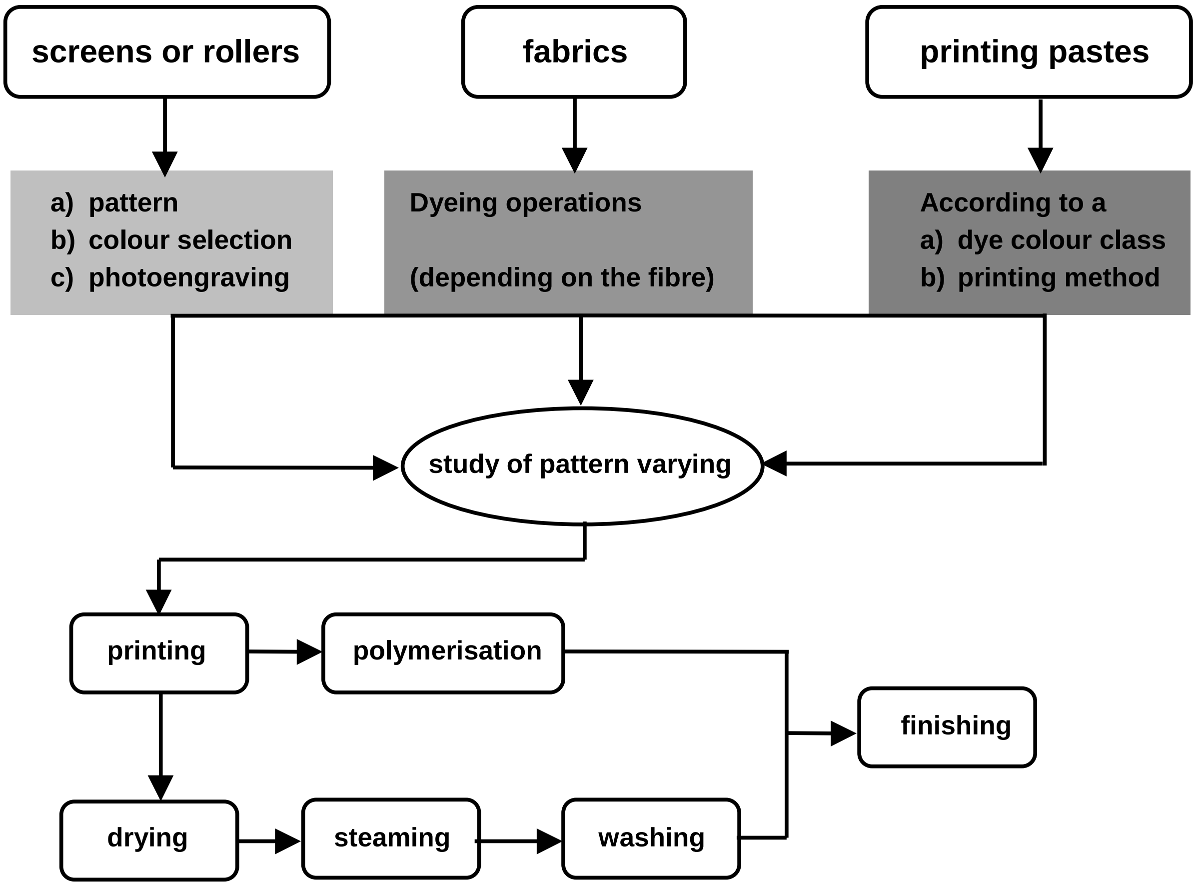
# PRINTING

Printing could be referred to as a sort of selective dyeing that makes an important contribution to fabric decoration thanks to the combination of colours and dyeing methods.
To obtain sharply defined, precise and reproducible patterns, the dyebaths traditionally used are not sufficient, because of the capillarity and/or hygroscopicity of fibres and migration of dyes that cannot grant sharp and well-defined colour patterns.
It is therefore necessary to use special liquids, conventionally called "printing pastes", whose main characteristic is a high degree of viscosity (improperly called density); in other words these printing pastes colours are fluids which oppose a high resistance or friction to sliding or motion.
As a consequence, the dyestuff applied on the fabric in well-defined areas to reproduce the desired pattern cannot migrate to other areas of the fabric. It is also worth considering that the high viscosity of printing pastes will make the dye adhere to the surface of the fabric and the fibres, but not penetrate into and fix on them. These operations (which may be referred to as diffusion and fixation during the dyeing process) will be carried out afterward with a steaming process.
The application of the print dye on the fabric is carried out by forcing it through the gray fabric on special printing blocks or perforated hollow rollers applied onto the fabric; the dye is then generally fixed by means of a steaming process.
Now we will briefly outline the main operations resulting in a printed and finished fabric:



# Printing Methods

There are different types of prints, depending upon the printing method, the desired colour pattern and the results to be obtained. Another approach to the printing classification can depend upon the process and therefore upon the machine used (manual screen printing, conveyor belt, hand printing, hollow roller printing).

### Direct printing

*This method involves the following steps: printing, drying, steaming and washing.*

This type of printing is generally used for white or dyed cloths (usually dyed in pastel shades), by applying the sequence of all the colours, until the original pattern has been reproduced.
This is the most common printing method and can be used with all the main colour classes of dyes and on fabrics produced with any kind of fibre (some problems may only arise with blends).
The technical limits of this printing method appear with endless design patterns (particularly those obtained with screen printing methods, while no problems occur for roller printing). Some problems may also arise when printing on backgrounds dyed with pastel shades: in fact, this could create problems on several areas of the design to be printed in light shades, thus limiting the number of reproducible pattern variants.

*Pigment printing represents an alternative to direct printing*

With pigment printing there is no need to carry out a steaming process, as steaming is replaced by polymerisation (generally carried out simultaneously with drying). This type of printing process is very simple, low-cost and can be carried out easily on all types of fabrics, particularly on blends, since pigments can adhere to all fibres; there is no need to use dyes of different colour classes. On the other hand, the adhesives, which bind the pigments to the fabric, can give serious problems when the fabric hand varies. For prints with a low coverage ratio, the hand variation can be acceptable but it is not acceptable when the coverage ratio is high, or at least for all uses. Furthermore, the pigment lies on the surface and has low fastness to friction (this depends mainly upon the type and quantity of binding agent and upon the polymerisation degree). Some valid alternatives to this type of printing can give special effects such as *printing with swelling agents* (generally synthetic polyurethane-base pastes are used), with covering pigments and glitter (metal powders or particles of plastic materials) etc.

*Four-colour printing*

In the four-colour printing process, primary colours (magenta, yellow and cyan, plus black) are used. The different shades are obtained by applying dots of the primary colours in variable densities: this technique also takes advantage of the ability of the eye to combine colours when observing them from a certain distance. Design patterns with different hues and tones can be obtained by using only four printing plates. This method however limits significantly the possibility of pattern varying. This technique is used only for fixed patterns and pure saturated colours cannot be reproduced.

### Discharge printing

Basic steps are printing, drying, steaming and washing. This technique is used on dyed fabrics (usually in dark shades).
The fabric is dyed in the piece and then printed with a chemical that destroys the colour in designed areas. Sometimes the base colour is removed and another colour is printed in its place; but usually a white area is desirable to brighten the overall design.
This printing method is generally used to obtain designs with tiny details, sharp and well-defined edges on coloured backgrounds, patterns with low coverage ratio on coloured backgrounds, and to avoid pattern matching problems on endless design patterns with coloured backgrounds. The results obtained with this printing method could be hardly reproducible with direct printing since it would be very difficult to obtain wide backgrounds, smooth and well penetrated, with sharp edges without seam defects.
A problem for this printing method is represented by the need to choose perfectly destroyable dyes for backgrounds, which cannot be affected by the discharging agent used as brightener. The selection restricts the number of applicable dyes and above all, for some colour classes, very few dyes grant a good fastness to light and moisture, but excellent colour effects. With this type of printing carried out on black or navy blue backgrounds it is also impossible to check if the various colours are correctly positioned; any mistake will be visible only after the steaming process and at that point it would be impossible to correct it. This problem could be limited by testing the printing result on a white cloth before beginning the printing process.

**Resist printing**

With the old method of physical resist printing, (hydrophobic) products or printing pastes were applied to the fabric to avoid contact and penetration when the fabric was subsequently immersed in the dyeing liquor (Batik).
Now the most diffused printing system is the chemical resist printing carried out with different printing methods, using pastes containing chemicals, which avoid fixation of background dyes (particularly for "reactives on reactives" applied on fabrics made of cellulose fibres). Some of the printing methods are detailed in the following:

a) Resist printing on covered background: a pad dye is applied and dried; the printing is carried out with printing pastes containing products avoiding the fixing of background colour (but they do not avoid the fixing of any brightener used). The fabric is then dried, steamed and washed (this is the most diffused resist printing method).
b) Resist printing by overdyeing: the operations of the resist printing method previously detailed are carried out in inverse sequence; therefore the fabric is first printed and then covered.
c) Resist printing by overdyeing: this method is similar to the previous one, but the covering operation is replaced with the roller printing of the background.
d) Printing on polyester: polyester printing must be carried out applying the resist-discharge printing method. Printing pastes containing both the discharge and resist products applied on covered background must be used.

**Transfer printing**

This printing method is used for printing on synthetic fibres, particularly P.L. With this efficient method disperse dyes, previously printed on special continuous paper on the fabric, are transferred on the fabric by means of rollers with engraved frames. The design is transferred by contact between the paper and the fabric, which is then passed through heated rollers at a temperature of 190-210°C. With this method, disperse dyes sublime (i.e. change directly from the solid to the gaseous state without passing through the liquid phase) melt, penetrate the fibres and bind by heat and pressure onto the fabric surface in a few hundredths of a second.

Recently many manufacturers have used this printing method also with acid dyes on PA and reactives on cellulose fibres.

