16
PRINTING AND DECORATION

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Introduction

Detail on printing and decoration as applied to planar surfaces such as paper and board can be found in many textbooks. However, the decoration and printing of packs, packaging materials and packaging components, many of which are non-planar surfaces, involves processes additional to the conventional ones. This chapter therefore briefly discusses these many processes, which continue to increase (comparatively recent additions include ink jet, laser and thermal printing).

Knowledge of the methods employed and the materials used, i.e. inks and the drying mechanisms, etc. are important to those in the pharmaceutical industry, as printing can be a source of contamination. This suggests that printing is best carried out either on presealed containers or after a container has been filled and closed. It also should be noted that it is somewhat difficult to achieve good colour matches using different printing processes on different materials, e.g. flat or radiused, glossy or matt.

Decoration or printing is the means of providing for a packaging material:

1 aesthetics or graphic design (to attract, enhance, stimulate sales of a product during display and use)
2 product identification
3 information related to 'labelling', e.g. product names, directions for use, warnings, shelf life, expiry date, use before, storage conditions, manufacturer and address, batch number, covering fixed and variable requirements.

Where the essential function is one of graphic appeal, effective overall design requires consideration to and understanding of a number of factors, such as:

1 knowledge of the product and the market (how, when, by whom used, etc.)
2 knowledge of the packaging materials to be employed (functional and structural detail, i.e. dimensions and tolerances of the item, area(s) to which decoration/printing may be applied, type of surface, etc.)
3 knowledge of the methods of distribution, marketing and sale
4 quantities of item to be supplied per year and quantity per order
5 knowledge of any legislative requirements (relating to general laws or specific products, e.g. foods, pharmaceuticals, dangerous chemicals)
6 knowledge of the various printing or decorative processes, including inks and drying methods
7 size, shape and colour of the background material (colour—clear/opaque, tinted/pigmented, opalescence, pearlescence, etc.).

Aesthetic design and decorative appeal which are covered by consideration of the above factors, may be improved/modified by both non-printing and printing processes.

Some processes are not strictly related to printing but can provide decoration, including:

- roller coating—kiss coating
- spraying
- vacuum deposition, e.g. metallising
- painting
- anodising
- plating
- colour-based material (natural colour)
- indentation, i.e. debossing and embossing

- labelling—by various methods
- decorative sleeving, i.e. shrink and stretchable sleeving
- flocking
- etching, e.g. acid etching of glass.

Decoration: features and terms

Decoration or printing must provide certain additional features associated with colour, illustration and typography, etc. These need consideration of the following.

Finish of surface to be printed

This covers surface reflectance, texture, smoothness, roughness, as well as gloss, semimatt, matt, etc. Gloss may be achieved by the basic substrate, special inks, overlacquers, varnishes, or a transparent laminated film.

Rub resistance (resistance to abrasion)

This is relevant to various stages of the handling of decorative or printed surfaces, i.e. on the production line, during transit (vibration), during stacking and handling, at the point of sale, or ultimately during use by the consumer. Many factors may contribute to rub, e.g. ink thickness, ink type, state of 'dryness'. Tests for rub resistance in the UK (dry or wet rub) are covered by BS 3110.

Note that the way a printed or decorated component moves, vibrates, rubs, etc. will relate both to the shape of the article and to the type and configuration of the packaging materials which surround it. For example, a cylindrical bottle in a carton or a divisioned outer will move from side to side, up and down and rotate in a clockwise or anticlockwise direction. A rectangular, square or oblong container is unlikely to rotate. Since the rotational movement with the round container is likely to be predominant and more damaging to the surface decoration, this may require a higher level of rub resistance.

Chemical resistance

This is related to:

1 product contact, i.e. product resistance over a range of temperatures, associated with the environment, point of usage
2 specialised processing or storage, e.g. sterilisation, storage in a deep freeze
3 contact with other substances, e.g. water, soap (particularly if used in a bathroom or kitchen)
4 human secretions, i.e. perspiration from hands may also cause marking or even reactions (particularly if these secretions are sulphurous, acid, etc.).

Temperature

This is associated with climatic, processing or with special storage recommendations. Packs may have to withstand severe cold, i.e. should resist cracking or flaking-off, or extremes of heat could cause softening or hardening (brittleness). Also shop windows, storage under bright lights, in the sun, or the boot of a car—especially if black.

If part of a decoration falls within a heat sealing zone, special heat-resistant inks/over-lacquers may be necessary. Alternatively, heat seal areas can be kept free from print.

Pick

Decoration should not lift, flake or crack under conditions of heat and/or pressure, e.g. heat sealing or the application of pressure sensitive tapes, i.e. substrate surface lifts. Heat seal jaws may be coated with PTFE to reduce ink 'pick'.

Key

A good key or bond between the printing inks and the substrate to which they are applied is essential if detachment or 'pick' is to be avoided. In certain instances surfaces need pretreatment (e.g. gas, or corona discharge) or a surface primer.

Odour and taint

Freedom from odour and taint is essential in the case of oral products where they may be detected by smell or taste, e.g. from residual solvents, from printing inks.

Toxicity and irritancy

Foodstuffs, pharmaceuticals, toiletries, cosmetics, etc. must avoid contaminants derived by direct contact or by migration from printing inks. Food grade inks can be specified. See also 'migration/contamination/reaction' below.

Light fastness and discolouration due to light

Light exposure may cause either fading or darkening of both materials and colours. (Note that temperature/humidity also influences change.) Ink fade is normally checked by Xenontest type equipment (main supplier Heraeus) and is measured against the British wool scale.

Note that other simulated tests include carbon arcs, fluorescent sunlamps, various xenon arcs, etc. Tests tend to be comparative once conditions have been standardised. North and south window tests are also used.

Slip

Surface slip (friction) characteristics may be important in certain packaging line operations, especially form fill seal equipment, and in stacking. Anti-set-off spray during printing can affect slip, where printed surfaces usually become 'gritty' to the touch, due to the excessive application of anti-set-off (to prevent print transfer to the underside of adjacent surfaces).

Colour control

Colour control is achieved by the setting of light and dark colour limits, and can now be accurately measured by colorimetry. Colour has hue, lightness and saturation and covers wavelengths of just below 400 nm to 760 nm.

Migration/contamination/reaction

Pigments/dyes or other constituents in inks, adhesives, varnishes, etc. may migrate through certain materials, i.e. plastics, and give rise to contamination/interaction, which under certain circumstances may either react with the ingredient in a product or cause toxicity, irritancy problems, or loss of potency. This risk may also occur with certain label adhesives.

Powdering

Powdering is usually associated with the detachment of small particles from a printed or coated surface. Powdering of surfaces can cause discolouration (e.g. change in surface reflectance, increasing rub, general particulate contamination, change in slip characteristics).

Grain direction

Machine or cross direction is a factor to consider in the case of cellulose-based materials, i.e. paper and board. Grain direction is important when these materials are wetted or heated, whereby various degrees of curl may be induced due to the swelling or drying-out of the fibres differentially according to the 'grain' direction. The cellulose fibres exhibit greater swell or expansion across the fibre, hence when wetted or dried the axis of curl will be parallel to the machine or grain direction. Dimensional changes can cause print registration problems.

Print terminology

Some explanation is required of the basic terminology used in printing and in artwork.

1 Line—areas of solid (continuous) colour with no variation in density, based on the original lino-cut type of plate.

2 Halftone (tone)—the image is broken down into a series of cells or dots by a screening process, using 40–300 per linear inch, giving a series from coarse to fine screen. (Look at the coarser process used in newsprint through an 8–10× magnification hand lens.)
3 Reversed out of—where areas of a solid colour are broken by shaped area (nonprinted), which exposes the background surface or colour (see Figure 16.1).
4 Reverse printed or reverse side printed—applied on the underside of a transparent film which is then viewed via the top side. Eliminates external damage by abrasion or scuff.
5 Surface printed—direct printing onto a surface.
6 Sandwich printed—applies where printing is sandwiched between two materials, the upper layer being transparent.
7 Wet on wet—applies where a second ink is laid down on top of another while both are still wet. Not recommended but occasionally found (dry offset). Due to colour bleed and colour dilution, loss of clarity and general colour degradation may occur.
8 Print size—usually based on a point system, with 72 points per linear inch. Each type of printing process will have a minimum point size which will reproduce clearly. Most typefaces lie in the range of 6–14 point for main body text and 16–48 point for display text.
9 Print styles (typography)—found under various names, e.g. Modern Italic, Egyptian Bold, Modern Roman.
10 Contact printing—involves direct transfer of ink from plate to substrate or indirect transfer via an offset stage.
11 Non-contact printing—there is neither direct nor indirect contact (e.g. offset processes). Examples: ink jet and laser printing.
12 Origination and origination costs; originals. These phrases cover the photographic work and ancillary processes used to convert the original artwork (drawings, photos, transparencies, etc.) into film positives or negatives from which printing surfaces (plates, blocks, cylinders, etc.) can be produced, and the costs associated with them. These costs are usually recharged to the client.
13 Make ready time (printing machine). The make ready time is the time and labour required to set up a process ready for a print/decoration run. Since make ready times must be costed as part of a printing run, those costing the most to set up are usually associated with long runs and large quantities (e.g. gravure).
14 Stereos, forme, stereotype—various names related to the printing plate(s) and the machine location. A forme is usually flat whereas a stereo may be curved (around a cylinder).
15 Anilox roller. In the flexographic process ink is transferred from the ink fountain by a rubber transfer roller onto the anilox roller. The latter is usually an etched or patterned roller, giving cells of constant depth and size, from where it is trans ferred to the relief plate (cylinder), without the ink being squashed over the sides of the relief characters.
16 Fountain—this is basically the box, trough, machine section in which the ink is held.

