TEXTILE DYEING, PRINTING AND FINISHING

Textile Finishing:

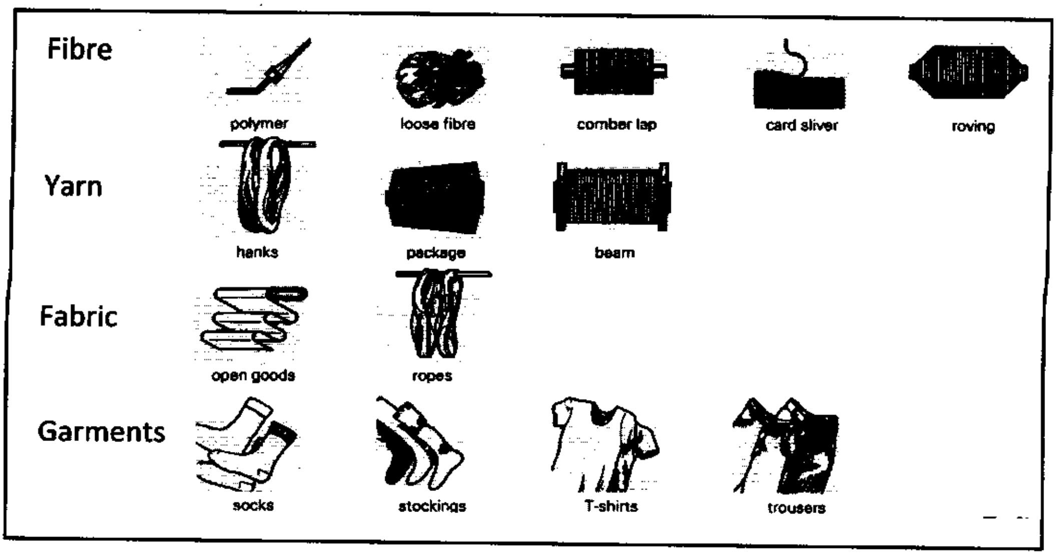
Textile finishing comprises all fabric processes, which are not included in fibre production, yarn production, and fabric formation. Finishing effectively means to improve or to beautify the material.

Importance of Textile Finishing:

Normally a raw fabric direct from the weaver or knitter cannot be used as such to make consumer products; various processes are required before it is suitable. For example, various substances, such as sizes or lubricants may have been added to the yarns as part of the manufacturing process. These, together with any soiling must be removed and faults may have to be rectified. An important function of the finishing is to enhance the appearance of fabrics by colouration, pressing, embossing, etc. Another aspect is to impart to the textile properties, which it would not normally possess; its handle and drape can be modified and it can be given better easy-care performance. The question of environmental conservation has a large impact on the finishing sector. Liquors used for colouration and finishing cannot be discharged to waste without some purification. The same is true of discharge gasses, such as solvent vapours.

Finishing at different stages in Textile production:

Finishing is most efficiently carried out on fabrics. However, there are times when a finishing process must be performed at some other stage. For example, in order to make colour-woven fabrics, either the loose fibre or the yarns must be coloured.



Preparatory Process or Pre-dyeing Treatments:

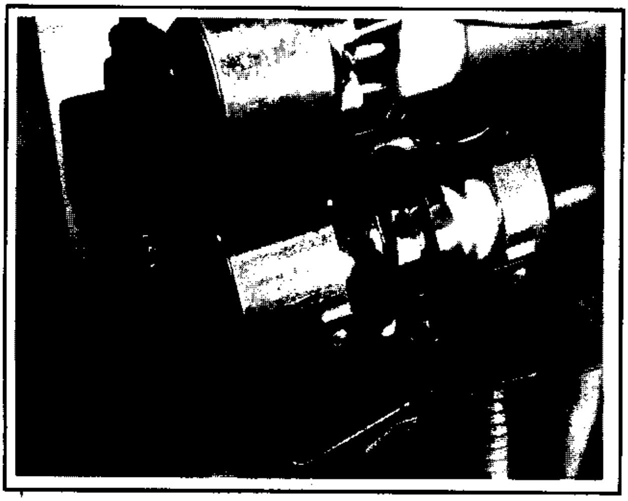
Preparation or the pre-dyeing stage includes a series of operations that prepare the textile product for subsequent finishing treatments such as dyeing, printing, and finishing. Any processing aids which may have been applied during spinning, weaving, or knitting must be removed. These might be spinning oils, waxes, sizes, etc. Any natural or adventitious contaminants must also be removed so that the fabric has the required purity for the following processes. Thorough preparation is a prerequisite for good results at the finishing.

These operations vary according to the type of fibre on which they have to be carried out, to the structure of the textile product (staple, top, sliver, yarn, fabric) and also depend on the subsequent treatments to be carried out, which may change according to various factors such as market demands, customer requirements, staff experience, and availability of machines.

The pre-dyeing stage includes for example desizing, singeing, mercerizing, scouring, and bleaching. Each process varies according to the processing conditions and the above-mentioned specific situations. Some of these processes (for example bleaching and mercerizing) can be considered either preliminary operations or finishing treatments; this depends on the type of the downstream processes to be carried out on yarns or fabrics.

Waxing

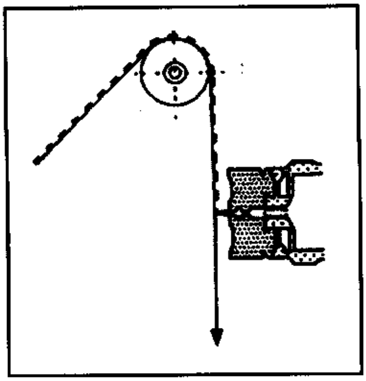
Waxing serves to lubricate the yarn, reducing to a minimum its coefficient of friction with the parts with which it comes into contact. This operation is normally carried out on yarns destined to be processed on knitwear machines, on which smooth running of yarns is essential.

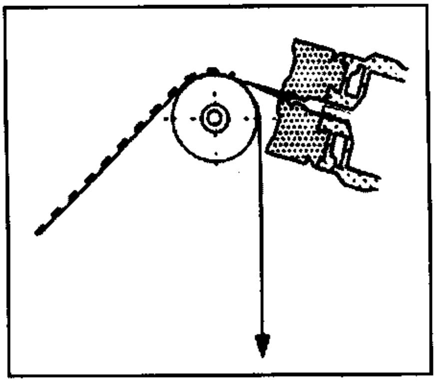


Waxing is carried out on the winding machine, which is equipped with a positive-drive adjustable waxing system that guarantees constant waxing of the yarn; there is also control device that stops the machine should the wax run out.

Singeing:

With this treatment fuzz and fibre ends are burnt off in order highlight the fabric weave. It is generally carried out on gray pieces and the residues are removed by a further washing process. An oxidizing flame, which does not leave any trace of sooty residue on fibres, is used to carry out this operation.


Fabric singeing with perpendicular flame


Fabric singeing with tangential flame

The flame can be perpendicular to the fabric, and only rarely tangential; the fabric is positioned at a distance of 1.5 to 4mm from the end of the flame and the machine is equipped with a suction device under the fabric, which attracts the flame and concentrates the heat on the fabric. The fabric speed can range from 60 to 120 metres per minute. The singeing process with perpendicular flame is the most common one, while the process with tangential flame is used for fine fabrics (light singeing).

Singeing is carried out rarely on knitted fabrics and frequently on yarns and woven fabrics. Instead of the traditional singeing process, it is possible to apply an enzymatic treatment (for cotton and lyocell fabrics), for example with cellulose, which uses chemical agents to corrode the fibre surface and remove the fuzz from the fabric.

Normally singeing is done to those knitted fabrics which will be mercerized later. A typical singeing machine has a detwisting unit, two types of brushes, eight gas burners, a cigger, felt rollers and other necessary units like suction duct, feed and delivery rollers etc. The fabric is singeing in tubular form and on face side only. The detwisting unit removes twist during fabric feeding in machine. Between two types of brushes one is heavy brush and another one is light brush. The brushes raise the hairy fibres. The cigger can be extended in circumference and by this it opens the tubular fabric in full circumference. In this state the eight burners situated at 2cm apart from all sides of fabric surface burn the hairy fibres. The fabric is passed through the fire ring about 70 to 80 m/min. This is a gas singeing machine.

Singeing is also done at yarn stage. For the yarn singeing it is an operation carried out in order to eliminate yarn hairiness. The singeing system consists of a package-to-package winder and a gas burner. The yarn is passed through the flame, which singes the protruding fibres that cause the hairiness. It runs at a rate of 400 to 1000 m/min. The machine must, in order to obtain even singeing, maintain a constant yarn speed and an even flame.

The singeing system, in addition to normal machine control devices, also has a fly fibre evacuation system and a flame temperature control system. Since this operation reduces the weight of the yarn, even by as much as 5-6 %, the yarn count will also be modified, and this must be borne in mind when designing the yarn.

Desizing:

This treatment is carried out on woven fabrics to remove the sizing substance from the warp. The size must be totally eliminated since the fabric must absorb the liquor of subsequent processes homogeneously.

Since amylaceous sizes are generally used for cotton yarns, it is possible to apply amylolytic enzymes (enzymatic desizing), which carry out a biological degradation process of the starch, transforming it into soluble by-products which can be then eliminated by washing. The enzymatic process depends on the quantity of enzyme molecules per gram of fabric, while the thermal stability of the enzyme depends on the bacteria strain from which it originates. The amylases only react with starch molecules and do not affect the other glucose polymer (cellulose), since they attack the 1.4 alpha-glucoside bond of starch and not the 1.4 beta-glucoside bond of cellulose.

This reaction makes the use of amylases profitable (when applying starchy sizes) compared to other desizing agents such as alkali and oxidizing agents (oxidizing desizing), which attack both starch and cellulose.

The oxidizing desizing process is used to remove non-starchy sizes that do not dissolve in water or to eliminate starchy sizes combined with polyvinyl alcohol (this treatment is carried out before the singeing process). This last treatment requires accurately controlled operating conditions to solubilise only sizes and avoid any possible fibre degradation. Enzymatic desizing can be carried out in discontinuous systems (jigger) but semi-continuous or continuous techniques are more frequent after the pad-batch wetting of the fabric. The most frequently used processes are pad-roll and pad-steam. If the size is water-soluble, it can be eliminated by hot washing.

Scouring:

On cotton fibres, this treatment removes fatty and pectic substances, softening motes and preparing the material to absorb the subsequent treatment agents. Scouring is usually carried out in soft water additivated with textile auxiliaries such as absorbing agents, detergents, emulsifying agents, caustic soda and/or Solvay lye and sequestering agents. Alkali makes the fibre swell and enhance the action of surfactants. This treatment can be carried out on filaments, yarns and fabrics.

Instead of the traditional scouring process, it is also possible to carry out an enzymatic scouring process (bioscouring) to remove non-cellulosic material from cotton fibres, to make them more easily wettable and enhance the subsequent absorption of finishing liquors.

The scouting process applied to synthetic fibres removes oils, lubricants and anti-static substances, dust, contaminants and can be carried out on yarns and fabrics (when warp yarns have been bonded, the treatment is called debonding). It is carried out by means of surfactants, detergents and emulsifying agents.

Scouring is usually carried out by means of continuous or discontinuous systems, with the same machines used for downstream treatments; temperature, processing time, p^H, concentration of reagents, depend on the fibre and on the machine used. Incomplete scouring processes usually originate dyeing and printing defects due to different degrees of wettability and to inconsistent affinity for dyes of the material.

Bleaching:

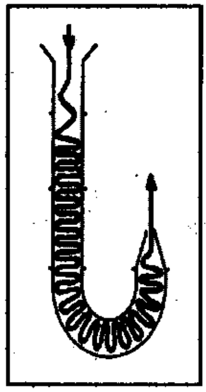
Bleaching treatments are applied to eliminate any impurity and obtain a pure white tone, to prepare substrates for low-density dyes or prints and to level off undesired tone variations. Bleaching agents mainly used for cellulosic fibres are sodium hypochlorite and hydrogen peroxide. They both require the addition of sodium hydroxide in the bleaching liquor to make it alkaline it by favouring the formation of the bleaching ion, which in the first case is the hypochlorite ion and in the second one is the perhydroxyl ion.

When using hypochlorite the p^H must range between 9 and 11 and the temperature must not exceed 30^0C. In fact, as far as the p^H is concerned, p^H values below 4 give rise to the formation of chlorine while p^H values ranging between 4 and 9 give rise to the formation of hypochlorous acid: these chemical substances affect the fibre negatively and do not perform a bleaching action. After the bleaching with hypochlorite it is necessary to carry out an antichlor treatment. Fibres must be treated with hydrogen peroxide, which completely removes the chlorine and avoids the formation of chloramines, which, in drying machines, could generate HCl dangerous for cellulose. With hydrogen peroxide, in the presence of alkali, little motes can be eliminated and the autoclave scouring can therefore be avoided. The optimum temperature ranges between 80^0 and 90^0 C and the p^H between 10.7 and 10.9. Hydrogen peroxide at a concentration of 1 – 2 vol can be used also for silk after degumming, with a p^H of 8 – 9, at 70^0 – 80^0 C for 1 – 2 hours.

From an environmental point of view, hydrogen peroxide is more suitable than hypochlorite since it has a lower impact on the environment and effluents can be decontaminated with simpler operations. It is recommended to add sequestering agents to the bleaching liquors. Another bleaching agent used in textile processing is sodium chloride (suitable for synthetic fibres) that takes advantage of the oxidizing action of chlorine dioxide generated as a result of the hot acidification of the solution of this salt. Unfortunately, chlorine dioxide is a toxic substance and attacks stainless steels; therefore it is necessary to work in hermetically closed units equipped with suction systems with resistant materials such as stoneware.

Bleaching operations can be carried out on yarns, woven fabrics and knitted fabrics with continuous and discontinuous process in circulating liquor machines (autoclaves, jigger, paddle wheel, jet, overflow), semi-continuous (pad-batch, pad-roll). Continuous bleaching can be carried out on knitted fabrics using a J- box. The products to be used on the fabric are applied by means of suitably positioned mangles; the fabric is introduced in the machine where it remains for the time necessary to complete the bleaching process.

Temperature, speed, pressure and p^H are controlled automatically. It is also possible to carry out optical bleaching using substances that do not perform a chemical action on the fibre but obtain a whitening effect by means of an optical compensation process of physical nature. These substances release a blue light compensating white and grey, and giving a dazzling white effect. For example an optical bleaching on wool can be carried out after chemical bleaching, using 0.2 – 0.6 g/l optical bleaching agent at p^H 4 – 5 for acetic acid, at a temperature of 50^0 - 60^0 C for 30 minutes.



J - box

Mercerising:

This is a typical treatment for cotton yarns and fabrics, which improves the fabric luster and wettability, ensures a covering effect for dead cotton, improves dimensional stability and dyeing efficiency.

This treatment is carried out using caustic soda, which determines the contraction and swelling of the fibres; they become translucent and increase their tensile strength, but reduce their flexural and torsion strength. The bean-like section of the fibre becomes first elliptic and then circular, allowing a better reflection of light with a consequent increase of luster. The treatment is usually carried out under tension, with caustic soda at 28^0 – 30^0 Be(bom)' (approx. 270 – 330 g/l). If the concentration is lower than 24^0 Be'(bom), the treatment is called causticization and aims at enhancing the dyeing liquor penetration into the fabric.

The liquor temperature usually ranges between 15 – 20^0C and its uniform absorption is assured by adding mercerizing wetting agents stable in alkaline environment. Once the operation has been carried out, alkalinity must immediately be neutralized by means of a diluted acid solution. From a chemical point of view, alkalicellulose is the first material to form; the next material, which forms after repeatedly water washing is hydrocellulose, which is more reactive than natural cellulose.

Cotton wetting entails shrinkage of the material, which must be kept under tension, to avoid a fuzzy and woolen appearance. Mercerising is carried out on yarns, fabrics or open or tubular knits. As far as yarns are concerned, before the mercerizing process in special machines, they undergo a singeing treatment to remove the fuzz and end fibres - which could otherwise prevent the perfect reflection of light after mercerizing. There are two different types of machines to be used for woven fabrics: a chain system and a cylinder system.

Chain mercerizing: with the chain mercerizing process the fibres achieve perfect brightness thanks to optimum tension control. This system runs slowly and allows no flexibility when the width of the fabric varies.

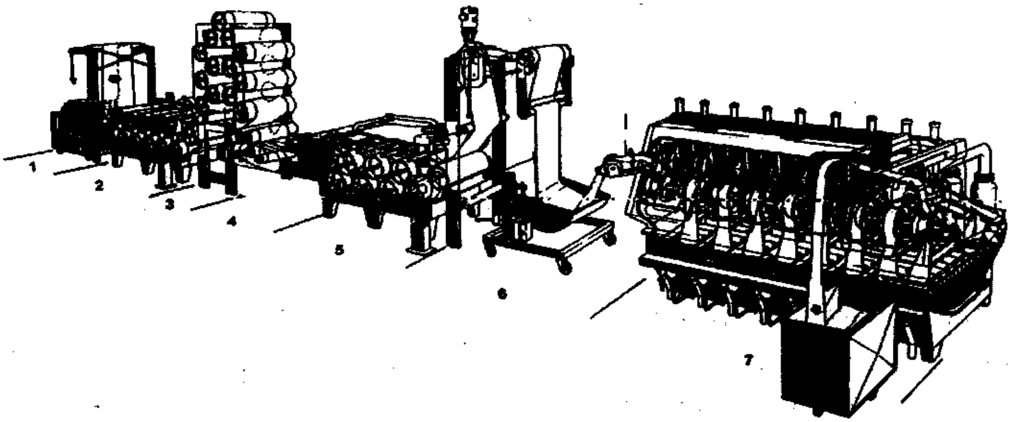
Cylinder mercerizing: this is a more compact and faster system compared to the previous one; cylinder mercerizing does not allow the contraction of the warp because the fabric is drawn in on the cylinders. The contraction of the filling yarns is also prevented thanks to the tension produced by the simultaneous action of the cylinders and of the fabric wetting. Cylinder mercerizing machines are also used for flat knits.