**Devoré printing**

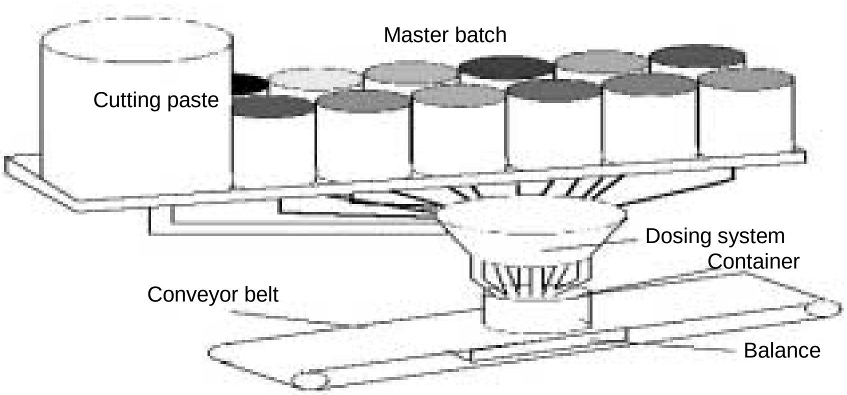
This method is generally used for P.L./cellulose blends (more rarely for PA/viscose, silk/viscose, wool/viscose blends) specifically pretreated, by means of acid pastes (potassium acid sulphate, chloride or aluminium sulphate); during the drying at 140-170°C, cellulose fibres carbonise, while synthetic (or protein) fibres remain unaffected by the carbonising process. A subsequent mechanic treatment (brushing or beating) and washing create transparent effects designs resembling to laces; these fabrics are generally used for upholstery, underwear and garments production. Devoré printing can also be carried out on polyamide/silk or polyamide/wool blends, using highly-basic resist pastes to destroy the protein areas of the fabric. Nowadays, manufacturers frequently combine devoré printing with direct or resist printing to obtain fabrics with extremely interesting effects. It is worth considering that the fabrics must be carefully evaluated before applying this printing method: to obtain clearly visible effects. The quantity of fibres to be removed must make up for the 50-60% of the whole fabric, while the remaining fibres must be part of both warp and weft, forming a weave structure with a adequate stability on devoré-printed areas.
There are also many other types of printing “hybrids”, which have two or more different characteristics or types of structures that cannot be referred to as printing or finishing methods:
*Flocking:* a patterned design is transferred onto a fabric using a suitable adhesive (instead of a dye); then flocks of different materials (fibres length range between 2 and 10 mm) are applied to the fabric in a manner that causes it to adhere in an upright position and produce a pile-like, velvet-textured design. The length of the fibres ranges between 2 and 10 mm and before being flocked onto the fabric, fibres pass through a gray cloth and then through a magnetic field, which sets all fibres in a vertical position. The fibres are then fixed by means of subsequent drying and polymerisation process of the adhesive; finally, unfixed fibres are removed.
*Metal foil printing:* after printing the heat-adhesive product, the fabric is covered with a film made of polyester on which a thin metal coloured layer, or a thin metal foil has been deposited. The adhesive is then polymerised at 150-170°C and after cooling down, the film, removed from the fabric, remains on some areas of the fabric. The areas where the adhesive was applied will be covered with printed designs

**Preparation of printing pastes**

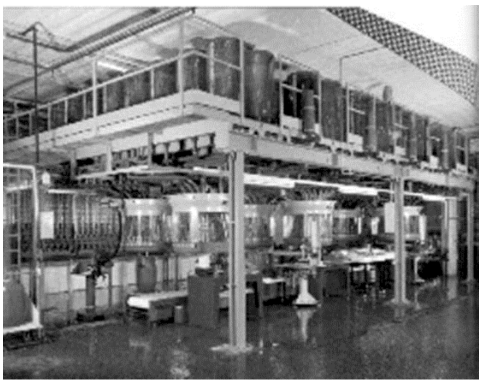
The preparation of printing pastes greatly differs from the preparation of liquors: during the dyeing process the liquor is prepared directly when used, while printing needs a different approach passing through the preparation of "master batches" and “cutting" pastes.
*Master batches* are printing pastes containing a high percentage of dye and all the necessary auxiliaries (except for specific cases where the auxiliary could alter the dye or the paste stability). Usually, for each dye class 12÷14 master batches are prepared with selected dyes so to reproduce the widest possible range of colours.
Therefore, combining the various master batches in specific quantities can reproduce any colour; the master batches will be then suitably "cut" (diluted) with the cutting paste, made of a paste containing the same auxiliaries of the master batch (with the same or lower concentration), but without the dye.

**Colour kitchens**

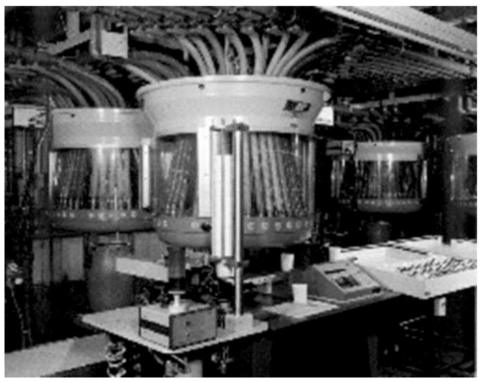
The colour kitchen can be a manual system where all the operations for preparing the thickener, weighing the dyes and the auxiliaries, dissolving and preparing of master batches and cutting pastes is manually carried out by the operators working on the colour kitchen.
This approach to work entails some problems both for health protection and results; small inaccuracies, momentary distraction of the operator as well as different ways of working of various operators can compromise the reproducibility of results.
Now many manufacturers use automatic colour kitchens both for sampling and production purposes. In these colour kitchens the various master batches and the cutting thickeners are stored in big containers from which they are automatically taken by means of pumps to be then used or to prepare the cuts. Special automatic distribution systems can reproduce the stored recipes (by recalling them by means of the keyboard) and accurately weigh, blend and mix the components.
In several colour kitchens the balance incorporating the container for preparing the pastes is placed on a trolley, which is moved automatically under the dispenser nozzle of the containers (for cutting and blending the various master batches). In other colour kitchens distribution nozzles are assembled all together above the balance. The products must be perfectly blended before use.




*Picture 78 - Scheme of a colour kitchen*



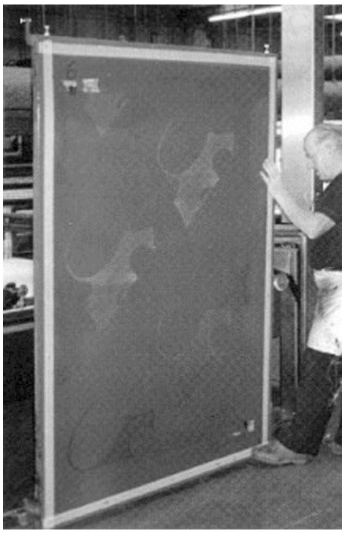
*Picture 79 - Colour kitchen used for production purposes*



*Picture 80 - Colour kitchen used for sampling purposes*

**Flat screens, cloths and hollow rollers**

The printing screen is made up of a metal frame, on which a cloth is firmly fastened in place. The cloth is usually made of single-filament or ply polyester fibre. Three screws are incorporated on one side of the screen for centering the inward-directed cavities: one of the screws touches the block on one side and is used for warp-wise motions, while the other two screws are used both for warp-wise motions and rotations. The cloth can have a bigger or smaller number of yarns per centimetre (from 40-50 to 90-100) depending on the type of fabric to be printed and on the fineness of the pattern to be reproduced.
A coating of light-sensitive emulsion is applied uniformly on the cloth; the screen is then dried with a hot-air blow (40-50°C). A film is positioned on a sensitised printing screen; the printing screen is then photoengraved by means of special lamps: the radiation starts the polymerisation reaction of the light-sensitive emulsion, which takes 120-240 seconds and makes it insoluble in water. Where the film has been blackened, radiation does not reach and does not affect the emulsion, which is not polymerised and remains soluble.
In the following washing process carried out with water, the non-polymerised emulsion dissolves, leaving the openings on the cloth open where the colour has been reproduced on the film; through these openings the printing paste will be forced onto the screen through the fabric.
After accurate inspection and manual rectification of small defects, an impermeable substance or lacquer is spread on the photoengraved cloth to enhance the resistance of the emulsion and therefore the durability of the screen. The cloth passes on a suction opening (to remove the lacquer from the cavities) and is subsequently dried.
The above mentioned operations are repeated for each colour, with as many screens as colours.




*Picture 81 – Flat printing screen* *Picture 82 – Rotary printing roller with flange*

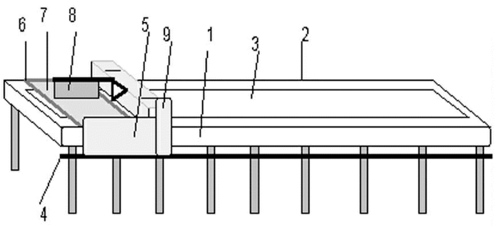
The hollow roller has been replaced with a seamless nickel-made roller (prepared for depositing by electrolysis the metal on a special die) where the printing pastes are forced through the meshes.
The number of meshes per centimetre (also known as mesh size, i.e. the size of screen or particles passed by it in terms of number of openings per linear inch in each direction), also for rollers, depends upon the type of fabric to be printed, the design, the shades and colours to be reproduced. The mesh size is generally fixed in 40-215 mesh/inch, corresponding to 15-85 mesh/cm).

In the Como district the most commonly used types of rollers have mesh sizes ranging from 125 to 185 mesh/inch, with pentagonal or hexagonal mesh and widths ranging from 160 to 200 cm.
The cylinder diameter and consequently the circumference (which determine the pattern ratio) have fixed values, which is certainly a limit for pattern reproduction (64, 86,102, 120, 240 cm.).
Costs are proportional to the width and increase rapidly as the mesh size and the circumference increase.

# Printing Machines

### Manual flat screen printing tables

These are wooden printing tables (1), with metal legs, usually 40 to 80 m long and 1 to 2 m wide; they are covered with a felt coating on which a resin cloth is laid (2) - possibly covered with a polyethylene film coated with the adhesive which causes it to adhere to the fabric and prevent the cloth from moving during the printing process (3).
An upright rail (4) is fixed on the edge of the printing table, where some blocks (5) are arranged to lock the frames, keep the pattern ratio and maintain the precise position on the table for proper registration and alignment.
The printing paste is accurately applied to the fabric, by spreading it on the cloth (7) of the screen (6), by means of squeegees (or paddles) (8).
The screen centering is obtained by means of three screws; two screws are arranged on one side of the screen in contact with the rail (they lift, lower or rotate the screen) and the remaining one is arranged on one side in contact with the block (it moves the screen lengthwise).
The squeegee is moved manually.



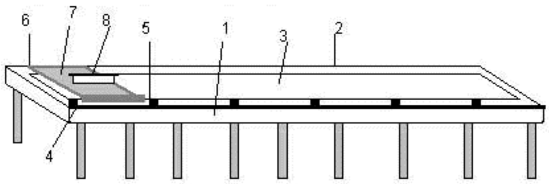

*Picture 83 - Scheme of hand screen printing table*

Nowadays, this type of printing is used only for high quality products and for small lots, or it is carried out on small tables (8-10 m.) for sampling purposes.
The material is dried directly on the printing tables (30-50° C) heated by means of resistances positioned under the cloth¸ with hot air jets (40-50° C.) directed on the printed cloths laid down on the table, or removed and hung above the printing table to air-dry.