Decoration/printingÐgeneral proesses

Decoration/printing may be carried out as follows.

1 In the flat as sheets or reels, e.g. paper, board, tinplate, films, foils and laminates. Materials in both sheet and reel forms may be further processed to give packs which may remain in the flat (e.g. collapsible cartons) until erected or are directly fabricated into a three-dimensional container (tinplate containers, composite drums, rigid boxes, etc.). Distortion printing also falls into this category.
2 After fabrication, e.g. two-piece metal cans, glass and plastic containers, collapsible metal tubes. Containers are manufactured and then printed or decorated by a secondary process. Since material and container shape impose certain restrictions, i.e. process used, design limitations, etc. some fabricated containers may use labels, printed sleeving, etc. rather than a direct decoration/printing process.
3 During fabrication—adding print during the fabrication process includes embossing, debossing and in mould transfer labelling.

Certain materials may need some form of pretreatment before they are printed. Examples include the following.

1 Applying a coating of enamel on flat metal sheets prior to fabrication into a container, or a round container after it has been fabricated. Both are carried out by a roller coating process followed by a curing/drying operation.
2 Applying a primer or key coating to aluminium foil.
3 Pretreatment of certain polymers such as the olefins to oxidise the surface by either flame or corona treatment.

A summary of the main decoration processes is given in Table 16.1.

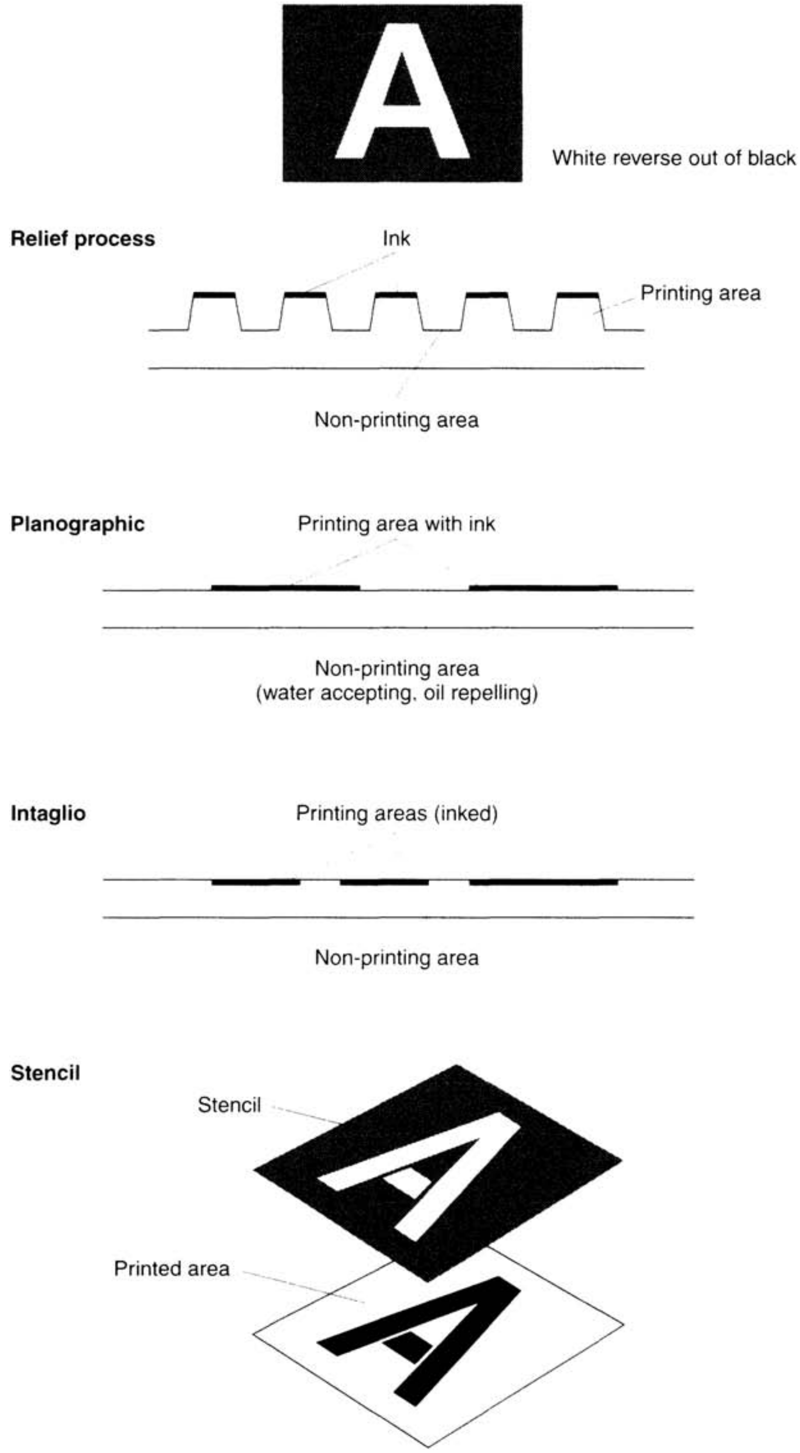

Figure 16.1 Printing processes

Graphic reproduction (`origination')

Graphic reproduction may involve the simple action of typesetting, a combination of typesetting and artwork, pure artwork, or computer-based artwork. Typesetting may be carried out by hand (compositing), typesetting machine (linotype, monotype), via a special wordprocessor or a photographic process. Artwork may be based on monochrome (single colours) or multicolour. Artwork can be further divided into line (areas of solid colour with no variation in density) and half tone, where colour gradation is achieved via a series of dots per linear inch.

The conversion of original artwork through to a form (plates, blocks, cylinders) that can be reproduced can involve various stages, as follows.

Table 16.1 Main decoration processes

Process		*In the flat*	*After fabrication*
Printing process (contact)			
1	Letterpress	✓	
2	Flexography	✓	
3	Lithography	✓	
4	Gravure	✓	
5	Screen	✓	✓
6	Hot die transfer (gold blocking)	✓	✓
7	Dry offset letterpress		✓
8	Pad transfer (cliché)		✓
9	Thermal printing	✓	✓
Printing process (non-contact)			
1	Laser	✓	✓
2	Ink jet	✓	✓
Transfers			
1	Therimage		✓
2	Dinacal		✓
3	Letraset		✓
Miscellaneous			
1	Moulded in decorations (Transfer)	During fabrication	
2	Spraying	✓	✓
3	Roller coating (paint or enamel)	✓	✓
4	Anodising	✓	✓
5	Polishing and brushing	✓	✓
6	Dipping		✓
7	Vacuum metallising		✓
8	Bronzing	✓	
9	Flocking	✓	✓
10	Plating	✓	✓
11	Kiss coating	✓	✓
Preprinted items			
1	Labels (paper, plastic)		
2	Shrink/stretch sleeving		

Camera work and artwork

Camera work varies according to the type of artwork. It may involve photographic reduction or enlarging, colour separation, line and half tone reproduction, the production of negatives and positives, etc. These include the following.

Line artwork—single colour print

The artwork is photographed to produce a negative, usually on film.

Line artwork—multicolour print

The artwork may be pre-separated or composite.

1 Pre-separated: Each colour is drawn separately (in black on a white board) in registration, usually as a base artwork with overlays. Separate negatives are made for each colour by photographing the base artwork and each of the overlays.

