CHAPTER 1

Traditional methods

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1.1 A HISTORICAL PERSPECTIVE

Textile printing is the most versatile and important of the methods used for introducing colour and design to textile fabrics. Considered analytically it is a process of bringing together a design idea, one or more colorants, and a textile substrate (usually a fabric), using a technique for applying the colorants with some precision. Several techniques have been used and the colorants available have multiplied. This chapter presents an overview of the changes that have occurred, together with an examination of some techniques that have almost ceased to be of commercial importance, for their own intrinsic value and because we can learn from the lessons of the past.

The desire to create garments and other artefacts that reflect the beauty of the world around us and provide for the expression of our artistic nature has been evident from early in human history. The decoration of the body presumably predates the production of clothing. Early men and women used the colorants that were available to them, such as charcoal and coloured earths (ochres), mixed with oils and fats, applying them at first with their fingers and sticks to a variety of substrates. Staining of fabrics with plant extracts provided a different approach; patterns could be produced by applying beeswax as a resist to the dye liquor or by tying threads tightly around the areas to be resisted. The realisation that certain colourless materials could be used as mordants to fix some plant dyes was a vital step in the prehistory of dyeing and printing. The discovery that different mordants, applied first, gave different colours with the same dye (for example, from the madder root) must have seemed litle short of magical and suggested a style of printing (the dyed style) that was to become of cardinal importance.

Where this style of printing originated – whether in India, Egypt, China or elsewhere – is not clear. Brunello states that an early variety of cotton dyed with madder around 3000 BC was found in jars in the Indus valley [1]. Taylor gives evidence of madder on flax found in Egypt and dated at 1400 BC [2]. In China the dyeing of silk was developed very early, and China is credited with the invention of paper printing and therefore may well have seen the birth of fabric printing.

1.1.1 The use of block printing

The word 'printing' implies a process that uses pressure, being derived from a Latin word meaning pressing. The German word *druck* for print also means pressure. And there is no doubt that the first textile-printing technique (making impressions) was that using blocks with raised printing surfaces, which were inked and then pressed on to the fabric. By repetition, the image from a single block builds up into a complete design over the fabric area. Some early blocks were made of clay or terracotta, others of carved wood. Wooden blocks carrying design motifs were found in tombs near the ancient town of Panopolis in Upper Egypt. In the same area a child's tomb contained a tunic made of fabric printed with a design of white rectangles, each enclosing floral motifs on a blue background. Pliny (born AD 23) described in his book *Historia naturalis* how in Egypt they applied colourless substances to a fabric that was later immersed in a dyebath that quickly produced several colours. As Pliny also records that the best-quality alum was obtained from Egypt, it seems likely that alum was one of the mordants used and that the dye was madder.

By the 14th century the use of wooden blocks for printing was certainly established in France, Italy and Germany, but the craft was practised by 'painters', using mineral pigments rather than dyes. One of the early European uses of blocks was to produce church hangings that imitated the more expensive brocades and tapestries. Cennini, writing in 1437, described in some detail the production and use of brick-sized wooden blocks to print a black outline on brightly coloured cloth, which was then hand-painted with other bright colours [1]. In 1460 the nuns of a convent in Nuremberg described the block printing of mineral colours in boiled resinous oils, of gold and silver leaf, and of wool 'flock' on to a printed adhesive. The later development of block printing is described in section 1.2.1.

In the 15th century Portuguese traders were discovering the potential for trade with India, where the dyed style was used to produce cotton fabrics of great beauty that were quickly in demand in Europe. As early as the first century AD there was an Indian centre famous for the production of painted fabric [3], and the use of madder was by then long established. Early in the 17th century hand-painted Indian cottons were reaching London in significant quantities. They were both colourful and colour-fast, and introduced a richness of novel and stimulating design styles. Paisley designs, for example, were derived directly from one of these styles and the words 'calico' and 'chintz' were adopted into the language at around this time. A substantial and lucrative import trade began, reaching a peak about 1700. In 1708, Daniel Defoe wrote that 'everything that used to be wool or silk was supplied by the Indian trade'.

The craftsmanship applied to produce these prints can be judged from the following summary of the process. The cloth was wetted with milk and burnished to achieve a smooth surface. The design was transferred from paper, using charcoal powder that was rubbed through holes pricked in the paper. The main outlines were painted in and the fabric was then waxed, except for the areas that were to be blue or green. The latter were dyed in a bath of reduced indigo, and the wax was then removed by scraping and washing. After drying, the reds, pinks, lilacs, browns and blacks were painted in with the appropriate metal acetate mordants, aged and developed in a madder extract dyebath. If necessary, the pale areas were rewaxed and darker colours obtained by a second dyeing. Thorough washing removed most of the unfixed dye, and then bleaching in the sun whitened the ground. Painting in a saffron yellow for green and yellow areas completed the work.