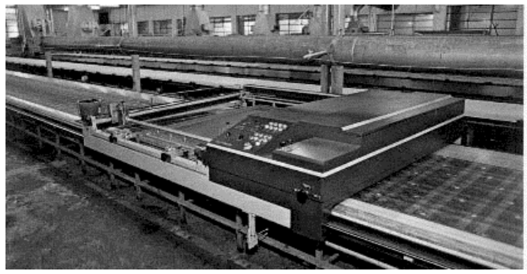
### *Flat screen printing with automatic carriage*

For this type of printing, manufacturers use 40 to 80 m long printing tables, equipped with an automatic feed carriage (5) sliding on special rails; the printing screen is fixed on the carriage (6). A special device fitted in the carriage lowers and lifts the printing screen and moves the squeegee (8); the pressure applied and the number of passages are entered by the operators.
The pattern is centered by the operator by means of the set screws of the screen or by any other device arranged on the frame of the carriage moving screen warp- and weft-wise or making it rotate.
In automatic screen printing, a pre-set amount of the appropriate colour is released on the fabric (3) which adheres to the resin-coated conveyor belt (2) of the printing table (1); the printing paste is spread uniformly on the fabric by moving the squeegee on the cloth (7) of the screen (6); after the squeegee has passed over the screen, the screen is progressively moved to the next section and lowered again to repeat the same cycle till the end of the piece.

The screen is then replaced with another one and the cloth to be printed receives the next colour; the number of screens corresponds to the number of colours.




*Picture 84 – Scheme of printing table equipped with computer-controlled carriage*

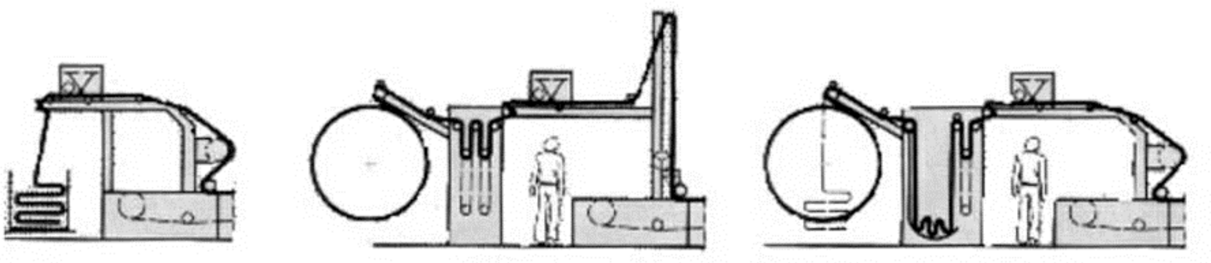


*Picture 85 – Printing table with carriage*

The motion of the carriage and of the squeegee on the printing tables can be controlled by electric motors, gears and chains or by means of a pneumatic system.
Nowadays all manufacturers have equipped their automatic carriages with a computer (9) on which the printing data are entered and stored; this computer control system allows a considerable reduction of operating times, labour, possible inaccuracies and errors, thus improving reproducibility.
The drying process is carried out on heated printing tables (30-50° C) or with hot air jets (40-50° C) directed on the printed cloths laid down on the table, or removed and hung to air-dry.
All the printing tables can be equipped with a rack to hang the printed cloth and a washing system after printing.
This printing method is used for good-quality small and medium yardages.

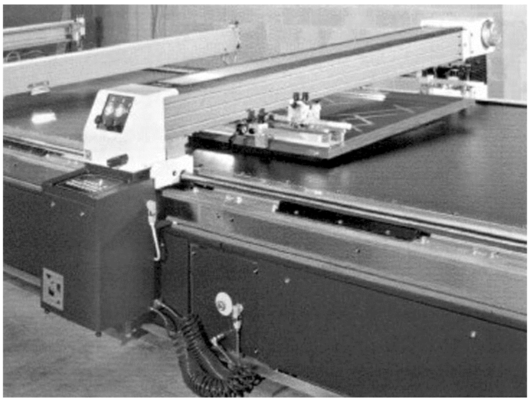
***Flat screen printing machines with rubber conveyor belt***

These machines (Picture 88) include a printing table (6) with a length ranging from 20 to 35-40 m., on which a conveyor belt (3), covered with resin-coated rubber, is progressively moved. The fabric (1) adheres to the conveyor belt, after passing through a feeding system provided with a spreader and a warp-centering and straightening unit controlled by photocells or other devices.



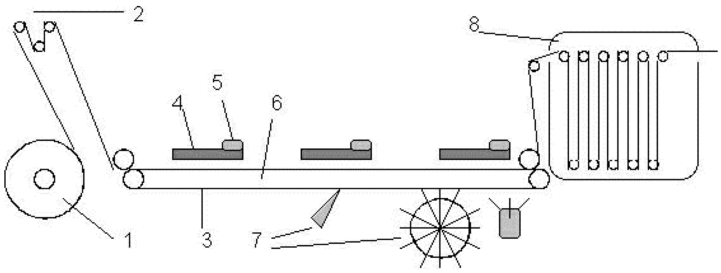
*Picture 86 - Screen printing with conveyor belt:*
*Feeding system* *a) with collecting system* *b) without collecting system*

The printing stations (4) (8, 12, 18 or more stations can be assembled on a printing system, depending upon the length of the table and the size of the screens) are arranged on the conveyor belt; the screens are fixed on the printing stations. Each printing station is equipped with a keyboard for setting and adjusting the printing data (5). Each time the conveyor belt stops, the screens simultaneously lower, the squeegees pass over the cloth (in line with the data entered by the operator), spread the dye, lift up and move to the next section.

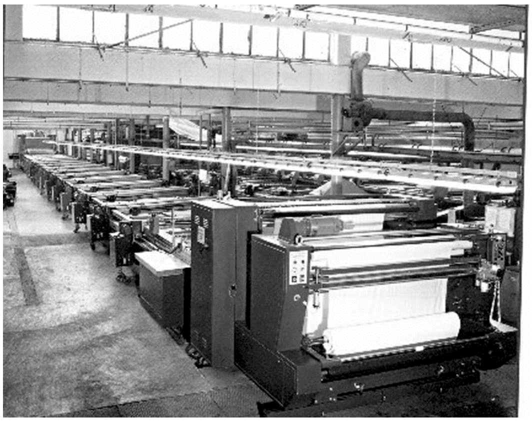


*Picture 87 a) Bridge printing station b) Gantry printing station*

The fabric, once reached the end of the printing table (engraved with the whole pattern design), is removed from the conveyor belt and fed into the synchronised drying loft at the printing speed (8). The conveyor belt, washed with water jets and rotary brushes and then dried (7), passes under the printing table and is ready to be used for another printing cycle.




*Picture 88 - Scheme of a printing machine with conveyor belt*

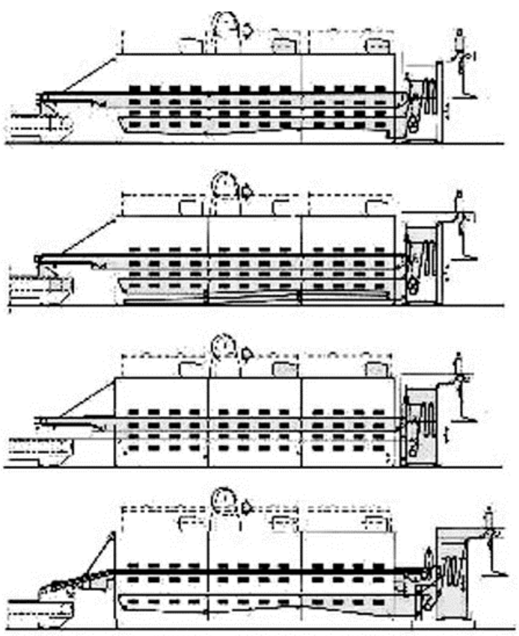


*Picture 89 – Conveyor belt washing*

*Picture 90 – Screen printing machine with conveyor belt*

The main advantages of this system, compared to the screen printing carried out with automatic carriages, is an improved output rate since all colours can be printed in one run allowing high throughput rates (maximum output ranges between 400-500 m/h). Also the printing quality is inversely proportional to the operating speed. The adjustments to be carried out before printing are time-consuming since the printing stations must be moved progressively and carefully to the other sections or to the successive patterns.
In case of new designs or possible modifications, the printing stations must be carefully centered and adjusted to be aligned with the centering recesses.

Furthermore, the screens must be removed, washed and assembled again on the printing system.
The drying process is carried out in a drying loft, i.e. inside a circulating-hot air continuous drier, positioned at the end of the printing machine. The drier operating speed is synchronised with the average printing rate. The air blow can be adjusted at a temperature ranging from 80 to 150-160°C, in order to dry, polymerise (pigment printing) or carbonise the fibres (devoré printing).



1- Three-run drying with hot air (the fabric lays in the conveyor belt during the first drying run).

2- Same as 1, but with 5 runs for polymerisation.

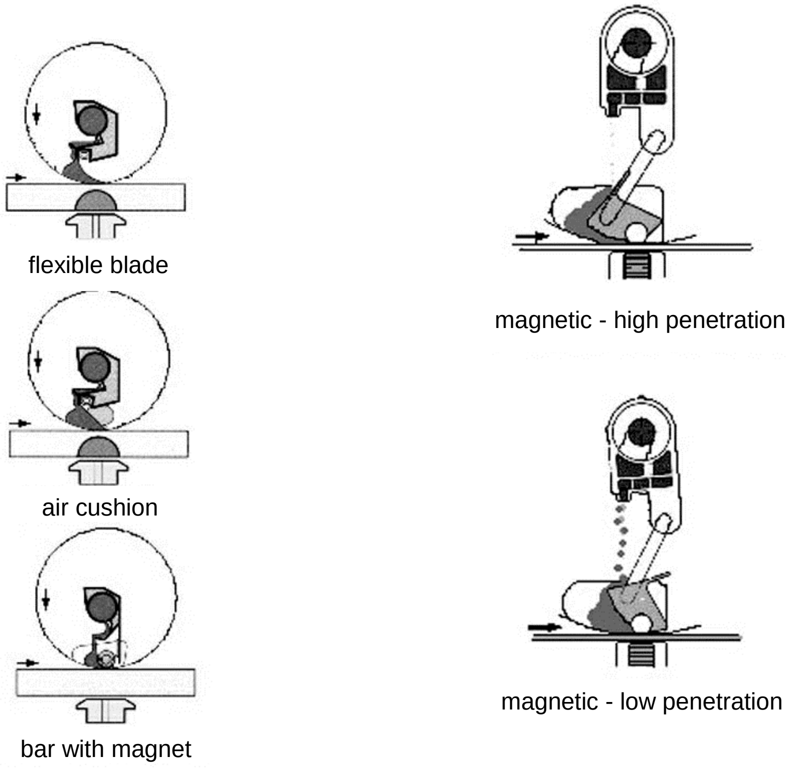
3- One single run with blown air

4- Transfer with pin chains for delicate fabrics and feed-through printing

*Picture 91 - Drying lofts for manually operated machines and rotary systems*

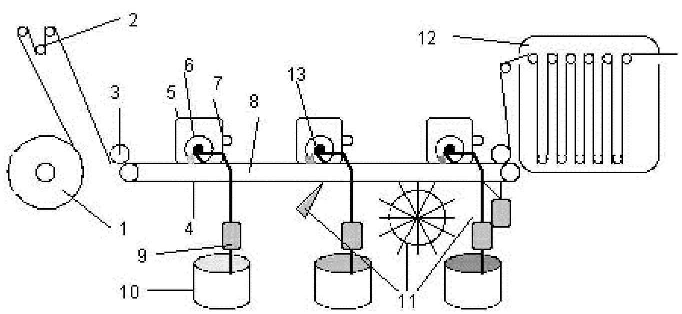
***Flat-bed rotary printing machine (with hollow rollers)***

This machine is used for large and medium yardages, of medium-good quality fabrics.
The machine (Picture 93) employs an endless conveyor belt (4) made of resin-coated rubber on which the piece of fabric (1) adheres, after passing through a spreader and a warp straightening unit controlled by photocells (2).
The printing stations (5) are arranged along the whole length of the conveyor belt (min. 8, max 12-16 printing stations depending upon on the length of the printing table and the manufacturer’s need), on which are assembled the engraved rollers (6).
The doctor knife (13) (different models are available depending on the machine manufacturers) is introduced inside the photoengraved roller together with the feed unit (9) of the printing paste, which is fed by the distributor (10).