Mercerising process can also be carried out on tubular knitted goods: after the wetting process, the fabric is left reacting in a padding mangle. The withdrawal of the fabric width is controlled by means of an adjustable ring spreader while the withdrawal of the fabric length is controlled by "slowing down" the fabric before the final squeezing. The sodium hydroxide concentration is brought down to approximately 4^0 Be' by means of a circular shower. The fabric is then washed, neutralized and rinsed.

A typical mercerizing process for tubular knitted fabric as follows. The mercerizing machine has a detwisting unit, a water trough, a sodium hydroxide liquor trough, swelling unit, four washing units and a neutralizing unit. The detwisting unit removes twist from fabric during feeding. In water trough required water is supplied for caustic. In sodium hydroxide trough required amount of caustic is come from a central reservoir. The central reservoir store caustic at particular concentration. There is also a chiller which maintains the caustic temperature. The swelling unit has some dancing rollers which control the fabric tension. After swelling unit the fabric enters into first washing unit and then second washing unit. Each washing unit has cigger which extends the fabric circumference as washing can be done very well. The cigger widths are kept same for first and fourth and same for second and third. But the temperatures are kept different for the all four washing units. Before entering third and fourth washing units the fabric is passed through neutralization padder. Here acetic acid is used and impregnation temperature is kept 70°C.

Another well-proven mercerizing agent is liquid ammonia, which has to be applied for very short times (about half a second). There are very few systems based on liquid ammonia due to the difficulties connected to the use of liquid NH_3.

Engineers have recently developed continuous mercerizing cycles and machines for combined mercerizing and bleaching process.



1-Entry, 2-Wetting with sodium hydroxide, 3-Exposing, 4-Spreader, 5-Stabiliser, 6-Exit, 7-Neutralisation and bleaching.

Continuous mercerizing and bleaching system for tubular knitted fabrics

Heat Setting

This operation is crucial for fabrics made of synthetic fibres (PE, PA, elastomers), for triacetate, and partly for PAC fibres (setting), since it grants excellent dimensional stabilisation and creaseproof properties, maintained till the fabric is exposed (by air blowing) to temperatures exceeding the heat setting one (after being treated with water at a temperature above the second order glass transition temperature, i.e. 80-85°C for acrylics).

Heat setting is carried out on gray fabrics (scarcely applied), on scoured fabrics (frequently applied) and on dyed fabrics (scarcely applied). The process grants excellent dimensional stability and good crease-proof properties. As far as operating conditions are concerned, the fabric must be treated in accurately controlled moisture and temperature conditions.

Fibre	Min T. °C	Max. T. °C	Time (in seconds)
Polyester (PE)	170	210	15 – 5o
Polyamide PA 6.6	170	210	15 – 40
Polyamide PA 6	160	180	15 – 40
Triacetate	160	180	15 – 40
Acrylic (PAC)	160	180 – 200	15 – 40
Elastomers	170	180 – 200	15 - 40

Machines used: stenters.

Fluctuating temperatures inside the stenter cause a consistent variation of crystallinity in the fibre structure, which leads to different affinity for dyes. The moisture in the fibre produces soft hand, but variable moisture percentages in the different fabric sections create the above mentioned defect (variable crystallinity). Too low temperatures do not allow a good setting while too high temperatures and too long setting times cause yellowing (PA and elastic fibres), stiff hand (acrylics), and loss of elasticity (elastic fibres).

The presence of combustion gas (NOx) produces a yellowing of the elastomers. The heat setting process carried out before scouring could fix the stains on the fabric or make the scouring process more difficult due to the modification of the lubricating products (cracking with emission of polluting gas). Heat setting after dyeing could lead to the sublimation of disperse dyes (if not accurately selected).

Decortication (only for polyester)

This treatment is aimed at providing a silky-smooth hand to polyester fabrics (till a few years ago this process was also used to obtain microfilaments by increasing the fibre fineness), a lustrous effect and an enhanced drapability. The best results can be obtained with fabrics produced with coarser yarns.

The open-width decortication process can be carried out on jiggers or beam dyeing machines; rope decortication is performed on jet or overflow systems (batch systems). Decortication is carried out after scouring and heat setting; it is better to carry out a heat setting treatment also after the decortication process.

Operating conditions applied: the process is carried out at a temperature varying from 90-95°C to 120-130 °C for 20-35 minutes, with 30-50 g/l of NaOH 36°Bé. Once the process has been completed, the fabric is washed and neutralised. Processes and machines used: open-width process on jiggers or beam dyeing machines (batch systems) or special tensionless open-width continuous machines.

Elastic Fabrics

For elastic fibres, treatments depend on the chemical composition, which can be extremely variable. As far as the fabrics containing segmented polyurethane fibres are concerned, the suggested treatments to be carried out are the following:

- relaxation
- heat setting
- scouring
- bleaching/dyeing/printing
- finishing

Relaxation: Before carrying out any further treatment, it is recommended to relax woven or knitted goods to obtain a uniform shrinkage and avoid stitch distortion or fabric deformation, creases or wrinkles. The fabric relaxation is a crucial step to allow good shrinkage and give excellent elasticity since the fabric width on looms is always bigger than the finished one (tensioned yarns on the loom). Many techniques are used but here are some of the most frequently used ones: table steaming, steaming carried out at the entry of the stenter, scouring carried out with hot solvents, relaxation in hot water with tensionless scouring; these techniques give poorer stabilisation results and do not provide permanent crease resistance to textiles and fabrics.

Heat setting: This process is crucial to give the fabric an optimum dimensional stability. It is recommended to carry out a heat setting treatment before any further wet treatment in order to avoid the formation of possible creases and folds. An optimum heat setting requires a temperature ranging between 180°-200°C, which must be maintained constant for at least 45 minutes. An optimum heat setting also requires the use of an indirect-air heating stenter, allowing more uniform temperatures and no-gas conditions, which could lead to fibre yellowing. The fabric is weighed at the entry of the stenter and then subjected to steaming. Since the fabric shrinks during the heat setting treatment, the fabric width on the stenter must exceed the desired width by 5-10%. An excessive heat setting could decolorise the fabric while an insufficient heat setting will result in poor fabric stability.

Scouring: It is necessary to carefully consider the characteristics of the fibre combined with the polyurethane elastomer.

Bleaching: This treatment is carried out using sodium hydrosulphite; a suitable optical bleaching agent can also be added.

Washing

Rinsing and washing are the operations carried out most frequently during a complete textile finishing cycle. They are almost always connected to key treatments and aimed at removing from the fabric insoluble matters, matters already in solution or an emulsion of other impurities. During the fabric preparation process, for example, washing is carried out after desizing, boiling and other bleaching and mercerising processes; in dyeing, the washing stage is necessary to complete the dyeing process itself or to eliminate the dyestuff which has not been fixed; during the printing stage, washing performs a finishing action. When using vat dyes or disperse dyes, the washing process aims at removing insoluble pigment substances from the fibre surface by means of wetting or dissolving agents.

This could therefore be considered a crucial treatment in the whole textile process, because of the frequent use and strong economic impact. Manufacturers increasingly focus their attention on reducing water consumption, which leads to subsequent energy and hot water saving as well as a reduction in wastewater. Together with traditional washing systems with vats equipped with "vertical cylinders" the market offers horizontal washing units, which reduce the liquor ratio and the energy and water consumption for each kilogram of washed material. Washing includes a chemical-physical process, which removes the dirt from the substrate, and a series of physical operations aiming at improving the "feedback action".

The sequence of the various washing steps is the following:

a. formation of the detergent liquor (transfer of matter + energy by mixing);
b. reaching of the process temperature and wetting (transfer of the liquor to the material);

c. separation of impurities and emulsification (transfer of matter from one step to the other);
d. removal of the liquor from the fibre (transfer of macroscopic matter);
e. drying (interstage transfer of heat and matter).

Often these steps occur simultaneously. The use of surfactants (detergents) during the washing stage is extremely important to speed up the wetting of the textile material, to facilitate the removal of dirt from the substrate, thus keeping the emulsion inside the liquor and preventing the particles laying down again on the fibre. Crucial factors are water (which must be quite soft to avoid precipitation of Ca and Mg salts which could give a rough and coarse hand to the textile) and chemical products to be used (emulsifying agents, softening agents and surfactants).

Contaminants to be eliminated

Obviously the use of detergents, as well as operating conditions, depends on the nature of the chemical substances to be eliminated, which need to be generally classified. A general classification is shown here below:

I) Spinning oils: We must distinguish between fabrics made with yarns spun from combed or carded fibres, which are extremely different in terms of quantity (5 and 1 % respectively) and the nature of the substances added: as far as nature is concerned, the substances most frequently used are in both cases synthetic or mineral oils. These oils are usually made selfemulsifiable by means of suitable additives (materials must always be accurately evaluated since a wide range or products and prices are now available on the market); olein can be used for woollens (oleic acid) while for worsteds a good alternative can be represented by vegetal oils;

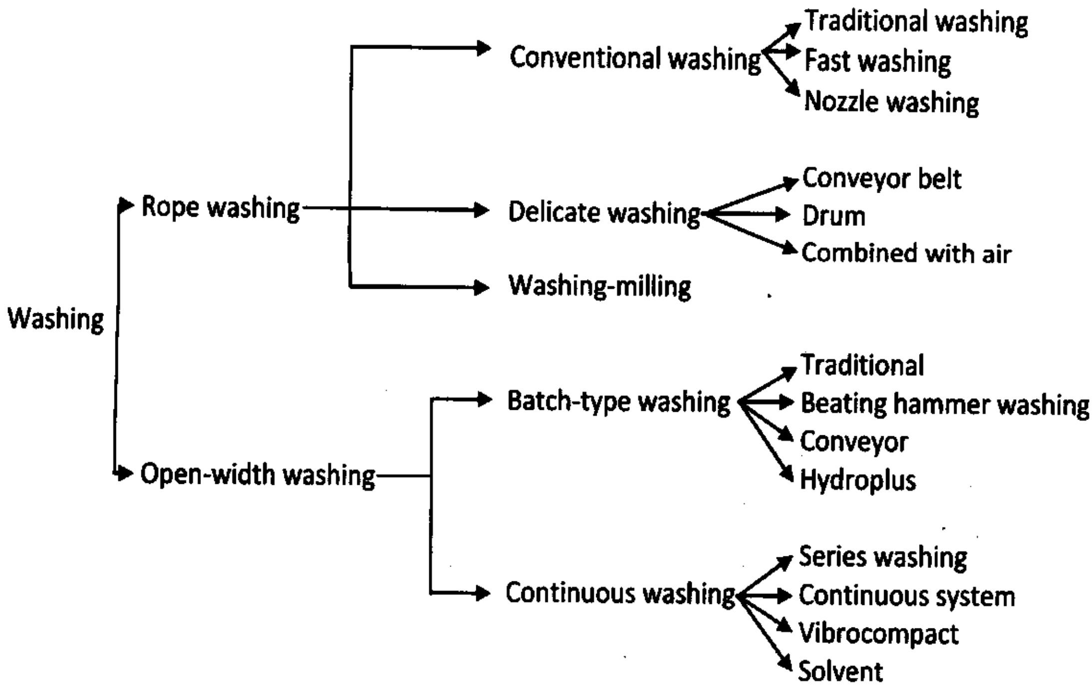
2) Sizes: For treating wool (opposite to cotton, where it is possible to use finish, which requires a special treatment), the stuffs now used (carboxymethyil cellulose or polyvinyl alcohol) can be easily eliminated and do not give particular problems;

3) oily stains: It is very difficult to eliminate these types of stain due to their characteristics and to their deep degree of penetration in the fabric; oily stains usually require a pretreatment with solvents sprayed directly on the stain (by means of a special "spray gun"). They can also be removed using special expensive detergents containing solvents, or by means of dry washing;

4) solid residues of various nature (dust, non-fixed dyestuffs, etc.), usually fixed on the fabric by means of fatty substances. To eliminate these residues, general cleansing rules must be observed and applied and special attention must be given to the mechanical action of friction. It is worth specifying that the above mentioned discussion is not at all exhaustive; in particular, it is not a text relating to the treatment and elimination of severe stains (colors, metals, microbiological attacks, etc.), which cannot be treated with standard cleansing processes. Readers are recommended to consult the specific literature available on this subject.

Washing machines:

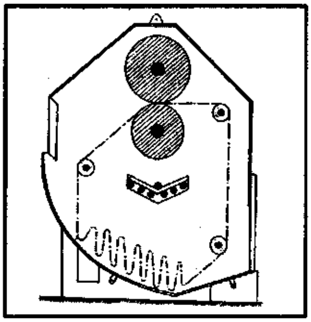
The scheme below shows all the categories of machines now in use; washing-milling machines are not included (combined washing and milling machines):



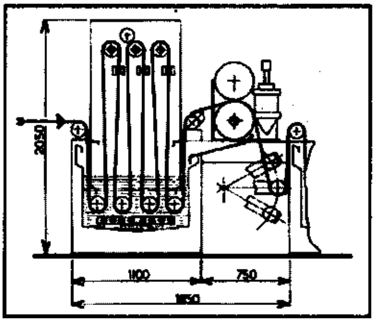
Washing can be performed on fabrics either in *open-width* or in *rope* form. Rope washing is more effective than open-width washing thanks to a stronger mechanic action, which favors the cleansing, and the relaxation of the fabric structure; for delicate fabrics an open-width washing must be preferred to avoid marks and creases. Open-width washing is also the best choice for processing huge lots.

Rope washing:

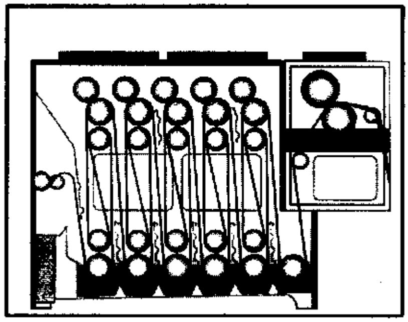
Substantially, batch piece washing machines are made up of a couple of squeezing cylinders, which make the fabric swell (the fabric is previously sewn on top and bottom and takes the shape of a continuous ring); these cylinders are assembled inside a vessel, whose lower part contains the detergent liquor. It is possible to wash a fabric inside this vessel, by feeding it into restricted area without laying it stretched out. The efficiency of this operation is enhanced by the mechanic action, which facilitates both detergency and tension relaxation. This operation is highly cost-efficient because open-width washing allows only one working position and therefore only limited loads can be processed (max. 180 kg) while a rope washing machine can include from one to eight ropes, with an overall weight exceeding 600 kg. Furthermore rope washing machines grant reduced operating times thanks to a more effective mechanic action.



Rope washing machine



Open-width washing machine



Open-width washing unit

Open-width washing:

An open-width washing machine is usually a system featuring a vertical path washing with driven cycle of multiple action baths, with a resulting 30/40% water and steam saving. This operating unit is manufactured in several versions (10-15-30 meters) and can be used for every kind of preparation and finishing treatment. Four different washing actions alternate inside this machine:

1) washing on rising paths;
2) washing on sloping-down paths, carried out by means of spray nozzles, which atomise on both face and back of fabrics, performing a strong penetration action;
3) "vibraplus" effect washing, which removes from the fabric the threadlike elements (fibrils) that do not dissolve in water;
4) extraction washing by means of vessel intermediate squeezing.

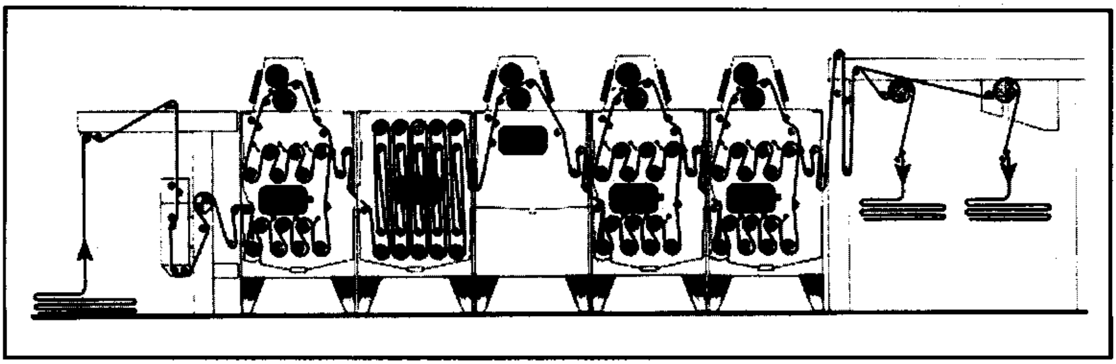
The longitudinal tension of the fabric remains perfectly unchanged on the whole path; it can be adjusted between 5 and 20 kg by means of upper cylinders equipped with self-adjusting control system which generates a sliding motion crease-and-fold proof also on extremely delicate fabrics. Plush fibrils are removed from the vessel with no need for brushes or liquor dilutions. Another type of machine divides the washing process into single steps, which are systematically repeated. In this way the whole process can be not only constantly monitored but also accurately calculated.