The desire to imitate these prints in order to compete in the new market was soon aroused. Merchants who had earlier organised the production of larger quantities by the Indians, and who had also encouraged them to speed up the process by using block printing, turned to the foundation of factories in Europe near the main ports of entry. In 1648 the first recorded calico-printing factory was set up in Marseille. In 1676 there were units in Amsterdam and London. Among the merchants who financed the trade was one of the best known Huguenot families, the Deneufvilles, and before the end of the century the Huguenots had established the new industry in Berlin, Bremen, Frankfurt, Neuchatel, Lausanne and Geneva [4].

The importance of printing in the commerce of Europe was very significant in the 18th century and the growth of the textile industry was clearly stimulated by the demand for prints. The British prohibition of printed cotton in 1721 actually helped because Lancashire-woven linen/cotton 'fustians', which used flax grown in the Fylde area, were exempt. The linen yarn provided a strong warp, and the developing industry moved from London to the Manchester region, and also to Northern Ireland and Scotland where flax was also grown. The factory system of spinning had not yet been developed; it was not until 1766 that Hargreaves invented the spinning jenny. Yet in 1729 there were already four Dutch printers employing more than 100 workers in each unit. In Britain the number of calico-printing firms grew from 28 in 1760 to 111 in 1785, with annual production rising to 12 million yards, and in 1792 it was estimated that at least 60% of the white cotton cloth produced was sent to the printers. After 1774, when Richard Arkwright achieved the repeal of the 1721 Prohibition Act, most of the growth was in the printing of 100% cotton fabric. Liverpool now became the centre for raw cotton import.

How had the European printers acquired the necessary skills? Making wooden blocks would not be too difficult but finding suitable thickeners may have taken time. Gum Senegal and tragacanth seem to have emerged as useful, and starch was added to improve the colour yield. A combination of block printing and painting (usually described as pencilling) was used for some time. The biggest problem was that of achieving bright and fast colours. Madder was the most important dye that was able to satisfy the need. It had been known, and used with a mordant, since Saxon times but not in prints or on cotton. Awareness of what the Indians had achieved was important, and information about their methods would be gleaned from merchants and from returned missionaries. As late as 1742 details of the method were being sought from a French Jesuit in Pondicherry by a friend in France. The importance of pretreating the cotton with milk fat may have been a vital piece of information, though olive oil became the preferred material in Europe. Attaining a bright red was a preoccupation for many years, and recipes became more and more complicated. The processes of ageing the print and clearing the last traces of madder from unprinted areas also presented new problems that were not solved immediately.

1.1.2 The use of engraved copper

The most significant innovation of the century, however, was the adoption of the intaglio technique, first in Dublin by Francis Nixon in 1752, then in London [5]. European artists had discovered the possibilities of reproducing pictures from an engraved metal plate in the 15th century. Copper could be incised by hand with a sharp steel tool, and was the preferred metal. Application of ink to the plate and cleaning the unengraved surface with a cloth preceded the careful laying on to the plate of a sheet of moistened paper which was then passed, on a board, through a press. This consisted of two rollers, with blankets providing some resilience and ensuring good contact with the ink. Nixon realised that this technique could be used in modified form for printing textile fabrics, thus providing a vital step in the movement towards a machine-based industry.

The Italian word *intaglio* had been applied to engraving of gemstones and metal. Wood engravings were obtained by printing from a surface left raised after cutting away negative areas, as for block printing on fabric. Intaglio prints produce much finer line and stipple effects. The effort required for hand engraving was soon reduced by application to the plate of a thin coating of blackened wax, which is easily scratched through to allow a controlled etching of the copper in an acid bath. Tonal effects are obtained by recoating with wax, except for the areas for dark tones, which are then etched to a greater depth. Artists who excelled in the use of this technique included Dürer, early in the 16th century, and later Rembrandt, Turner and Picasso.

The ‘obvious’ extension to prints on fabric had only occurred, before Nixon’s time, in the production of maps on silk and similar applications where fast dyes were not required. Nixon took his technique to London in 1755, where there was already an established group of printers using block and wax-resist techniques, and by 1761 ‘an entirely new type of printed fabric decorated with figures, landscapes and architecture’ confirmed the English pre-eminence in the field [5]. It was the delicacy of these prints, together with the boldness of large repeats, that made London the world fashion centre for a while. It was also a recovery of the fine but bold style of the best Indian prints but with a European signature. Schuele took the technique to Augsburg in 1766 and Oberkampf started using it in Jouy in 1770.

Copper plate printing did not displace block printing, because the skills required were greater and it was difficult to ensure that the design repeats fitted satisfactorily. The fabric was moved with the plate for each impression and the plate had then to be returned. The fabric tended to move out of line and its position and squareness had to be corrected by hand. The perfect answer to the fitting problem was to turn the copper plate into a cylinder, and this would allow truly continuous production at high speed. Even as early as 1699 it was claimed that an engraved (presumably wooden) cylinder had been used successfully [1], and patents were taken out in England in 1743 and 1764 for cylinder machines. It was 1783, however, before all the requirements for successful engraved copper roller printing were actually worked out and patented by Thomas Bell, a Scotsman. The first machine was in use in 1785 in Lancashire, and by 1840 there were 435 machines in England alone. The vital feature of Bell’s machine was the use of a sharp steel ‘doctor’ blade to remove all the colour paste from the unengraved surface of the roller. The name given to the blade was derived from the word abductor, because it took away the unwanted ink.