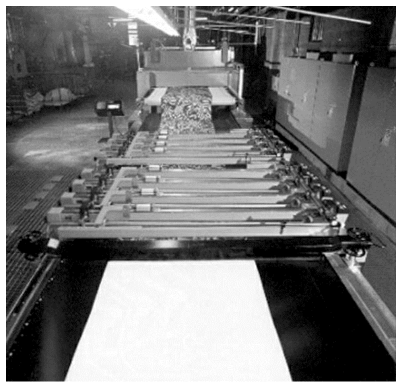



*Picture 92 - Different types of doctor knives*

The rollers drop the printing paste on the fabric sliding underneath and the printing stations, arranged at a multiple distance from the succeeding section (usually at a distance of 64 cm.), reproduce the designed pattern.
At the end of the table the fabric is removed from the conveyor belt and fed into the drying loft (12); the conveyor belt (11), washed with water jets and rotary brushes and then dried (7), passes under the printing table and is ready to be used for another printing cycle.




*Picture 93 - Scheme of a rotary printing machine*



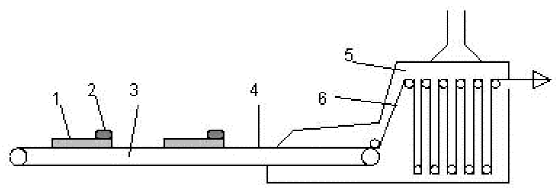
*Picture 94 - Picture of a rotary printing machine*

The main advantages concern the output rate; in fact the non-stop process allows an average operating speed ranging between 30-60 m/min, and maximum operating rates ranging between 100-110 m/min. The complex setup and the amortisation costs of older machine models limit their use to large printing runs; on the contrary, the most recent machines can be used for manufacturing cost-effective medium or small printing batches thanks to a quick setup of the design and a fast roller washing (to be carried out upon each colour change for every printing). Anyway the quality is inversely proportional to the machine speed.

The use of roller printing machines is limited by the design ratio: usually roller printing machines incorporate cylinders with a circumference of 64 cm, and therefore the design ratio is the same of the circumference or of one of its submultiples (32, 16, 8). Now many manufacturers supply cylinders with different circumferences such as for example 101.8 and 120.6 cm, with widths ranging from 1.6 to 3.2 m (the width depends upon the machine model); some machines incorporate 240 cm-circumference cylinders, featuring a width of 320 cm.
Some manufacturers also supply combined machines with both rollers and screens.

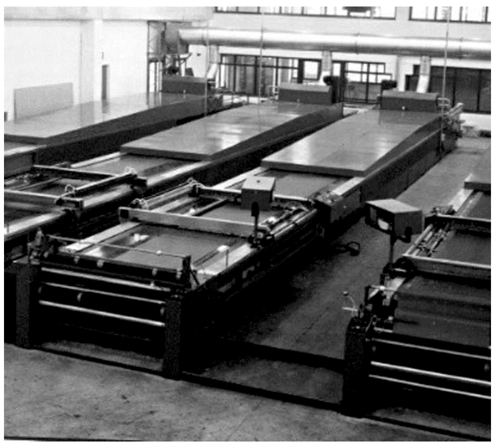
### *Rotary-table printing machines*

This machine has a variable-length table (from 10 to 40 m). A conveyor belt made of resin-coated rubber slides on this table. The length of the conveyor belt ranges from 20 to 80 m., according to the machine structure and model; a piece of fabric of the same length adheres to the conveyor belt.
1 or 2 printing stations equipped with screens (and/or rollers) are arranged along the conveyor belt. On one end of the conveyor belt a circulating hot-air drying loft dries the fabric partially at each fabric run. When the head of the fabric comes back to the printing stations, new screens (or rollers) are arranged on the table and the operation is repeated at each run for all the colours thus making up the entire patterned design. After the last run, the fabric is removed from the conveyor belt to be dried thoroughly, the conveyor belt is carefully washed and a new printing cycle can be started.




*1- Printing stations (screen or roller printing systems)*
*2- Keyboard for data input*
*3- Table*
*4- Resin-coated conveyor belt*
*5- Drying loft*
*6- Path of the fabrics at the end of the printing process*

*Picture 95 - Rotary table scheme*



*Picture 96 - Rotary table*

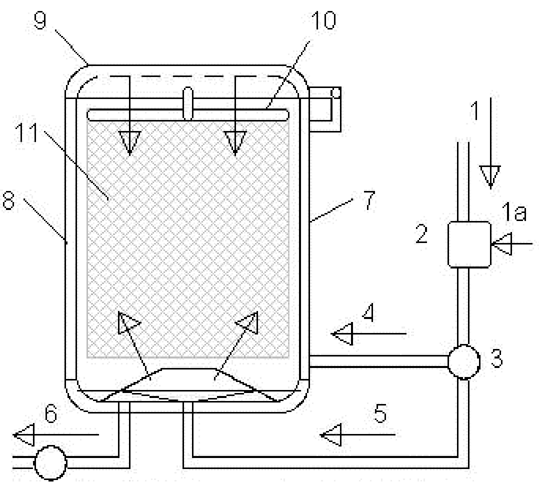
The operating mode of this machine is partly similar to the rotary system, and partly to manually-operated machines and screen printing systems; it is used for high-quality small/medium lots or for samplings for rotary and/or manually-operated printing systems.
In the printing field very few mechanical innovations have been introduced in these last years; anyway, small mechanical improvements and the coming up of electronics have allowed excellent quality results also on machines with high output rates. Furthermore these improvements have remarkably cut stand-by times, labour costs and energy, water and auxiliaries consumption.
Here are some examples:
- Conveyor belt washing system with water recycling.
- Automatic synchronisation of printing speed and drying speed by means of inverter controlled by special processors.
- Automatic adjustment of the exhaust units of the drying lofts to maintain the best drying conditions.

- Holding systems to maintain the roller or screen centering, which must be adjusted in case of a slight shifting of the conveyor belt (±0,03 mm accuracy).
- Synchronisation of the roller speed with the one of the conveyor belt; it can be slightly modified depending on the fabric.
- Automatic transfer progressively moving to successive stations on manually operated machines controlled by a computer.
- Storage of all the printing options for the different patterns and colours (ratio, travel, speed, pressure and inclination of the doctor knife or squeegee etc.).
- Feed distribution of the printing paste in the various sections of the roller, depending upon the printing paste consumption.
- Roller washing carried out directly on the machine (in 8-10 minutes) to change the print.
- Roller machines allowing removing and assembling the rollers with the doctor knives when design is changed, with a remarkable reduction of operating times.

## Steaming Machines

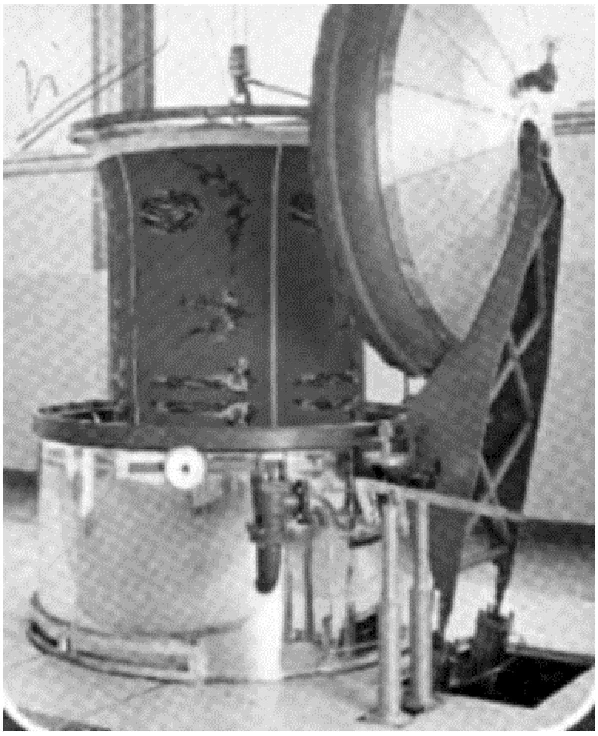
*Static steaming machine (star-type)*

This steaming machine is the oldest steaming system. It consists of a cylindrical heater with a jacket to allow the steam to be blown from the top and the bottom of the cylinder (the steam heats the walls avoiding the formation of drops of condensation). The cover is sealed hermetically to allow the machine to operate under pressure.
The fabric is firmly hung by its selvages and is fixed to a special backing cloth (Bengaline). The whole is wound on a star-shaped carrier by means of hook-shaped pins. The carrier with the fabric are loaded into the heater; steam is then forced into the heater removing the air from it. The cover is then closed and the pressure is kept constant by introducing or extracting the steam. Once the steaming process has been carried out, the cover is opened, the carrier is unloaded and the fabric is removed.




| | |
|---|---|
| 1. Steam feeding system – | 1st moistur. water |
| 2. Saturator | 3. Steam feeding setting. |
| 4. Steam from the top | 5. Steam from the bottom |
| 6. Steam exhaust | 7. Steaming machine body |
| 8. Jacket | 9. Sealed cover |
| 10. Star | 11. Fabric + Bengaline |