Inside every separated washing unit, an exchange takes place between the washing liquor and the chemicals-mixed-with-impurities on the fabric in a percentage ranging between 50 and 80%. The washing liquor absorbs both impurities and chemicals. Thanks to a squeezing step carried out by means of squeezing drums assembled at the exit of each unit, the dirty liquor does not leave the unit with the fabric. In the next unit the liquor exchange process repeats once more, but the washing liquor contains always-lower quantities of dirty particles. The repeatability of the process together with the addition of fresh water, are basic elements to estimate in advance the efficiency of the washing process. High-performance washing units, equipped with double-rope system and upper supporting cylinders made of rubber, recommended above all for medium and heavy fabrics, allow the maximum washing efficiency. Upper cylinders, individually driven and equipped with supporting squeezing cylinders, grant an accurate system control. In each washing unit the fabric is soaked twice in the liquor, which washes the fabric by passing through it, and squeezed by the cylinders. The powerful liquor exchange in the fabric is also enhanced by the synergic crosswise flow of the bath.

Continuous washing systems:

From an output point of view, the continuous treatment of fabrics for open-width washing allows operating speeds of at least 25 m/minutes: these speeds are extraordinarily higher than the one obtained with batch open-width or batch rope washing. The output is also strictly related to the overall dimension of the system (quantity of washing and rinsing units) and can be substantially increased. From a technical point of view, the main problems to be solved in a continuous-system plant, are detergency and relaxation of internal tensions, essentially related to washing processes, above all when carried out with open-width systems. We sketch here below the example of an up-to-date plant, including:

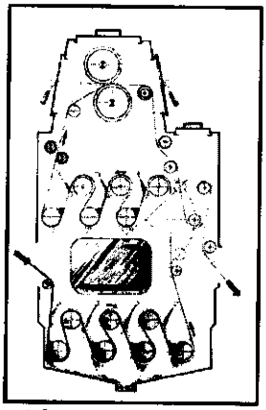
1. A prewashing unit, where the fabric is sprayed with a detergent solution atomized by 7 nozzles: the treatment takes place outside the bath. The solution is collected into the cavity created by the slanting path of the fabric and is forcedly driven through it (Idropress system); the alternating direction of the solution passage allows the treatment on both sides and the particular design of the driving rollers (the roller inside part is driven by a motor and the outside by the fabric) allows a minimum tension on the fabric;



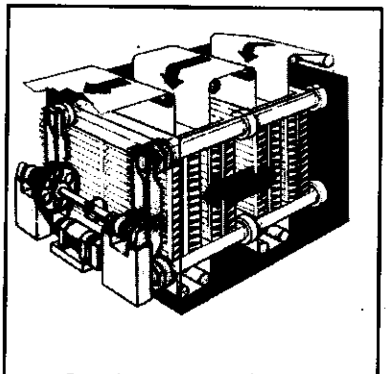
Continuous washing range

2. A soaping.washing unit (working when the fabric is not immersed in the bath), whose capacity (25 and 50 meters respectively) determines the output speed of the plant, since the time needed for the operation cannot be changed (1 min);
3. Two or three rinsing units, by means of Idropress system.

An extremely innovative machine features a basic element made up by 8 vibrating fabric guides, which push the water under pressure against both fabric sides, beating them alternatively against the fabric guides; since the flow follows the fabric motion, the effect of the driving tension is also contrasted; this is crucial to allow fabric relaxation in the direction of the warp (obviously, also in all the other machine versions, manufacturers pay the maximum attention to keep tension as low as possible).



Idropress system



Continuous washing
Detail of vibrating system

Water-blade washing system

Some machines feature special water blade devices (replacing spray nozzles) which convey a huge quantity of water, homogeneously and at high speed, on the whole width of the fabric, thus performing a really efficient wash. The system includes a pipe with a special nozzle releasing water jets similar to blades; these water blades perform a powerful action on the fabric and remove filaments, thickening agents, non-fixed dyestuff, etc. Many of these machines have modular structures, and therefore can be adapted to specific operating requirements.

Among all the possible solutions, manufacturers offer also counterflow washing systems where the fabric flows from the dirtiest section of the washing bath to the cleanest. Through a series of recycling processes it is possible to use the washing liquor many times.

Drying:

The frequency of processes, requiring impregnation of the textile substrate (washing, impregnation in dyeing or finishing liquor, desizing and so on), consequently leads to the need of subsequent drying processes, with a high impact on processing costs. Depending on their nature and structure, textile fibres absorb greater or lower quantities of water; the water absorbed by the textile material is partly retained between the fibres and in the pores of the fabric and partly more deeply in the fabric by the swollen fibres. The water between the fibres or on the fabric surface can be eliminated mechanically while the water in the swollen fibres can be eliminated with a drying processes.

General remarks on drying techniques:

The drying process aims at eliminating exceeding water and achieving the natural moisture content of the fibre. Excessive drying can negatively affect the final appearance and the hand of the textile. It is possible to adjust automatically the drying process by means of modern electric gauges. When choosing a drying technique, the cost efficiency of the drying system must be carefully evaluated: the cost-efficiency of a drying process includes many factors such as the quantity of steam, water and energy required to evaporate one kilogram of water as well as the evaporation capacity of a machine, expressed in kilograms of water evaporated in one operating hour.

Adjustment of the moisture content in the drying process :

The drying speed is determined by the difference between the tension of water steam on the textile surface and the tension of the water steam in the drying unit: it increases proportionally to the decrease of the moisture content in the air of the unit. In order to keep this content on low levels it is necessary to blow in the drying units huge quantities of heated air at the same temperature of the drying unit, which leads to huge energy consumption. When setting the desired moisture degree of the air in the drying unit, it is worth considering that the best degree results from a correct proportion between efficient output speed and costeffective energy consumption.

Adjustment of the drying speed:

The optimum time a fabric spends within a drying unit must correspond exactly to the time necessary to eliminate the moisture on the surface and between the free spaces of the fibres; the stay time must not exceed the optimum drying time (this would cause an extra drying) since the "natural" moisture of the textile must not be eliminated. The feeding speed of the fabric is adjusted by means of the special devices assembled at the exit of the drying unit, which vary proportionally to the moisture of the fabric leaving the unit.

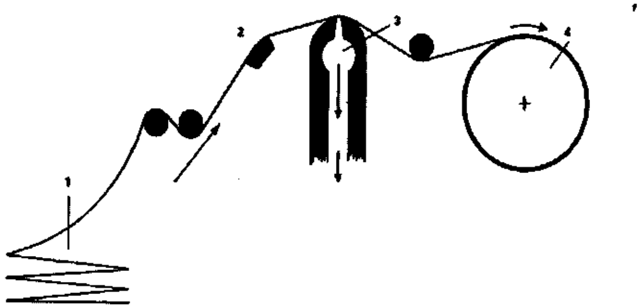
Heating of the drying unit:

The drying units are usually heated by means of steam with an average thermal efficiency of about 64%. Better thermal efficiency is granted by dryers heated with thermal fluid (about 80%). Highly efficient heating is obtained by means of direct gas combustion, with an efficiency of almost 95%. The operating temperature can be reached in very short times and heating can be stopped simultaneously with the machine.

Hydroextraction:

This process removes the water (the water quantity varies according to the type of fibre) dispersed in the fibres by mechanical action; this process aims at reducing energy consumption and is carried out before the final fabric drying or between the various wet processing stages (washing, dyeing). It can be carried out in the following ways:

- **Squeezing:** The water dispersed on the surface and in the spaces of the fabric is removed by means of the pressure applied by two cylinders.
- **Centrifugation:** This process eliminates the greatest quantity of water dispersed on the surface of the textile by centrifugal force. It is applied above all to resistant yarns, knitted goods and fabrics.
- **Steam pressure:** A high-speed steam jet blown on the whole width of the stretched fabric passes through the cloth and eliminates the water in excess. Extracted water and steam are condensed and reused.
- **Vacuum:** This method applies vacuum technology and is used to dry very wet fabrics or delicate fabrics that do not stand up to the pressure of the cylinders of a squeezing unit, which could negatively affect the surface structure. The stretched fabric slides open-width above the opening of a cylinder-shaped structure connected to a suction system. The air drawn from outside removes the exceeding water when passing through the textile cloth.



Vacuum drying machine

Drying systems:

The water dispersed in a textile material by chemical-physical process is generally eliminated by the action of hot air, which makes the water evaporate; during the drying process, it is very important to carefully consider the way heat is directed on the fabric. The drying process can be carried out:

- by heat convection
- by contact with heated metal surfaces
- by infrared radiation
- by means of microwaves or high-frequency waves
- by combustion

Yarns and textile materials in bulk are generally dried inside hot air compartments. For the drying of piece fabrics, manufacturers have designed different drying units, which applydifferent principles, briefly described here below.

Drying by heat convection:

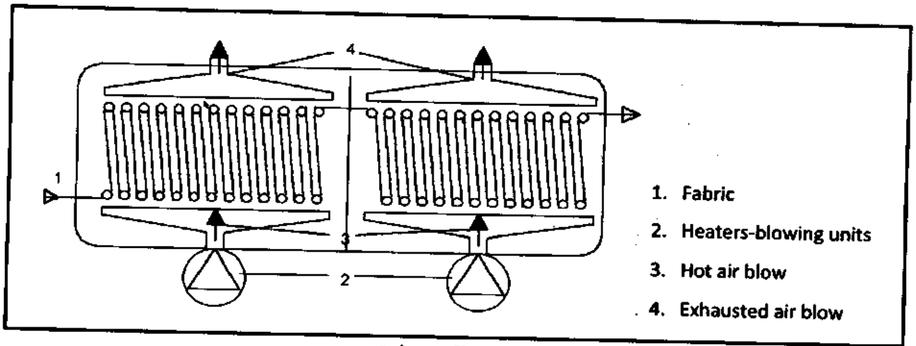
The heat diffusion onto the wet fabric is carried out by means of hot air circulating inside the drying unit. There are two different types of dryers applying this operating principle: compartment dryers and tunnel dryers.

1 . Compartment dryers:

Suspended fabric dryer: it is made up of hot air compartments where the folded fabric with a maximum width of 3 meters is suspended on a series of rotating cylinders leading the fabric toward the exit. The circulating air is blown slowly downward. This system is suitable for light and medium-weight fabrics that can withstand the stress of mechanical feeding.

Short-loop dryer: this system eliminates almost completely the tension applied by the fabric weight; it also avoids the risk of possible downward migration of dyestuff or finish.

Hot-flue dryer: the vertically folded fabric is guided through a hot air compartment. The feeding motion is determined by means of different sets of rollers, while special cylinders separate the fabric folds. The drying temperature ranges between 80 and 100° C. This drying system is suitable for printed fabrics, above all for light and medium-weight fabrics, as well as the intermediate drying after printing, after impregnation in general, and after the application of background dyes and other similar operations.



A hot-flue

The use of belt or perforated-drum dryers is often extremely effective to cut costs and increase output rates in continuous drying processes on fabrics and yarns in various forms. Thanks to suction effect of the hot air drawn into the cylinder through the holes, the fabric perfectly adheres to the external side of the rotating cylinders, moving forward inside the drying unit where it is dried gradually.

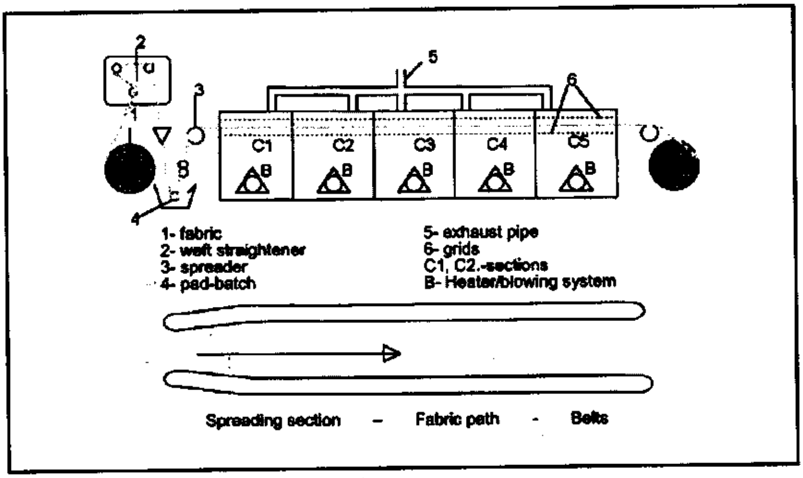
2 . Tunnel dryers:

Supporting nozzles dryers: the fabric is suspended on an air cushion generated by blowing nozzles arranged in proper layout.

Stenter: it is made up of modular elements (arranged lengthwise and heated by means of forced hot air circulation) where the fabric passes horizontally, supported by a belt, by supporting nozzles or by air cushion. When the hot air comes into contact with the fabric, it cools down and removes the evaporated moisture. The air is partly drained and replaced by an equal quantity of fresh air. The remaining air is recycled, added to with fresh air and passed again through the heating element.

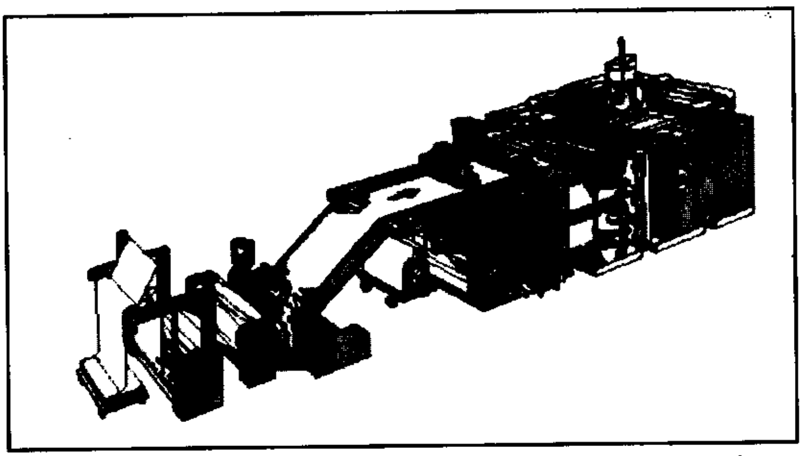
Air flows inside a stenter featuring a hot air convection drying system

This machine is extensively used in the fabric drying sector, but is also used for the heat setting and polymerisation of finishing or bonding agents in pigment printing processes; it includes an "entry" area for the fabric provided with a pad-batch, where finishes and finishing products are applied or where the fabric is simply squeezed. The use of a drum coated with porous material, which dehydrates the fabric before the drying step, proves particularly efficient.



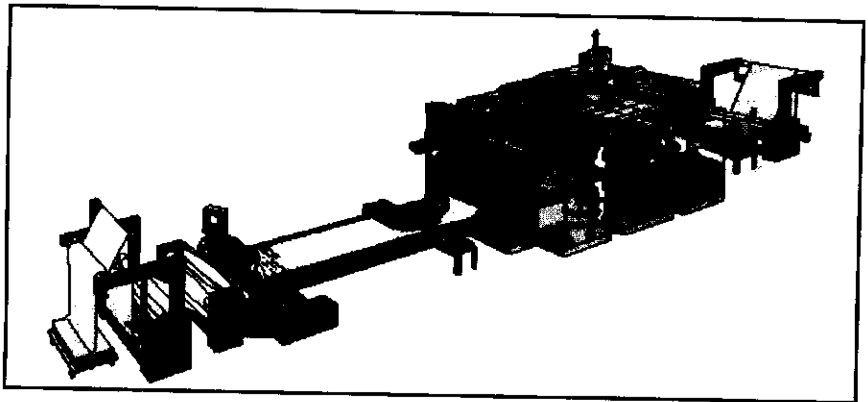
A stenter

The unit is equipped with a stretching system to keep the fabric stretched and also with a special device that controls the perpendicularity of the weft to the warp. All the drying systems are assembled in the second section; they include a feeding system equipped with a fabric guiding system and the drying unit. The endless chains, with clips or pins for fastening the fabric, are positioned all along the front part, the drying compartment and the exit section; they guide the fabric by the selvedge. At the exit the fabric is released automatically from the fastening devices and wound up.



Multi-level stenter with fabric entry and exit on the same side

In the latest generation of stenters, manufacturers have tried to improve the quality of the fabrics with more rational fabric feeding systems and innovative solutions for heat treatment and reproducibility of the various processing stages. Together with an increased output in continuous operating conditions, manufacturers also aim at improving the machine utilization, reducing maintenance to a minimum and cutting energy consumption.



