Jet Dyeing Machines

INITIAL (Understanding)

Knit goods usually wet process (i.e. pretreatment and dyeing) through Jet dying machines. These machines are fall under the category of batch dyeing machines. It follows the principle of Exhaust Dyeing which has been discussed in Dyeing section (at Dyeing Theory).

In these machines, both liquor and material move are used for rope dyeing and preparation; the fabric is carried over and driven through the machine only by the fluid force. These systems run with high temperatures (maximum temperature ranges between 135 and 140°C), with very limited liquor ratio (1:5-1:15).

TYPES

We can divide these machines in different categories:

1. Partially filled with liquor, suitable for treating PET or PA fabrics and for synthetic filament fabrics

2. Completely filled with liquor, used for more delicate fabrics (the fabric is carried over more delicately and is always immersed in the liquor). Now the trend goes towards the production of machines with a more delicate fabric drive, which adds to the hydraulic drive of the jet system a mechanic drive carried out by means of a large-size reel; this makes this multi-purpose system more flexible and therefore suitable for treating a steady wider range of fabrics.

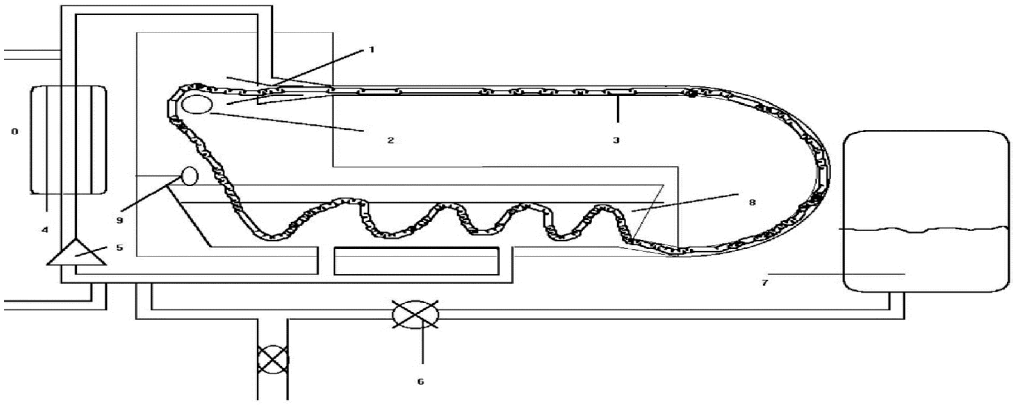
3. Overflow Jet Dyeing Machines

4. **Soft Flow / Air-flow (Air Jet) Dyeing Machines,** most recent types of JET dyeing machines and are in usual practice in the dyeing houses. So, we will consider this particular advanced Jet dyeing machine in detail.

1. Partially filled jet system (Picture 49): The external part of the machine is made up of an autoclave, generally horizontal and cylinder-shaped, with a turret on one side, provided with an access door and glass window; the jet nozzle from which a tube starts, is usually assembled inside the turret. The tube passing over or under the autoclave fits on the opposite lower side of the autoclave, thus assuring a continuous connection

The folded rope fabric moves slowly in the autoclave inside a special vat, partially immersed in the liquor, till reaching the lifting compartment (the turret). Inside the turret the rope is lifted up and, running on an idle or power-driven cylinder (reel), it is immersed in the jet nozzle. The rope moves along the return tube and is sent back (folded) to the opposite side of the vat to begin the cycle again.

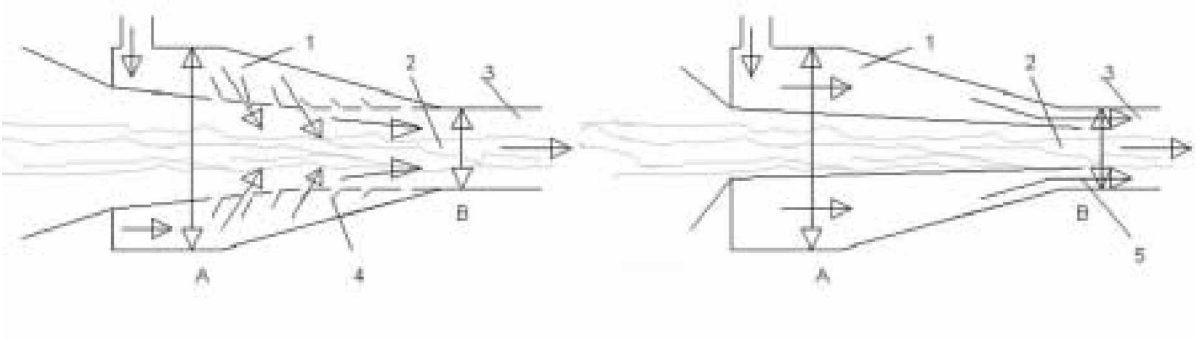
The liquor circulated by means of a centrifuge or axial multi-step pump passes through a heat exchanger before being sent to the jet nozzle.



Picture 49 – Drawing of a partially filled jet system

1- Jet	*6- auxiliary pump*
2- Guide roller	*7- vat for adding liquor*
3- Transport tube	*8- fabric and dwelling vat*
4- Heat exchanger	*9- magnet signal system*
5- Liquor circulating pump	10- by-pass valve

The external part of the jet transport system (applying the Venturi principle) (Picture 50), is made up by an external funnel (nozzle) for fabric passage assembled in a position coaxial with the tube; the liquor, forced through the tube with a specific pressure, is progressively accelerated in the smaller section of the funnel (Sections A and B in Picture 1A), until it reaches very high speeds (500-1400 m/min., depending on the flow and on the diameter). The liquor flow is powerfully directed toward the fabric inside the transport tube. The friction generated by the rapid liquor flow between the dye solution and the rope makes the fabric float through the tube; at the same time, the powerful motion of the flow facilitates the removal of creases on the rope.