*Picture 97 – Drawing of a static steaming machine*

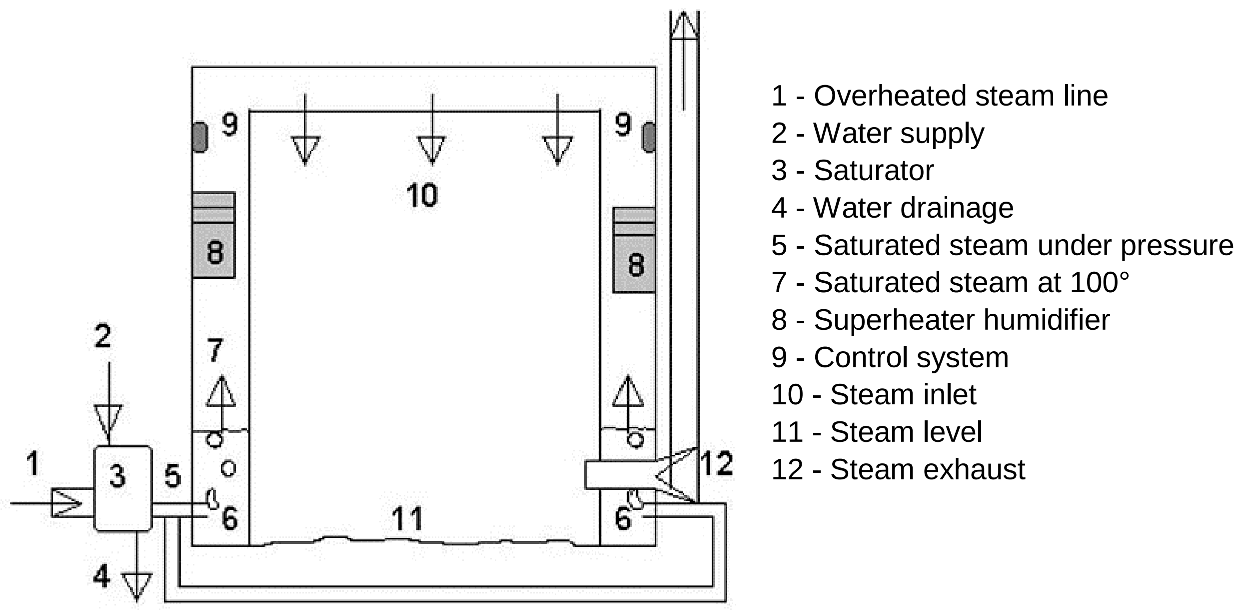


*Picture 98 – A static steaming machine*

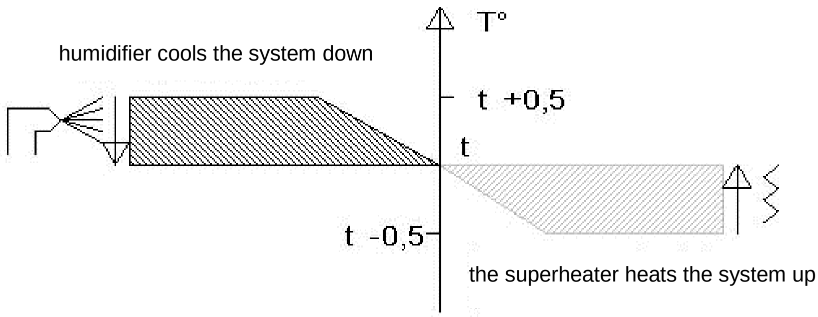
Due to the poor steam exchange, this system is not suitable for discharge printed fabrics. On the contrary, it gives excellent results with synthetic fibres since it allows working at temperatures ranging between 130 and 135°C and pressures of 1.8 bar (i.e. with dry saturated steam and high temperature). This system gives a good colour rendering but possible head-tail defects (when forced incorrectly, the steam stratifies at different temperatures and with different moisture contents; therefore print dyes are fixed more consistently in the lower end of the fabric).
This system is now rarely used since only small lots can be treated (max. 400 m long cloths are treated in 10-60 minutes) and many operators are required, thus entailing high costs.

*Continuous steaming machine*

It is made up of a parallelepiped-shaped container (recent systems have closed bottoms while old ones were opened at the bottom) with double-wall structure preventing external heat transmission.
In the lower part of the jackets, the steam, coming from the boiler and passing through the saturator, is caused to expand and boil in water. In this way, the saturated steam at atmospheric pressure raises and heats the walls and the ceiling of the jackets (preventing condensation drops from forming and dripping onto the fabrics, as a result avoiding possible defects). The steam lowers from the top of the steaming machine through the ceiling openings, drives the air away (air is heavier than steam) and fills the steaming machine.
The equipment to control moisture and temperature of the steam feeding the steaming machine is positioned in the jackets; the real-time control devices work interactively and start immediately some spray-water humidifiers, each one is cascade-connected with superheaters also assembled in the jackets. Thanks to this system all the variables can be controlled in real-time (the temperature difference allowed is ±0,5°C of preset values, and steam density between 96 and 98%). If necessary, the steam can be heated at temperatures of 170-180° C at atmospheric pressure passing through the jackets.

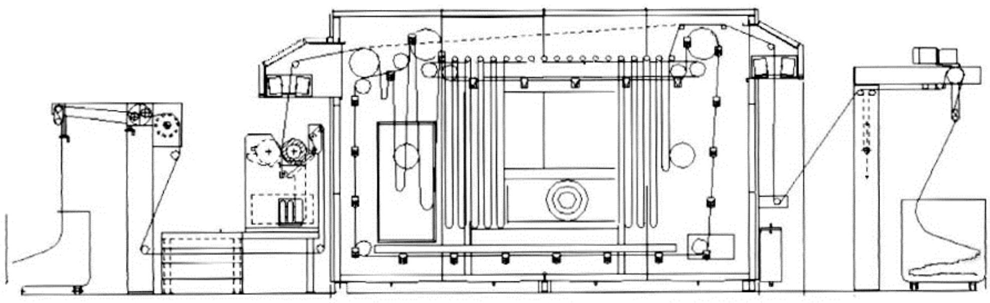



*Picture 99 – Drawing of a continuous steaming machine*




*Picture 100 – Temperature control*

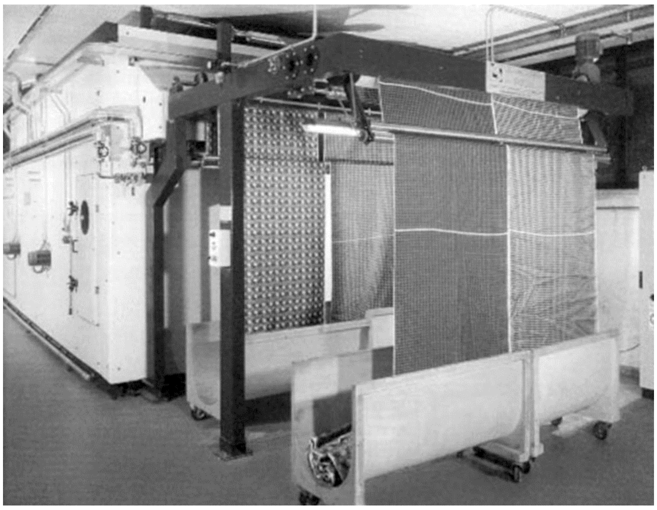
The fabric passes through the steaming machine folded on sticks; the sticks rotate all along the path and change the contact point with the fabric continuously to prevent any fixation defects in contacting points. Furthermore the fabric, by effect of the rotation of support sticks, constantly changes its position to reduce the formation of defects due to possible steam stratification. The steam exchange is carried out by means of one or more exhausters. At the end of the path, the fabric gets out of the steaming machine, while the sticks pass in the lower part of the machine and grip another piece of fabric at the entry of the steaming machine. Special inlet and outlet devices, together with a slight pressurisation, prevent the air from entering (max. O2 allowed = 0.3/1000 volume).



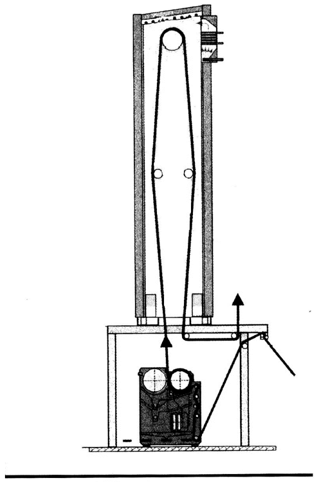
*Picture 101 – Drawing of a steaming machine (the fabric moves in pieces or on sticks)*

Continuous process allows a better output capacity and a reduced number of operators; the costs are therefore lower than the static steaming machine ones. It can be used for all kinds of print, by opportunely changing the operating conditions, and gives better results above all in discharge printing since it allows the removal of decomposition gases generated by reducing agents and a better temperature control, thanks to the huge exchange of steam.
For this purpose all the steaming machines built in those last years have closed bottoms; this gives a better control of process variables (temperature, pressure, moisture, oxygen, steam circulation and exchange) and allows the creation of a slight pressurisation to prevent oxygen from entering.
The operating speed depends upon the quantity of fabric in the steaming machine (number and length of the fabric pieces), upon its width (it is possible to steam two fabrics simultaneously) and upon the time necessary for fixing the dyes; these values also determine the steam requirement and exchange.
To offer the customers a wide variety of steaming machines, builders have designed models in different structures and sizes, equipped with special devices to control the moisture of the fabric

fed into the machine (water atomisers), the steam fed into and extracted from the machine, as well as all the other process variables.
Some continuous machines for folded pieces can also be used for quick steaming cycles (from 1 to 2 min,) by moving the fabric on the sticks; in this case it could be useful to use flash steaming machines with short fabric paths.



*Picture 102 - Continuous steaming machine*



*Picture 103 - Flash steaming machine*

## Washing Machines for Printed Fabrics

After printing and steaming, the pieces have a rough hand due to the use of thickeners and the colour shade is not the final one.
The washing process aims at removing the thickening agents, all the chemical auxiliaries and the unfixed dye remained in the thickener or passed into the fabric.
If correctly carried out, the washing process can enhance the colour brightness to obtain the maximum fastness for both fibres and dyes and offset the fabric tensions.
Obviously the washing process must not affect the fabric (felting or other negative alterations of the fibres, change of dimensional stability etc.), as well as the printed patterns (undesired colours must not affect white or unprinted fabric section or areas printed with light colours, while the dyes removed with the washing process must not affect the colour shade).
To obtain the desired results a powerful washing is not sufficient: dissolving dyes (conditions similar to the dyeing process) do not fix on fabric sections printed with different colours, do not dye or bleed on white areas.
That’s why it is crucial to select the right

- washing machine
- conditions
- auxiliaries

bearing in mind that the results obtained are also the outcome of all the upstream operations.