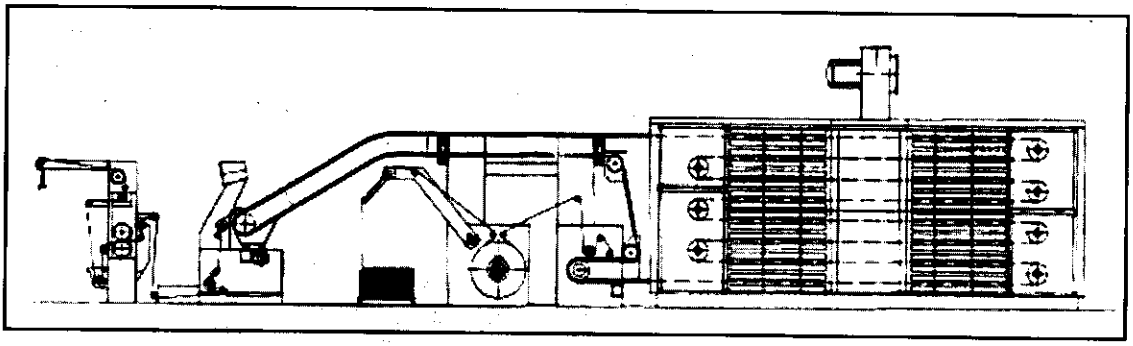
Multi-level stenter used for coating processes and incorporated on an existing operating line

Multi-level stenter:

Thanks to an excellent ratio between capacity and overall size, the multi-level stenter is also particularly cost effective for treatments requiring a certain standby time, such as for example the heat setting of synthetic fibres, chemical treatment setting and carbonising.

Advantages of the multi-level stenter:

- Compact structure: thanks to the multi-level design, the overall space required for the installation of the stenter is smaller than the one required for a standard flat stenter with the same output rates.
- High-performance drying process: for heavy textiles the efficiency of the machine does not depend on the evaporation on the surface but on the time required for the drying process. Powerful ventilation, generally applied to flat stenters, could cause an excessive drying of the textile surface and damage the material, while fibres inside the fabric could remain wet. The internal moisture migrates very slowly to the surface.
- Delicate drying: in a multi-level stenter, the drying process does not affect the material negatively and eliminates the moisture in the best possible way. In fact, we know that a delicate treatment, e.g in a drying or heat setting process, can be ensured only with a slow ventilation of the material. Furthermore a longer treatment time, even at lower temperatures, gives a better appearance to the finished material, compared to tougher treatment conditions. The result is a bulky fabric with a softer hand, which gives the sensation of more weight.
- Lower operating costs: thanks to reduced number of operators, smaller space required, slight reduction of the yield for heavy textiles and reduced consumption of energy with the same output rate of a flat stenter.



Longitudinal section of a multi-level stenter with internal exhaust channels

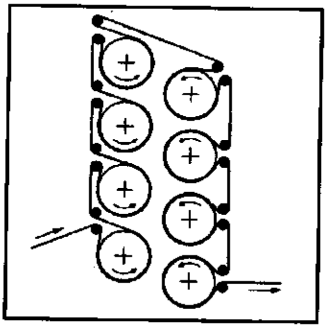
Limits of multi-level stenters:

- only a few multi-level stenter models can be equipped with pin chains.
- in the path between one level and the next one, the fabric must be sustained to avoid the formation of wrinkles and therefore deformation. Telescopic drums are used to convey the piece of cloth by moving forward the whole fabric width thus sustaining it from one selvedge to the opposite one; unfortunately with delicate textiles, such as raised velvets and very lustrous viscose fabrics, this system causes evident and unpleasant stripes and marks on the surface.

Flat stenter

Contact drying:

Drum dryer: with this system, the fabric moves forward arranged on several heated drums. The drying temperature ranges between 120-130° C and the cylinders are heated by means of steam at a pressure of 1-3 atm. This very efficient and low-cost drying system is particularly suitable for flat fabrics, with slightly evidenced structure, which cannot be easily affected by tension during feeding. Used for intermediate drying and for light finishes; this system is not suitable for durable thermosetting resin finishes.



Drawing of a drum dryer

Dyeing (Colouration):

The dyeing process is aimed at giving woven or knitted fabric its intended colour, crucial to its ultimate use. The dyeing process can be carried out at different stages of fibre processing, i.e. in different forms: *staple, yarn, fabric (rope or open-width), and piece.* When the dyeing process is carried out during the first processing stages, for example on staple fibres, a better colour fastness can be achieved; bulk dyeing refers to the system used to dye a staple fibre before it is spun, this process is carried out in perforated baskets and although there may be areas where the dye does not penetrate completely, in subsequent spinning operations these areas are mixed with the thoroughly dyed fibre, thus ensuring an overall even colour.

Yarn dyeing is carried out after the fibre has been spun into yarn. Yarn dyeing is preferred for manufacturing Jacquard or striped fabrics; this dyeing method grants a good colour fastness since the dye penetrates the fibres and reaches the yarn core. Skeins are dyed in hanks, spools are dyed in autoclaves and warp yarns are dyed in perforated beams loaded in autoclaves.

Piece dyeing is carried out on several types of machines and the material can be open-width or rope dyed. A good dyeing strictly depends on different parameters and conditions that can be evaluated immediately (such as good consistency of the dye and repeatability) or which require specific fastness evaluation (manufacturing, use, dry or wet processing) that can be controlled only by means of subsequent laboratory tests.

The machines used are chosen according to the material to be processed. The crucial requisites are the following:

- protection of the substrate
- repetitiveness of the results
- cheapness of the process (depending on process time, machine automation degree, liquor ratio, cost of the products used and wastewater purification).

Textile materials are dyed in aqueous solutions or dispersions of dyestuffs, together with dyebath additives such as salt, alkali, acids and other auxiliary chemicals. The dissolved or dispersed dyestuff must first be absorbed on to the fibre surface and then diffuse into its interior where finally it must be fixed.

To carry out a dyeing process it is necessary to:

- Dissolve or disperse the dye in a water bath (with manual, semiautomatic and automatic colour kitchens according to specific preset rules).
- Feed the dye solution in the machine after suitable filtering (automatic colour kitchen, supplementary vats, pumps and filters).
- Transfer the dye from the liquor to the fibre (process and machine).
- Distribute the dye homogeneously on the fibre (process and machine).
- Let the dye penetrate in the fibre structure and fix it (time and temperature).
- Wash or rinse the material to remove the dye on the surface or the unfixed dyeing liquor.

There are two different methods to transfer the dye from the liquor to the fibre:

Exhaust dyeing (discontinuous systems):

The dye is dissolved or dispersed in the dyeing liquor. The material is immersed in the dyeing liquor and is removed only when the dye has mostly transferred onto the textile to be dyed, distributed homogeneously, well penetrated into the fibre and fixed. At the end of the process the material is washed or rinsed to remove the unfixed dye.

Pad dyeing (continuous or semi-continuous systems):

This process is carried out using mechanical means (pad-batch wetting). The dyeing liquor is distributed homogeneously onto the fabric (i.e. also the dye is distributed homogeneously). In a second stage the dye penetrates into the fabric and is then fixed. At the end of the process the material is washed.

Some operations must be carried out for both exhaust or pad dyeing:

- dissolve or disperse the dye in water and filter.
- achieve an homogeneous contact between the dyeing liquor and the fibre.
- make the dye penetrate into the fibre.
- fix the dye in the core of the fibre.
- final washing.

Preparation and Dyeing Machinery:

The choice of dyeing equipment depends on the type of fabric (woven, knitted, nonwoven), and the fibres it contains. Polyester fibres often have to be dyed at temperatures over 100^{0}C and so machines, which can operate under pressure, must be used. The dyeing process may be continuous, discontinuous (batch) such as Winch, Jigger and Jet dyeing machine or semi-continuous.

There is a wide variety of machines used for finishing processes (pre-dyeing, dyeing andfinishing treatments).As far as dyeing machines are concerned, the most important aspect to be considered is the consistency of the dye distribution (or of other chemicals) that the machine must ensure in the shortest possible time. Generally, the systems allowing a homogeneous distribution of the dye also allow a good removal of dirt, and a uniform contact of bleaching reactants with the material; therefore what we say about dyeing, in most cases can be also applied to pre-dyeing and finishing treatments that require the application of chemicals.

Classification of machinery:
The machines used for preparation and dyeing processes can be classified as follows:

- **Classification according to the textiles to be processed:**
  The machines to be used are chosen according to the type of material to be processed.
  - Machines for dyeing staple or yarn (in skeins, packages or beams)
  - Machines for dyeing woven-knitted fabrics or rope knits (the width is not spread)
  - Machines per dyeing open-width fabrics (the fabric is opened and flattened)
  - Machines for dyeing made-up garments.

- **Classification according to the processing method:**
  The processing method to be applied depends on the quantity of materials to be processed and on the type of finishing process.
  - Discontinuous (batch) systems.
  - Semicontinuous systems.
  - Continuous systems.

- **Classification according to the operating principle:**
  The system to be used depends on the elements that make up the material (fibre and eventual weave), as well as on the type of treatment to be carried out.
  - Circulating liquor systems.
  - Systems moving the material.
  - Systems moving both the dyebath and the material.

- **Classification according to the process conditions:**
  The system to be used depends on the type of material (fibre form) and on the process to be carried out.
  - Systems that can work under pressure at high temperatures (HT autoclaves)
  - Open systems, or, systems that run at a max. temperature of 100°C.

Here below the reader will find a brief description of the (A) category; each system is described in detail hereinafter.

Machines to process staple, sliver and yarn (General remarks):
These machines are used for dyeing staple fibres (and also for carrying out other treatments such as bleaching, scouring or finishing) and more frequently for dyeing yarn fibres in different forms (packages, cheeses, etc). With the use of modular and interchangeable carriers it is possible to carry out loading and dyeing processes using packages of different diameters. These machines are equipped with automated systems, such as automatic loading and unloading racks positioned above

the machine, centrifugation and drying systems, to best satisfy the growing demand for system optimisation.

Open-width dyeing machines (General remarks):

These systems are used for dyeing open-width and well-flattened fabrics. These systems can be used also for carrying out pre-dying treatments (for example upgrading, bleaching, mercerising), dyeing treatments and wetting operations for both types of treatment. Among the systems used for open-width treatments it is worth pointing out mercerizing machines, jiggers, pad dyeing machines, beam dyeing machines, continuous washing systems, stenters.

Rope dyeing machines (General remarks):

These machines process the fabric fed and driven lengthwise to form a rope. The hydrodynamic effect is obtained by means of the motion of the fabric rope, or by means of the simultaneous rope-and-dyebath motion, which ensures a homogeneous contact of the material with the dyeing liquor and a quick exchange of the dyeing liquor dispersed in the material. Machines running according to these operating principle are suitable for treating almost all the fabrics made up of extremely different fibres, woven or knitted fabrics, during preparation and dyeing stages, with only some problems occurring with loose-weave fabrics. During the treatments the fabrics run freely weft-wise and therefore can freely shrink and set thus eliminating almost all tensions. Suitable operating conditions and technical adjustments also reduce to the minimum warp-wise tensions, and continuously move the wrinkles of the rope.

An unquestionable benefit obtained with these machines is the extremely soft and fluffy hand, particularly suitable for fabrics to be used for garments. Possible problems are connected to the formation of permanent wrinkles on the fabric, or to uneven dyeing shades, always connected to the problem of the rope wrinkles; for fabrics made up with very delicate or short staple fibres, mechanical stresses can cause losing or extraction of the hair on the surface.

Piece dyeing machines (General remarks):

These are discontinuous processing systems; the most modern machines are equipped with rotating systems, which apply low liquor ratios; the material is packed in a perforated basket, which rotates at variable speed. Once the dyeing process has been completed, the system removes the liquor in excess from the fabric by centrifugation before unloading. These machines are equipped with automated systems to optimise the process.

Autoclaves:

These machines are used for dyeing staple and yarns in different forms (package, cheese, beam etc.).

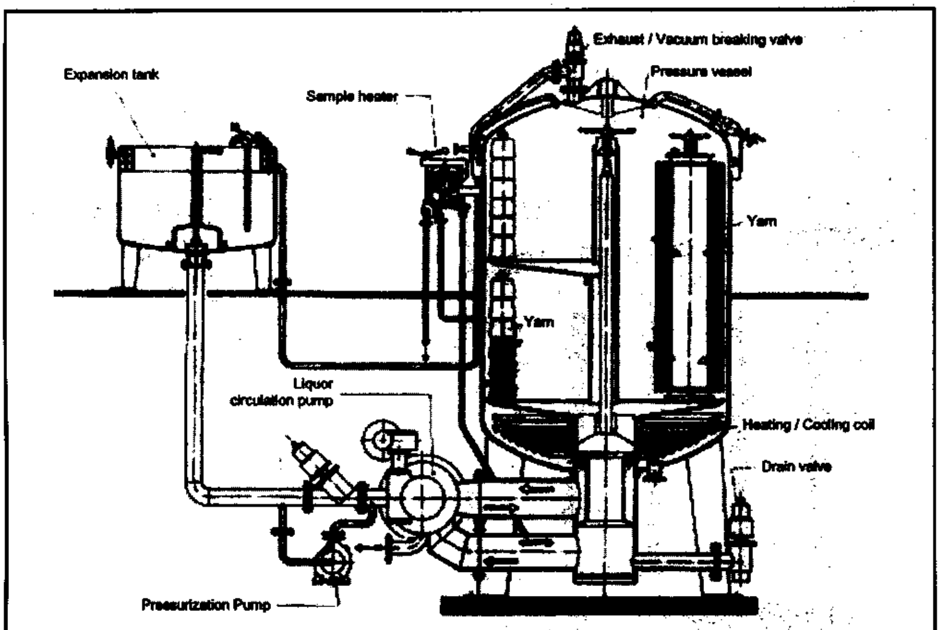
These systems are essentially made up of:

- Vertical or horizontal autoclaves, made of stainless steel, where interchangeable carriers areplaced for dyeing different textiles at any stage of their development (baskets for staple dyeing,package carriers, cheese carriers, fabric beams, etc.)

- Circulating liquor pump (with flow reversal system)
- Expansion vat to balance the increase in liquor volume, where the necessary dyes and auxiliaries can be added without stopping the operating cycle.
- Static pressure pump (which can be introduced whatever the operating temperature)
- Sample heater
- Control board for partially or completely automated dyeing cycle.

All manufacturers can now supply these machines equipped with microprocessor or PLC programming system for controlling and setting all the operating functions (filling / exhaust / heating / cooling / stage / dosing etc.) of the whole production cycle and, in specific cases, for adjusting the pump flow according to preset parameters. Some autoclaves are also equipped with Air Pad pressurizing system, which offers the opportunity to reduce the liquor ratio and the energy consumption; when the machine is running only the carrier, the heat exchanger and the circulation pump are completely immersed in the liquor, while the free space is filled with compressed air.

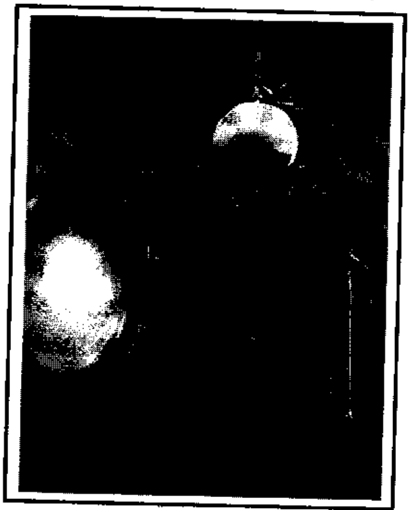
Systems equipped with volume or air reducers are actually used to satisfy the increasing demand for machines where batches with different weights can be loaded and treated (thus keeping a steady nominal liquor ratio). Thanks to these systems, the machine can process from '1' to an 'infinite' quantity of packages for each shaft entailing considerable energy saving, cutting plant and production costs, as well as a considerable reduction of delivery times. In the past, the reduction of the loading capacity thanks to the air cushion could only be ensured with vertical autoclaves; now it can also be obtained with horizontal units.



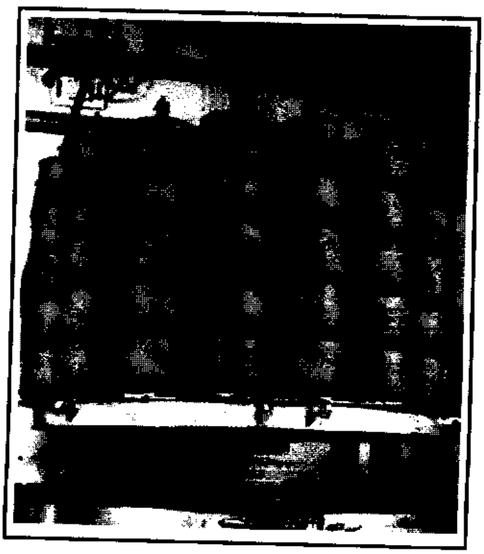
Vertical autoclave

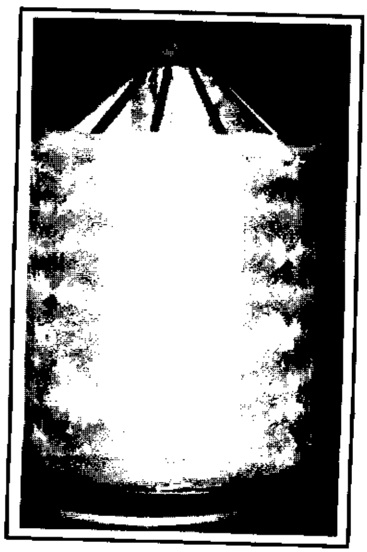
An autoclave model used only for packages includes many small horizontal heaters (basically coils) instead of a single heated vat; each small heater can be loaded with a single package carrier shaft.

This autoclave allows working with an extremely low liquor ratio. The material to be dyed must always be accurately arranged to avoid possible disproportion in the liquor forced under pressure through it, in both directions alternately, from the core to the outer surface and vice versa, according to programmable times (for example from 2 to 4 cycles per minute).