2 Composite: The complete design is drawn in black on a white board with the required colour separation indicated. A set of identical negatives is made by photographing the artwork, with the negatives equating to the number of colours to be printed. From these are produced separate negatives for each colour, by painting out with an opaque lacquer the unwanted areas on each negative in turn.

Tone artwork—single colour print

The illusion of tonal gradation is produced by printing equi-spaced dots of varying size, the highlights (i.e. lighter areas) having small dots and the shadows large dots which may merge.

The artwork is photographed in the usual way to produce a negative, but the image on the artwork is broken up into varying sized dots on the negative by the introduction of a ‘cross line screen’ into the camera. This screen is a glass plate ruled with lines at right angles, varying from 50 to 300 lines (or more) per inch. Coarse screens are used for newspaper work, but for high-quality package printing screens of 150 lines per inch, or more, are used.

Tone artwork—multicolour print

The multi-coloured image is reproduced by printing, in close proximity, dots of varying size of three or more basic colours. The eye blends these coloured dots, giving the illusion of reproducing the original picture. This requires the production of separate printing plates for each basic colour and these are made from film negatives which are produced by ‘colour separation’ from the full colour artwork.

The artwork is photographed successively through coloured filters (together with the cross line screen which is always necessary for tone work) to produce negatives as follows.

Note that continuous tone negatives and positives are black and white gradations of colour. The filters used are complementary to the final colours required, i.e. a blue filter will darken yellow but lighten green or blue (similarly red-blue (cyan) and green—magenta (red). Red, green and blue are the light or additive primary colours, whereas cyan, magenta and yellow (the complementary colours) are known as printer’s or subtractive primaries.

For attraction, definition and sharpness it is usual to include an additional black printing plate. The black plate is produced by using a combination of filters. The three colours plus black are the minimum colours necessary for good reproduction of, say, a colour transparency photograph, being known as the process colours. This is the basis of four colour printing.

If there are large areas of a single predominant solid colour in a design, it is normal practice to use a special additional colour plate. For high-quality reproduction, fine screens and six to eight colour printing is frequently used (see gravure).

Printing down

The printing surface (plate, cylinder, screen, etc.) is coated with a light sensitive emulsion and light is passed through the negative (or positive) on to this emulsion. Multiple images may be produced and accurately positioned on the printing surface by the ‘step and repeat’ technique.

Developing and etching

The exposed image is developed and then processed in varying ways, depending on the type of printing surface being produced.

Desktop publishing (DTP) and digital artwork and reproduction (DAR), i.e. preprint to press (PTP) systems.

Modern wordprocessing and computer technology (electronic processing) can drastically speed up the preparation, proofing and correction of artwork. Reproduction of the design can be more rapidly followed up by the use of plateless (i.e. non-impact printing systems) or ‘plate’ printing systems. Such processes, initially used in their infancy for clinical trial supplies, are now being extended into production options.

Mechanical contact printing

The principles of the main printing techniques are based on mechanical contact printing (with reference to printing plate): see Figure 16.1.

1 Relief—print area is raised above the non-print area—letterpress, flexography, dry offset letterpress, hot die stamping.
2 Planographic—print area and non-print area are in the same plane—offset lithography, dry offset lithography.
3 Intaglio—print area lies below the non print area—rotagravure or photogravure.
4 Stencil—ink is forced through a stencil or screen, i.e. screen or silk screen.

Inks

The above printing processes (excluding hot die stamping) involve the use of inks which during the printing process are fed to the printing plate then transferred to the substrate being printed. These inks may be dried, fixed or hardened by:

- oxidation—chemical actions
- adsorption/absorption—penetration
- evaporation—loss of solvents
- precipitation
- curing
- heat setting.

The drying processes may be aided by:

- exposure to air (air drying)
- hot air—to aid air drying
- stoving—higher temperatures, i.e. a curing process
- direct heat—infrared
- UV drying (curing).

The ink involved may be oil-based (originally based on oxidisable oils), water-based, solvent-based (hydrocarbons, esters, alcohols, etc.), or heat-based (only mobile when heated).

Ink drying mechanisms

CHEMICAL ACTION, OXIDATION

Originally based on linseed oil; other oils have included tung, dehydrated castor oil and various resins. Drying action involves resinification by atmospheric oxidation. Drying can be accelerated by the addition of certain metals (lead, cobalt, manganese) as driers. Time to ‘dryness’ may be a few hours to a matter of seconds.

ADSORPTION/ABSORPTION—PENETRATION

Taken up initially on the surface and then absorbed into the media (can be very rapid, i.e. a fraction of a second with newspapers, where the pigments tend to remain on the surface, are powdery and therefore may rub easily).

EVAPORATION

Depends on volatile, solvent-type liquids such as alcohol, toluol, xylol, which evaporate very rapidly. With heat (hot air, infrared, etc.), setting takes only a few seconds. Water-based inks may also partially dry by evaporation.

PRECIPITATION

Caused by either moisture in the air or moisture already within the material being printed. This means that a solid (usually a resin) is made to precipitate out of a solution by moisture—hence the term ‘moisture setting’ inks.

POLYMERISED AND CATALYSED SYSTEMS

These are usually made from a two-component system which when mixed has a short life. Uses involve the screen printing of polythene containers, with either air drying or hot air drying.

The ideal ink system has to meet the requirements listed at the beginning of this chapter with instantaneous drying. The latter can already be achieved with a polymerised ink system used in conjunction with UV drying. Although UV systems are expensive to install, with an additional ink cost, their advantages usually outweigh any disadvantages.

ELECTROSTATIC PRINTING

This is increasing in use for variable wording. It relies on the attraction of dissimilarly charged surfaces, i.e. ink particles and surface to be printed of opposite charges (positive/negative). Design may be achieved by a screen or stencil. Note that modern photocopiers use an electrostatic principle coupled to a heat fixing process. See also ‘Inkjet printing’ below.

Main printing processes’ specific drying methods

Letterpress—originally dried by oxidation but now a combination of penetration/oxidation. May also use quick-setting inks, moisture setting inks (mainly letterpress—low odour level), heat set, and oxidation on non-absorbent materials.

Offset lithography uses thinner inks than letterpress and originally oxidation (linseed oil), but now quick-setting inks are more widely used. On metal containers, oxidation was accelerated by heat but synthetic resins are now employed, thus giving a combination of polymerisation and oxidation. Heat also permits some evaporation, giving more rapid drying with a harder finish.

Photogravure—mainly evaporation (plus absorption with paper). With hydrocarbons the solvent is usually toluol or xylol. Alcohol is also used, particularly where a low odour is required. Nitrocellulose inks are thinned with esters, i.e. ethyl acetate. Use of UV inks plus UV drying is increasing.

Flexographic—evaporation. Inks may be alcohol-, solvent- or water-based, depending on material being printed. (With papers absorption is also involved.) UV inks and UV drying are available.

Screen—various combinations of evaporation, oxidation, penetration, polymerisation, etc.

Ceramic (glass) is a screen process employing powdered glass, pigments, plus carrier base. The pigmented glass is fused onto the surface by heat.

Colours may be achieved by dyes or pigments. Dyes are soluble; pigments are insoluble solids.

Thickness of ink film, dryness/drying time, ink rub are all interrelated, hence slow drying may lead to ‘set off’, i.e. the partial transfer of inked surface onto the underside of the surface above (sheet or reel). This may necessitate the use of an anti-set-off spray which in turn may change the surface film texture.

Printing ink thickness

The amount of ink which can be ‘laid down’ varies significantly between the processes. Average figures are:

- lithography, 2 μm
- letterpress, 3 μm
- gravure, 5 μm
- screen (thin ink), 10 μm
- screen (thick ink), 30 μm.

The choice of ink, printing process, etc. will depend on the form of the article to be printed and the substrate (material), i.e. the print drying process largely depends on the substrate, e.g. whether it is absorbent or non-absorbent, whether it will withstand the temperatures associated with the drying process. Printed plastic materials can be dried by air drying, hot air drying, UV curing, flame drying, infrared drying, again depending on the temperatures they will withstand. With air drying the inks may dry in stages, i.e. although they are sufficiently dry to be handled, drying may continue for a prolonged period before the ink is fully set. The more recent processes include flame drying (similar to flame pretreatment) and the use of special UV curing inks. The substrate material variables are paper, board, wood, plastic, metal, glass, fabric, etc.

Printing machine terminology

Before expanding the printing processes in detail, it is necessary to introduce some general printing machine terminology.