To optimise the washing of printed fabrics, an accurate evaluation of all the process steps is also fundamental; we can point out three basic different but overlapping steps:

| *Step* | *What happens* | *What makes the operation easier* | *Measures to be taken before washing* |
|---|---|---|---|
| **1** | reimbibition and thickener swelling | - quick and high absorption of the liquor<br>- presence of wetting agent<br>- contact time | - type and quantity of thickener<br>- thickener stability to steaming |
| **2** | release, dissolving, removal of thickener and dye | - mechanical action<br>- squeezing<br>- suction<br>- water exchange | - quantity and type of thickener<br>- dye fixation degree |
| **3** | exchange, dilution, dispersion of unfixed dye | - temperature<br>- detergent<br>- dispersing agent<br>- time<br>- dye<br>- Alkali+reducing agent | Dye selection |

**Step 1:**
The thickener film, touching the washing liquor, rehydrates, swells and progressively reduces its viscosity. At the same time, water solubilises or dissolves part of the dye remained in the thickener, and, penetrating the fibre, starts solubilising the unfixed dye.
The presence of a suitable wetting agent in the washing liquor and the possibility to direct powerful jets and liquor atomised mist on the fabric, accelerates the wetting step, while a correct contact time of the material with the dye facilitates this step; the thickener swelling completes the dye dissolving.

**Step 2:**
Once the correct viscosity degree has been achieved, by effect of the powerful action of water jets, vibration, squeezing and/or suction, most of the thickener dissolves along with the dye and the auxiliaries inside it.
Simultaneously, part of the dye remaining on the surface of the fibre or dispersed inside, but unfixed, dissolves or diffuses in the liquor.
During this step the dye reaches its maximum concentration in the washing liquor (which becomes very similar to a dyeing liquor); it is therefore extremely important to work at low temperatures to avoid conditions that could facilitate the dispersion of the dye in the fibres; the washing liquor should be quickly withdrawn from contact with the fabric to protect white background tones.
These first washing steps are crucial since they can lead to the elimination of more than 80% of thickener and unfixed dye but it is fundamental to work at low temperatures and avoid continuous and protracted contact of the fabric with the liquor. This grants an optimum protection of white backgrounds also during subsequent hot washings; the dye eliminated through a cold process will affect the fabric in subsequent hot treatments.

**Step 3:**

At this point it is fundamental to eliminate the remaining 15-20% of thickener still fixing to fibres and to restore the fabric's original hand; is also crucial to eliminate simultaneously the dye, which has not suitably fixed to the fibres and obtain the maximum fastness to liquids and rubbing.
For natural fibres it is suitable to operate at the highest temperatures allowed by the various fibres (which obviously depend upon the material to be processed); an appropriate dwelling period for the fabric before the powerful hot washing stage, facilitates the swelling and the dissolution of the thickener blocked in the fabric and the elimination (by diffusion) from the fibres of the dye which passes to the diluted liquor solution. The low concentration of dye (if the two first steps are carried out correctly), the high temperatures reducing their affinity level as well as the use of suitable dissolving agents and detergents, protects the white backgrounds of the fabrics from being affected. For synthetic fibres and particularly for polyesters printed with dissolving agents, the dye on the surface is destroyed by means of reducing alkaline liquors at 70-80°C, always with a suitable dissolving agents. The most part of the dye contained in the thickener should be eliminated during the first and the second step; in fact, to destroy the dye not fixed on the fibre or remaining on the surface it is necessary to continuously add alkali and the reducing agent (these continuous additions could be excessive due to the presence of the dye remained from the previous steps). At this point the fabric goes through a hot soaping treatment.

**Step 4:**

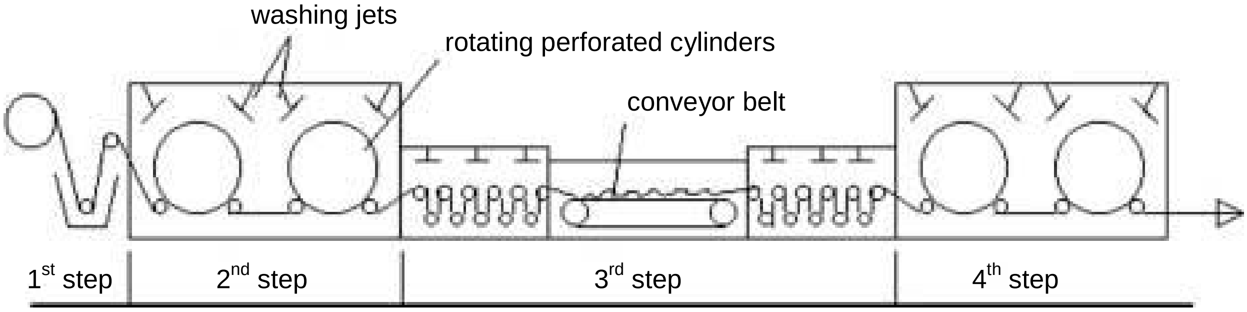
Rinsing and/or neutralisation.

The second step includes the choice of the most suitable washing machine.

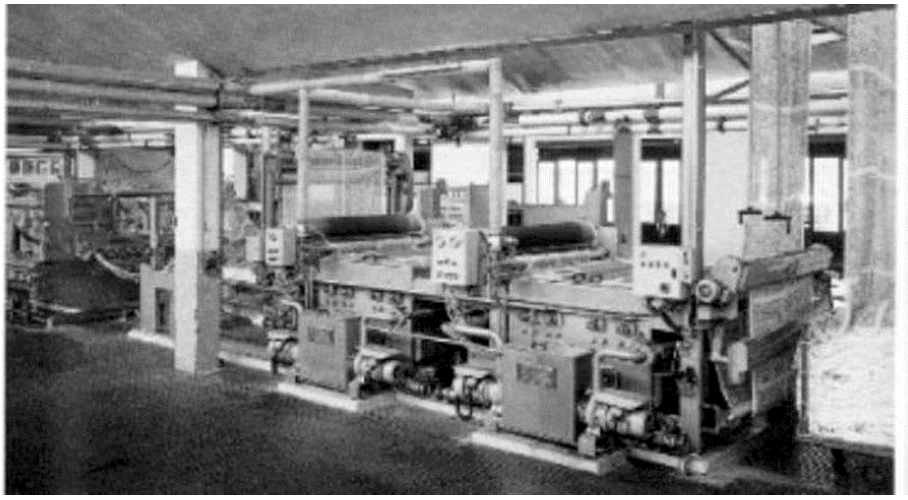
Washing can be carried out:
- with an overflow system (rarely) or in winch machines (rope discontinuous washing which can ensure good final results, cost efficiency and high output, must be evaluated for each specific conditions).
- in winch machines equipped with various vats (continuous rope washing), or continuous washing units: this kind of washing can grant high output and cost efficiency but often the quality is really poor).
- in continuous open-width washing units for printed fabrics.

The washing process is often considered a real bottleneck in the finishing cycle but a reduction of the washing times will certainly lead to poor results (inevitably entailing a further washing stage with the resulting loss of time, increase of costs, delivery delays and possible fabric damage).
These machines are designed for washing printed material and are equipped with all possible systems to avoid the most common problems (duplications, contamination of background colours, etc.).

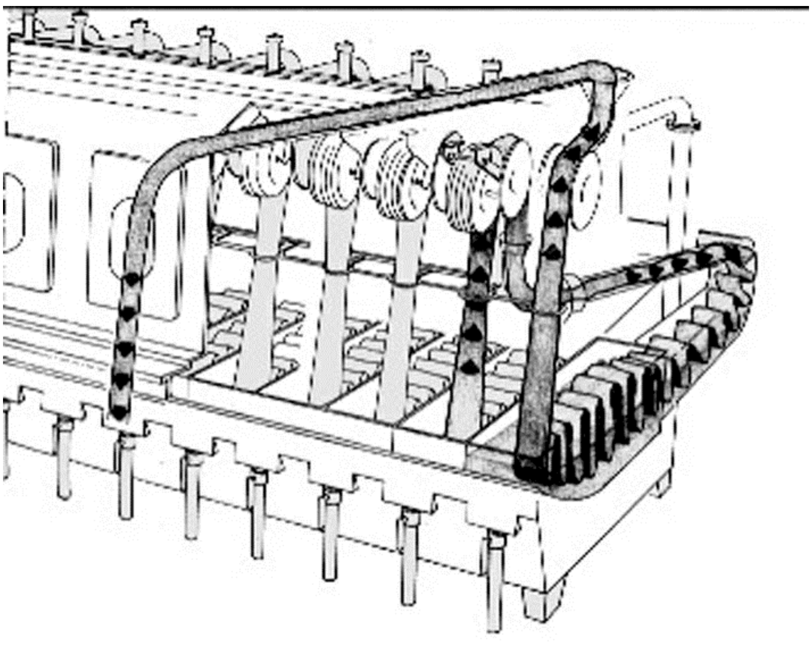
The most successful systems are continuous open-width machines; they assure the best washing results. In recent times, combined machines (with an open-width washing section and a rope washing section) ensure excellent washing results and also optimum hand for some types of fabrics.