Picture 50 – Ejector

1 – Jet system
2 – Fabric
3 - Transport tube
4 – Fins
5 – Neck

The circulation speed of the fabric can be adjusted: in older machines, a by-pass provided with an adjustable valve controls the liquor flow to the nozzle and consequently the transport speed of the fabric; in more recent models this adjustment can be carried out by means of variable- flow pumps equipped with inverters and/or adjustable nozzles.
Generally the liquor must be recirculated at least every 30-60 seconds: at each recirculation the liquor passes through the heat exchanger thus performing an excellent control of the temperature also for fast heating or cooling; this allows a fast and uniform dyeing. The fabric rope must carry out a complete cycle every 1-2 min. (to avoid wrinkles due to excessive dwelling times inside the vessel).
The type of nozzle and its size also determine the weight range of the fabrics to be treated. Some machines are particularly suitable for light, medium- or heavy-weight fabrics while others can process fabrics of different weights by replacing or adjusting the nozzle.
The operating conditions of this type of machine ensure a fast and uniform distribution of the dye (or of other chemicals) on the fabric and therefore short process times; the cloth is moved along the tube at very high speeds (up to 400-600 m/min) and short staple and delicate fabrics can be negatively affected by scratches or the formation of hairiness on the surface. The great difference of speed between the liquor and the fabric rope flowing inside the tube as well as the lifting of the fabric from the collection vat can cause possible distortions on stretch-sensitive fabrics.

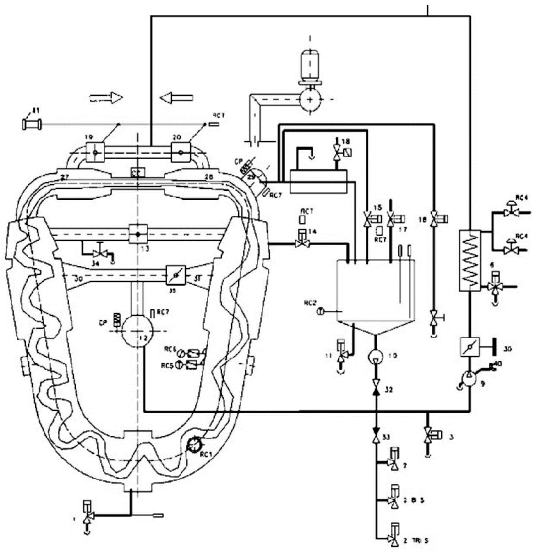
2. Completely filled jet machines: the shape can vary depending on the manufacturer‘s design; the access door is generally positioned in the upper part of the machine, near the nozzle, which is always immersed, as well as the processed fabric. The transport principle of the rope is similar to the principle of external-nozzle jet systems, but in complete filling jet systems the flow directed on the rope in the Venturi tube (nozzle) is more delicate; this avoids excessive tensions, stretches during the lifting and frictions with metal parts. Also the maximum fabric circulation speeds

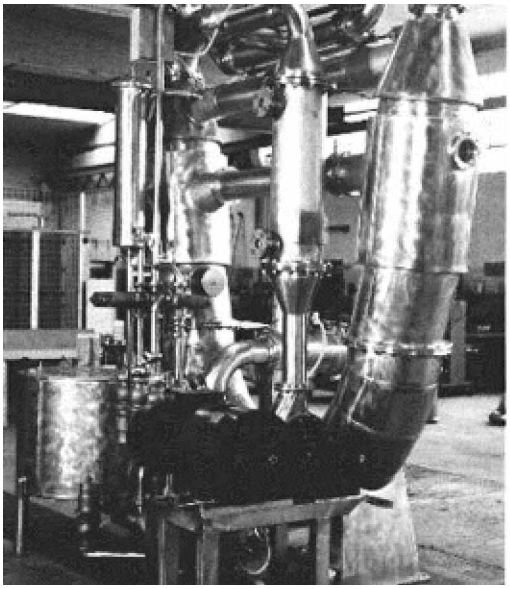
are limited (200-230 m/min.) if compared to those of partially filled jet systems. As a result, it is possible to treat delicate fabrics, more subjected to peeling or the formation of hairiness on the surface.

In reality, these machines have been working in mills for years, but they run with high liquor ratios (1:15-1:25) at high costs deriving from huge energy consumption (heating, maximum demand for pumps), from considerable water, chemicals and therefore effluent treatment costs, and finally from long process times (lower number of cycles per minute).

Completely filled jet dyeing machines now available on the market have been designed to run with limited liquor ratios (1:7-1:12) which allow the processing of delicate wool or blend fabrics, with short process times and low costs.

Picture 52 shows a completely filled jet system, which can work with a liquor ratio of 1:12, and three cycles per minute; this provides a non-stop control of the temperature and ensures an excellent exchange between the liquor and the material. A special device including two jet systems has been designed to allow cloth motions in both directions, thus enhancing the dye consistency and preventing ropes from entangling.





Picture 52 - Drawing and picture of a completely filled jet machine

3. Overflow Jet Dyeing Machines

This dyeing machine is used for pre-treatment and dyeing of rope fabrics, with both liquor and materials moving (Picture 53); the architecture and the design of the system and the liquor ratios are similar to the jet machine ones.
The main difference is the fabric transport system, driven partly by a motorized reel, and partly by the sequential flow of the liquor. The jet system nozzle, based on a Venturi tube, is replaced by a vessel containing the liquor; the liquor enters the straight pipe section and then flows through the transport channel, together with the fabric rope. During this stage, the fabric is subjected to slight tensile stresses and to small friction forces, due to the progressive acceleration caused by the drop of the liquor and to the limited speed on one side and to high liquor flow and to the large-size transport tube on the other one. This machine is therefore suitable for delicate fabrics, too œ provided they are not wrinkle-sensitive.
The transport speed of the fabric is adjusted by the reel speed and by the water flow that the pump forces into the fabric transport tube (60-250 m/min.).