Although considerable skill was required to engrave and use copper rollers, the increase in productivity resulting from their use was so great that block printing inevitably declined. Turnbull says that ‘where by block it was only possible to print of the simplest pattern about six pieces per day, it was now possible to print by machine up to 500 pieces per day of a similar pattern’ [6]. This was a revolution even more significant than those occurring in the spinning and weaving sectors, and there were inevitable disputes and strikes. But there could be no putting the clock back. Edmund Potter said in a lecture to the Society of Arts in 1852 that the output of printed calico in England increased from 1 million pieces (of 30 yards) in 1796 to 7 million in 1821, and to 20 million in 1851. By 1851 the number of machines had reached 604, while the number of blocking tables declined from 8234 in 1840 to 3939. By 1880 very few tables were still in use, except for the printing of silk and specialist styles. The rise of the roller machine reached a peak in 1911, when production from British printworks amounted to 1400 million yards, of which 90% was exported [7]. Worldwide, roller machine production accounted for more than half of the total yardage printed until 1976, almost 200 years after Bell's 1783 patent.

While copper roller machines proved ideal for high-volume, low-cost printing of woven cotton fabrics, there was always a market for small-scale production of individual designs, especially on silk, wool and, later, on man-made fabrics. For these, roller printing was not suitable at all. The costs of engraving and setting up the machine for each run were high, and long runs were therefore essential. Block printing satisfied the demand for some time, but an alternative, fundamentally different approach emerged.

1.1.3 From stencils to rotary screens

The technique of stencil printing, initially used for simple patterns on walls and for lettering, was developed into an intricate craft for fabric printing in Japan [8]. In the 17th century the idea of tying together parts of the stencil with human hair initiated the development. Then in 1850 in Lyons the first use of a silk gauze as a supporting stencil base was employed, and the technique soon became known as screen printing (Chapter 2). This proved to be the answer to the requirements of the couture business, partly because the designers found it well suited to their needs, but also because strong, bright colours could be obtained with minimal restriction on repeat dimensions. The use of hand screen printing grew in the period 1930 to 1954 and was ideal for the growing quantities of man-made fibre fabrics, especially the knitted fabrics. With the successful mechanisation of flat-screen printing and ultimately the use of rotary-screen machines, the days of the copper roller machine were numbered. In 1990 the worldwide production from the latter was estimated to be only 16% of the total, while 59% was from rotary screens (Figure 1.1). In the UK the switch from copper roller printing was initially slow but then accelerated, the technique's share falling from 90% in 1960 to only 6.6% in 1992. In the same period the output from rotary-screen printing grew from perhaps 1% of the total to 82.8%. Thus the machine introduced in 1785 dominated the industry for some 160 years, but is now fast disappearing. The use of copper rollers is still important in the gravure method of printing in colour on paper (see section 3.2.2). The dimensional stability, uniform thickness and surface smoothness of paper makes it possible to achieve a much greater precision than is possible on textile fabrics. Even in the paper printing sector, however, cheaper methods have captured a significant fraction of what was the market for gravure machines. This is relevant to our consideration of textile printing in relation to transfer printing (Chapter 3), which provides a valuable approach to garment printing and for the printing of polyester fibre fabrics, and which currently holds about 6% of the total market.

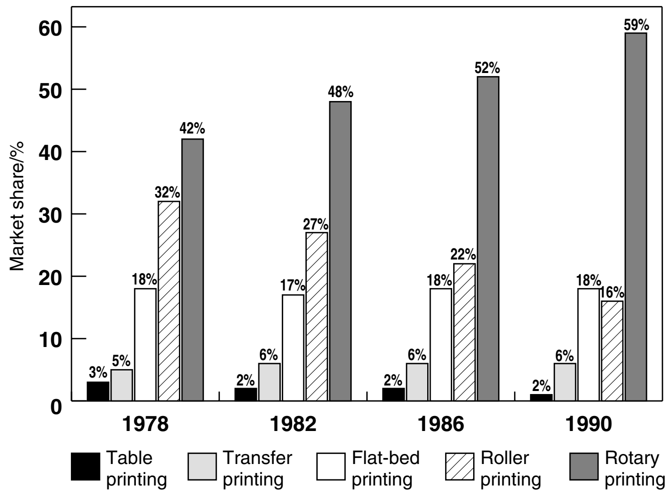


Figure 1.1 Relative contributions of printing methods to total world printed textile production (Stork BV)

1.1.4 Other methods

Apart from transfer printing, there are five essentially different approaches to the printing of any substrate. We have seen that three have achieved historical importance in the textile field – the surface (block), intaglio and screen methods – and that nowadays screen printing is the predominant approach. A fourth approach, lithography, has been used to a very small extent for printing smooth surface fabrics but is of more importance in paper printing, including transfer paper.