*Picture 104 - Drawing of a continuous open-width washing range*

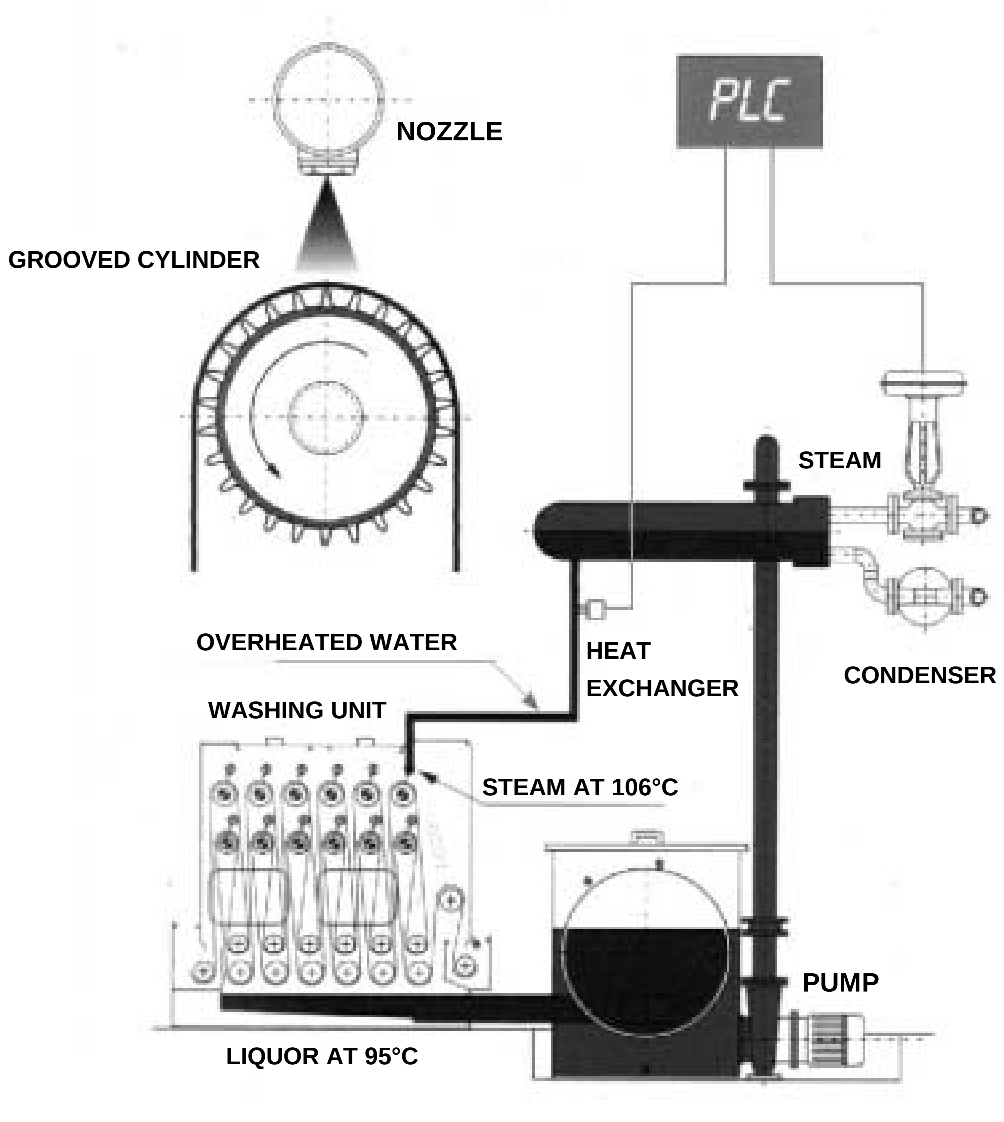


*Picture 105 - Continuous open-width washing range*



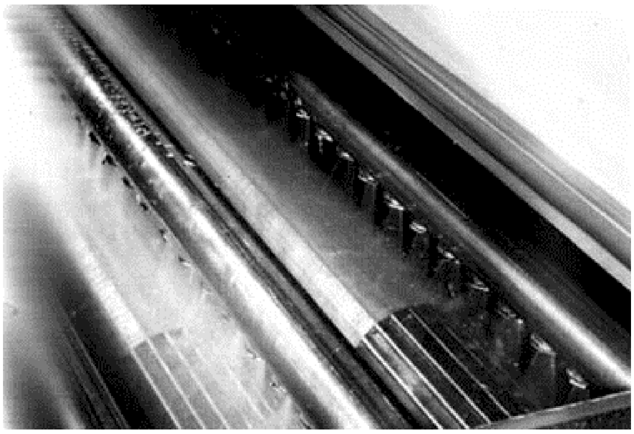
*Picture 106 - Continuous rope washing range*

A new-concept continuous open-width system is particularly interesting. Particularly suitable for washing reactive printed fabrics, thanks to its versatility this method can also be used for washing reactive dyed fabrics or for preparation treatments (desizing).
Picture 107 shows the diagram of a treatment until the fabric, thanks to a vertical double-positioning system, is exposed on both sides to the powerful washing action of the overheated liquor. The complete and quick removal of soluble products and dissolved solid residues is performed by the action of the bath (with high kinetic and thermal energy, at 105°C) sprayed by water jets nozzles assembled on the whole width above the upper grooved cylinders (Picture 109); the shape of the grooved cylinders directs the washing liquor laterally and forces it powerfully through the fabric.
The washing system operates with a reverse flow of the liquor (counterflow washing) on more washing units; in each unit the washing liquor is filtered before being fed to the superheater by the pumps.
A PLC (displaying the parameters on a special screen) controls, regulates and monitors every process.




*Picture 107 – Scheme of a washing unit with upper grooved cylinder.*

*Picture 108 – Detail of the washing unit*

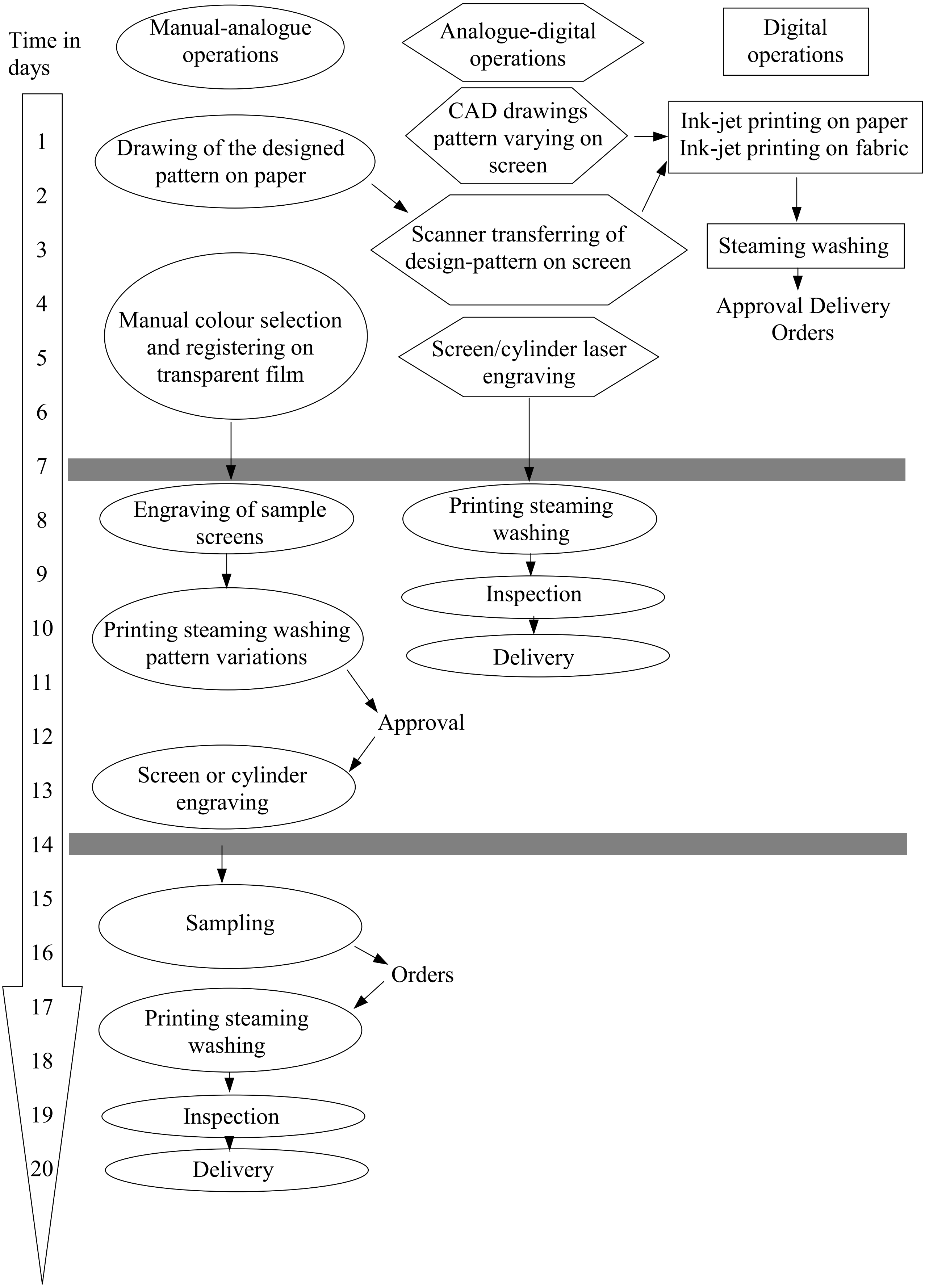


*Picture 109 – Detail of the spraying nozzles*

An accurate dimensioning of the system associated with a correct setup grants an optimum degree of reliability in terms of results, thus keeping water consumption low and the output rate good.
Thorough control and suitable choice carried out during previous steps also allows considerable reduction of polluting wastewater.

The selection of the right washing auxiliaries is another crucial step: a good wetting agent can accelerate the rewetting phase of the thickener thus facilitating its elimination in cold processing conditions and in relatively short times.
Since the elimination of the thickener and of the dye can be carried out completely in cold processing conditions, high temperatures can be used only in the subsequent steps of the process.
These conditions cause a dangerous increase of the fixing speed of dyes, which could entail the possibility of affecting white backgrounds.
Suitable anionic-nonionic or nonionic detergents-dissolving agents can bind to the dye, stabilising it as a solution or dispersion, also in relatively high concentrations.
This allows a good and smooth protection of white backgrounds. Another important feature is the foam creation: a low foaming ability avoids or reduces the use of anti-foaming agents, with the consequent benefits.
To conclude, washing conditions strictly depend upon the type of printed fabric, the type of fibre and applied dyes.

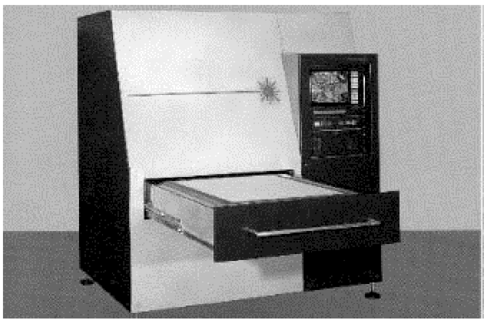
## Developments in Screen and Cylinder Engraving Techniques and in Textile Printing



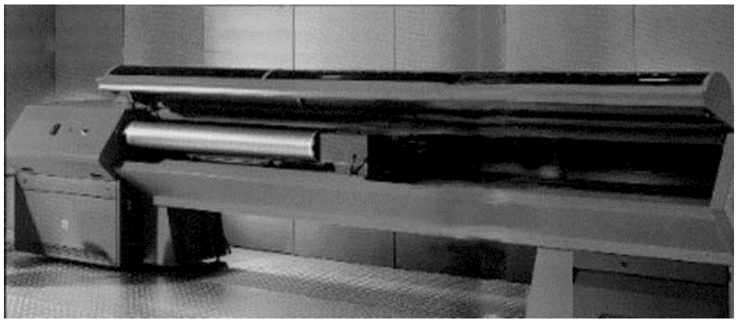
The traditional engraving of print screens and cylinders is carried out with the following operations:

- drawings are sketched on paper (manual operation);
- colours are selected and a transparent polyester film is prepared for each colour to be printed and the (continuous) design is registered (the operations are carried out by hand and/or by photolithographic process);
- small panels are engraved for fabric pattern grades;
- colour grades are printed on fabric with sample screens, and then steamed and washed;
- the customer approves the design and pattern varying;
- the screens or cylinders are engraved (traditional photoengraving with photosensitive gels and transparent films);
- sample printing, steaming and washing;
- production fabric printing.

