by how well the systems can handle the large computer files that are needed to be able to print large-scale images. Many of the RIP and spooling software packages that have been developed are specific to an operating system, so files must be converted and saved in formats that are acceptable across platforms (Mac, Windows, UNIX, etc.).

9.4 Role of end output: artist and industry approaches

This section will include an analysis of the ways in which the textile and apparel industry, as well as artists, are using the technology. The approach will differ greatly depending on the end use. Many artists have adopted the technology to create one-of-a-kind or limited edition artworks. Small-scale companies such as Gild the Lily, based out of Providence, Rhode Island in the USA, print scarves and garments on demand as they are ordered from their pre-designed choices on the Internet. Digital textile printing use is now almost completely integrated into the apparel and interiors manufacturing industry as it is used for sampling and prototyping. More recently, companies like Direct Digital Printing (DPP) in Sydney, Australia have begun to focus on collaborative production quantity digital printing for the interiors and apparel markets.

9.4.1 Recognising the role of the end output

To get the right output, digital textile print providers must choose the right software, integrator, printer, ink, fabric, RIP and the right studio. Because many of the printer manufacturers traditionally are coming from a graphics perspective, research and development investments are not allocated for textiles. Users must understand the special features of the components to be used with the printers, i.e. inks, media and RIPs. For every given end product, there will be different requirements for speed, quality, colour matching, colour fastness, etc.

9.4.2 Sampling

The first really cost-effective approach to users of DTP was to apply the technology to print pre-line or sales samples, design proofs or strike-offs. Much research and development has gone into making the prints that are coming off the ink jet printers look as close to screen printed fabrics as possible. This somewhat odd use of the technology makes great sense when the cost of a digitally printed strike-off is compared with one created traditionally at a mill. The technology can also be used to make a sample product to use as a prototype or production floor example. Perhaps the digitally printed sample could be used for a photo shoot to create catalogues for distribution to the public prior to beginning the production process for the product in an overseas factory. Other uses for sampling could include indoor banners/soft signage or tradeshow backdrops.

For this type of use, pre-treatment of the fabric allows inks to be printed to the sample fabric without wicking or bleeding, promoting the highest quality image possible. The pre-treatment also allows more ink to be applied, resulting in more saturated colours. In most cases, these samples do not need to be water resistant, so no post-processing may be required.

9.4.3 Production

Production style printing can be approached from a number of different angles, but the key similarity is that the end product needs to conform to the ultimate consumer's expectation for style, innovation, usability, purchase-ability, and serviceability. Fabrics printed for production will most often need to be post-processed for colourfastness. Possible output for short-run production could include products used for marketing, sales or promotional activity (e.g. the cosmetic company Clinique could give away digitally printed bags to their customers to promote the company). One-of-a-kind products like garments sold in speciality boutiques, costumes for cinema or theatre productions (like the Austin Powers movie, for example), or artwork to be displayed in galleries would also qualify as production style printed media. In the more recent months, a few companies across the world have started providing production printed yardage to the apparel and interiors industries by using printers like the DuPont Artistri® 3210 or the Reggiani Dream® Machine.

Pre-treatment with post-processing allows inks printed for these circumstances to bind to fabric. Most of the inks used for production printing penetrate the fabric, instead of simply resting on the surface. Some ultraviolet curable inks allow colours to be UV protected. The inks used for production will typically be water resistant after post-processing.

9.5 Ensuring accuracy and uniformity

A brief discussion on using and creating profiles for the different media types will begin this section. This will lead into a survey of the different RIP software packages that are currently supporting textile printing. Profiling and testing is increasingly complex if the intention is to create wash-fast fabrics; and so ensuring accuracy will involve not only calibrating printers and monitors for the media, but also using consistent methods for steaming, rinsing and finishing the fabrics.

9.5.1 Process colour systems

Looking at the different process colour printing systems will help in understanding the realistic colour capabilities and expectations one should have of these systems.

CMYK is a four-colour printing process using three subtractive colour primaries with black, cyan, magenta and yellow. The colour limitations of CMYK lie in the difficulty of reproducing bright reds, greens and blues, as well as many of the colours required by the textile industry. The CMYK process is improved by including extra colours that cannot be reproduced by dithering or mixing cyan, magenta and yellow.