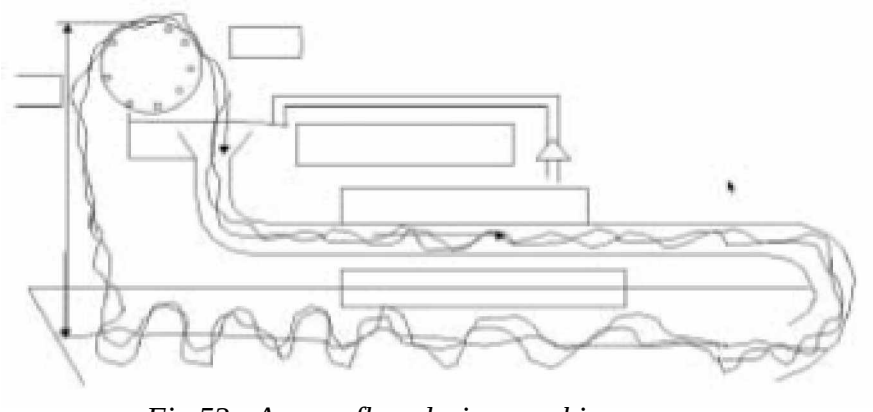
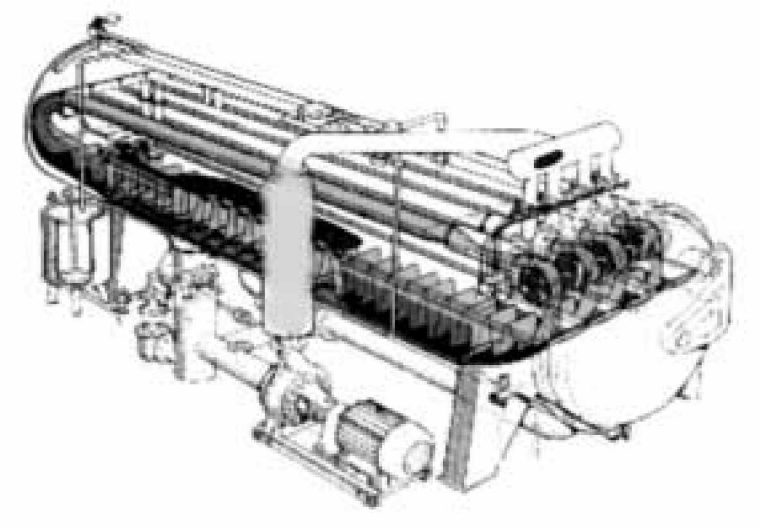


Fig 53 - An overflow dyeing machine

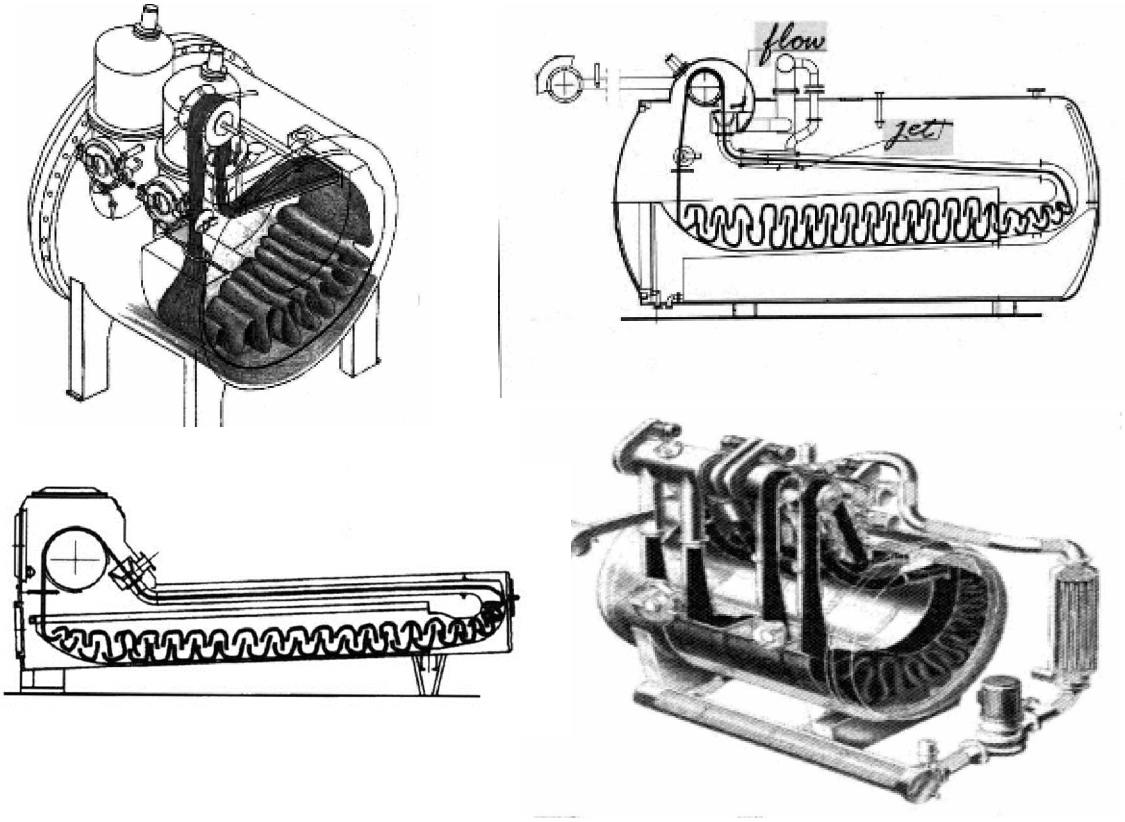


Picture 54 – Drawing of a four-rope overflow system

The builders of overflow systems supply machines working at high temperatures (from 130 to
140°C), particularly suitable for processing synthetic fibres and synthetic fibre blends, and machines running at atmospheric pressure, particularly suitable for treating natural fibres (these machines generally reach operating temperatures from 98 to 108 °C and are slightly pressurised to avoid cavitation effects in circulation pumps when working with temperatures near 100°C. Now different types of jet and overflow systems are available on the market and manufacturers have designed special devices to make them even more versatile and suitable to meet the ever- changing customer needs.
The most interesting solutions are:

- Flow-jet systems: to transport the fabric these machines apply a system based on the Venturi principle also known as drop principle and a motorised reel (Picture 55 B and D).