1 Feed—the input stage of the item being printed.
2 Printing plate—the area that carries the design or wording which receives the ink.
3 Plate cylinder—cylinder carrying the plate.
4 Impression cylinder—the cylinder which applies pressure to the item being printed, thus assisting the transfer of the print from either the plate cylinder or an offset cylinder.
5 Blanket or offset cylinder—cylinder onto which the cylinder image is transferred.
6 Ink rollers—those which take up the ink, provide for an even film thickness and then transfer the ink to the printing plate by direct contact.
7 Damping rollers—these apply water (similar to the ink rollers) to the non-print area of a lithographic plate.
8 Delivery cylinder—exit point from printing unit whereby item is delivered to winding-up or stacking point.
9 Fountain cylinder—cylinder in contact with ink reservoir.
10 Anilox roll—an engraved cylinder which transfers from inking rollers to the printing plate on a flexographic unit.

Printing machines and processes

Relief process

A printing plate can consist of two areas, one of which receives ink (printing area) and the other to which ink is not applied (non-printing area). In the relief process the printing area is raised above the non-print area. The main printing processes using this relief principle are now detailed.

Letterpress (either line or half tone)

Platen

This may be a V type hinged machine which may be fed by hand or automatically (see Figure 16.2). One arm of the V is stationary; this carries the printing plate which is inked when the machine is open. The hinged arm of the V opens and closes, carrying with it each time a paper for printing. The process is relatively slow.

Flat bed

The printing plate is laid on a flat bed or forme which passes backwards then forwards (reciprocating bed principle) (see Figure 16.3). At one end of its travel it is inked by rollers and then as it returns the printed item is passed between an upper impression cylinder and the plate. The impression cylinder then rises to allow the forme to return for inking. Due to the reciprocating action, speeds are relatively low, say 3,000 sheets per hour.

Rotary

Here the plate is on a curved cylinder and operates as in Figure 16.4. Speeds are high: 8,000 to 30,000 revolutions per hour. Feed is usually reel, but can be sheet. Plate cost varies—can be around 200–250 per £colour (depending on size and screen). Main applications of letterpress are for the printing of paper and board.

Flexographic

Originally known as the aniline process, due to the use of water based aniline inks on paper (see Figures 16.5 and 16.6). Flexographic is a rotary letterpress process employing cylinder plates made from rubber, nitrile rubber, or special polymers. Excessive pressing may lead to squeeze-out, hence limitations to coarse half tones on certain equipment.

Rubber blankets are suitable for spirit, aniline/glycol based inks. Special inks require ketones in PVC inks, hydrocarbons in polythene inks. (Nitrile rubbers are resistant to hydrocarbons.) Many inks now use pigmented polyamides (for plastics/foil)—silicones in waxes may be added to aid 'slip'. UV inks may also be employed, otherwise dry by evaporation.

Four colour process with common impression cylinder (4 in Figure 16.6) gives excellent registration with extensible materials. Now a relatively high-quality process. Printing plates are relatively inexpensive—around £175.

To be effective, foil requires a primer wash prior to printing (1–3 gm), e.g. nitrocellulose, vinyl resins.

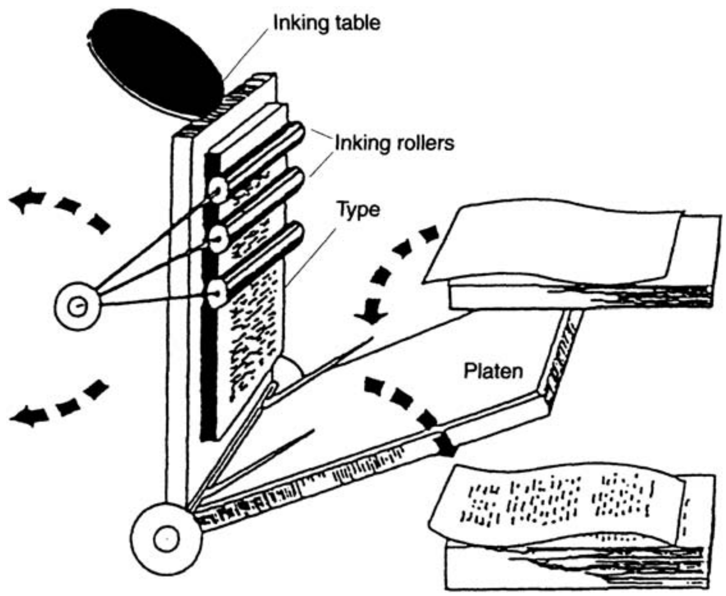

Figure 16.2 Letterpress platen

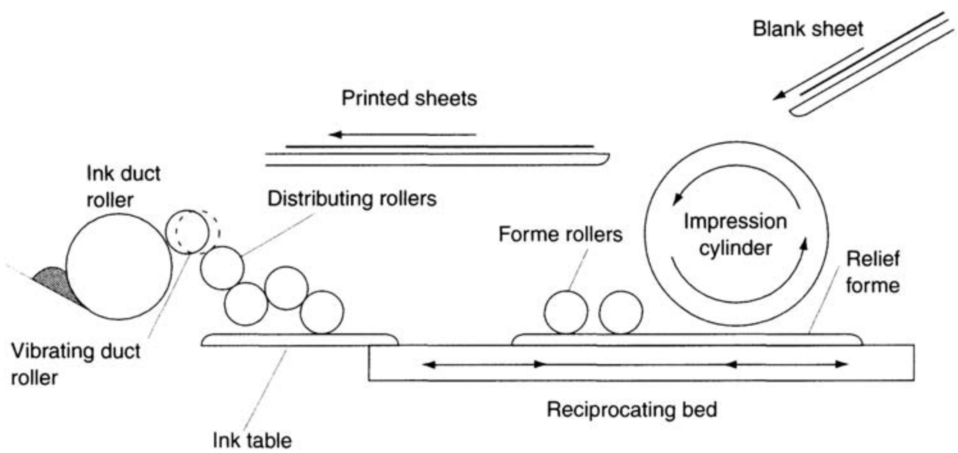

Figure 16.3 Letterpress flat bed

Dry offset (letterpress)

The term has more than one interpretation, as some dry offset work is performed on conventional offset-litho presses (minus damping) using shallow relief plates. Alternatively, there are special machines for printing round or cylindrical items, i.e. plastic bottles, collapsible tubes, rigid tubes (seamless) (see Figures 16.7 and 16.8). These are normally two or four colour machines, using letterpress plates. Some six colour units are also used.

Printing ink is transferred via a relief printing plate to an area on an offset rubber blanket. Kiss contact (the tube is held on a mandrel and, in the case of a plastic bottle, these are pressurised) is made with the item being printed which then makes one circumferential revolution. The print area is therefore slightly in excess of the circumference of the article (allows slight overlap in many instances). In the case of metal containers, printing is made on top of a roller coat of enamel. Drying is achieved by heat (hot air drying ovens).

Hot die stamping and gold blocking

In this process a carrier material is coated with a foil or pigment which under pressure and heat can be transferred to another surface (see Figure 16.9). It has certain advantages: no drying or surface preparation, quick for colour changes, no cleaning down. It can be printed on raised, on level or into recessed surfaces. Plates may be silicone rubber or metal. Soft plates provide for a kiss transfer whereas metal plates can be used to give a distinct impression into which the pigment or foil is deposited.