The strongest complaints about digitally printed fabric from the textile industry are the visible dither of colours and limited colour range (or total gamut – hue, saturation and value) compared with traditional textile screen printing (Gordon, 2001). The dithering results from the printers' lack of ability to create a sufficient number of steps in value of any given colour. So, when a very light colour is reproduced on the fabric, it is printed as very few dots spread out across the surface of the fabric. Because the dots are in isolation, they become more perceptually visible. The introduction of 7, 8, and even 12-colour ink jet textile printers brings the gap closer to achieving the results desired by the industry. As a general rule, the greater the number of colours (not print heads) that are in a printer, the larger the gamut of colours that can be reproduced. For example, a 12-colour printer with ten individual colours and two light shades will provide a much larger colour gamut than a 12-colour printer using CMYK with light shades. It is important, however, to have a balance of colourants to light shades to eliminate visible dither. When using textile inks such as reactive, acid or disperse, the full potential of these colour spaces are not realised until the colours have reacted with the fabric, which occurs during any post-processing such as steaming and washing (see Fig. 9.3).

The hardware and ink options available to the textile industry are a reflection of a growing market that has yet to develop any standards. As an example, Mimaki and Mutoh printers are available in versions that support both CMYK and Hexachrome® colour systems. The Mimaki can be configured with any six or seven colours as well as CMYK with light shades or in Hexachrome®. DGS offers the Luxor 7, which is a Mimaki printer that supports three different inksets, using CMYK with special colours such as

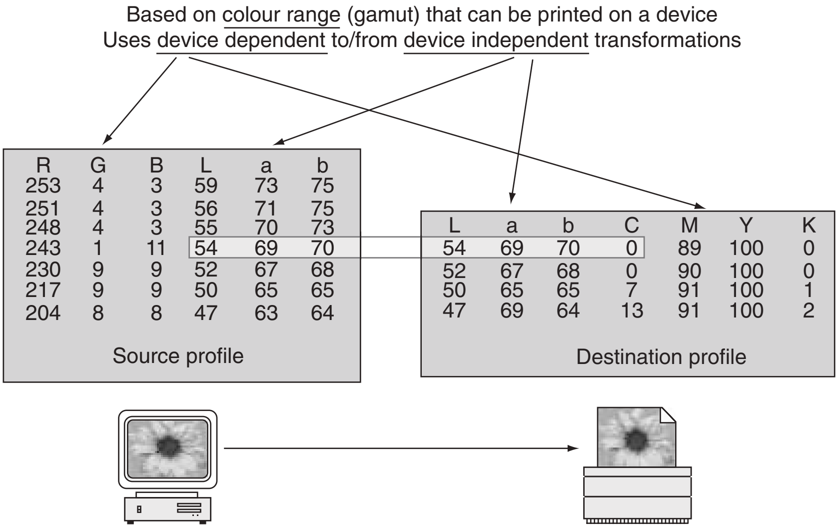
CMYK + (blue + green + gold), CMYK + (blue + grey + gold), CMYK + (C light + M light + K light). In addition, the ColorSpan 12 colour printers can be configured as either CMYK with light shades of cyan and magenta, or to use an 8- or 12-colour textile inkset. The inks determine the colour space, but the RIP drives and manages those colours.

Digital textile printers are developed, tested and marketed with the use of specific inksets in co-operation with ink vendors offering inks specially formulated for the textile market. While established users such as fine artists and graphic designers have been known to stray from these established formulae in hopes of finding their unique niche in the market, playing with ink chemistries and established ink/hardware formulas is not for the faint at heart. Nor is it advisable for companies under tight timelines (Gordon, 2001).

9.5.2 Defining and profiling colour

Components of RIP packages and colour management systems that should be considered are described below. The colour management system (CMS) and RIP software must be able to work together to create consistent colour from monitor to fabric. The International Color Consortium (ICC) CMS is the most common and it employs device-independent references of the International Commission on Lighting (CIE) *L*a*b** colour space. ICC's CMS characterises input colour devices, colour displays and output colour devices by using software and a spectrophotometer to create a small data file in the form of a conversion chart, which is called a profile. The profile creates a conversion chart by cross-referencing information from the input, display, or outputs' colour space and determining the equal value of that information in the CIE *L*a*b** colour space. An example of a cross-reference chart is shown in Fig. 9.4. CIE *L*a*b** colour space is one of the colour standards used by the textile industry. The CIE realised that every colour the human eye perceives could be defined using three numbers: *L** indicates luminosity, lightness from white to black. The *a** and *b** are the chromaticity coordinates that indicate colour directions: +*a** is the red direction, –*a** is the green direction, +*b** is the yellow direction, and –*b** is the blue direction. The centre is achromatic – hues of grey. As the *a** and *b** values increase and the point moves out from the centre, the chroma or purity of the colour increases. The pythagorean distance between two colour points plotted in the colour space relates to the visual colour difference between those two points. In this way, colour variation between points and a standard may be expressed using numbers (Gordon, 2001).

