# WORSTED WOOL SPINNING

## Scouring of Greasy Wool

### Composition of a scouring line

Greasy wool is generally supplied in large lumps (sometimes entire fleeces) where fibres are entangled, mixed with waste products or bunched and kept together by yolk and hardened mud. In these conditions, greasy wool cannot be scoured since the big lumps cannot be properly cleaned; fibres can be cleaned only after being separated, i.e. when the mass of fibre is "opened".
Furthermore, when lumps are opened and dust removed from the material fed into the scouring vats, the evenness of the fibre is increased and the efficiency of scouring improved.
In order to reduce the dimension of large lumps of greasy wool, the material contained in the bales is "plucked", i.e. it is separated into smaller pieces, coarsely blended, "opened" and "beaten"; after that, the fibre mass is more open and cleaner since bigger and heavier impurities (earth, dung, etc.) entangled with the fibre mass come to the surface and can be separated and eliminated.

After that, greasy wool is "scoured", with water and detergents, to eliminate yolk and suint and then "dried" to let the water evaporate, as excessive water hinders the proper processing of fibres.
The drying process is carried out in two stages to allow (between one stage and the other) further opening and blending of the lumps, granting a constant degree of moisture in the fibres.
The scouring process of greasy wool includes the following stages (Figure 106):

- pre-opening, by means of a bale plucker, for baled material, or rough opening, by means of an automatic feeder, when fleeces have already been opened or when fibres are loosened,
- rough blending of fibres in special blending boxes
- opening and beating, by means of the "a1" automatic feeder and the "a2" beater,
- scouring, in special scouring vats, "b1.1 ÷ b1.5", each one followed by a pair of "b3" squeezer rollers fed by the "a3" automatic feeder and by the "a4" weighing table,

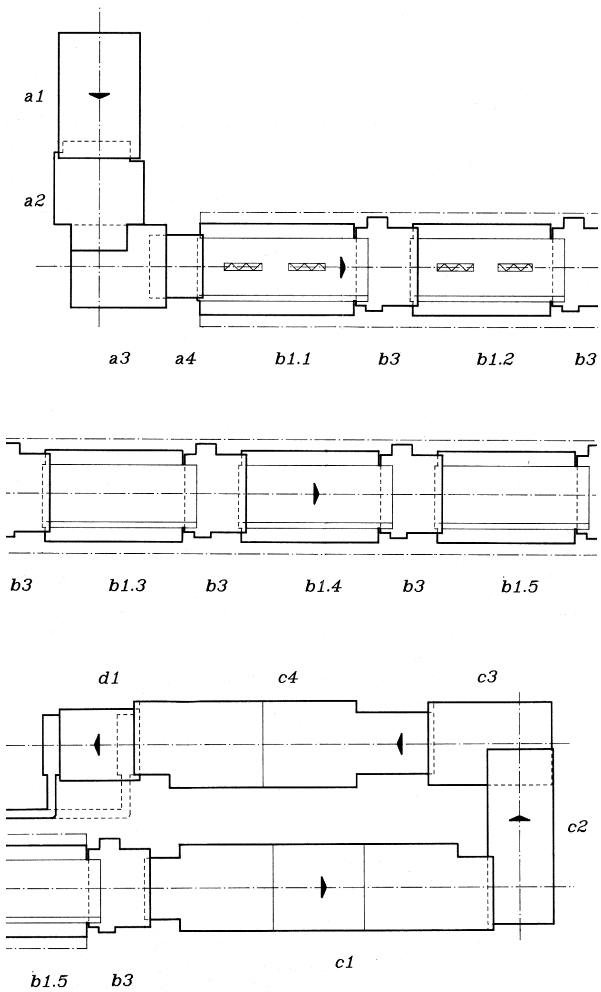



*Fig. 106 – A complete scouring line*

• pre-drying “c1” , in the drier,
• opening and reblending, by means of the “c3” intermediate automatic feeder assembled after the “c2” a conveyor system,
• final drying, in the “c4” dryer,
• opening and final reblending, by means of the “d1” beater.

## Pre-opening

The bale opener (Figure 107) includes the “To” two-section horizontal conveyor on which the greasy wool bales are loaded; the bales pass from one sector to the following one and are turned upside down and are partially divided into big tufts of wool.
The “To” conveyor conveys the fibre mass very slowly towards the “Ti” slant apron; it is covered with large-diameter spikes which are bent in the direction of the feeding material, and the apron moves faster.
The wool, supported by the spikes of the “Ti” slant apron, is brought upwards; the bigger tufts of material are driven back or their dimension is reduced thanks to the action of the spikes of a leveller or overflow roll (“R”) which rotates anticlockwise. The position of the “R” cylinder can be automatically adjusted to calibrate the opening and the evenness of the fibre mass.