Horizontal autoclave for packages

In all these autoclaves, the dyeing liquor is kept circulating by means of centrifugal or helical pumps: these pumps must keep the liquor circulating through the mass of fibre, so that the fibre surface is saturated with the dye. To do that, the liquor must overcome all the resistive forces generated by pipes and by the textile mass (pressure drop) and reverse the direction of the liquor circulation at different times to obtain an overall even colour; in specific cases, the speed of the pump impeller can be set by means of inverters (frequency inverters) which adjust the flow of the liquor through the fibre mass.

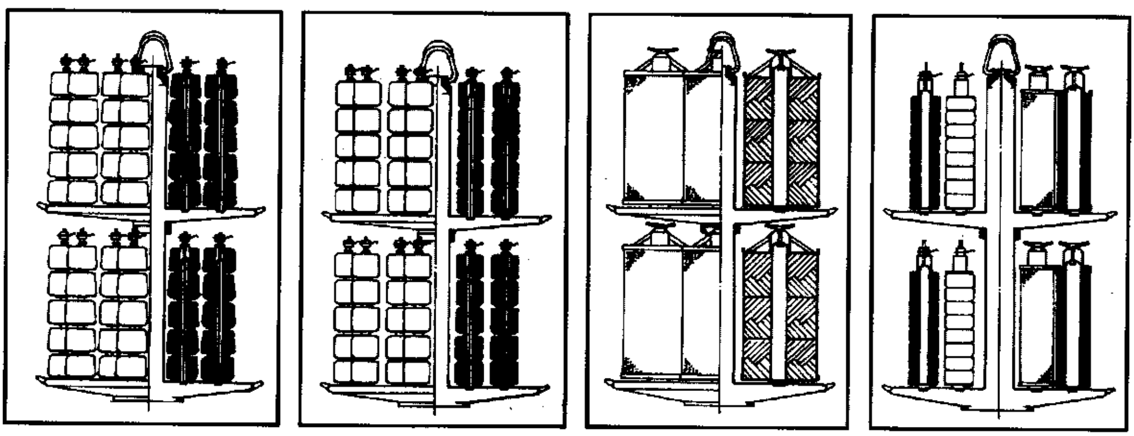

Package carrier


Staple carrier

These machines, built and tested according to the European PED standards, can operate at a maximum operating pressure of 5-6 bar, and are statically pressurized by means of a pump or of a compressed air cushion; they are suitable for treating synthetic fibres up to an operating temperature of 145°C, avoiding load-carrying drops due to cavitation of the liquor circulation pump. The average liquor ratio is approximately 1-10.

Automated dyeing cycles grant excellent quality and reproducibility of results. Some autoclaves also integrate dyeing, centrifugation and drying systems. These machines, used for dyeing various types of fabrics or blends can also be employed for scouring and bleaching tasks. We describe below several carriers made of two overlapping levels, which can be separated for easier loading and unloading. In fact these machines, besides packages, cheeses, tops, etc, which can be loaded in single-level machines or in machines equipped with horizontal heating vat, can be loaded with fabric beams; they also allows cutting the loading capacity in two (see drawings of the different carriers) thus increasing the operating flexibility.

With reference to the drawings above, we only need to add some detailed information about package yarn dyeing. This dyeing system is more popular than staple and hank dyeing (cheeses are no longer used) since it is more cost efficient and environment friendly. The diameter, and therefore the weight, of each single package greatly varies according to the type of fibre, to the count, to the final use and to the different classes of the dyestuffs used. Packages can be prepared by winding the yarn on perforated taper or cylindrical tubes of different height and diameter; the weight can range between 700 grams for very fine cotton yarns for shirts and knitted goods to 3.5-4 kilograms for large polyester packages.



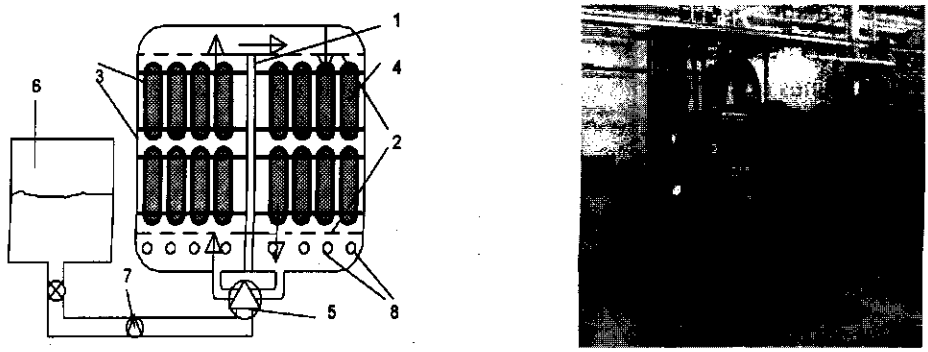
Cones | Cylindrical packages | Cheeses | Tops

Different types of two-level overlapping carriers

The dyeing sector has recently undergone a very incisive improvement in automation and robot control. Particularly, the handling of the packages is reduced to a minimum; simple and reliable robots load and unload the package carriers and carry out the subsequent dehydrating step by means of automatic hydroextractors and drying by means of fast dryers with forced air circulation or high-frequency heated tunnels (see chapter on drying).

Hanks:

Hanks are used for the dyeing of skeins; a hank is made up of a parallelepiped-shape vat divided into compartments by perpendicular partitions. The skeins are arranged on special carriers, which can be locked in special grooves inside the machine; the liquor circulates in both directions (up-and-down flow) and the yarn mass makes only a moderate resistance since it not very tightly packed. The machine operates with reduced liquor ratios and the liquor itself is kept circulating by means of major flow axial pumps (suitable for delicate yarns), assembled in the front part of the machine.



1 central wall; 2 perforated separators; 3 perforated supports; 4 skeins; 5 circulation pump; 6 expansion vat; 7 auxiliary pump; 8 serpentines.

A skein dyeing system (hank)

The liquor flow inversion is obtained by reversing the rotation direction of the motor; the liquor is generally heated by means of serpentines assembled inside the machine or by means of heat exchangers. The hank can also run under pressure at a maximum temperature of 110° C and at pressures of 0.5 kg/cm2. If the pressurisation is obtained by means of an air cushion, it is possible to avoid the external circulation of the liquor in a lateral extension vat. As a result, the liquor can be maintained at a constant temperature, reducing energy, steam and cooling water consumption. The only negative aspect is the need to unload and load the machine each time it is used. Hanks can also be used for washing and bleaching treatments.

Winch Dyeing Machine:

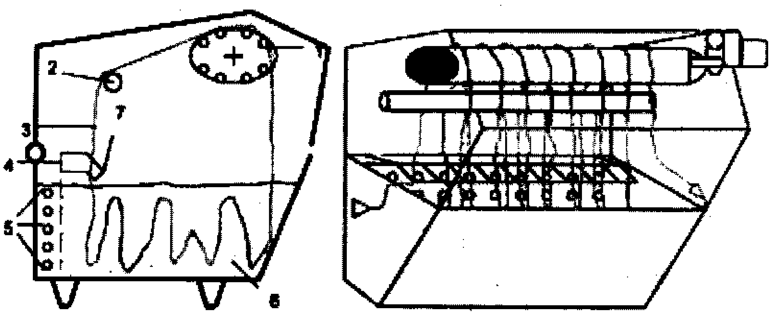
This is a rather old dyeing machine for fabrics in rope form with stationary liquor and moving material. The machine operates at a maximum temperature of 95 – 98^{0}C for open bath winch but for closed winch, the machine operates at a maximum temperature of 130^0 – 160^0 C. The liquor ratio is generally quite high (1:20 – 1:40) for open bath winch but for closed or high temperature winch the liquor ratio is 1:8 to 1:10.

The system includes a vat with a front slant side acting as chute for the folded rope, while the rear side is entirely vertical. A perforated separating compartment, positioned at a distance of 15 - 30 cm from its vertical side, creates an interspace for heating and for adding reagents. Heating can be supplied by means of direct or indirect steam heating. The fabric motion is driven by a circular elliptic winch coated with a special blanket to avoid the fabric slipping during the dyeing operation with subsequent possible fabric scratches.

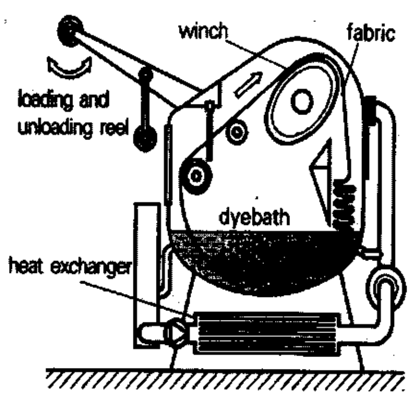
The rope to be dyed then passes through a rack on the vertical perforated divider, which ensures the separation of the various folds of the rope and avoids possible entangling; the rope is then transferred onto a cylinder, which guides the fabric during the lifting from the vat carrying out a partial squeezing with subsequent liquor exchange. The rope (carried by the winch) folds while passing through the liquor. Obviously when the fabric is loaded into the machine it is necessary to sew the tail with the head of the rope (the fabric must be sewn according to the grain line or direction).

The maximum motion speed of the fabric must be approximately 40 m/min., since higher speeds could cause peeling; an excessive stretch during the lifting stage could cause deformation while high circulation speed could cause excessive rope beating with subsequent entanglement. The fabric must not remain folded and kept stationary inside the vat for more than two minutes to avoid possible defects or wrinkles; therefore the rope must be relatively short.

The winch dyeing method is suitable for all fabrics (especially for knit and lightweight woven fabrics), except those which tend to originate permanent creases or which could easily distort under the winch stretching action (due to their fibre or structure composition).



1 – Winch; 2 – Guide cylinder; 3 – Fabric rope; 4 – Perforated separator; 5 – Heating coils; 6 – Liquor; 7 – Rack



Winch Dyeing Machine

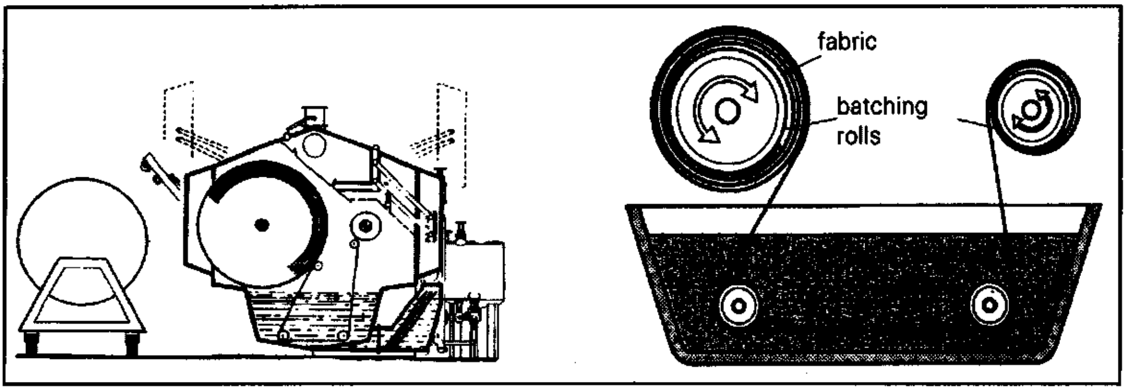
This machine is used preferably for pre-dyeing treatments (scouring, washing, bleaching) since the high liquor ratio ensures excellent results; when used for dyeing treatments this system requires high energy consumption, extensive use of auxiliaries, dyes and water, which leads to high operating costs; furthermore, an inaccurate temperature control (the liquor does not move and the heating system is assembled only on one end) and the limited freedom of the rope folds could negatively affect the dyeing results.

This is one of the oldest systems used for finishing treatments, but it proves to be still extremely functional thanks to its flexibility, above all for scouring and bleaching treatments to be carried out on small production runs. This system can also be used for carrying out continuous washing processes; the fabric is loaded from one side, driven through the machine with a spiral motion (by means of the rack) and then unloaded from the opposite side.

Jiggers:

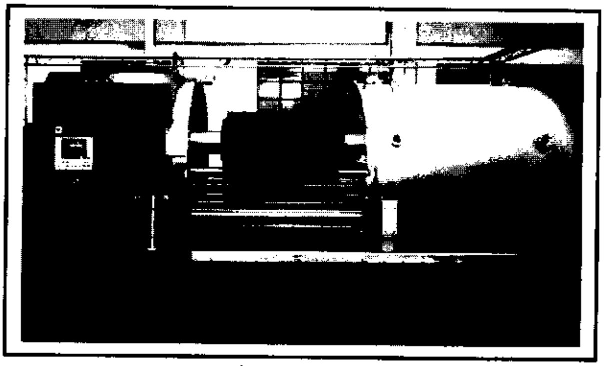
These machines have been used for a long time to treat medium-size lots of woven with an open-width exhaust dyeing process. The fabric moves while the liquor stands still, except for the very latest machines, which are also equipped with a circulation pump.

The fabric pieces are sewn together tail-to-head, forming a sort of .ribbon.. At the head and at the tail of the ribbon two cloths are added (4.5 m long) to allow the regular dyeing of the whole pieces, also leaving the machine drawn-in once the dyeing process has come to an end. The assembled pieces are taken down from a roll, pass through the liquor (they are kept in the correct position by means of transport cylinders and a tension equaliser, which avoids the formation of wrinkles). The fabric is then wound on a takeup roll until the dyeing process has ended.



Jigger

The piece through speed and tensions are adjusted by special devices to avoid any change in dimensional stability, above all when treating lightweight fabrics and/or delicate fibres. The maximum diameter of the roller can be 1,450 mm with a width of the piece of cloth ranging between 1,400 and 3,600 mm. The piece through speed is adjusted between 30 and 150 m/min. and kept constant during the whole operation. Also the tension must be constant and it can be adjusted between 0 and 60 kg. Since the passage time is very short, dyeing occurs above all on the fabric wound on the rolls.



A HT Jigger

The composition of the liquor absorbed must be as uniform as possible on the whole width and length of the fabric piece; for big lots, many additions may be necessary to avoid the so-called head-tail defects. Lightweight fabrics (viscose, nylon) that are stretched excessively during the takeup step can show .shading. defects. Jiggers work with a quite low liquor ratio (from 1:1 to 1:6). Together with standard atmospheric systems, builders also offer HT jiggers inside autoclaves working at high pressure. Jiggers are suitable for dyeing all type of fibres.

Dyestuffs:

The desire to colour textiles is an old as spinning and weaving. Natural colouring materials have been used for thousands of years; mineral pigments such as yellow and red ochre, cinnabar; vegetable dyes such as indigo, litmus, logwood, madder, saffron; animal dyes such as cochineal, Tyrian purple. Synthetic dyes were first produced in the 19^{th} century and have now almost completely replaced the natural colours. Environmental and product safety aspects are currently very important.

With the exception of pigment/binder systems the type of dyestuff has to be chosen to suit the fibre substrate, because the formation of a physical or chemical bond between dye and fibre depends on the chemical and physical structures of both dye and fibre. A broad spectrum of colours is available in countless shades and a wide range of fastness for the different fibre types and blends.

Colour Fastness:

Colour fastness means the resistance of the colour to various insults which textiles may suffer during manufacture and use. Fastness depends on the type of dyestuff and the fibre substrate; there is no universal colour with the same fastness on all substrates. Moreover, different end uses have different fastness requirements; underwear has different requirements from furnishings. There are standardized methods (ISO 105) of evaluating the different types of fastness. The most important are:

Rubbing fastness: Resistance of the colour to rubbing, either wet or dry. Even the best dyeings, in a very deep shade, may lose some colour in wet rubbing.

Washing fastness: The fastness to washing determines the wash program, which must be used by the consumer. Nowadays, fastness to a strong wash at 60^0C is expected.

Perspiration fastness: Resistance to the effects of perspiration is important for underwear, outerwear, and sportswear.

Colours may also be required to be fast to light, weather, sea water, solvents, ironing, etc.

Different types of Dyestuffs in relation to the fibre substrate:

- **Reactive Dye**: Applicable for cotton, linen, viscose, wool, silk. The dyestuff forms a chemical link with the fibre. It has very good fastness properties.
- **Disperse Dye:** Applicable for polyester, nylon, acetate. It is water insoluble; applied from dispersions; diffuse into the fibre at high temperature. It has also good fastness properties.
- **Vat Dye:** Applicable for cotton, linen, viscose. The insoluble dyestuff is made soluble in a reducing vat so that it can diffuse into the fibre. After diffusion is complete, it is then re-oxidised into its insoluble form. It has high fastness to washing, chlorine, boiling, light, weather, rubbing and perspiration.
- **Direct Dye:** Applicable for cotton, linen, viscose, silk. Simple diffusion into the fibre, from aqueous solution. It has relatively poor fastness properties to light, washing and perspiration. These fastness properties can be improved by aftertreatment.
- **Basic Dye:** It is suitable for acrylic fibres (other fibres by mordanting). It reacts with acidic groups, or mordants(a chemical which can react or complex with a chromophore to form an insoluble colour) in the fibre. It has good fastness properties on acrylic fibres.
- **Acid Dye:** Applicable for wool, silk, nylon. Applied from an acidic dyebath. The fastness properties of this dye-stuff depends on the fibre type.

There are also some other dyestuffs such as sulphur, azoic, metal complex, chrome dyes etc.