The fifth approach, jet printing, is a 20th century method of building up a design from ink drops. It is already important for printing pile fabrics (Chapter 4) and paper, and could become a serious competitor to screen printing. It is the only approach that can provide the really rapid response to changing demand that is increasingly expected, because there is no requirement for the production or changing of patterned screens or rollers; in addition, instantaneous use for sampling or long runs is potentially available. The significant development in these last decades of the century has been the success of computer technology, so that computer-aided design (CAD) systems and colour match prediction are in regular use. The scanning of an original design can now provide the data required for its reproduction by any technique, but fits into the jet printing route more directly because the jets require only electrical control. It remains to be seen, however, if the development of jet systems that are practical and economic for a wide range of fabrics can be achieved. The first commercial production unit, based on Canon bubble-jet technology, is being built in Japan [9].

1.1.5 Colorants

The earliest colorants used in printing were undoubtedly mineral pigments, although the dyed style was also in early use. Today the availability of a wide range of excellent organic pigments and of reliable pigment binders (section 5.2.2) has led to the increased importance of pigment printing. More than 50% of the world's textile prints were pigment-printed in 1990. The substantial importance of polyester/cellulosic blends has increased their use, because of the complexity of printing these substrates with dyes.

It has proved possible to reduce, though not to eliminate, the extra costs (and risks) attached to the general use of dyes, due to their requirement of steam fixation and after-washing. In 1984, Schofield recorded the impact of changes in dyes over a 50 year period [7]. Reactive dyes now account for 25% of print colorants, disperse dyes 10%, vat dyes 9% and azoics 3%. In all dye ranges a high priority has been given to selection for 'robustness', or the ability of a dye to give reproducible results due to low sensitivity to likely variations in conditions. The tasks facing colourists in the early years of the century were far harder than those of their successors today but their achievements, as judged by prints to be seen in the museums, were highly creditable.

The development of printing techniques from the earliest days has been reviewed. In the following chapters those techniques now in substantial use are considered in detail. Here we must examine the surface and intaglio techniques in sufficient detail for an appreciation of their past and present value.

1.2 SURFACE PRINTING METHODS

1.2.1 Block making

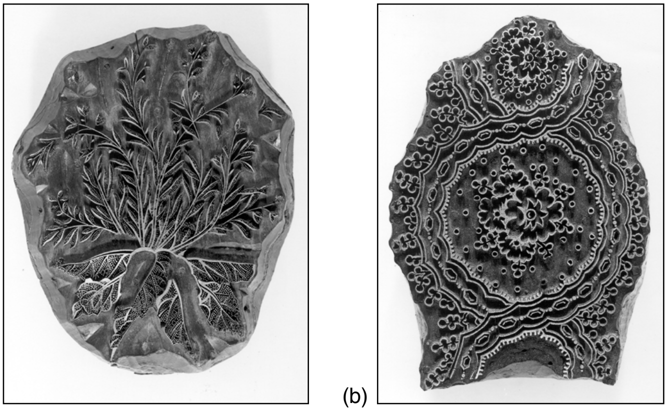
The typical hand block print had no large, uniform areas of colour but was skilfully built up from many small coloured areas, because wooden surfaces larger than about 10 mm in width would not give an even print. This had the advantage that a motif such as a flower would have an effect of light and shade obtained from three or four blocks, each printing a different depth of the same colour, or a different hue. This obviously meant that a lot of blocks were required, and considerable care was needed in fitting the adjacent parts of the design. If the design had a large repeat there would be a multiplication of the number of blocks because the size of a single block was limited to about 45 cm square and its weight to about 5 kg. Most blocks were much smaller than this, perhaps because many printers were women.

Block making required patience and skill. A fairly hard wood was required, such as pearwood, and four or five layers were usually glued together with the grain running in different directions. The design was traced on to the surface and a fine chisel used to cut away the nonprinting areas to a depth of perhaps 1 cm. To obtain more detail from some blocks, strips and pins of copper or (more usually) brass were hammered into the wood. In the 19th century some blocks were made with the printing surface entirely in brass (Figure 1.2), which gave very delicate prints. Another technique used for complex designs was to prepare a mould, use this to cast the image from molten type metal, fasten the casting to the block, and then grind the surface perfectly flat. When large areas of solid colour were required, the areas within metal or wooden outlines were filled with felt, which would absorb and print the paste uniformly. Finally, each block required corner 'pitch pins' which printed small dots; these allowed the succeeding blocks to be correctly positioned by accurately locating the pitch pins above the already printed dots.

A less precise form of block printing is practised in the production of, for example, Africa prints (see section 6.5.1), using large plywood blocks with polyurethane foam printing surfaces.

1.2.2 The printing table

A very solid table was needed; it was topped with flat slabs of stone or iron covered with a resilient blanket and a sheet of waterproof material. A back-grey of plain cotton was usually stretched over the table, to absorb any surplus colour. Ideally the back-grey would be gummed to the table and the fabric to be printed could be pinned to it, for tight-fitting patterns.