- Jet system with adjustable nozzle to allow a non-stop change of the transport effect (when the nozzle is closed the jet effect is very powerful while when the nozzle is open the machine runs in the overflow technique) (Picture 55 A and C œ Variable nozzle in Picture 56).
- Vertical machines where the fabric is lifted at 1-1.5 m. from the liquor level, with a certain stress on the fabrics (these machines ensure high transport speeds, suitable above all for continuous artificial and synthetic fibres) (Picture 55 A, B and D).
- Horizontal machines, where the fabric is slightly lifted from the liquor level, with subsequent low tensile stresses and transport speeds (suitable for delicate fabrics) (Picture 55 C).
- Machines with long (Picture 55 A and C) or short transport tubes (Picture 55 A and D) or with differently shaped tubes to better suit the various types of fabric (Picture 55 A, B and C).



Picture 55 – Various types of jet and overflow systems

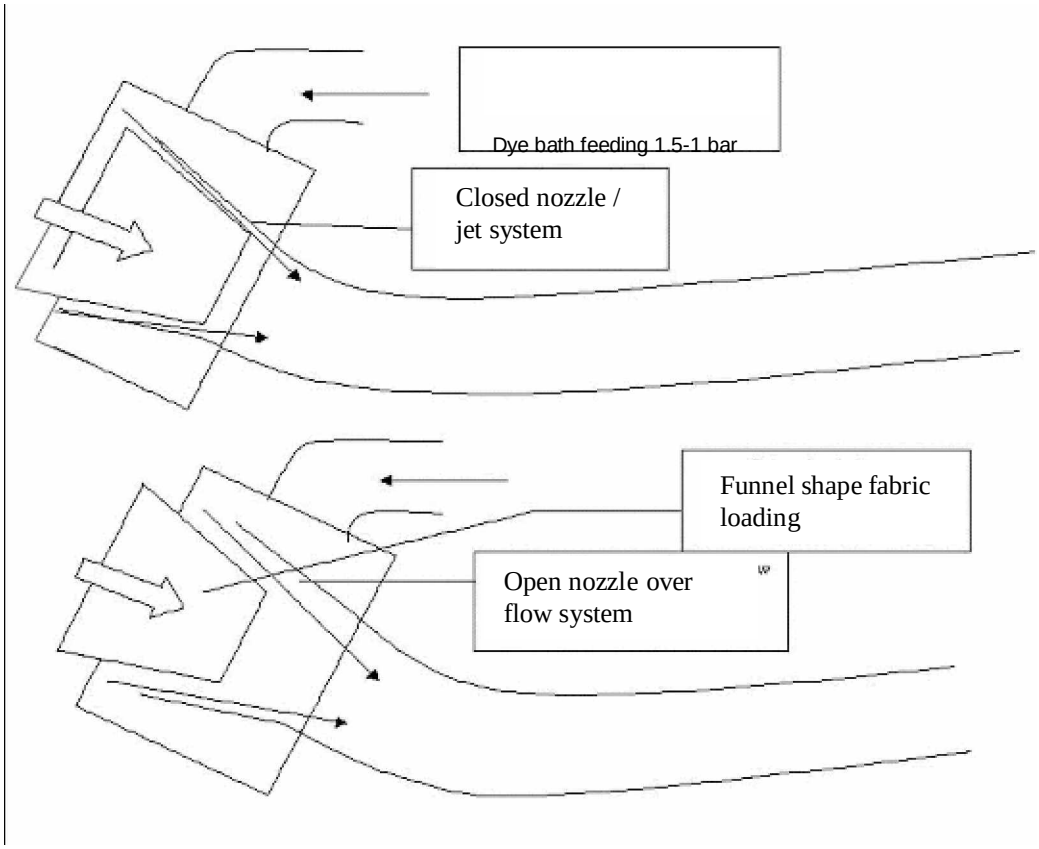
Machines with slant or Teflon-coated collecting vats to improve the sliding thefolded fabric and reduce the problems of fibrillation, abrasion and/or projecting yarns (Picture 55 C).

- Transport tubes slightly leaning upward to reduce the friction of the rope with metal surfaces (the fabric is drawn always immersed in the liquor) (Picture 55 C).
- Air blowing in the nozzle or in the flow to improve the shifting of the rope folds
- Air jets blowing under the reel to reduce possible abrasions on the fabric.

- Separation of part of the rope liquor in the last part of the transport tube, to reduce the speed of the fabric when entering the collecting vat, thus avoiding irregular folding and entangling
  (Picture 55 C).
- Hydraulic system to improve a uniform folding/plaiting of the fabric without entangling
  (Picture 55 D).
- Possibility to drain the liquor at temperatures exceeding 100° C (if possible, in order to reduce the process times) (Picture 55 D).