Colour management and RIP software manage colour by creating profiles or characterisations specific to the printer, ink, fabric and any post-processing, such as steaming and washing. All of these variables have an



Based on colour range (gamut) that can be printed on a device
Uses device dependent to/from device independent transformations

R	G	B	L	a	b
253	4	3	59	73	75
251	4	3	56	71	75
248	4	3	55	70	73
243	1	11	54	69	70
230	9	9	52	67	68
217	9	9	50	65	65
204	8	8	47	63	64

Source profile

L	a	b	C	M	Y	K
54	69	70	0	89	100	0
52	67	68	0	90	100	0
50	65	65	7	91	100	1
47	69	64	13	91	100	2

Destination profile

9.4 An example of a cross-reference chart.

impact on colour and each variation must be profiled to ensure accurate colour match. When a design is printed, a profile is selected based on the printer/ink/media combination to ensure that the colours in the original design or target colours match the digitally printed output.

The process of creating a profile or characterisation of a digital printer begins by printing out a linearisation file of the inks in the printer, typically from 0–255 saturation. The linearisation chart is measured with a spectrophotometer to calculate the distance between mathematical tonal ink values and actual printed tonal ink values. Next, a number of colour targets are printed and measured to map the colour space of printable colours. From all of these data points an algorithm is used to calculate the colour space and the profile is created.

Various software packages offer different levels of profiling capabilities, from supporting standard ICC profiles created in third-party profiling software, to vendor supplied profiles, to end user capability to create custom profiles using proprietary colour systems. The International Color Consortium (ICC) colour profile is a standard profile format that characterises the colour-reproduction capabilities or colour gamut of devices such as scanners, digital cameras, monitors and digital printers.

The price points of various software packages are often determined by the level of profiling and colour management capabilities. For instance, a RIP without profiling capability may be less expensive than one that uses proprietary systems to enable the end user to generate profiles. These options offer colour management of digital printing systems to customers who may not want to delve into profiling themselves.

9.5.2 Raster image processors (RIP)

The RIP software is essentially a sophisticated printer driver that allows for greater user control in rasterising the image (converting the data) for the printer. The RIP software must be written for the specific printers in order to take full advantage of the hardware capabilities. The RIP ultimately controls the printer and the colourant.

In addition to colour management capabilities, textile specific software is needed to handle print design images such as flat and continuous tone designs, separation files and files prepared for repeat printing. Important software features for DTP include its ability to accept textile industry file formats from CAD design and screen separation programs (such as CST, MST, PUB, GRT, SEP, SCN, XPF, etc.). The software must also be able to accept common graphic file formats like TIFF, Indexed 8-bit TIFF, PSD, EPS, AI, BMP, TGA, etc. Print layout functions such as step and repeat, design colourways, colour chips, multi-image placement, scaling, rotating, spooling or batching are also desirable features. A good RIP package for textiles should also be able to manage expanded ink sets beyond CMYK. In addition, it should allow for extra ink control functions to manage the higher ink densities required for colour saturation of printed fabrics. It should be able to create colour catalogues, colour palettes, and/or use the Pantone Textile Color System®. Profiling may be supplied by the vendor, but it is rare that the vendor would have appropriate profiles for all of the different fabric types and ink sets available, so custom profiling can be an important capability of RIP systems. A special feature of some RIP packages is the ability to create a colour gamut visualisation and comparison to see if the target colour is attainable. The screen print simulation features of software like DuPont's Color Control and Management System (CCMS) are highly desirable if the digital output needs to match to screen printed production yardage. For the large sector of users who are solely trying to create strike-offs for screen printed fabrics, it is helpful to have screen simulation features that can be viewed on screen to bridge the gap between digital and screen printed fabrics. Several software vendors have incorporated features useful in simulating and matching to screen printed production fabric, such as simulating screen resolution, raster simulation or screen mesh size; colour mixing, colour overprinting and colour trapping; incorporating gradation curves for tonal separations; and even profiling the textile printing mill's colour space to link colour data to a textile mill's colour kitchen.