(a) (b)

Figure 1.2 Wood blocks with (a) brass strip and pin inserts, (b) a cast type-metal printing surface (without pitch pins)

1.2.3 The printing process

Colour paste must be applied to the block surface in a controlled manner, and this was achieved by using a 'sieve'. A small tub was nearly filled with a starch paste and a waterproof fabric, stretched on a frame, rested on the paste. A piece of woollen fabric was stretched on a slightly smaller frame and fastened to make the sieve. The sieve was saturated with colour paste and placed on the waterproof fabric. For each impression, the 'tierer' (a boy) spread the colour paste on the top surface of the woollen sieve with a large brush and the printer charged the block by pressing it on the wool. The block was then carefully positioned on the fabric, using the pitch pins as guides, and struck with a mallet. After printing a table length with the first block, the second was printed and then any others required to complete the design. The fabric was then transferred to a few elevated rollers or rods and allowed to dry, while the next table length was printed.

1.2.4 Mechanisation

In 1834 a machine that automatically performed all the actions of block printing was invented by Perrot (it became known as the Perrotine), and achieved some success. It was limited to three colours and a maximum repeat of only 15 cm and its operation could not be truly continuous, but the three colours were printed simultaneously. Storey gives an illustrated account of this machine, and of hand block printing [3].

Much earlier, attempts had been made to obtain continuous surface printing using wooden rollers, but the difficulty of uniform application of the colour to the roller was the common problem. In about 1805, however, a rotating woollen fabric 'sieve' was introduced in Accrington, and used successfully thereafter (Figure 1.3) [6]. The other essential step was the preparation of a raised pattern on the roller by inserting copper outline strips and felt, just as in hand block printing. This technique was used until recently for printing furnishing fabrics and for wallpaper, but was never as important as the copper roller method. It had the advantages of requiring low pressure and avoiding the colour contamination that occurs on engraved roller machines, because no contact was made with previously printed colour, but the cost of roller making was high. Wallpaper printers found that inexpensive rollers could be cast from epoxy polymers and the nonprinting areas were easily cut away, but they did not carry enough colour to print most fabrics.

Essentially the same method has been used for printing polymer film, other packaging materials and transfer paper, but is then usually known as flexographic printing. As described in section 3.2.2, the design is built up on wooden rollers by the application of rubber mouldings and the colour is applied by uniformly engraved metering rollers.

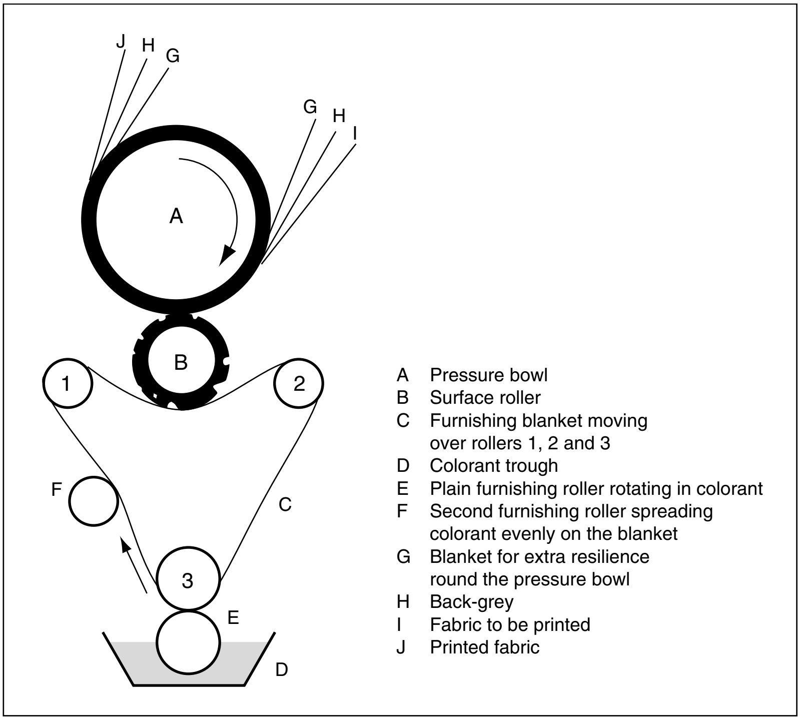


Figure 1.3 Surface printing machine with woollen fabric sieve

1.3 ENGRAVED-ROLLER PRINTING

1.3.1 Principles of operation

A traditional two-colour machine is shown diagrammatically in Figure 1.4. Each engraved cylinder (F), mounted on a steel mandrel (L), is forced against the fabric being printed (E) as it travels around a pressure bowl (A) with resilient covering (B). The machine must be of robust construction because pressures of several tonnes are applied and each mandrel is driven by a single large crown wheel. As the rollers rotate, a furnishing roller (G) transfers print paste (colour) from a colour box (H) to the engraved cylinder, filling the engraving and smearing the whole surface. This surface colour is almost immediately removed by the steel blade known as the colour doctor (J). This doctor must be precisely ground, sharpened and set, at the optimum angle and tension, to leave the surface perfectly clean. Engraved areas retain the colour in parallel grooves and the doctor blade is 'carried' on the crests between the grooves.