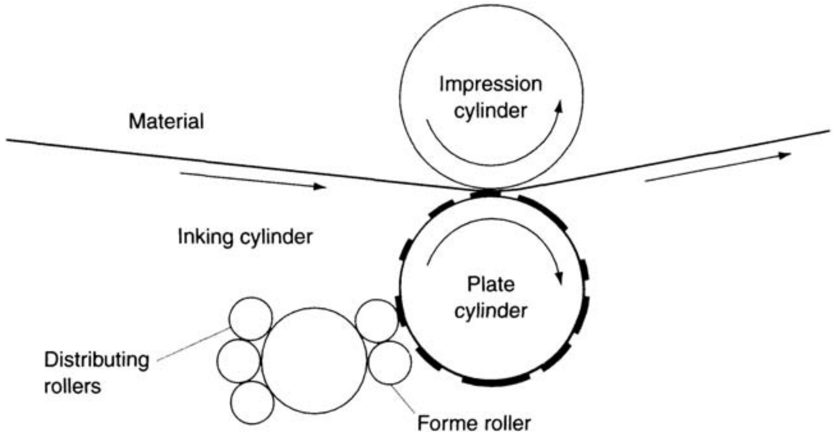

Figure 16.4 Letterpress rotary

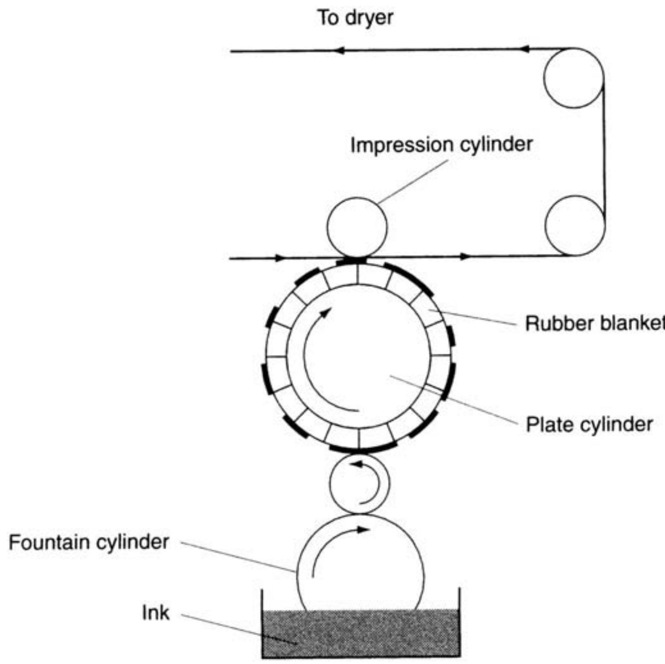

Figure 16.5 Flexographic, one impression

The carrier may be glassine, cellulose film, and polyester film. The choice of carrier relates to speed and transfer temperature. Polyester (i.e. Melinex) is the most common base. It is suitable for flat, cylindrical or radiused surfaces. The process is used for online printing. Metallic 'foil' consists of a carrier, release coating, lacquer metallised layer and a hot melt type adhesive specially formulated for the substrate.

Planographic

This process is usually the most difficult to understand. The printing area and the nonprinting area lie on a common plane and are differentiated by the treatment of the printing plate. The print area accepts ink (oil) and the non-print area water, thus relying on the fact that water and oil do not mix. As seen in Figure 16.10, the plate is first wetted in the non-print area by damping rollers and then ink is applied by ink rollers to the print area. Only one printing process with variations uses this method, as explained below.

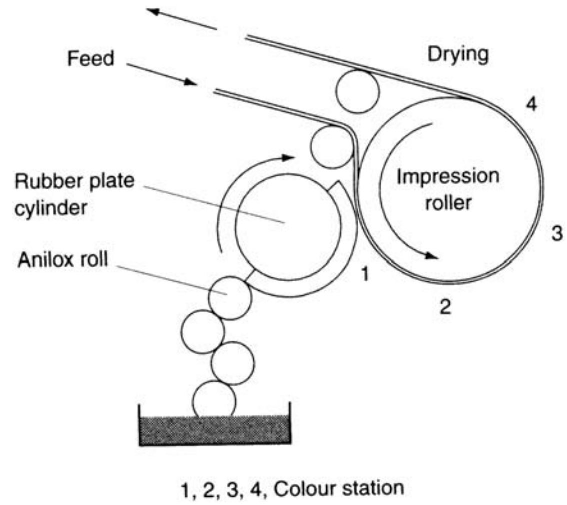

Figure 16.6 Flexographic process

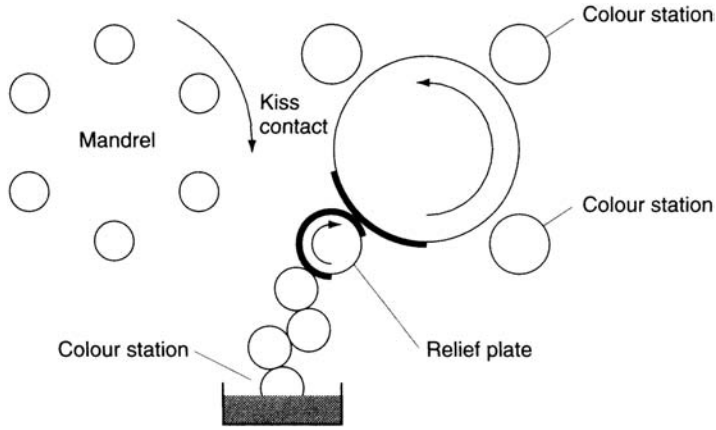

Figure 16.7 Dry offset, four colour

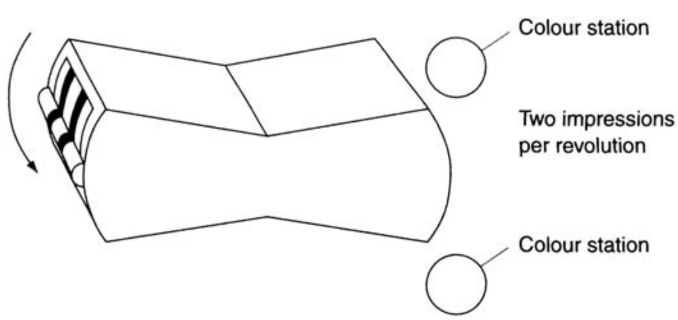

Figure 16.8 Dry offset, two colour

Offset lithography

Plates may be either line or half tone. The inked image is offset onto a rubber blanket and then printed from this blanket onto the item being printed. It is used to print paper and board, metal in the flat sheet (tin plate) and occasionally plastic or foil. Offset lithography applies a relatively thin film of ink.

Dry offset lithography

Special plates are available where only the print area accepts ink without prior damping of the non-print area. These special plates are more expensive than conventional wet offset plates.

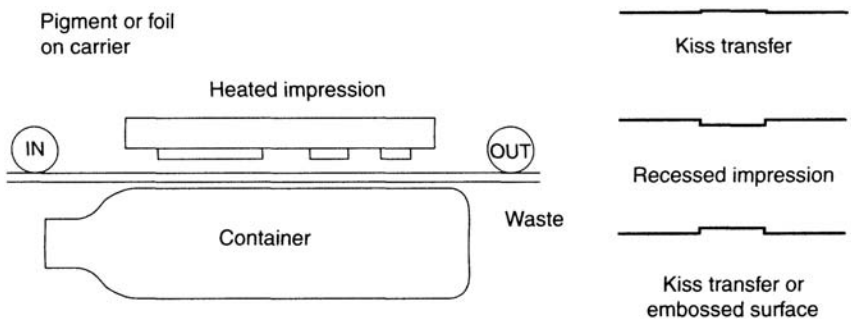

Figure 16.9 Hot die stamping or gold blocking

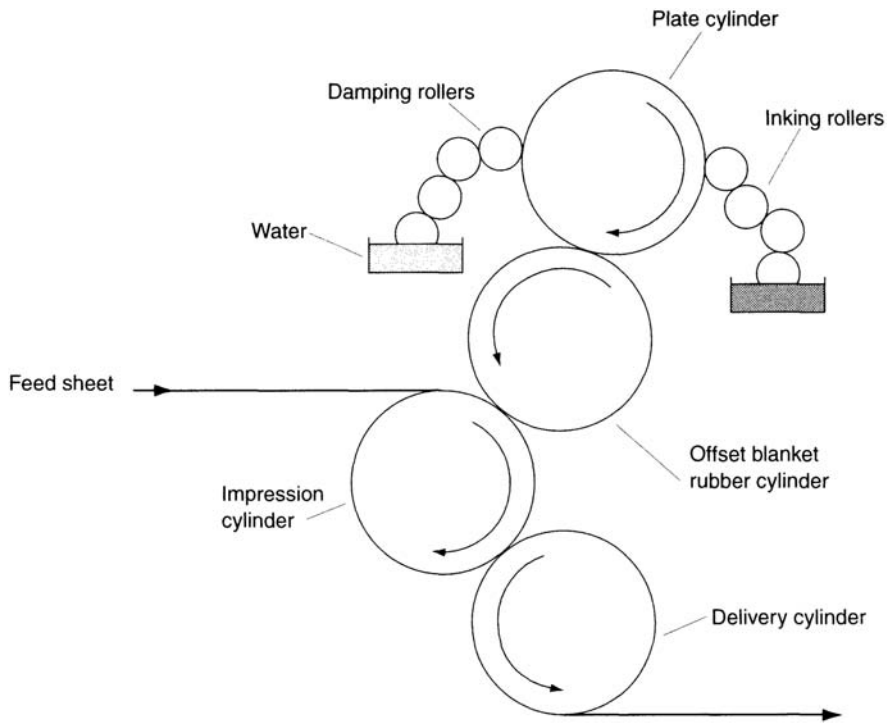

Figure 16.10 Offset lithography

Web fed offset

This is now widely used for newspapers and uses heat to speed drying. This had disadvantages on paper and board (due to shrinkage), but has been used for certain carton board. It can produce over 40,000 sheets per hour.