Table 9.4 displays the companies offering colour management and RIP solutions for digital textile printing. The colour management and RIP soft-

Table 9.4 Raster image processing software packages, with key features indicated

RIP package	Vendor	Printers supported	File types supported	Colour management	Special features
Artistri CCMS	DuPont®	Dupont®3210	Stork®Public, Stork®Separated, Tiff, RGB, TiffLab	Custom printer profiles specific to ink and fabric, mill characterisation and colour profile Gamut mapping to compare ink jet printer gamut vs. textile printing mill gamut Supports black, cyan, lt. cyan, magenta, lt. magenta, yellow, orange, and green inkset	Screen print simulation features CCMS links the colour space of both the digital printer and the textile screen printing mill in order to create digitally printed fabric that matches the textile printing mill. This is accomplished by creating a Mill Characterisation and colour profile of a mill's unique color set, and a printer profile to map combinations of fabrics and ink.
Evolution textile RIP and RIP Plus	Digifab Systems	HP printers, Roland, Mutoh, Epson 9000, Mimaki TX1600s, Encad 1500TX & 800 series	All standard graphic file formats	Set of ICC profiles included with RIP Supports ICC profiles created by third party programs	Step and Repeat, scale, rotate, flip, multiply, mirror, cut, measure, and layout capabilities. RIP Plus adds a colouring system, colourways, colour gradient, advanced colour management, colour database and colour chips

MatchPrint II	DGS Dua Graphic Systems	Mimaki Tx & Tx2, Encad 850, FabriJet XII	Standard graphics formats	Custom profiling, built in colour atlas, direct linearisation	Can be combined with Ramsete III software to do screen print simulation and generate colour recipes
Vision simulating printed fabrics (SPF)	NedGraphics	Encad, Mimaki, Colorspan, HP, Konica and Iris	Stork, PS2, all industry standard formats	Colouring tools: colourways, colour editing, colour catalogues, custom catalogues, Pantone Textile Color Library included Colour gamut mapping Printer calibration: custom profile creation by vendor, Colour data link to colour kitchen	Preview of design on multiple substrates, using multiple printing and dyeing techniques Step-by-step UNDO function Simulation features: print order, overlapping colours, rasterisation, screen mesh, dye type, trapping, pad or resist effects, dye opacity/fabric absorption simulation
PrinterServer	Lectra and Stork	Stork Amber, Amethyst, Zircon, and TCP 4000	Stork, Lectra, Tiff and other CAD files	Colour gamut mapping Printer calibration: custom calibration profiles, vendor supplied profiles Colour data link to colour kitchen	Print functions include step and repeat, job queuing, spooling, multiple image layout Screen simulation features Network to multiple CAD stations
ProofMaster Studio, Mill, and Pro	DPInnovations Inc.	EPSON Stylus Pro 3000 to 9500, ENCAD TX1500 and PROe	Indexed 8 bit TIFF, CST, MST, PUB, GRT, SEP, TIFF, BMP, AI, TGA,	Colouring tools: colourways, colour editing, colour catalogues, Colour gamut mapping Adjustment of colours	Print layout function includes step and repeat, page positioning, scaling, rotating, mirroring, cutting out, colour chips, spooling, batching, etc.

Table 9.4 (Cont.)

		series, HP DesignJet series, Mimaki TX1600S and JV2, Ichinose, ColorSpan DMXII and FabriJet XII printers	PSD, etc.	on multiple substrates, i.e. non-white fabric Ink control functions: maximum ink level control, user controllable ink mixing Printer calibration: profile wizard to guide end user step by step, vendor provides set of profiles, colour data link to colour kitchen	Simulation features: print order, overprint and reservation, trapping, tonal screens such as Penta, Nova, Galvano, Gravure, tonal gradation curve Monitor ink level in printer to insure sufficient ink for print job
TexPrint	Ergosoft	EPSON Stylus Pro 3000–10 000, Mimaki (all), HP, ENCAD, ROLAND HifiJet FJ 40/50/500, MUTOH (all) ORION, Fargo Pictura 310S, SUMMA DuraChrome, PC 1500, SELEX SG-950,	All standard graphics formats	Colour and brightness correction Specifying colour values for imported separations: colour separations (DCS or monochrome TIFF files) for output Separation for screen printing: Using the colour management to create separations Spot colour support via Photoshop spot colour channels or DCS files with more	Scaling, Rotation by 90°, 180°, or 270°, Tiling, Cropping Textile repetition with any number of repetitions horizontally and vertically including displacement and mirroring OPI support: PostScript files with Tiff files which are linked using OPI links Font converter for MAC PS fonts Setting up various print environments Optional features: Print and cut module