The fabric is then forced into the engraving and most of the paste is transferred. The cushion between the pressure bowl and the engraved roller clearly plays a critical

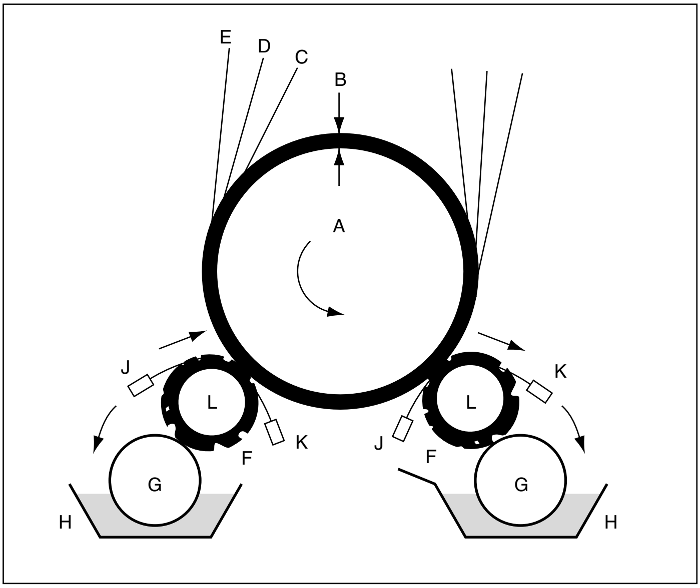


Figure 1.4 Two-colour printing machine (for key see text)

role in the uniform transfer of colour across the fabric width and along its length. The cushion is obtained by rolling about ten layers of a lapping fabric with linen warp and woollen weft around the pressure bowl. Any irregularity, including any ridge at the end of the lapping that may develop if it is not perfectly matched with the first end, can cause a visible fault in a critical print. The cushion progressively hardens with use and requires changing from time to time. Because the lapping must be protected from colour printed beyond the fabric edges or forced through the fabric, an endless printing blanket (C) must be used and washed and dried continuously before returning to the point of printing. In addition, a back-grey (D) is used to absorb colour and give greater resilience, unless the blanket provides enough resilience and is able to hold the excess colour satisfactorily (for example, in fine grooves in a neoprene surface). In the printing of lightweight or knitted fabrics the woven back-grey is often 'combined' with the fabric to be printed, using small amounts of a suitable adhesive (see section 2.2). This helps to maintain dimensional stability under the tension applied during printing.

After transferring its colour, the engraved roller is cleaned by a brass blade known as the lint doctor (K). This removes any loose fibres that may have stuck to the surface of the roller and could become trapped under the colour doctor, where they could cause a colour streak to be printed. The lint doctor on the second (and any subsequent) roller may be seen to remove a significant amount of the previously printed colour that the roller takes up from the fabric. Without the lint doctor, this colour would be carried into colour number two and cause rapid contamination, although some contamination is unavoidable because the lint doctor will push a little colour into the empty engraving.

The printed fabric is now separated from the back-grey and blanket and carried on to the drying section of the machine (Figure 1.5), avoiding any contact of the print face until some drying has been achieved. In the UK drying cylinders were often used in the past, but hot-air dryers are more universally appropriate.

On a multicolour machine the printing rollers, with colour boxes and other auxiliary equipment, are arranged around a larger pressure bowl with minimum separation of the rollers. Setting and maintaining the correct registration (that is, fitting each colour of the design relative to the others) requires an arrangement for separately rotating each roller a small distance while the drive to all the rollers is engaged. The original box-wheel device was elegantly simple but introduced a serious hazard to the printer's hands as it required the insertion of a rod, or tommy key, into a hole in a wheel rotating near the meshing drive gears. A safer device has been described by Gleadow [10], who has also given a more detailed account of engraved-roller printing.

It is necessary to correct the pattern fit from time to time during printing, because each roller will have a different effective circumference if there are significant differences in the area engraved or the pressure applied. Thus the fabric will be stretched or allowed to relax to a minute degree between rollers and the fit of the design will gradually be lost. As already noted, combining with a back-grey can improve stability.