Cost of lithographic plates is around £275 per colour.

Intaglio

In this process the printing area lies below the non-print area (see Figure 16.11). The whole area is flooded with ink, which is then scraped off the non-print area but left in the print area. The item being printed is pressed against the plate which results in the ink being lifted out of the ink cells. For example, gravure cylinders use a copper base and are relatively expensive to produce (£850–1,200 per colour/cylinder), but are ideally suited to long runs. Inks are usually solvent- (dried by heat) or water-based. Used mainly for the printing of board, paper, films and foil, usually where long runs are involved.

It should be noted that two types of gravure plates exist. Conventional gravure have cells of the same surface area which vary in depth. Areas of deep cells result in all ink flowing together to produce a solid area. Gravure also uses a process known as inverthalftone. Here the area of the cells vary so that small cells produce light tones and larger cells produce darker tones (i.e. variations in cell depth and size).

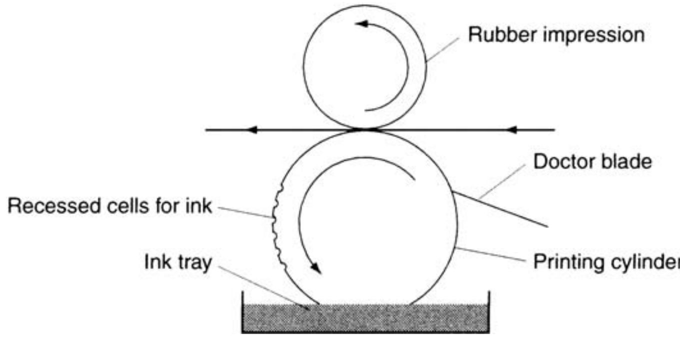

Figure 16.11 Photogravure or rotagravure

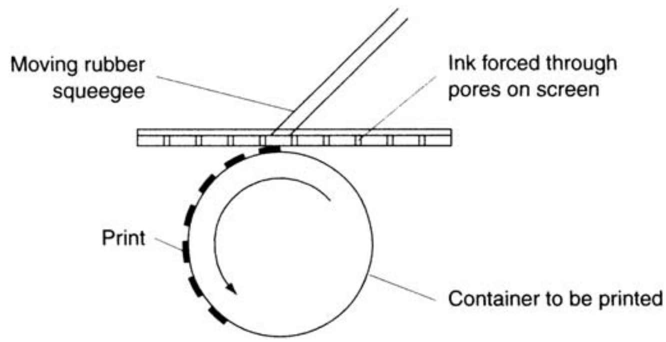

Figure 16.12 Screen printing

Stencil: screen

This process can use either solid stencils or screen (mesh) stencils (see Figure 16.12). The latter is called screen printing and was originally known as silkscreen, as silk-type screens were employed. Present day screens are made of nylon, polyester or steel and are relatively low in cost, £45–75. Each screen may give 15,000 to 50,000 impressions. The ink is forced through the screen by a squeezer. Prior to this action the screen is separated from the item to be printed by a lift-off gap. This gap is reduced by the pressure of the squeezer whereby contact is made between the screen, ink and item. Screen inks are relatively thick, and are either air or hot air dried. The screen process can produce coarse half tones with thin inks.

Contact may be flat bed or cylinder, hand, semi-automatic or automatic fed. The speed of the process is limited by the drying. One to three colours can be printed in one pass by the use of split screens. The process is used to print paper, board, plastic or occasionally foil. Can be used for flat, cylindrical or radiused surfaces on preformed containers.

A costing of 1 p per pass is generally accepted. As more passes are employed the cost rises due to rejections, i.e. first pass 1 p, second pass +1.25 p, third pass +1.5 p, etc., giving total costs of 1 p, 2.25 p, 3.75 p respectively.

Due to the thickness of the ink, screen printing offers good body and a high gloss. Half tone type printing is achievable by the use of special thinner inks, particularly with UV inks and drying.

Other printing processes

Several named processes are based on transfer, i.e. Therimage, Letraset, Dinacal, etc.

Therimage is used for the printing of plastic containers. The basic image is printed by gravure onto a carrier material somewhat similar in construction to that described for pigmented foils under foil stamping above. Special turrets (costing around £3,000) are required to effect the transfer of the image under heat. When applied the printed image substrate has a greater affinity for the plastic being printed than the carrier base. Several types of heat sensitive bases are now available. Note that the image to be transferred is printed as a 'wrong reading'.

Letraset

This offers two basic transfer processes:

1 for in-mould decoration of plates

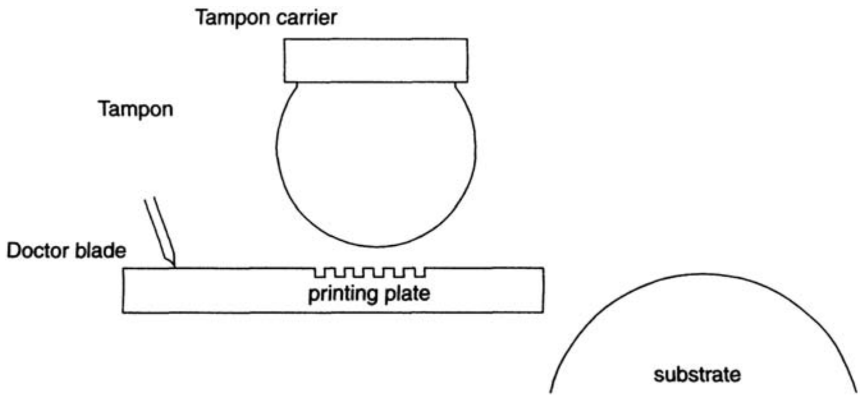

Figure 16.13 Tampon printing: transfer process

2 transfer printing of fabricated plastic containers.

Both employ a preprinted transfer (up to six colours). In the in-mould process the transfer is placed within the mould prior to bottle blowing or injection moulding. During the moulding cycle the printed transfer becomes 'fused' to the container. The printing can be produced by either screen or gravure and can be line or half tone.

Cliché or tampon transfer process, pad printing

Consists of either flat gravure plates (usually one to four colours) or solid line recessed plates which are flooded with ink, wiped with a doctor blade followed by a tampon descending onto a plate and lifting the ink from the recessed cells (see Figure 16.13). It then transfers it directly to the item being printed. With this process it is possible to print directly onto irregular or multicontoured surfaces (i.e. it is the only three-dimensional printing process: trade names Tampoprint, Padflex). The tampons usually consist of glycero-gelatin or silicone rubber.

Thermal printing

This involves two processes. In the first, a heat sensitive coating on a carrier changes colour on the application of heat, e.g. hot needles are used to give a dot matrix type of image. The material can be printed in up to four colours and can incorporate a barrier varnish. Dots are usually 6, 8, and 10.5 per mm. The second process transfers a thermally activated ink from a carrier ribbon. Various colours may be employed. The process is relatively slow, e.g. ribbon moves 5 inches per second. Now a popular process for on-line printing.

Non-contact printing processes

Ink jet printing

The ink is ultrasonically (or mechanically) broken up in to small particles, some of which are then charged, and deflected to the substrate being printed via a screen or stencil, while the remainder are condensed and circulated back to the ink reservoir. A speed of 600+m/min (based on a single line of dots) is possible. Up to six lines can be printed (see Figure 16.14).

Laser printing

A CO_2 laser beam is used to etch (burn in) or burn out (as used for batch coding and expiry dating). In the latter, a prior printed or enamelled surface has some of the ink removed by burning off, as used for batch coding etc. Note that other forms of laser printing processes can produce a high-quality conventional image.

Embossing and debossing

'Embossing' means above the surface (raised). 'Debossing' means below the surface (recessed). Debossing or embossing may be achieved in a moulding operation by the use of male/female dies with or without heat. Embossing rollers or dies may also

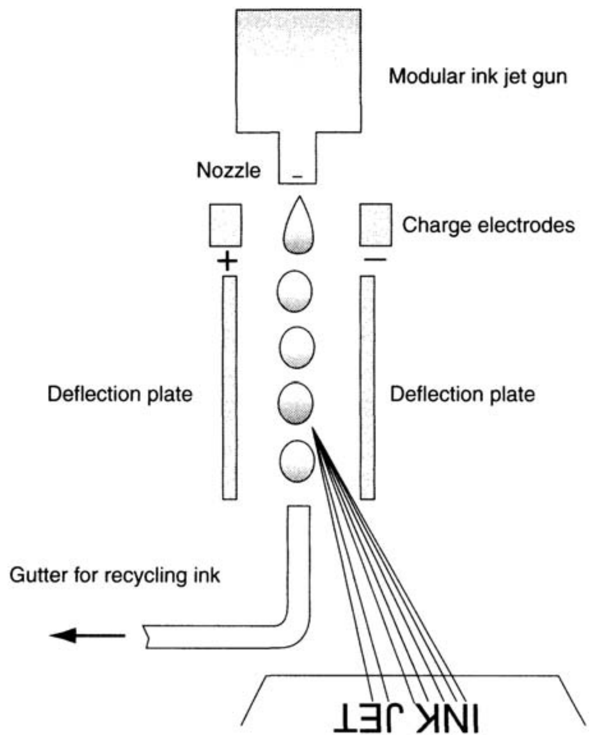

Figure 16.14 Ink jet printing

be used to produce surface designs/textures on foils, foil boards, papers and boards, metal containers and as a means of batch coding, expiry dating, etc., as part of an on-line production operation.