Printing:

Printing can be described as the controlled placing of defined areas of colour on to a substrate. The colourant must first be brought to the fibre surface usually in the form of a printing paste. If it is a soluble dyestuff, it must be diffused into the fibres. The colourant must then be fixed in place and finally, excess unfixed colour has to be washed out.

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.

In other words, printing is a form of localized dyeing. Printing processes or techniques and printing principles or styles can be distinguished. Printing processes include techniques such as roller printing, screen printing. Printing principles include direct printing, discharge printing, resist printing, flock printing, etc. Several of these processes and principles will be dealt with in the followings.

Printing Principles:

Regardless of the printing process, there are several basic printing principles:

Direct Printing or Overprinting:

The printing paste is applied directly to the prepared fabric surface. Overprinting indicates that a plain dyed fabric is printed with a pattern in a darker colour. 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.

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 overprinted with a discharge paste (chemical) that destroysor decolourises or changes the colour indesigned areas. A white discharge is when the original white is restored to the printed area. A colour discharge is when a separate colour is applied at the same time as the discharge paste. 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 welldefined 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:

The pattern is first printed onto a special type of paper with certain types of dyestuffs. These papers are prepared by specialist suppliers. The pattern is simply transferred to the fabric with the aid of a heated calender. The temperature is high enough to cause the dyestuffs to pass into the vapour phase (sublime). Since it is held in close proximity to the paper, under pressure, some of the dye vapour finds its way onto the fabric and diffuses into the fibres. The process represents about 6% of print production and finds its most direct and simple application on synthetic fibre textiles. Special techniques, papers, and fabric preparations have been developed for natural fibres and blends.

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.

Beside these basic principles, there are several types of printing technologies:

Flock Printing:

The fabric is printed with adhesive and cut fibre snippets are applied, which stick where the adhesive is present. A velvet-like appearance to the print can be obtained by electrostatic flocking, in which the fibre snippets are caused to stand upright in an electrostatic field as they are being applied.

Pigment printing:

Pigments are colours which do not dissolve and penetrate into the fibres. They have to be applied together with a film-forming binder. More than 50% of all printing colours are pigment types. 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 polymerization 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.

Printing Processes:

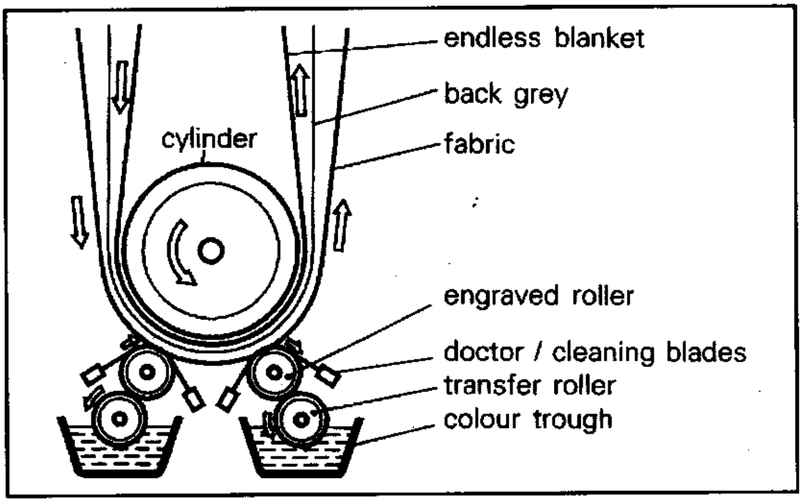
Hand Printing or Block printing:

This is the oldest method of printing but it is seldom used nowadays in the industry. The printing paste is applied by means of a wooden block which carries the design in relief, or by a stencil.

Roller Printing:

Roller printing is also referred to as intaglio or machine printing. The technique dates from the end of the 18th century (Scotland: James Bell) and has resulted in the disappearance of hand printing, which is a time-consuming printing technique. The technique of roller printing is especially used for very large batches but faces great competition from rotary screen printing.

The oldest mechanized method for continuous printing represents only about 16% of print production today, and is declining. Roller printing is capable of producing very sharp outlines to the printed pattern which is especially important for small figures. The maximum design repeat is the circumference of the engraved roller.



The design is engraved onto copper rollers, a separate roller for each colour. The rollers are mounted against the large main cylinder, around which the fabric travels together with a resilient blanket and a protective back grey. The printing paste is located in a trough. A transfer roller runs partly immersed in the paste and in contact with the engraved roller. A doctor blade, scrapes away all of the paste except for that contained in the engraving. A cleaning blade on the other side scrapes away any lint picked up from the fabric. The pressure of the engraved roller against the fabric causes the design to be transferred. Any excess paste which is squeezed through the fabric, is taken up by the back grey. This protects the blanket and prevents the design from being smeared.

Advantages and disadvantages of roller printing:

Roller printing is especially suited for printing large batches. Speeds can amount to approximately 1oo metres per minute. Moreover, roller printing can be used for very fine printing.

For small batches, however, the changing times between printing of the various batches are so considerable in the complete production process, that the efficiency (cost effectiveness) in machine utilization can drop to 50%. The changing time is necessary for adjusting and preparing the machines for a new series.

Another disadvantage is the crush effect. Applying several colours in one drawing is achieved by using several printing rollers. Each printing roller applies one colour. During the printing process, each colour will be "crushed" by the following rollers as many times as there are colours left to be applied. Consequently, the colour will be pushed more and more through the fabric to be printed. Deep colours are hard to obtain, which benefits screen printing. There may be a reduction in colour strength of up to 50%.

In roller printing, it is essential to apply the light colours before the darker ones because traces of the preceding colour can be carried forward into the following colour. Engraving the printing rollers is an expensive operation which raises the price of the roller printing technique considerably.

Screen Printing:

Screen printing is comparable to stenciling. A distinction is made between flat screen printing and rotary screen printing. In flat screen printing, rectangular frames (screens) are used with a thin gauze fixed to them. Rotary screen printing is done with cylindrical screens. The cylindrical screens contain the colour paste and rotate over the fabric to be printed. The dye is forced through the cylindrical screen which is perforated according to a particular design onto the fabric underneath.

Screen printing is becoming increasingly important. The designs are fairly simple to apply and the dimensions of the screens can easily be changed. The pressure which is exerted is also lower than with roller printing. Textured surfaces are not crushed and colour development is also better.

The screen properties are very important here. Stable screens are necessary. The frames used for flat screen printing are made of wood, or preferably of metal. The use of strong nylon or polyester gauze threads (hydrophobic materials) guarantees a tightly stretched mesh which will not bend under loading (with the colour paste). The paste is pushed through the screen by means of squeegees onto the fabric according to a certain design. The development of fully automatic printing machines for flat and rotary screen printing in the middle of the twentieth century has been an important step. It has contributed to rotary screen printing becoming the most important printing technique (> 60%).

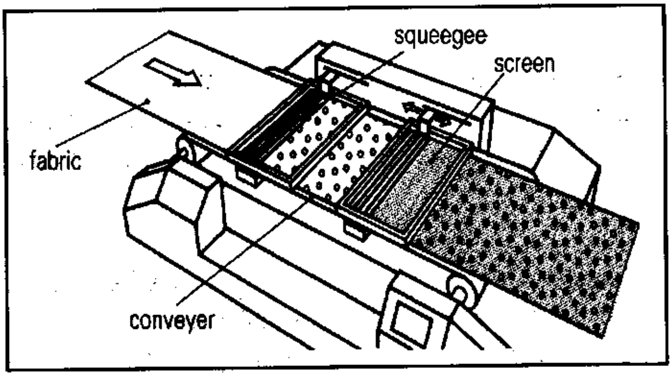
Flat Screen Printing:

There are three types of flat screen printing, such as hand screen printing, semi-automatic flat screen printing and fully-automatic flat screen printing.

Hand screen printing is to be considered a craft rather than a productive working method. The fabric is fixed to a blanket or back grey on a printing table where the screens are put on. Normally, another screen is needed for each colour of the eventual drawing. The print paste is spread across the screen by hand with a (rubber) squeegee blade forcing the paste through the screen. The manual method may cause irregularities.

In semi-automatic flat screen printing the squeegee is moved across the screen mechanically. It is impossible to reach a considerable speed of working with this method.

In both hand and semi-automatic screen printing, the various colours are applied one after another with intervals for drying (wet-on-dry method). Application with shorter intervals is known as the wet-on-wet method.



Fully-automatic flat screen printing: Increasing the printing speed can be done by applying (printing) all colours on the fabric simultaneously which leads to a continuous process instead of a batchwise one. In that case the fabric to be printed moves over a distance equal to the width of the repeat (intermittent movement) between each printing operation. The repeat is that part of a design or pattern which is repeated on equal distances in length and width. The design or pattern is the whole set of figures which are printed on the material. The material to be printed is gummed to an (endless) printing blanket or conveyer. This blanket can be easily stuck to and removed from the textile to be printed. It is then washed and dried during one working period (so-called Buser system). Adhesives can be applied and removed in each cycle, or can remain on the blanket and be active permanently (thermoplastic layer). Some products in the paste, however, may (gradually) affect the adhesive layer.

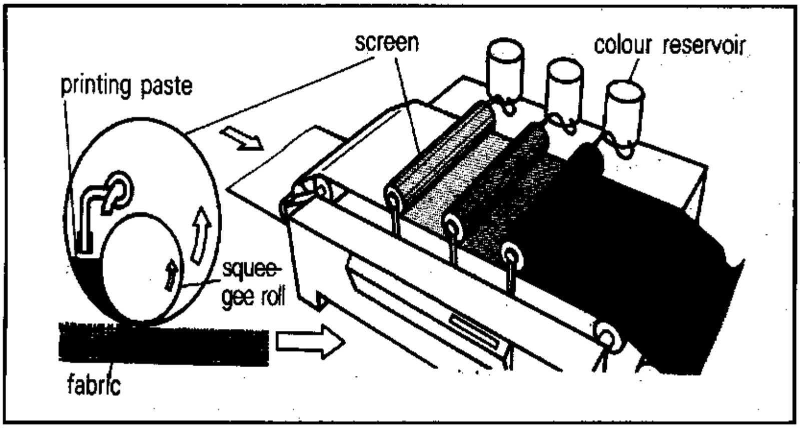
The use of flat screens requires squeegees that can spread the paste, usually across the width of the screen. The two most popular squeegee systems are:

- The double-blade squeegee,
- Magnetic rod squeegee

A blade squeegee has two rubber or metal tongues and pivots around an axis. It is always the rear squeegee which is in contact with the screen. The rod squeegee is driven intermittently under the blanket by an electromagnet.

Rotary Screen Printing:

Fully-automatic flat screen printing is not continuous yet. Rotary screen printing on the other hand is continuous. Rotating cylindrical screens are used which are automatically fed (by means of pumps) with paste from inside. Driving the screens can be done at either side. During printing, the paste is pressed through the surface (nickel: ± 0.1 mm thick) via openings in order to obtain the desired design. The cylindrical screens allow more screens to be arranged per unit length than is the case with flat screen printing. Speed range from 30 to 50 metres/min. The standard internal circumference of cylindrical screens is 640 – 640.1 mm. However, other dimensions are also possible.



Functional Finishing:

The chemical structure of natural, artificial or synthetic fibres determines some of the properties that are naturally present also in finished products. Some fibres (such as linen, hemp, silk, nylon, polyester) are stronger than others (wool, viscose, acrylic) according to more or less controlled distribution of macromolecules in the polymer mass, structure stiffness and any possible inter and molecular interaction between the chains; other fibres tend to distort when stretched (cotton, viscose), and others recover their original shape after being distorted (wool); some others easily burn (cellulose), burn slowly and self-extinguish (wool, silk) or burn and melt (synthetic fibres). The above mentioned characteristics and many others make up positive and negative properties of a textile material, which must be accurately considered in view of their final application. The textile product final application will be considered from many points of view: wearability, hand, mechanical resistance, wettability, washability, deformability, fire-proof ability and many others.

The word "textile finishing" defines a series of processing operations applied to gray fabrics to enhance their appearance and hand, properties and possible applications. The term "finishing" includes all the treatments applied to gray fabrics such as scouring, bleaching, dyeing or printing while we will use the term 'functional finishing' with reference to all the mechanical orchemical finishing operations carried out on fabrics already bleached, dyed or printed to furtherenhance their properties and possibly add some new ones.The terms 'finishing' and 'functional finishing'are therefore similar and both play a fundamental role for the commercial excellency of the results of textiles, strictly depending on market requirements that are becoming increasingly stringent and unpredictable and permit very short response times. Depending upon the type of textile substrate to be treated (staple, yarn or fabric) functional finishing processes are carried out using different means:

Mechanical means: involving the application of physical principles such as friction, temperature, pressure, tension and many others.

Chemical substances involving the application of synthesis or natural chemical products, which bind to the fibres more or less permanently.

Combined mechanical and chemical means involving the application of both chemical and mechanical processes.

The main purposes of functional finishing processes are the following:

- Develop the "product finishing" in all its fundamental elements such as hand and appearance;
- Give the finished fabric some properties that grant an optimum behaviour during the makingup and all through the life of the textile.

The parameters influencing the choice of the most suitable finishing process are the following:

- Fibre nature or fabric to be subjected to functional finishing treatments
- Final application of the fabric to be subjected to functional finishing treatments

Mechanical Finishing Treatments:

Mechanical finishing processes can be referred to as those processes generally carried out on open-width dry fabrics, with or without heat application, which give the fabric good dimensional stability (shrink proof and shape retention) and modify the "hand" of the textile product by altering its structure (at least its surface structure).

Dry finishing:

Calendering: a lustrous, dense and compact appearance can be obtained by means of friction, pressure and heat.

Ciréing: this calendering operation is carried out using special calenders and exploiting the combined actions of heat, friction and polishing agents.

Embossing: this particular type of calendering process allows engraving a simple pattern on the fabric.

Sueding: thanks to this process, the fabric has a much softer hand and an improved insulating effect thanks to the fibre end pulled out of the fabric surface. This process is carried out by means of a roller coated with abrasive material.

Raising: the fibre end pulled out to the fabric surface imparts an insulating effect. This process is carried out by means of hook-needles running in different directions on the fabric.

Shearing: the fibre ends on the fabric surface are cut by using special cutting tools.

Singeing: the fibre ends pulled out to the fabric surface are burnt by means of a flame (see preliminary treatments).

Wet finishing:

Wet calendering: this process is quite similar to the dry one. The only difference is the use of steam.

Fulling: the structure, bulk and shrinkage of wool are modified by applying heat combined with friction and compression.

Sanforising: the fabric is given an optimum dimensional stability by applying mechanic forces and water vapour.

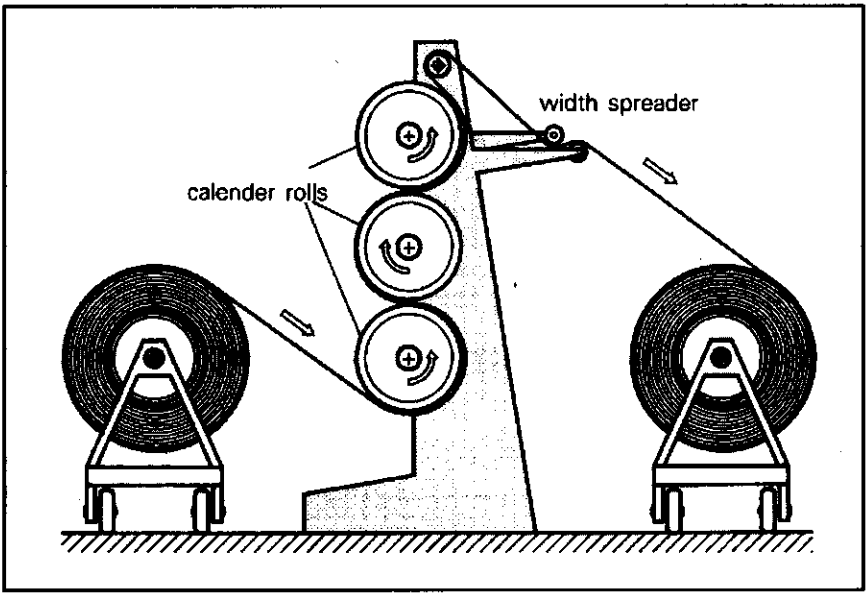
Decating: the lustrous appearance of the textile material is eliminated, the surface is smoothed and the fabric is given an optimum dimensional stability thanks to the action of dry or overheated saturated vapour.

Calendering:

This non-permanent mechanical finishing treatment is applied to fabrics made of cellulose, protein and synthetic fibres, by means of a calender. This machine generally includes one or a series of couples of rollers pressed one against the other with adjustable pressure and identical or similar tip speeds. The cloth passes through one or more couples of rollers, which exert a smoothing and a pressing action. Some rollers are stiff while some others are made of softer material. Stiff rollers are generally made of steel or hardened cast iron and the surface can be chrome-plated, nickel-plated or made of stainless steel and can be subjected to treatments that give:

- a matt appearance similar to the abrasive blasting;
- a cross-stripe engraving to improve the fabric resistance to sliding;
- a very thin diagonal stripe patterning with silk-sheen appearance;
- a patterned engraving with embossed effects.