Good pattern fitting also requires a perfectly rigid fit of the engraved cylinder on its mandrel. To this end, the cylinders and mandrels are tapered and a forcing jack is

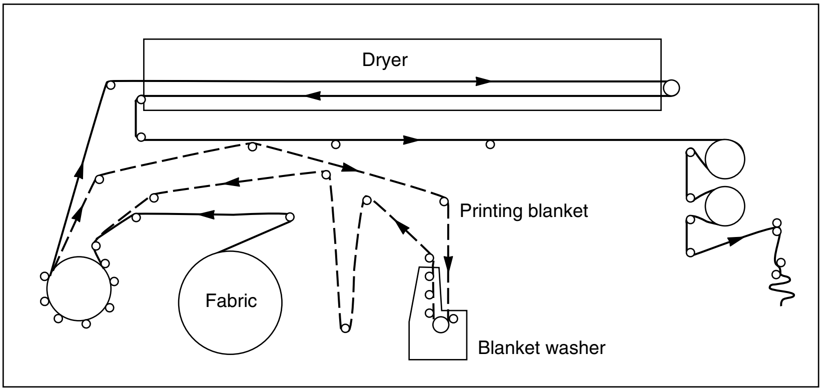


Figure 1.5 Overall arrangement of a six-colour machine with hot-air drying, showing blanket washer

required to mount and to remove the mandrel. In addition a key, or 'tab', on the inside of the cylinder engages in a slot along the mandrel.

1.3.2 Problems

A major disadvantage of engraved-roller printing that has shown up in recent years is that there is a limit to the fabric width that can be printed. The application of pressure to the mandrel ends inevitably produces some bending and the fabric edges tend to be printed more heavily than the middle. The printer makes some allowance for this by applying additional lapping to the centre of the pressure bowl, and the use of minimum pressure obviously helps; even so, it is not usually possible to print fabrics more than 1.8 m wide by this technique. Wider fabrics, essential in the home-furnishing market and showing cost advantage in most fabric areas, are therefore normally screen-printed.

Another disadvantage of engraved-roller printing is that the sequence of colours printed cannot be chosen arbitrarily, because of the colour contamination problem mentioned earlier. The pale colours should be placed early in the order, with the stronger ones at the end. Sometimes it is necessary to start by printing a dark colour (for instance, a black outline) to obtain the required depth when one colour falls on another. In such a case a plain roller may be inserted after the dark one, and a colourless paste used with it to reduce the contamination of the next colour. The effect of successive rollers, which take off some of the printed colour and push some further into the fabric, is described as the 'crush effect' and can reduce the visible colour strength by up to 50%. This is clearly another major disadvantage, compared with block and screen printing.

A third significant disadvantage is the time lost in pattern changing, due to the need to handle the heavy rollers and associated accessories and to difficult access. Effective printing time is often less than 50% of working time, and really short runs reduce this dramatically. Roller weight was reduced by using cast-iron cylinders with an electrodeposited copper plating, and damage to roller surfaces reduced by chromium plating. A redesign of the machine introduced by Brückner in Germany (Figure 1.6) provided improved access and, by increasing the contact time between roller and fabric, allowed a reduction in loading pressure and the use of shallower engravings. New thinking like this would probably have been accepted but for the rapid development of rotary-screen printing; the competition from the newer technique has decimated this section of the industry.

1.3.3 Roller engraving

Printing, originally a hand craft, developed into an industrial art requiring the

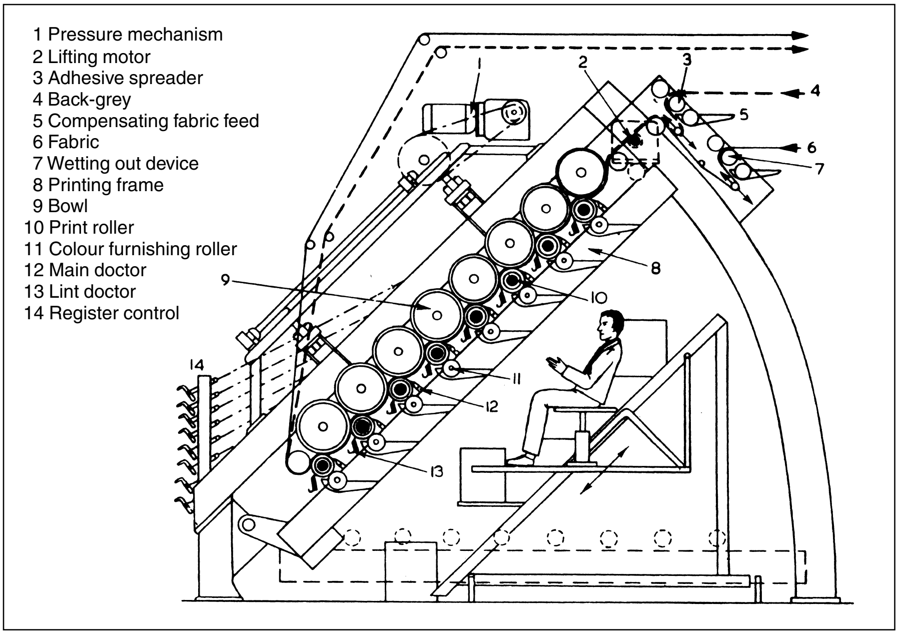


Figure 1.6 Roller-printing machine (Brückner)

contributions of a range of specialists, coordinated by someone with a clear vision of the desired end-product. The first of the specialists is the creator of the original design, which may already be suitable for reproduction but usually is not, and is sometimes little more than an idea. Another specialist is the engraver whose task is to convert the original design into a set of engraved rollers that will enable a printer to achieve an effective reproduction of the design on fabric. Sensitivity to the original design objectives and awareness of the printer's requirements are important as well as skill and accuracy.