Miscellaneous processes of decoration

There are several ways of creating a surface coating or colour. These include painting (using a roller or a brush) and spraying (usually carried out in special booths with air extraction; used mainly for metal drums).

Roller coating (also enamelling)

A coating is thinned by passage through a series of cylinders with the lowest one being in contact with a 'bath'. The upper, or contact, roller transfers the coating from the roller to the item being decorated. The coating may be an enamel, lacquer, varnish, etc., which may vary in coating thickness. Metals (e.g. tinplate, aluminium) are enamelled in the flat sheet and metal collapsible tubes as a cylinder, both prior to final printing.

Dipping

Metal and glass may be immersion dipped to give either a coating or an etch (glass into hydrofluoric acid). Plastic coated glass bottles (as used for aerosols) are coated by dipping into a PVC plastisol.

Anodising

A coating of aluminium oxide is deposited electrolytically onto the surface of the aluminium component (pre-cleaned). The oxide is then dyed by immersion into a dye solution and colour set by steaming.

Vacuum metallising

Plastics can have a layer of metallic aluminium deposited on the surface by vacuum. Although aluminium is basically a bright silver, it may be lacquer tinted to give a wide range of metallic colours. Polyester, polystyrene, urea and phenol formaldehyde, and polypropylene are readily metallised. Other plastics need a pretreatment.

Plating

Tin coating of mild steel is basically a surface coating process. This may be achieved by a dipping process or an electroplating process (see Chapter 9).

Polishing and brushing

Small metal articles (usually aluminium) can be highly polished or wire brushed (scratched) to give various patterns which are either random or controlled. These may then be covered by a transparent over-lacquer to improve the effect.

Sand blasting

This was widely used to give glass a frosted appearance.

Moulded decorations

Surface texture or moulded-in configurations can be provided by many plastic moulding processes. Raised surfaces can additionally be 'kiss' blocked or coated.

Coloured base materials

Paper, board and plastic can all be produced as a coloured material. With plastic, colour can be introduced by dry or wet colourising or masterbatching.

Sleeving

Pre-printed sleeves are now available as heat shrink sleeves (based on oriented PVC, PP, PET, etc.) or stretch sleeves (based on LLDPE with a memory built in).

General

The above decoration/printing processes may be used singly or in combination. If a matching series is designed involving different materials and different decoration processes there are likely to be problems in achieving a good match. Other relevant parameters, i.e. print area, registration, colours involved, ink coverage required, shape of surface being decorated (particularly when round is compared with flat), may all need special consideration.

Where pharmaceutical packaging is involved, special attention must be given to food grade inks which are non-toxic and odour-free. Inks which are solvent-based need special monitoring.

Finishing

Labels, wrappers, etc., irrespective of whether they are printed as sheets or reels, are printed by multi-impression processes. For example, an individual label could be printed as a sheet (180×98 cm) carrying some forty labels (as a gang pull). These would be converted into 'cut singles' by a guillotine process.

Such printing is only allowed in the pharmaceutical industry if one common label is involved. Composite printing where different products or strengths are printed on a common sheet is not permissible due to admixture risks. Similarly, printing of reel-fed materials as 'jumbo' reels would be reduced to a number of smaller reels. Reel joins should be minimised and normally 'flagged'.

Security systems

Accountability, reconciliation, counting, etc., are all part of print security. These may be coupled with various coding options (bar coding, colour coding, edge coding, punched hole systems, metallic strips, etc.) so that print can be identified and checked against some form of 'code' reading system. In some processes (e.g. thermal, ink jet), items may be consecutively numbered.

Registration marks

Registration marks (e.g. thick colour bars read by a 'magic eye') and similar devices are necessary on form fill seal types of process where design registration is essential. Randomly printed designs, conversely, do not need registration.

Holography

This is now used as a decorative process to prevent counterfeiting. Currently showing a steady increase in use. For more detail see Chapter 5.

Other factors

Although the main printing processes and materials to be printed are covered, other minor processes do exist and newer ones are being investigated. Some materials and containers create design limitations due to the processes available, as detailed below.

State of surface—preparation of the surface

1 Impermeable surfaces (film, foil)—evaporation drying, gravure or flexographic.
2 Rigid containers (plastic)—dry offset, hot die stamping, screen, pad printing, ink jet, laser.
3 Smooth permeable surface for high quality printing—use letterpress, litho or gravure.
4 Rough permeable surface—litho best then perhaps gravure, but expensive.

Pretreatment

Certain surfaces require some form of pretreatment prior to printing. Foil usually requires primer wash, and polyethylenes and polypropylenes need to have the surface oxidised. The corona process is almost invariably used for films and flame treatment for bottles. Whether a surface has received treatment or not can be detected by immersing it in water and observing whether or not the water runs off. An oxidised surface has a lower wetting angle. If the surface is not printed soon after treatment another treatment may be necessary. Inks will not 'key' onto non-oxidised PE and PP and will be removed when a self-adhesive tape test is employed.

A more sophisticated peel test can be used to check the degree of surface treatment, and a suitable procedure is detailed in BS 2782 method 310. Another wetting test uses a dye in nitroethane which will remain as an intact film for up to 30 s with a treated material. A non-treated surface will show coalescence and form globules rapidly once the item is removed from the test solution.

Print adhesion

Print adhesion on plastics (and foil) is normally checked using a self-adhesive tape peel test. A few inches of a suitable standard tape is firmly pressed onto the print area then pulled off, slowly at first, then more rapidly. An assessment of print adhesion can be made from the quantity (ideally none) removed. Adhesion can vary according to the type and colour of the ink, the degree of pretreatment, the surface involved and the printing process, etc. In order to test print under likely use conditions, product immersion tests may be necessary: 60°C (140°F) is a frequently used condition, for 3 to 6 h. If product-pack may be used with soapy hands, a solution of soap can be employed. A print adhesion test, as above, can then be carried out, on the washed material, after it has been cooled to room temperature.

Application of ink and ink drying methods:

1 Absorption offers rapid drying but poor rub resistance.
2 Oxidation dries slowly—gives good rub resistance and good gloss if required.
3 Evaporation—rapid drying, possible solvent troubles (toxicity, fire risk, cost, safety).
4 Precipitation—poor rub resistance but almost odourless.

Note that UV inks can provide a high gloss.

Method of feed (i.e. reel-fed or cut sheet)

Reel—flexo, gravure, letterpress, litho. Note that a reel-fed machine using sheet form offers approximately 50% output of reel.

Rub resistance

If colour is very strong, litho in thin layers is not so rub-resistant as letterpress because of low varnish level. Note that rub resistance and brightness can usually be improved by the addition of over-lacquers or varnishes (based on shellac (spirit), nitrocellulose, Saran, vinyl, epoxy, water varnishes, etc.) or lamination (cellulose acetate, polypropylene, PVC, etc.). Coatings or laminations may also provide heat sealability.

Printing technology has made great advances over the past 15 years, with sheet speeds up to 15,000 per hour and reel-fed or cylinder models making up to 60,000 revolutions per hour. Computer controlled LED equipment has improved registration and colour control and reduced wastage, as well as increasing output and reducing makeready times. Table 16.2 gives a comparison of the various processes.

Although decoration of paper and board is well covered by the literature, general understanding of the wider issues involved with 'other' materials has frequently been poor. This particularly applies when artwork is produced which although reproducible on paper or board, is unsatisfactory in terms of the printing/decoration processes available for another material.

It is also usual practice first to produce a design on paper or board then to endeavour to achieve a 'match' with other materials, when it would be somewhat easier to do the reverse. Matching of finished items is always difficult due to additional factors related to shape, surface finish, size, viewing/lighting conditions, etc.