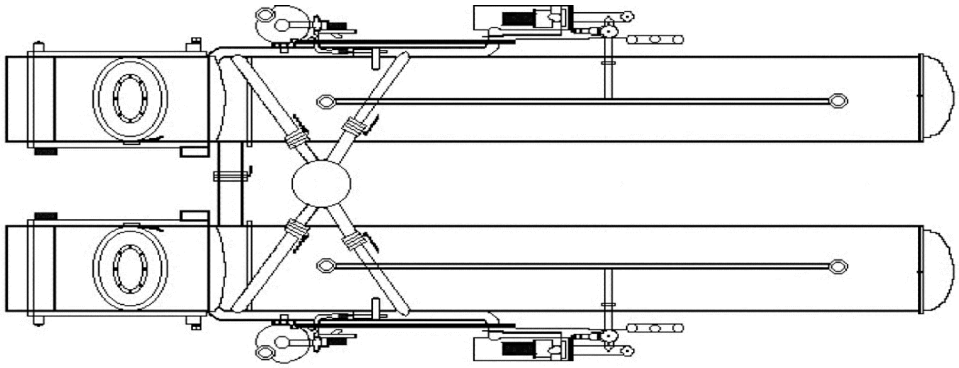
To optimise either output capacity and production flexibility, builders have studied different solutions. It is worth remembering that the loading capacity (in kgs) of the machine depends on the maximum liquor volume that can be used and on the liquor ratio; the weight of the fabric (as previously stated, the process time of one rope cycle must not exceed 2 minutes) can affect the maximum width of the rope and therefore the maximum load in kgs

Briefly, to process lots of different sizes (from 50-60 kgs to 800-1200 kgs) the manufacturers can build machines that can load many ropes (with separated collection vats - Picture 58, Overflow - Picture 54), or machines with only one rope and variable path (Picture 55 D).



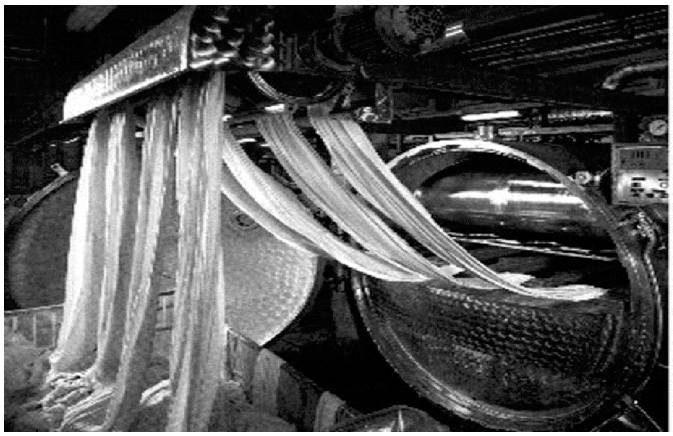
Picture 56 - Jet/flow variable-position nozzle

To increase process flexibility, the machines (with 1, 2, 3 or more ropes) can be twin-type; two identical machines that can work two different lots separately; if needed, the two machines can be linked and process simultaneously the same lot with the same liquor and the same operating conditions, thus doubling the loading capacity (Picture 57).



Picture 57 – Twin flow system

Both jet and overflow systems are equipped with a motorised reel for loading/and/or unloading the fabric. (Picture 58).



Picture 58 – Picture of a 3-rope flow system

4. Soft Flow / Air-flow (Air Jet) Dyeing Machines

These are the most modern rope dyeing machines currently available on the market. The operating principle is similar to the jet dyeing system, but the fabric, guided by a motorized reel, is exposed inside the nozzle to a stream of forced air, blowing from one or two turbines (or fans) which take the air from inside. During the transport stage, or at the exit of the transport section, or, if necessary in both areas, the rope is sprayed with a controlled quantity of dyeing liquor; the atomized quantity of liquor slightly exceeds the one that the fibre can actually absorb. When the fabric folds in the perforated collection vat, it releases the excess liquor, which is recirculated by the special pump.

The fabric transport speed can be also very high (between 250 and 1000 m/min) while the liquor ratio could be, in theory, 1:1 to 1:2; in standard processing conditions the liquor ratio is 1:3-1:8. This machine usually allows high temperature process.

The high speed of the fabric fed, together with the reduced liquor ratio, guarantee optimum dyeing results in very short times; it also reduces water consumption and the quantities of auxiliaries and dyes necessary for an optimum dyeing process, thus leading to considerable cost reduction (also with regard to wastewater treatment costs). This applies particularly to dyeing, above all in the case of dyes with low affinity for fibers and low exhaustion percentages. However, sometimes the low liquor ratio could cause problems due to the poor solubility of some dyes and/or during subsequent post-dyeing washing process, when higher liquor ratios would be more helpful.

These machines have been designed for dyeing fabrics made of NATURAL FIBERS, synthetic fibers, blends of man- made and elastic fibers, and micro-fiber fabrics; in reality these machines have proved to be extremely suitable for dyeing man-made filament. While air feeding facilitates the continuous motion of the fabric and reduces possible defects due to rope folding, the fabric tends to pack on the bottom of the machine for the extremely reduced quantity of liquor, thus leading to permanent wrinkles.