		GRAPHTEC JX2150, SignJet Pro 24/54, CALCOMP Techjet 5524/5536		than four separations	'Hot folder' to output printable data Print queue additional licences ICC profile generation for calibrating monitors, scanners, printers/media with colourimeters and spectrophotometers provided by X-Rite, Gretag, SpectroCam, Colortron, etc. Specifying mixed colours
Textiler	Image Technologies	FabriJet XII, Mimaki TX1600s, Encad series printers, Mutoh, Epson 7000/7500 /9000/9500	Tiff, CDI, Lectra NedGraphics, HighTex, SpeedStep, Sophis BMP, EPS PCX, etc.	Printer calibration; supports ICC profiles created by third party software programs, Linearisation capability	Print functions include step and repeat, colorways, colour editing, image positioning, scaling, rotating, mirror, and spooling. On screen visualisation of best colour match depending upon output device
Wasatch SoftRIP TX and SP	Wasatch Inc.	EPSON Stylus 3000 to EPSON 10000, ENCAD printers, MacDermid ColorSpan DMXII, HP DesignJet printers, Mimaki, Mutoh, Roland	All common graphic formats	Colour catalogue, colourways Printer calibration, supports ICC profiles	Print functions include step and repeat, colour editing, layout features Supports both indexed colour and photographic imagery within same print file

ware options available to the textile industry reflect a growing market and growing acceptance of digitally printed fabric for proofing, sampling and short-run production.

9.5.3 Workflow issues

To further ensure accuracy and uniformity in the process of DTP, design and printing studios must employ people who understand computer integrated design tools, colour, fabric issues and the components to use with the printers. Employers must have dedicated people to work with equipment, and must be organised with all of the variables, digital and non-digital.

One of the difficult workflow issues, even after profiles have been created, is in trying to attain true blacks in production-orientated digitally printed fabrics. This is an issue that pervades the entire textile industry, but is aggravated by the fact that it is predominantly acid and reactive dye-based inks that are available for the DTP market. These dye classes traditionally have a difficult time creating a true black. In addition, fabrics that are very absorptive or bulky will pull in and distribute the relatively small amount of black ink that is printed to the surface, so that the overall result is more of a dark grey. If the user tries to compensate by printing even larger quantities of black ink, then bleeding commonly occurs and destroys the quality of the image.

Another vexing issue is the continued need for calibration of printers and monitors, which requires a great deal of labour hours and downtime for printing. Without consistently scheduled calibration procedures, maintaining colour accuracy can be quite difficult. In addition, because of the relatively small lots of fabric that are being pre-treated for digital printing, when printing to natural fibre fabrics, it is very common for one lot to vary greatly from the next in terms of quality, absorbency and pre-treatment. This means that the user is likely to have to build or modify profiles of even the same fabrics from time to time.

9.6 Future trends

This section will have a discussion of upcoming improvements in the technology, as well as suggestions for future approaches to colour printing on textiles.

It is no longer enough to be able to simply print fabric digitally; the industry is requiring colour matching and management throughout the design workflow, from scanning, to calibrated monitors, spectrophotometers, to the printing. Future hardware and software developments for the textile industry may include increased combinations of spot and process printing systems, and customisation of a wider range of ink colours that can be selected depending upon the colour space requirements of the design to be printed. Print providers like First2Print®, in New York, are leading the way in testing various inkset combinations on the fly in order to get the results their customers desire. With all of these future developments, the colour management and RIP software will be the engine that swiftly drives these constantly evolving systems.

9.6.1 Business and marketing model

As a result of the continued growth and acceptance of the technology, quick response and short-run production will become more pervasive and help to shift some of the design focus away from large-scale production fabrics. As consumers become more aware of what is truly possible with DTP, there will be an increased move towards customisation and personalisation. Developments in the larger-scale production printers like the Reggiani Dream® machine will assist mills to become more effective with agile manufacturing. Digital textile printing may soon become combined as one component of the various production steps of print, cut and sew that are becoming mechanised for on-demand mass customisation practices of marketing. In addition, DTP will continue to provide a simplification of the path from apparel specification through to the manufacturing of finished product, and at the same time will help to meet the trend of vast customisation (the ability to customise a range of products in a variety of substrates: textile, paper, metal, glass, etc.).

9.7 Sources of further information and advice

[TC]^2, based in North Carolina in the USA, continues to be a leading non-profit research and support company for the textile and apparel industries. They host a textile and apparel technology information forum on www.techexhange.com that is an endless source of useful information. The Center of Excellence in Digital Ink Jet Printing at Philadelphia University, which is currently led by Hitoshi Ujiie, has been engaged in a great deal of research on the technology and often holds workshops for people who are interested in learning more about the technology. The Information Management Institute often holds conferences on ink jet technologies, including focused events on digital textile printing. As a newly formed institute, the Creative Institute for Design and Technology (KrIDT) in Denmark is likely to become another world leader in DTP research and teaching. These groups and institutions represent a growing number of people who are actively involved in continued research, development, design and production in digital textile printing. The issue of managing the application of colour to digitally printed fabrics will continue to be refined and evolve as these groups bridge the gap between consumers and producers of digitally printed goods.

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