The fabric passing through the rollers of the calender is subjected to a very uniform pressure all along its width; if the rollers rotate at a different speed, a vigorous friction effect is generated. Steel rollers may be equipped in such a way to be heated from the inside by means of steam, circulating fluids or electrical power. They are supported by a vertical central frame made of steel, having the same size of rigid rollers, while the surface is coated with softer material like cotton (to stand high temperatures), wool paper (to enhance the glaze finish), or jute, wool or plastic material such as polyamide. The rollers coated with paper/wool, containing 45-50% of wool, feature good elasticity and excellent resistance to wear and are suitable for a wide variety of applications; they can also be used in embossing calendering units. Rollers made of paper/cotton, are used almost in friction calenders and for treating .hard. fibres, thanks to their high resistance capacity. Cotton rollers, featuring higher elasticity than the paper ones, are mainly used for cotton and blends finishing and for a final full hand effect.



Calendering Machine

The life of cotton-polyester or polyamide rollers is considerably longer; in fact they are very resistant and cannot be easily etched by the passage of creases, knots or sewing. Thanks to their improved hardness, they produce on the fabric a particularly lustrous appearance and allow higher operating speeds. The effects on the cloth can be set permanently by using thermoplastic fibres or by applying suitable (thermosetting resin or reactive-based substances) finishing products.

The use of different types of calenders gives different effects such as:

Sheen appearance: it can be obtained by smoothing the cloth surface, which ensures a better reflection of light.

Better coverage: it is due to the compression of the cloth, which generates a flattening of each single yarn.

Softer hand: it is obtained thanks to a slight ironing effect, which produces a smoother, and softer cloth surface.

Surface patterns: they can be obtained by means of special effects ("embossing" for example) for decorative purposes or to modify the surface smoothness.

Yarn swelling and rounding effect: they give a modest glaze finishing to the fabric, a surface smoothness and above all a full and soft hand.

Embossing:

Embossing is a particular calendering process through which a simple pattern can be engraved on the cloth. The embossing machine is made up of a heated and embossed roller made of steel, which is pressed against another roller coated with paper or cotton, its circumference being exactly a whole multiple of the metal roller. A gear system drives the harmonised motion of the rollers, preventing them from sliding and granting a sharp engraving of the patterned design. After being engraved, the pattern can be stabilised by means of an appropriate high-temperature treatment or by applying suitable starchy substances.

The process can be applied of fabrics made of all types of fibres with the exception of wool. This finish is permanent when applied to fabrics made of thermoplastic fibres. It is not permanent when applied to untreated fabrics made of natural fibres or manmade fibres that are not thermoplastic; however, if these fabrics are treated with certain chemical resins, the embossing is considered to be permanent. To preserve the embossed finish of such fabrics, they should be washed in lukewarm water with a mild soap, never be bleached, and be ironed on the wrong side while damp.

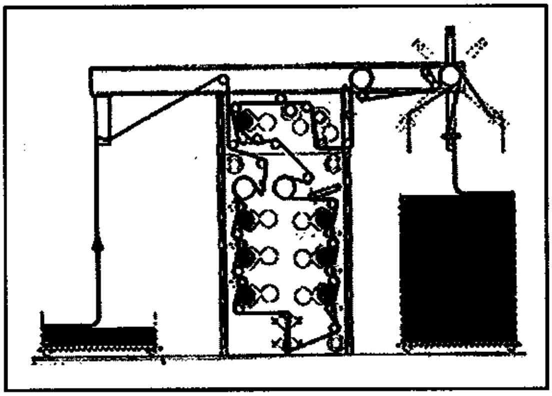
Sueding:

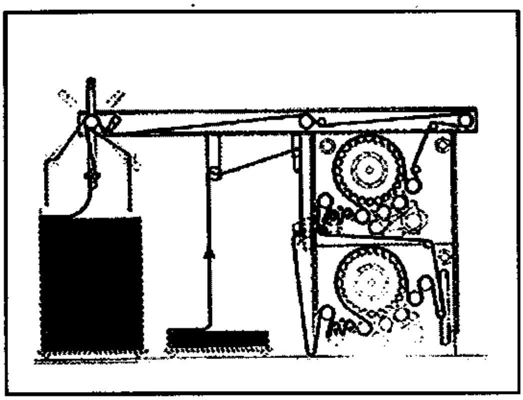
This operation is often carried out before the raising process to reduce the friction between the fibres making up the cloth and consequently to facilitate the extraction of the fibre end. The sueding process is carried out on both sides of the fabric and modifies the appearance and the final hand of the cloth; when touched it gives a soft and smooth sensation similar to the one given by a peach-grain surface.

The sueding machine is made up of some rotating rollers coated with abrasive paper, which emerise the cloth and produce a more or less marked effect depending upon the pressure exerted on the fabric by the abrasive rollers. The abrasive paper used can vary according to the desired sueding degree and must be replaced after a given number of operating hours, or when it does not properly carry out suitably the sueding function. In some cases, it is possible to use also metal rollers with the surface coated with uneven and rough grains or pumice rollers performing an excellent sueding action on both dry or wet fabrics. For a very superficial sueding, the natural abrasive power of pumice can be applied with successful results.

Gray fabrics as well as dyed ones can be subjected to the sueding process; the cloth to be emerised must be completely free from any finishing resin or adhesive substance remaining on the fabric surface after desizing. The sueding process reduces mechanic and dynamometric resistance of the fabric, thus making it more subject to tearing and seaming.

The fabric can run at different speeds inside the sueding unit; a smooth pressure is kept thanks to two balancing arms assembled at the entry and at the exit of the unit. The pieces of cloth must be sewn with abrasion-resistant material such as polyester or nylon. The gears must be suitably cleaned with compressed air jets since the presence of pile residues could clog the ball bearings or drop again on the fabric surface thus creating some problems with dyeing machines filters. The sueding process, which can affect the fabric with a very wide range of effects, can give some problem when applied to knitted tubular goods but it's widely used on woven fabrics with different weights and weaves (its application ranges from coarse jeans cloth to light and delicate silk or microfibre, coated fabrics and imitation leather).


6-cylinder sueding machine


24-cylinder sueding machine

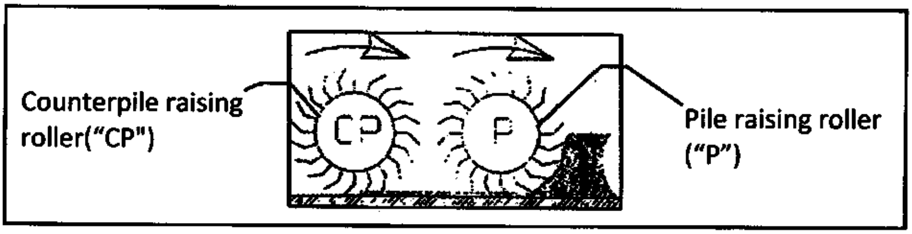
The sueding unit is equipped with 6 rollers performing the sueding action on the face of the fabric and 1 roller performing its action of the back of the fabric; an advantage of this system is the possibility to use sueding cloths with different grains on each single roller. Thanks to three dandy rollers, the sueding action can be automatically adjusted during the fabric processing thus allowing the sueding process to be carried out also on knitted goods.

The 24-roller sueding unit assembled on 2 rotating drums features some advantages if compared to traditional machines equipped with 4-6-8 rollers: the combined action of several rotating rollers and the beating effect grant a smooth sueding, and a much softer hand than any other machine; no differences are generated between the centre and the selvedge; no stripes are formed on the fabric; the wide contact surface allows very high operating rates. The great number of moving rollers performs a gentle action on each single sueding roller thus granting the maximum sueding smoothness. Furthermore the life of the abrasive cloth is much longer than the one assembled on conventional machines. In fact, 100,000.150,000 meters of synthetic fabric and up to 200,000.250,000 meters of 100% cotton fabric can be processed in standard processing conditions before replacing the abrasive; sueding units can also be transformed into raising (napping) units by assembling a special conversion kit. All sueding machines are equipped with a brushing unit assembled at the exit to reduce the powder resulting from the sueding process.

Raising or Brushing:

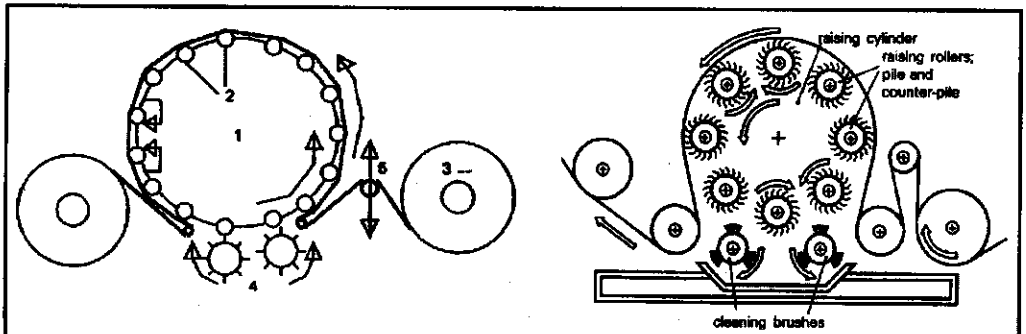
The raising process is a very old technique known also to Romans (as pictured in some paintings found in Pompeii). This operation is particularly suitable for wool and cotton fabrics; it gives a fuzzy surface by abrading the cloth and pulling the fibre end to the surface. During those last years this process has also been applied on polyester/viscose blends and acrylic fabrics.

By means of this process a hairy surface can be given to both face and back of the cloth providing several modifications of the fabric appearance, softer and fuller hand and bulk increase. This enhances the resistance of the textile material to atmospheric agents, by improving thermal insulation and warmth provided by the insulating air cells in the nap. The fuzzy surface is created by pulling the fibre end out of the yarns by means of metal needles provided with hooks shelled into the rollers that scrape the fabric surface. The ends of the needles protruding from the rollers are 45°-hooks; their thickness and length can vary and they are fitted in a special rubber belt spiral-wound on the raising rollers. These rollers are generally alternated with a roller with hooks directed toward the fabric feed direction (pile roller), and a roller with the hooks fitted in the opposite direction (counterpile roller).



Raising rollers

The machine also includes some rotating brushes, which suction-clean the nibs in pile and counterpile directions. Actually the trend goes towards a ratio of raising rollers/pile rollers equal to or 1/3. The two series of rollers have independent motion and can rotate with different speed and direction thus carrying out different effects.

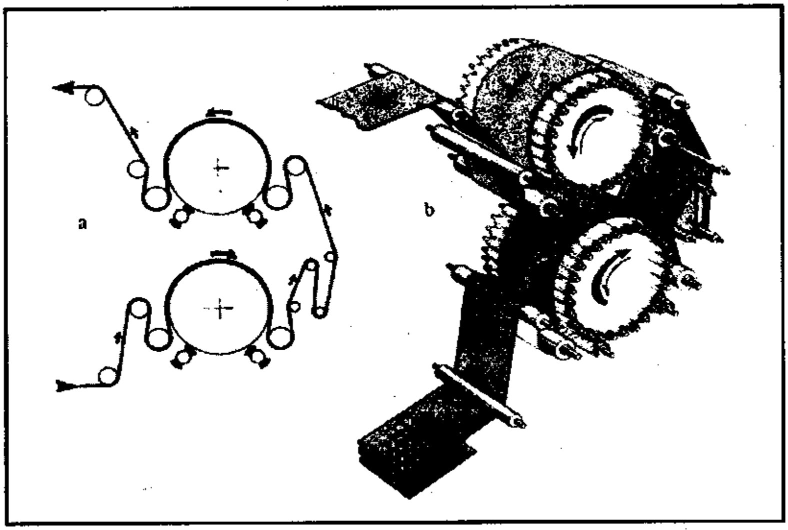


1: roller; 2: rollers equipped with hooks;3: fabric; 4: nib cleaning brushes;5: fabric tension adjustment

Raising (napping) machine:

The action of these systems is almost powerful and the results depend upon the effects and the type of fabric desired . The raising effect can be obtained by adjusting the fabric tension (5) or by adjusting the speed and the roller rotation direction (2). Once a certain limit has been exceeded, the excessive mechanical stress could damage the fabric: it is therefore better, when carrying out a powerful raising, to pass the wet fabric through the raising machine many times (dry when processing cotton fabrics) and treat the fabrics in advance with softening-lubricating agents. The pile extraction is easier when carried out on single fibres: it is therefore suitable to reduce the friction between the fibres by wetting the material or, in case of cellulose fibres, by previously steaming the fabric. For the same reasons, it is better to use slightly twisted yarns. The same machine allows different options of independent motions:

- fabric moving between entry and exit
- motion of large drum
- motion of raising rollers



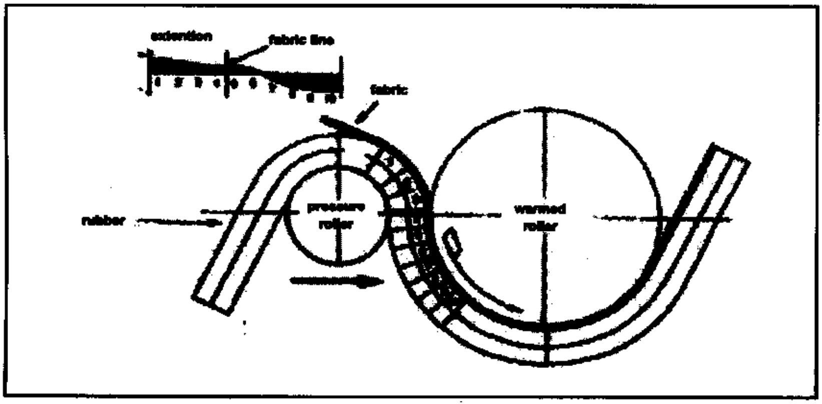
Raising the face and back of the fabric: a)scheme and b) view

The raising intensity can be adjusted by suitably combining the above mentioned independent motions, the tension of the textile material, the number of 'pilewise' or 'counterpile' raising rollers and their relative speed. It is possible to obtain 'combed pile' raising effect, "semi-felting" effect with fibres pulled out and re-entered in the fabric, and 'complete felting' effect.

Stabilisation:

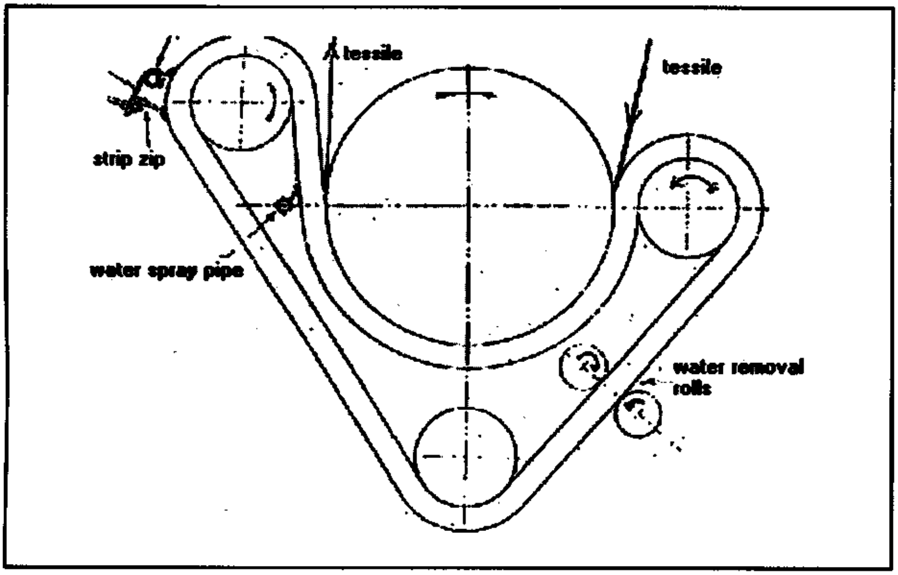
This process produces greater density and stability (e.g. the Sanforset process) and gives the fabric a controlled compression shrinkage, which eliminates distortions originated during previous processes. The fabric finished with this treatment keeps its shape also after repeated washing thus providing an excellent dimensional stability of the textile substrate. The fabric is fed into an opener/tension-adjusting device, and subsequently passes through a wetting unit where the quantity of water necessary for bulking the material is sprayed on the fabric. A steaming treatment can be carried out by passing the fabric onto a heated cylinder, which allows the water spreading in the fibre bulk and completes its swelling. The textile material passes to a stenter which gives the fabric the desired width and is then fed into the rubber-belt squeezing unit.

The fabric shrinkage is carried out with several simple operations: the rubber belt pressed between the squeezing cylinder and the drum is stretched and, once out of this squeezing unit, it again takes its original shape. The fabric is made to adhere to the rubber belt in the squeezing area and, since it can slide more easily on the heated and mirror-polished surface of the drum than on the rubber one, it is forced to follow it during the subsequent shrinkage. The resulting effect is a continuous and steady sliding between the drum and the rubber belt and consequently between the drum and the fabric. Since the stretching of the rubber belt depends upon the intensity of the pressure exerted by the squeezing cylinder, each pressure variation corresponds to a shrinkage variation. Therefore the higher the pressure the greater the shrinking effect.