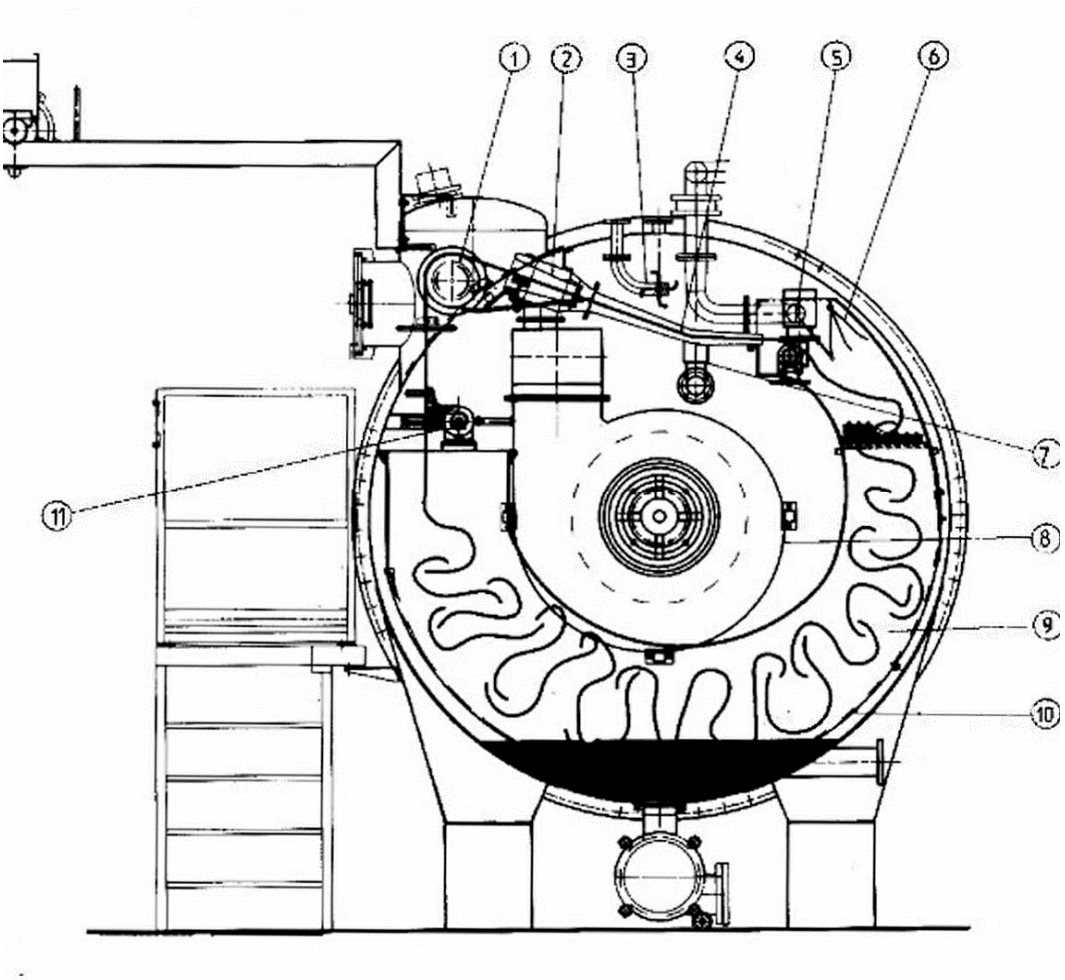
This problem becomes clear above all for fabrics made of synthetic fibers, particularly when they have not been efficiently heat-set, and sometimes it is amplified by the water blade beating the fabric at the exit of the nozzle.

These systems can process lots from 100 to 600-800 kgs, depending on the size of the machine and of the ropes.

Many solutions applied to jet and overflow systems are suitable also for air jet systems:
Teflon-coated vats, folding control, forced liquor drain, multi-tunnel (or rope) machines.
In detail, the machine shown in Picture 59 is equipped with:

1. Reel for feeding the fabric at variable speed ranging from 250 to 700 m/min. (1,000 with a pressurized machine).
2. Air blower feeding the ejector by taking the air from inside.
3. Machine‘s internal washing system.
4. Transport tunnel facilitating the progressive rope opening.
5. Spraying of the liquor atomized at the tube exit side (it reduces the impact of the fabric against the grid).
6. Adjustable contact grid.
7. Liquor spraying nozzle in the transport tube.
8. Air blower at the centre of the machine (for improved soundproofing).
9. Teflon-coated collection basket of gradually larger section.
10. Fabric collection system with external control.

(check out Animation, "Soft-Flow working principle" at VIDEOS & ANIMATION section).



Picture 59 - Air jet dyeing machine

(for more better concept check out, "Soft-Flow 3D FABRIC DYEING/PROCESSING enclosed Working Principle", at VIDEOS & ANIMATION section).

The application of electronics and IT systems has allowed the introduction of devices specifically aimed at storing dyeing programs and continuously keeping all

The operating conditions under strict control, displaying them on the control screen and eventually storing them in a central computer:

- Devices for detecting the passage of the magnet introduced in the sewn fabric, with consequent calculation of the average rope circulation speed and stoppage of the sewn fabric near the door for quick sampling strategies.
- Electronically controlled pumps, reels and variable-speed air blowers.
- Devices for measuring the transport tension of the fabric, and the subsequent adjustment of the rope feeding speed (if the tension exceeds preset values, it slows down the reel and reduces the pump flow, to avoid possible deformations and abrasions).
- Setting, storage, control and recording of the dyeing cycle (temperatures, operating times, dyestuff additions, etc.) feeding of additions from the automatic color kitchen (or from the addition vat), and light and/or acoustic alarms for the operator.
- Security systems for door opening in pressurized machines.
- Possibility of recovering heat by preheating fresh water with the exhausted liquor.
- Operations to be carried out during the process cycle:
- The process cycle is programmed or a previously stored one is retrieved.
- The water is poured in (cold/preheated/softened /hard water) and the level is controlled.
- The fabric is fed into the machine: unwound from a beam, or folded on a carrier, by means of jet or flow system.
- The head of the fabric is recovered from the collection vat and the piece head is sewn with its tail.
- A magnet is introduced in the sewn section (for machines working with high temperatures).
- The cycle is started.
- Possible addition of chemicals/dyes (automatically from color kitchen, semi-automatically or manually from addition vats).
- The variable process conditions are monitored by means of control board; visual control is carried out from the glass window.
- In dyeing processes, color matching must be controlled at the end of the process cycle. The door is opened and a sample is taken near the top/bottom sewing (if necessary a re-dyeing cycle must be started).
- The fabric is eventually washed and/or rinsed.
- Once the cycle has been terminated, the sewing is removed and the fabric is unloaded by means of the motorized reel.
- Washing machine.

Winch Dyeing Machines

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°C. The liquor ratio is generally quite high (1:20-1:40).
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 interspaces for heating and for adding reagents. Heating can be supplied by means of direct or indirect steam heating.