An original design must be put into repeat (Chapter 2) and the dimensions adjusted so that one or more repeats will fit accurately around the roller circumference. If the repeat is small it may be that the mill-engraving method should be used. This starts with the hand engraving of a few repeats on a small soft-steel cylinder, which is then hardened. The design is then obtained in relief by running the first cylinder (the die) under pressure in contact with a second soft-steel roller. This relief roller (the mill) is hardened and run in contact with the copper cylinder to obtain the desired depth of impression, and this is repeated across the cylinder until the full width is engraved. The raised copper around each groove must then be polished off.

Photoengraving, a more widely applicable method, uses a chemical etching technique to remove copper from the areas that will hold colour. Each roller, which (as in all methods) has previously been turned to size, polished and cleaned, is given an even coating with a photosensitive polymer solution (using a safe light). The essential steps in the process are then as follows.

1. A master copy of the design is drawn, in outline, and a copy made for each colour. Colour separations are made by blocking out with opaque paint all the areas except those of one colour, repeating the process for each colour in the design. At the same time, adjustments must be made for any overlap of colours required or allowance for colour spread. These separations can now be made by electronic colour scanners with appropriate computer software.
2. The negative colour separations are converted into positive images (diapositives) on stable photographic film, and at the same time the ground lines are introduced by exposing through a grid of lines of the required spacing (Figure 1.7). At the same time an outline around the solid areas must be obtained, by using suitable spacers.
3. A step-and-repeat machine (section 2.5.4) is used to produce a full-size positive film for each colour that will cover the complete roller surface.
4. The complete set of films is assembled and checked by transmitted light to ensure perfect register.

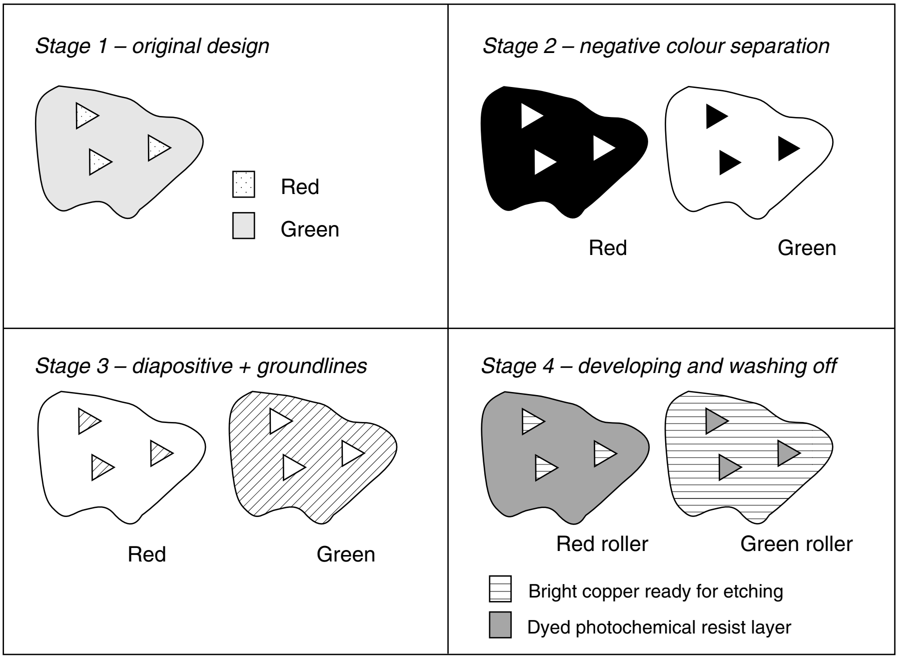


Figure 1.7 Schematic representation of the main steps in the photoengraving process

5. Each film is accurately positioned and fixed and the image is transferred while the roller rotates under a suitable light. Within those areas that are exposed to light the polymer coating is altered chemically and becomes insoluble and acid-resistant. Unchanged polymer is washed off the unexposed areas.
6. Etching is carried out in a bath of acid or iron(III) chloride solution, until it is clear that the adjacent V-shaped grooves have almost met each other (small pieces of polymer float off at this point). The number of grooves per inch, the scale, corresponds to the grid spacing and determines the depth of engraving obtained and the amount of print paste held. A scale of 55 gives a depth of about 0.11 mm (0.005 in) and may be suitable for a smooth-surfaced synthetic fibre fabric, whereas a scale of 35 gives a depth of 0.20 mm (0.008 in) and would be more suitable for a cotton fabric.

Engraving for photogravure paper printing follows similar lines except that, instead of producing grooves to carry the colour, the engraver produces small hollows of controlled depth and spacing.

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