Special considerationsÐpharmaceutical and cosmetics

Both pharmaceuticals and cosmetic packaging demand a high standard of decoration, with integrity, clarity and permanency. Colours in the form of dyes, pigments, inks, etc., must be non-toxic, non-irritant, fade- and/or discolouration-resistant, product-resistant and rub-resistant. In short, the highest quality standards are demanded in terms of visual appearance, functional usage, and safety. Although safety standards related to food substances may appear to be adequate, additional tests may be necessary as the 3–5 year shelf life required of a pharmaceutical pack may be considerably longer. Increased 'contact' time may therefore give rise to adverse effects associated with migration, interactions, absorption, adsorption, etc.

Although design and decoration are closely associated, wording requirements, particularly in pharmaceuticals, may be directly related to legislation. The gradual increase in the requirements related to the latter is leading to some concern, as the

Table 16.2 General comparisons (rough 1996 prices; IPH, items per hour)

	Letterpress	*Litho*	*Flexo*	*Gravure*	*Screen*
First costs including plates (per colour)	Low to medium £ 200–250	Medium £ 250–300	Medium £ 150–200	High £ 1,000	Low £ 60–100
Make ready	Medium	Low	Medium	High	Low
Production speed	1,500–2,000 IPH	500–2000 ft/min 1,500–45,000 IPH	500–2000 ft/min Up to 6,000 IPH	500–2600 ft/min Up to 35,000 IPH	Up to 35,000 IPH
Print quality (paper)					
Good material	High	High	Medium/high	High	High (design limitations)
Poor material	Low	Medium	Medium/low	Medium	High
Plate life	Medium to long	Long	Medium	Long	Short

The above provides only a very general comparison. For instance, costs/plate life will relate to the type of plate produced.

original concept that a pharmaceutical product should readily be identified is gradually being lost. Although colour has widely been used to differentiate products, or to provide association with a family series, it is generally not advised as a means of identifying different strengths of dosage form as in these circumstances there is no substitute for reading. The advent of coding systems, such as electronic bar codes and universal product codes (UPC/ANA/EAN etc.), must considerably improve product security, but again space to segregate these from the rest of the wording/design is not always easily found. Similarly, different printing processes have varying restrictions in terms of the amount of wording/colour which can be employed and the sharpness/clarity of print and the bar-type codings.

Decoration or aesthetic appeal obviously have different functions to perform between ethical and OTC pharmaceuticals. However, in the case of pharmaceuticals, functional and aesthetic appeal frequently become segregated, with the functional aspects receiving early attention, and the final aesthetic stages are not fully investigated and may be overlooked.

To conclude, thorough knowledge of all the decorative processes is essential for the packaging technologist who deals with both pharmaceuticals and cosmetics, as he or she must be capable of advising on all aspects related to aesthetic and functional design, plus safety. A day or so in the design/artwork and plate-making section of companies printing by the various processes will frequently convey more background knowledge than either a lecture or a textbook.

Finally, remember that printing has been recognised as a relatively 'dirty' process in the past. The industry is now attempting to 'clean it up'.

Recent trends

The introduction of computers has revolutionised print technology from origination, preparation of artwork, production of plates, on machine register and colour control, plate change-over, machine make ready, etc.

Desktop publishing (DTP) and digital art work and reproduction (DAR) are shortening publishing times, improving general quality and reducing origination times. Although this in many instances leads to some increased costs, subsequent downtime, wastage, etc. can be drastically reduced.

The new technology can be applied to both large-scale and small-scale production. In the latter case this is particularly relevant in the office and the production of special labels such as those used for clinical trial supplies.

Office printing

Earlier days saw limitations to office printing where stencils, typewriter (initially with a dampening pad, then a ribbon, a golf ball, etc.), and inked rubber pad were widely used. However, small-scale or office printing can now be achieved by a range of processes, i.e.

- photocopiers, based on an electrophotographic process
- laser printers (note: this is not burning out)
- LED (light emitting diode) printing
- ink jet printers
- colour copying
- dot matrix printers
- ion deposition
- direct thermal printing (usually as used on a fax)
- thermal transfer printing
- magnetography.

Virtually any of the above can be computer (or wordprocessor) led. Some of the above have been developed on a larger scale (magnetography) or find special usage (laser printing of proofs etc.). Other newer processes include the waterless version of offset lithography which uses special plates which accept ink on the print area without passing through a prior damping stage. These plates are more expensive than conventional wet/dry lithographic plates.

Printing inks may themselves be a source of contamination, particularly when based on solvents or oils. This risk usually lessens when water-based inks are employed (a current trend). As printing (and decoration) is a basic part of pharmaceutical packaging, knowledge of the processes and materials involved is essential if risks from these are to be avoided. As with the law, ignorance is not a viable excuse if problems arise.

Printing and printing inks

Printing inks vary in their composition and drying processes employed, according to the substrate and the printing process involved. Irrespective of the process, inks are usually at one stage 'wet' or mobile, even if at the later stage a 'dry' transfer (e.g. hot die stamping) is involved. Inks may vary in composition according to the process and the substrate, which may or may not be modified or pretreated in order to give a good ink key. Inks may be made to flow by the use of water, oils, or solvents. The last of these frequently falls under the UK Regulations, Control of Substances Hazardous to Health (COSHH) and prior to these The Health and Safely at Work Act (1974).

Solvent-based inks

Gravure acid flexographic inks have been conventionally based on solvents, particularly as the materials printed by these processes have typically been non-absorbent (i.e. foil, plastics). Solvents which are considered hazardous if inhaled include benzene, methanol, methyl and ethyl cellulose, hence these are no longer employed. A typical solvent based ink contains:

- 4–12% pigment or dye
- 0–8% extender
- 10–30% resin binder
- 2–10% additives
- 40–60% solvents.

This ink may be further diluted prior to use to give over 70% solvent. This solvent is lost via evaporation and drying. The solvents used include alcohols, esters, aliphatic hydrocarbons and glycol ethers, with a limited use of ketones and aromatic hydrocarbons. To prevent the venting of solvents direct into the atmosphere, solvent recovery or incineration systems may be used. Alternatively, water-based inks are being increasingly employed, possibly coupled to UV drying. However, even water-based inks may contain up to 15% of solvent, e.g. methylated spirit or isopropyl alcohol, and take more energy to dry (due to the high heat of evaporation of water).

Foils frequently use a wash coating of 0.5–2 g/m^2 as a print substrate. This may be a shellac, nitrocellulose or vinyl solution. Since many foil-based materials are heat sealed and foil is a good conductor of heat, most printing inks need to exclude light levels of wax and low melting point resins in order to avoid ink lift or pick.

Oil-based inks

As detailed earlier, offset lithographic printing operates on the principle that oil and water do not mix. With paper-based materials, conventional inks usually dry by oxidation and absorption. Early screen inks were also based on oil, drying by oxidation. These were used to achieve a thick film of 20–30 μm. Thinner inks were obtained by the use of non-nitrated cellulose derivatives, modified resins and white spirit. Ultra-thin film inks were subsequently introduced which gave films between 5 and 10 μm, thereby enabling the use of half-tone images.

Early oil-based inks were based on linseed and tung oils. Ink drying was speeded up by the use of cobalt driers (also manganese and lead), followed by high boiling hydrocarbons which allowed the introduction of quicker setting inks.

Heat setting inks

These were initially produced for higher speed rotary letterpress printing using inks based on synthetic resins in high boiling point hydrocarbon solvents which are rapidly dried with heated rollers. Heat set inks are still widely used for web printing and involve newer resin and solvent systems.

The growth in the use of synthetic resins and the variety and purity of solvents have allowed the use of many other drying processes: UV, IR, microwave, electron beam curing, etc.

UV curing inks frequently consist of 100% solids with no solvents (as used by screen processes). Since the use of UV creates some hazards (direct contact with UV and ozone residues), special equipment and precautionary procedures are essential.

Water-based inks

The risks associated with the use of solvents (toxicity, irritancy, flammability, etc.) and the costs of solvent control (e.g. extraction or incineration) have encouraged the development of water-based inks. Since water is a poor solvent for most synthetic resins, emulsions and dispersions have been developed. Water-based inks are used for gravure, flexography, screen and letterpress processes.

Conclusions

Inks, like rubber and plastic, need pigments or dyes as colouring agents, and several types of ‘additive’ to provide certain selected properties. The other main component is a carrier which may be based on oil, water or solvents, together with various synthetic resins.

The additives include slow or fast reducers, driers, retarders, varnishers, waxes, slip additives, stabilisers, etc., which may be specific to a particular printing process and the drying process associated with it.