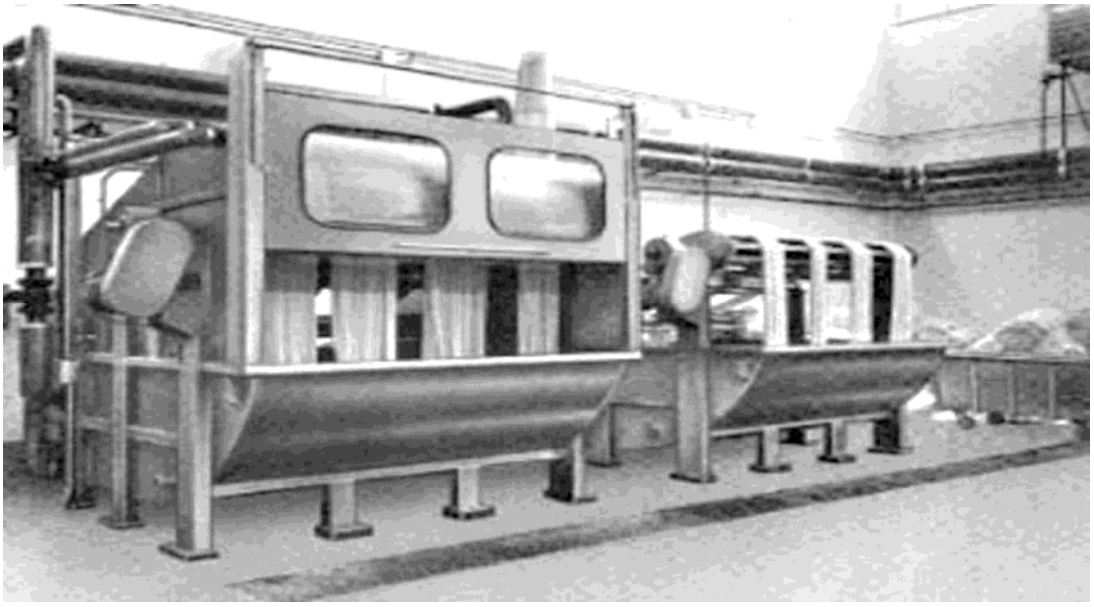
The fabric motion is driven by a circular elliptic winch coated with a special blanket to avoid the fabric slipping during the dyeing operation with subsequent possible fabric scratches.

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 direction).

The maximum motion speed of the fabric must be approx. 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 2 minutes to avoid possible defects or wrinkles; therefore the rope must be relatively short.

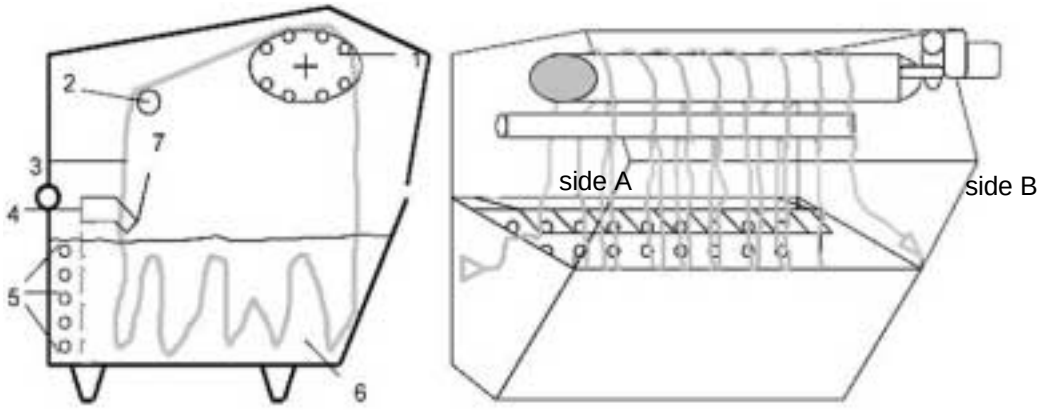
The winch dyeing method is suitable for all fabrics, except those which tend to originate permanent creases or which could easily distort under the winch stretching action (due to their fibre or structure composition).

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.



Winch dyeing machine

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 (A side, Picture 47), driven through the machine with a spiral motion (by means of the rack) and then unloaded from the opposite side (B side).



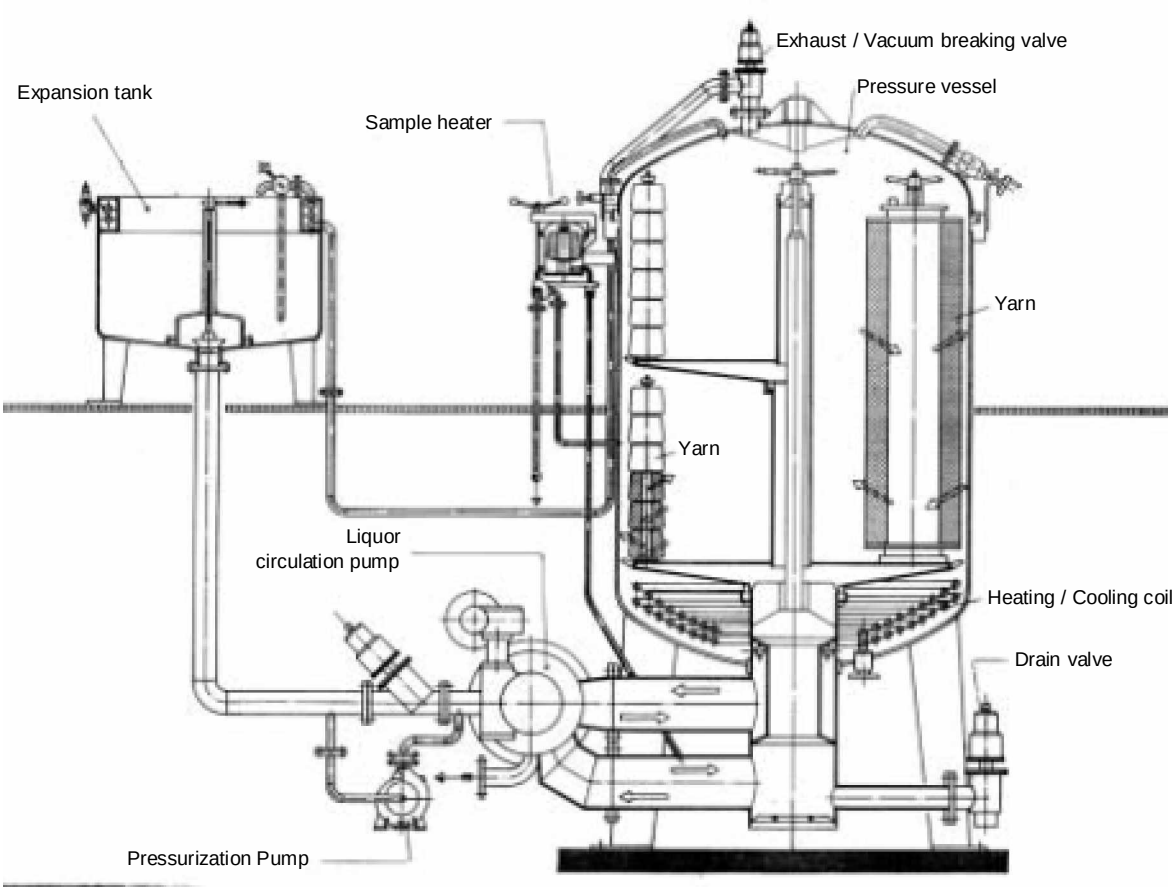
1 – Winch
2 – Guide cylinder
3 – Fabric rope
4 – Perforated separator
5 – Heating coils
6 – Liquor
7 – Rack