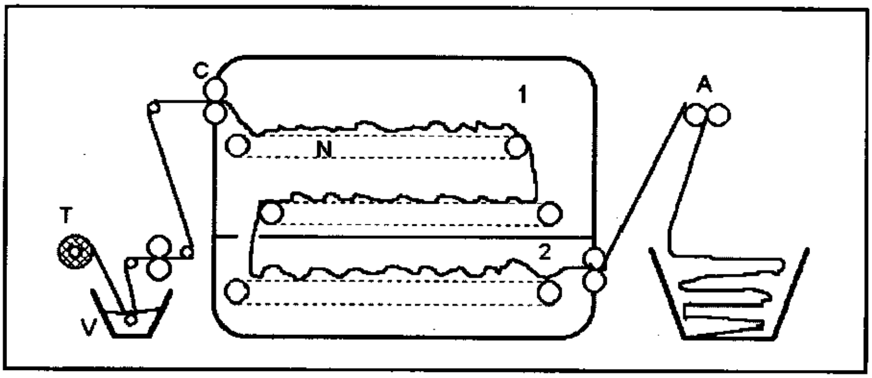
Compacting Process

After leaving the squeezing unit the fabric is sent out to the drying unit (180°-190°) with the slightest possible tension. The fabric is fed into a felt calender, which sets the shrinkage. The fabric immediately after the squeezing compression must be subjected to the slightest tensions and the moisture must not exceed optimum values.



Shrink area

Tubular knitted goods can be treated on stenters (to impart dimensional stability), only after the cutting operation and eventual bonding. Drying and dimensional stabilisation of tubular knitted goods can be obtained by passing the relaxed fabric into belt drying units and by steaming them in the final path.



Compacting Process for Tubular Knitted Fabrics

The fabric (T), wet or dampened with a solution containing softening agents in a vat (V), is laid down, overfed by a little calender (C), on metal-mesh vibrating conveyor belts (N) into a drying unit. On the first two conveyor belts, the fabric is dried with hot air (1) while vibrations make the fabric shrink freely; the steaming treatment (2), which sets the dimensional stability, increases the fabric bulk and gives a soft hand to the fabric, is carried out on a third conveyor belt. The fabric is then folded in a special folding unit (A). In case of further cutting and bonding units, a shrinking machine can be added to the system.

Decating:

This process is mainly carried out on wool by exploiting its elastic properties in hot and wet conditions by the direct action of the steam on the fabric. This treatment gives the processed fabric the following characteristics:

- dimensional stability;
- setting of pile after raising;
- reduction of possible glazing effect after calendering, thank to the swelling caused by steam blown on fibres;
- modification of the hand, which is much more consistent after the treatment;
- pre-stabilisation to autoclave dyeing

This category of treatments does not include the stabilisation of wool fabrics such as potting, where the dimensional stabilisation is obtained thanks to the "plasticisation" phenomenon occurring when the wool fabric is immersed in hot water. On fabrics made with other fibres, the same treatment can be carried out as "steam ironing" alternatively to the calendering treatment, when an excessive "glazing effect" could result from the treatment.

The steam decating, which is also referred to as dry decating, is carried out on decating machines in one continuous treatment or two discontinuous ones, according to the following operating techniques:

- drum decating (alternated at atmospheric pressure);
- autoclave vacuum decating (KD);
- continuous decating.

Chemical Finishing Treatments:

By applying chemicals of different origins, a fabric can receive properties otherwise impossible to obtain with mechanical means. Chemical finishing treatments:

- allow the stabilisation of fabrics already subjected to mechanical finishing processes, such as calendering;
- give fabrics some properties (e.g. flame retardancy and water repellency), which would be otherwise absent

The products used can be classified as follows:

- **Natural** (adhesives, fats, oils, starches)
- **Artificial** (modified starches, modified cellulose)
- **Synthetic** (synthesis products) including: N-methylol derivatives (thermosetting, reactants), linear reactants (carbamates, epoxy resins), thermoplastic polymers (vinyl, acrylic, polyethylene), polyurethanes and silicones.

This classification, helpful for students, does not coincide with the products actually sold on the market since these products are blends containing also catalysts and auxiliaries which interact and produce complementary effects. It is therefore necessary to underline how chemical finishing can affect the textile product by altering its mechanical properties, sometimes changing the colour shade or its original colour fastness. Different techniques are available for applying the above mentioned finishing substances: by solution, dispersion, and emulsion, pad wetting, exhaustion, coating, spraying, etc. The most appropriate technique must be carefully studied for each fibre type, and the most suitable chemical finishing process applied to obtain optimum results and grant a reasonable safety margin for any possible error.

Application of the finish:

The operations to be carried out when applying the finish to a textile substrate are mostly conditioned by the structural and hygroscopic properties of the material to be processed, by the desired effects, by the physical and chemical nature of the elements that make up the finishing substance and by the machine.s output rate. In textile finishing, we can distinguish between five main application techniques:

a) padding;
b) spraying by means of atomisers;
c) exhaust process in treatment liquor;
d) coating carried out by means of doctor knives;
e) controlled application of low liquor quantities.

Padding is by far the most common among the various finishing techniques.

Padding:

This is certainly the most popular process for both the most conventional and innovative finishing treatments. The machine used for this process can be referred to with various definitions such as padding unit, squeezing unit, etc. After ensuring that the textile substrate can be padded by evaluating its mechanical and structural properties, this technique can be applied to carry out all wet finishing operations, except for some cases.

Spraying:

The application of finishing substances by spraying is used for carrying out gentle finishing processes which leave on the textile material a small concentration of products, and is particularly indicated for applying softening, anti-static and anti-mildew agents. For a good and homogeneous penetration and diffusion of the finish in the textile material, it is better to let the sprayed and wound fabric rest for some hours before drying. In the last few years, a very important field has been developed in the textile sector, i.e. the production of webs made of synthetic fibres. For this particular type of product, the resincoating process is carried out only by spraying the finish directly on the fibrous substrate and by generally applying synthetic resins in aqueous emulsion.

Exhaustion:

The treatment of yarns or fabrics in exhaustion liquor is recommended above all when stable chemical products are applied on the textile substrate. The manufacturing process undergone by the material is useful to precisely evaluate the best method for applying the finish, for example on hosiery or tubular knitted goods. From a chemical point of view, the most suitable products for the exhaust process are those with cationactive properties. In particular cation-active softening agents are often applied with this process, as well as paraffin- and wax-based emulsions, and more recently, cation-active polymer emulsions.

Coating:

At present, after the launch and diffusion of synthetic resins, the so called "coating and bonding" applications have been experiencing an extraordinary growth, above all in Italy.Coated and bonded fabrics are now simply classified, according to their end use, i.e. forgarments, upholstery, draperies and tapestries, footwear, leather goods and technical articles.Generally the process starts from a fabric or from a non-woven fabric as a 'backingAll fibres can be used, from light silk to linen and hemp, from synthetic fibres to glass fibres.As regards the resins used for the coating layer, manufacturers once employed only natural substances, but are now using almost exclusively synthetic polymers of high molecular weight.

Today manufacturers are constantly in the search for coating substances that are more and more elastic, able to withstand different mechanical stress and washing conditions, and above all resistant to wearing and weather agents. These coating polymers are bonded to the fabric backing by means of calenders, in the form of thin sheets or are mainly spread in the form of aqueous dispersions or solutions in solvents.

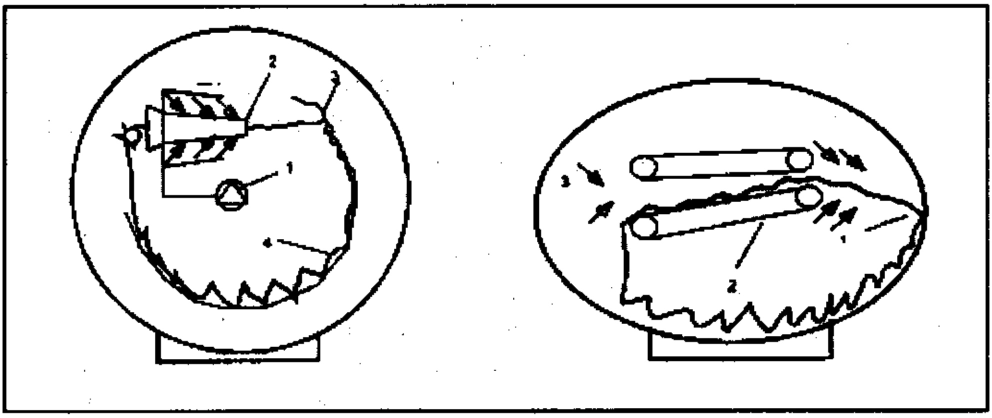
The characteristics and the properties of coated fabrics depend on the chemical structure of the coating resins applied and the type of backing fabric used. The coating layer undoubtedly plays the most important role for appearance, hand and resistance properties: its elasticity, its behaviour at high and low temperatures, its resistance to abrasion, to solvents and to the effect of ageing and weather agents, depend on its chemical composition as a substance with a high molecular weight and more or less thermoplastic qualities.

Softening:

As a general rule, each fibre has its specific softness value, which depends on its chemical composition and physical structure (less crystallinity = greater softness). The fineness of the fibre or of the filament directly affects the softness of the yarn (woollens, worsteds, microfibers etc.). The yarn twist ratio is inversely proportional to its softness. The weave also contributes to reducing (closer weave = plain) or increasing (looser weave = satin) the fabric softness. Furthermore, a greater number of yarns per centimetre increase the stiffness of the fabric, thus reducing its softness. Softening is carried out when the softness characteristics of a certain fabric must be improved, always carefully considering the composition and properties of the substrate. It is also worth underlining that no standard methods have been developed and established to determine exactly what the softness of a fabric is. This evaluation is therefore almost personal and carried out on the basis of operator.s experience. It is anyway possible to distinguish between many types of softness:

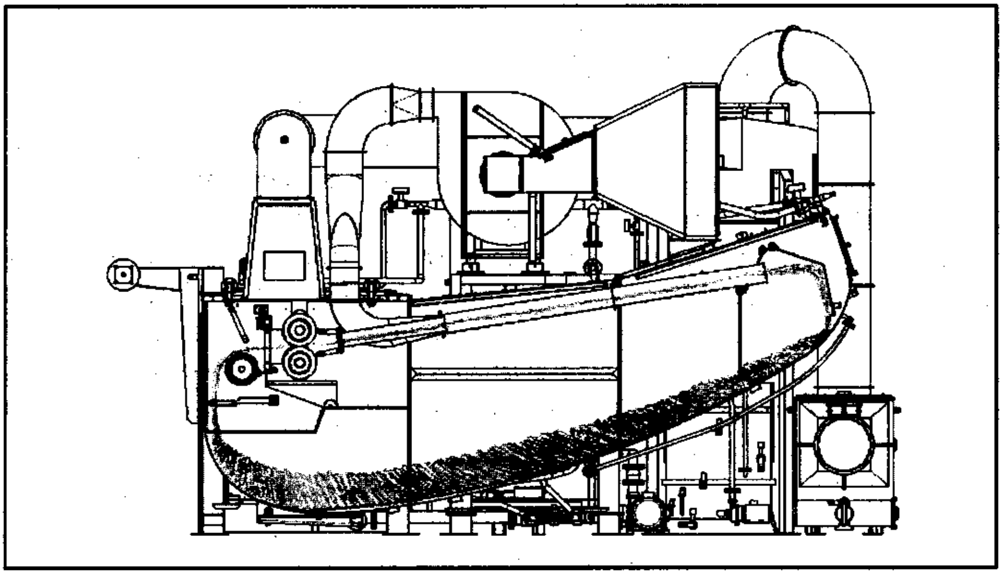
a) surface softness,
b) surface smoothness,
c) elasticity (to compression and stretching).

To change the hand properties of a fabric, we can apply mechanical, physical, chemical or combined techniques; some of these methods (sueding, raising) have already been explained indetail in previous sections of this handbook, while some others refers to machines that give different degrees of softness, by means of high-speed rope processing in wet or dry conditions,with the drying stage carried out during the treatment (with or without softeners or enzymes.) The functional core of these machines are the two tunnels where the fabric is fed through twoVenturi tubes. The energy applied for drawing the material is produced only by air and pressure.The fabric flowing through the Venturi tubes is pushed at high speed against a grid on themachine rear side; the fabric then slides on Teflon-coated chutes and reaches the machine frontside to start the cycle again; the fabric can reach a speed of 1000 m/min., depending on the type and weight of the different textiles to be processed and according to the desired results.



Schemes of fabric softening machines

The following picture details an industrial softening system.



A fabric softening machine

Anti-static Treatments:

Wool and such manmade fibres as nylon, acrylic, and polyester develop static electricity from the friction caused by wearing and general use. As a result, the fabrics attract dirt particles, cling and climb, crackle, even spark, and cause very minor but discomforting shock to the user. Some companies do apply antistatic treatments, sometimes in combination with other finishes which may have antistatic components in them. One form of Zepel is such a finish. These vary in effectiveness and durability. Some manmade fibre producers are making types of fibres which have built-in antistatic properties. There are several household products used in laundering that provide nondurable antistatic properties.

Being characteristically hydrophobic, synthetic fibres present a low electrical conductivity, so low that, after rubbing against other bodies, they can retain an electrical charge for a long time. Indeed, when two bodies, characterised by a neutral electrical charge and each having a different chemical composition, are rubbed together, the electrons of each of them will attract those of the other in such a way that both bodies acquire an electrical charge. Generally speaking, the body with the higher dielectric constant takes a positive charge, while the substance with the lower dielectric constant takes a negative one. A potential difference, of as much as several hundred millivolts, is created between the two contact surfaces. If these two bodies, both charged with electrical energy, are separated, the potential is increased, even as high as many tens of thousands of volts. As far as fabrics are concerned, this discharge of energy occurs mainly between the innumerable fibrils. It is responsible for creating the familiar crackling sound and for the formation of the tiny sparks and the genuine electrical discharges that can cause perceptible discomfort. To reduce this phenomenon, one can operate in a controlled environment that has high relative humidity, use conductors that can discharge the material, ionise the atmosphere, or apply hydrophilic chemical substances. Chemical products that confer an anti-static effect on synthetic fibres form, on the fibre surface, a thin film whose electrical conductivity is higher than that of the fibre. These substances are anionic, cationic, amphoteric, or even non ionogenic. The conductivity of a synthetic fibre is thus increased when it is covered with a surface-active substance in which the hydrophobic groups are oriented towards the fibre and the hydrophilic groups are oriented away from it.

The presence of mobile electrical ions is, however, important. Depending on the substantivity of the chemical products used, it is possible to choose between different application processes: immersion, exhaust or padding. Anti-static finishing treatments are rarely applied through spraying. Chemical products that have the capacity to confer a permanent anti-static effect condense at high temperatures; they can even condense when stored at ambient temperature in hermetically sealed rooms or containers (as can epoxy resin-based products). All the anti-static products available on the market can be applied by padding, while only a few can be applied using the exhaust process. The material is immersed in liquor containing the anti-static chemical product, squeezed (to 40-60% absorption) and finally dried in a stenter at 80-100°C. If the stenter is equipped with additional chambers that can be used to carry out heat setting processes, then it is also possible to condense, at the same time, anti-static products able to confer permanent effects.

Anti-mildew Treatments:

In certain ambient (humidity and heat) conditions, cellulose can be permanently damaged. This damage can be due to depolymerisation of the cellulose or to the fact that certain microorganisms (mildews) feed off it. The situation is worsened, during long storage periods, by the presence of starch finishing agents. This damage can be prevented by the use of antiseptics, bacteria controlling products containing quaternary ammonium salts, and phenol derivatives. Dyestuffs containing heavy metals can also act as antiseptics. Permanent modification of the fibre (cyanoethylation) is another possibility.

Cellulose fibres are particularly susceptible to mildew; silk and wool are also susceptible, but to a lesser extent. Such untreated fabrics will become stained, malodorous, and eventually deteriorated by the fungus if allowed to remain in a moist condition for a period of time. Shower curtains or other cotton fabrics may be mildewproofed at home by soaking the material in very soapy water, then, without rinsing, dipping it into a solution of copper sulfate. Antiseptics, such as boric acid and carbolic acid, also prevent rapid growth of the mildew fungus. One compound that is not easily washed out is a 0.05% solution of phenyl mercuric acetate in water. This is one of the most effective mildewproofing agents. Certain organometallic compounds, such as of tin and copper, are powerful mildew retardants. Copper imparts a greenish colour to fabrics. Certain resins based on melamine formaldehyde are also valuable for mildewproofing. Rotproofing, an extension of mildewproofing, is very important in agricultural applications

Dimensional stability:

Cotton knitted fabrics in tubular form often show excessive lengthways shrinkage on washing unless given a pre-shrinking treatment based on compressing the fabric lengthways. A new technique is to pre-shrink the fabric by transferring it from one suction drum to another, the second operating at a lower surface speed than the first.

The Koratron durable-press finish has been applied to polyester-cotton weft-knitted fabrics with a resulting improvement in dimensional stability on washing. A combined mechanical-chemical finish, namely, "Perset", has been applied to cotton and polyester-cotton fabrics and washing shrinkage has been restricted to about 5% in each direction by this treatment.

The Micrex Process is also a combined chemical-mechanical treatment when applied to open-width knitted fabrics containing a substantial proportion of cellulosic fibre. The sequence is (a) pad with resin, (b) dry, (c) compressively shrink lengthways, and (d) cure, treatment usually by means of infra-red radiation. For fabrics containing a large proportion of polyester or polyamide fibre, the padding and drying stages are omitted, the fabric being compressed and then heat-set in a relaxed state. Fabrics treated by this process are claimed to have a lengthways shrinkage on washing of less than 1%, and improved shape retention, lengthways stretch, and handle.