For more than a decade, designs (sketched directly with a computer or scanned and eventually modified) have been digitally reproduced by means of CAD stations. With digital images and dedicated programs, registering operations and colour selection (transparent films are created/stored on a computer) the process has been considerably shortened and simplified. Furthermore thanks to the possibility of manipulating drawings on a computer and reproducing them in the form of transparent films, every pattern variant can be made directly on the screen (with an extremely quick operation) or printed on paper and submitted for customer's approval (unfortunately colours are reproduced almost roughly and the fabric cannot be really touched, but the operation is carried out in a few minutes).
Now printing times and (partially) costs have further reduced thanks to the latest innovative technologies such as powerful lasers, investment casting and, recently, cold laser (which directly engraves cylinders or flat screens).



*Picture 110 – Laser engraving of a screen*



*Picture 111 – Laser engraving of a cylinder*

However, it is still necessary to engrave panels and cylinders to print the final design on fabric and submit it for the customer's approval: these operations need time to be carried out and this the fashion sector cannot stand. Also basic costs for making and storing panels (some designs will never be sold) make this system particularly expensive and difficult for printing today's most required small yardages.
An important step forward to partially solving these problems has been made with ink-jet printing techniques.

## Ink-jet Printing

Today, the digital printing technology allows printing fabrics, in particular silk, and cotton fabrics (purposely prepared) but also other substrates, with good quality results for some types of design patterns. For the time being this system is used to prepare samples and small (and possibly customised) lots. Short times are undoubtedly the main advantage for choosing this printing method: in 2-3 hours it is possible to pass from pattern to print with speeds ranging from 1 to 3-4 m per hour.

**The principle of digital printing**

In digital printing, small droplets of dyes, in aqueous solution, are sprayed on the fabric to reproduce the pattern. The viscosity of the solutions is low and therefore, to strictly keep the pattern profiles (this problem originates from the capillarity of textile material) and allow a good definition of the pattern, the fabric must be prepared with a special pad-wetting process with thickeners and auxiliaries (typical of traditional printing) and then dried.

The printing operation will be followed by a steaming process (to fix the dye) and washing, like traditional printing.

Digital printing has several advantages if compared to traditional printing systems: no costs to produce screens, rollers or other printing equipment (production costs range approximately from 210 to 230-520 euro per colour), and the possibility of printing patterns in a few hours (not days or weeks) in all the desired colour variants. Furthermore, limited yardages do not excessively increase costs and patterns can always be slightly modified or customised. For environmental protection and cost reasons, it is also worth considering that this system applies controlled quantities of dyes, thickeners and auxiliaries, avoiding printing paste residues (usually excessive when prepared with traditional printing methods) and their consequent disposal.

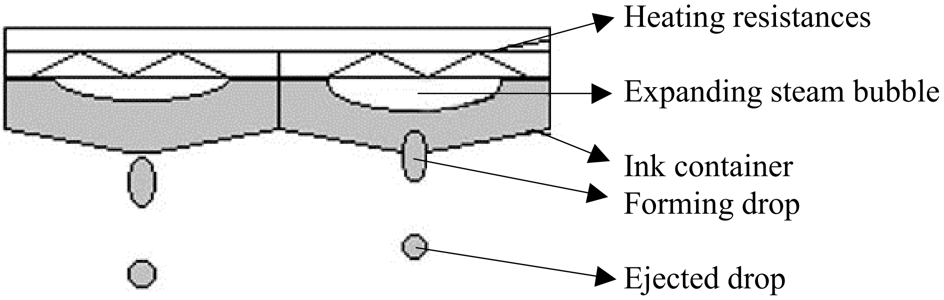
An inconvenience due to ink-jet printing is the low output efficiency and difficult reproducibility (by changing program or printer), the reduction of the colour space and above all the poor penetration of the dye onto the fabric, with evident discrepancies between the two sides of the fabric. All these problems make this printing system suitable for specific uses.

**Drop-spraying techniques**

The Drop-on-Demand technique, i.e. the direct application of a drop of dye on the fabric is the most diffused digital printing technique applied to the textile field. In particular, the nozzle technique used to spray the drop of dye determines the size of the drop itself, the spraying frequency, the accuracy, the evenness and partly also costs and reliability related to the machine. The type of nozzle used also influences the choice of dyes/inks used. *Thermal nozzle (HP Technology, Bubble-jet):* a small quantity of dye in aqueous solution is heated at 300-400°C inside a small container. The steam bubble created causes the drop of ink to be forced through the nozzle and adhere to the fabric, while the quick cooling of the ink creates a concentration of dry ink particles and an immediate stop of the drop. A very high jet frequency can be obtained with this system.

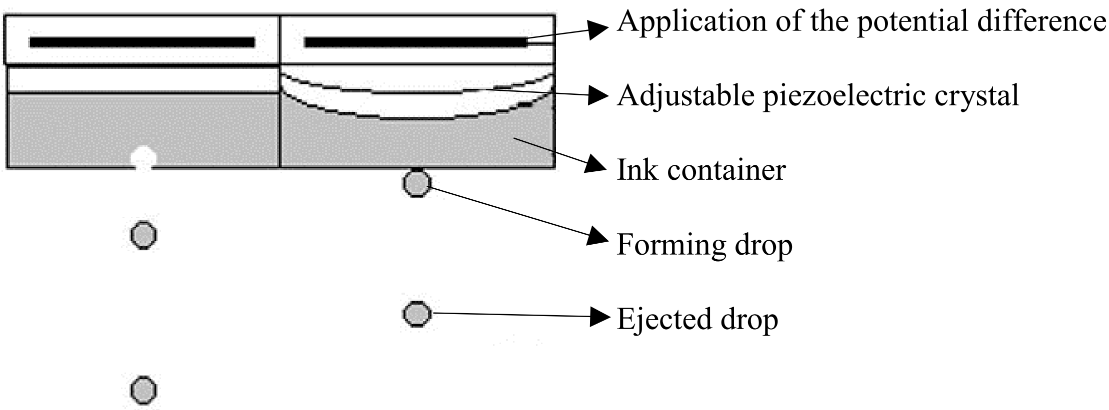
This technique makes it possible to use plates with a very high number of nozzles at quite low cost but one of the problems lies in the application of special inks that can be used at high temperatures.

Furthermore the nozzles can be subjected to continuous and quite rapid deterioration due to deposits (originating from the decomposition of dyes and/or precipitation of salts) produced by high temperatures in the steaming unit. We can briefly conclude by saying that this technique is scarcely reliable due to the colour variations connected with deterioration, and also because when a single nozzle does not efficiently work in a printing head featuring a very high number of nozzles (even though a single nozzle is quite inexpensive) the whole printing head must be replaced thus entailing process interruptions and higher costs.




*Picture 112 – Heated nozzle system*

*Piezoelectric nozzle (Epson, Canon, Roland, Mimaki etc. technology):* this technique is essentially that of ejecting drops of ink contained in a small unit by effect of the deformation of a crystal subjected to the action of an electric field. This technique is more precise and reliable that the previous one because crystals are much more strong and hard-wearing than resistances and also because the system reliability remarkably improves thanks to the elimination of the deposit problem; furthermore less sophisticated (and therefore less expensive) dyes/inks can be applied with this system. This technique makes it possible to vary the size of the dye/ink drop by varying the intensity of the electric field. It is still impossible to use plates (printing heads) featuring a very high number of nozzles, and each head is much more expensive than the previous ones.



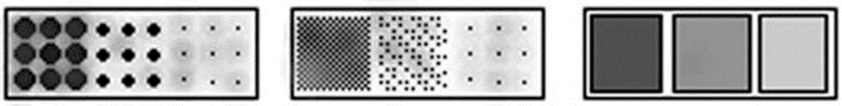

*Picture 113 – Piezoelectric nozzle system*

**The Process printing technique**

This system essentially reproduces design patterns by means of a technique similar to digital printing (dietering): by using four (four-colour printing with 4 printing heads) or seven colours (seven-colour printing with 7 printing heads) and by mixing and/or spreading on the fabric dye drops of different colours (this step is controlled completely by special software) different shades can be accurately reproduced. The intensity can be adjusted:

- VDS Process (Variable Dot Size by analogue modulation): the drop size determines the intensity of the colour shade.
- FDS Process (Fixed Dot Size by digital modulation): the number of drops per surface unit determines the intensity of the colour shade.

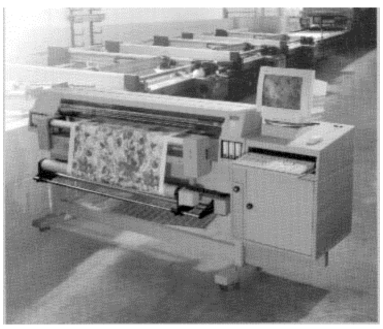
This system allows (by using 4 or 7 standard colours and the same number of plates with nozzles) a quite easy reproduction of a wide coloured area, but creates problems in reproducing patterns with backgrounds in pastel shades (marked dotting, poorly uniform backgrounds), and very unsatisfactory penetration of pastel colours (poorer quantity of liquid ink). Some problem could arise also for the combination of shades and light colours. It is worth considering that the manufacturers of these printing systems are always more oriented towards nozzles granting more and more sharply defined printing (1200-2000 dots per inch), with always smaller droplets: this is an excellent technique for paper printing but not for textile printing, since very high definitions are not necessary and cause reliability problems (nozzles with very small holes which often clog), poor penetration and slow printing.

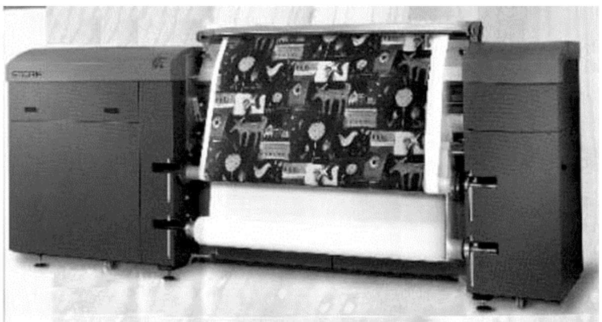


*Process VDS* *Process FDS* *Spot*

**Spot printing technique**

The colours to be reproduced are prepared by mixing master batches (similarly to traditional printing) and suitably diluted (a special colour kitchen must be set up). Therefore it would be necessary to use as many inks as the colours of the pattern and as many printing heads as the colours. This technique allows the printing of the fabric with the same number (maximum number) of ink drops per surface unit, by eliminating dotting problems, unevenness and enhancing the penetration in design patterns with background in pastel colours. Obviously patterns with a huge number of colours cannot be reproduced (each colour must have its corresponding printing head and an excessive number of printing heads would make the printer less reliable). This makes the printing process very difficult and requires using a special colour kitchen, and washing the printing heads at every pattern varying, thus causing time losses and serious problems for nozzles, particularly for piezoelectric nozzles (drop ejecting holes with diameters of 10-12 micron).





*Picture 114/115 - Pictures of ink-jet printers*