Picture 46 and 47 - A winch dyeing machine

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 are placed 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.

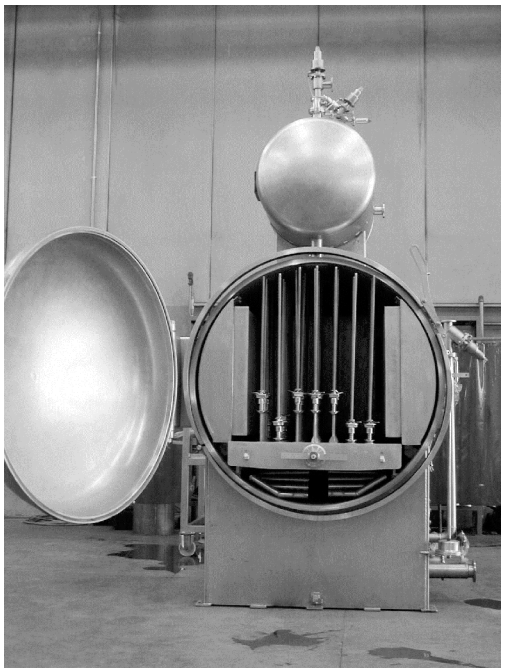


Picture 40 - Vertical autoclave (section)

** Some passages and pictures of this chapter have been taken from the book "Nobilitazione dei Tessili" by Franco Corbani, published by Centro Tessile e Abbigliamento (Textile and Clothing Centre) in 1994.*

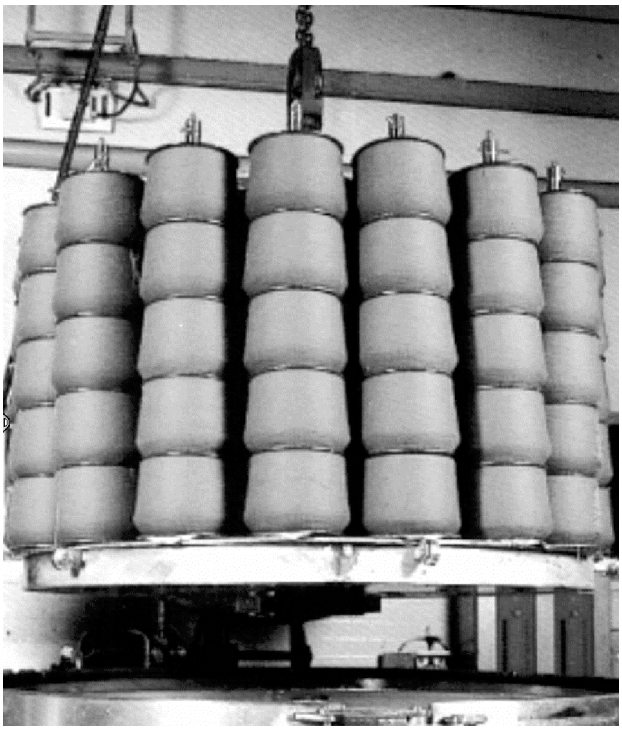
All manufacturers can now supply these machines equipped with microprocessor or PLC programming system for controlling and setting all the operating functions (filling / exhaust / heating / cooling / stage / dosing etc.) of the whole production cycle and, in specific cases, for adjusting the pump flow 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.

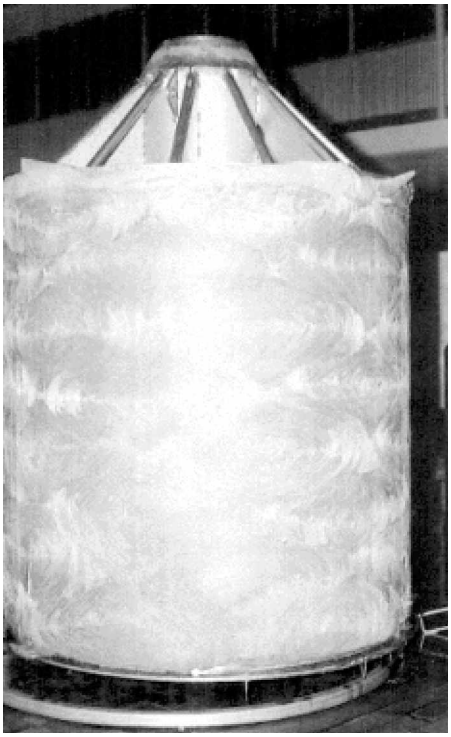


Picture 41 – Horizontal autoclave for packages

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).



Picture 42 - Package carrier carrier



Picture 43 - Staple

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.

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.