The “S” cleaning roll rotates clockwise and its spikes knock back (on the horizontal conveyor) the lumps of wool left between the spikes of the leveller roll, which is therefore always kept clean and efficient.
The combined action of the “leveller” and the “cleaner”, besides adjusting the quantity of material, opens the greasy wool with adjustable intensity and prepares it for efficient beating.

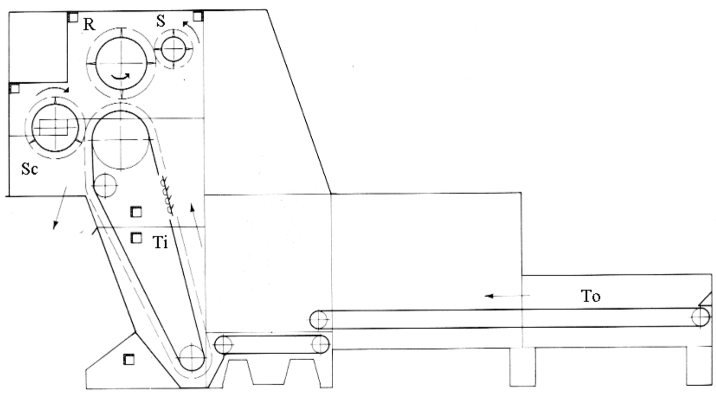
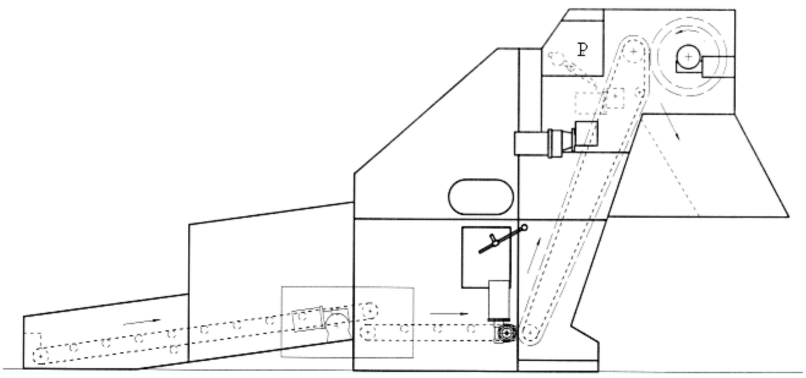



*Fig. 107 – Bale opener*

After the leveller, the wool slips off the spikes of the slant apron (which are now bent downwards) helped by the spikes of the “Sc” beater roller, which turns clockwise a lot faster than the “Ti” roller.
A small quantity of waste is also separated from wool at the picking points.

The available working widths are 1,000, 1,600 and 2,000 mm; the average output with a 2,000 mm width is approx. 1,500 kg/h for finer wools.
The feeder described on Figure 108 can be used successfully when the material fed into the machine is mainly composed of already opened or loose fibres. The feeder, besides ensuring more delicate fibre handling, does not force the fibres onto the cleaner roller. In this case, in fact, the cleaner is no longer needed since the leveller is replaced by an oscillating comb (“P”) which prevents fibre winding and which, like a leveller, knocks back the wool lumps conveyed




without touching the spikes of the slant apron, thus making the dimension of lumps as uniform as possible.
The operating width and the output are similar to the bale opener.

*Fig. 108 - Automatic feeder*

## Blending

The wool batch is usually made of many lots of different origin; a partial opening of the material allows the blending of multi-origin greasy wool, making up a wool batch of the desired composition.

The composition of the batch is determined inside special “blending rooms”, containing min. 100 bales; the blending rooms are filled from above, in horizontal layers, with wool coming from the bale opener or from the automatic feeder. The blending rooms are unloaded by picking the material in vertical layers, with carriages or picker cylinders, which ensures a minimum degree of evenness for the blend fibre mass.

## Opening and beating

Listed here are the operations to be carried out before sending the greasy wool to the blending rooms and to the scouring vats:
1. opening, to further reduce the dimension of the big lumps of wool and to additionally separate fibres to make the cleansing action of the scouring process even more effective,
2. “beating”, to eliminate the heaviest contaminants (waste), which would otherwise absorb part of the scouring liquor thus making the process more expensive

The wool can be opened by means of an automatic feeder (Figure 108 and “a1” shown in Figure 106) while for the beating stage after the blending feeder, it is possible to use a multiple slant opener-beater (Figure 109 and “a2” in Figure 106; this unit includes 3 spiked drums inclined 30° ÷ 50° with respect to the horizontal plane), or a horizontal opener-beater with 2 drums.
On the slant opener-beater, the speed of the beater rollers is increased from the first roller to the last one; several mote knives (“c”) are placed between the rollers; the mote knives can be precisely adjusted as well as their operating space. The “G” lattice under each cylinder is made up round bars separating the wool from the substances that pass through the spaces (approx. 1 cm).

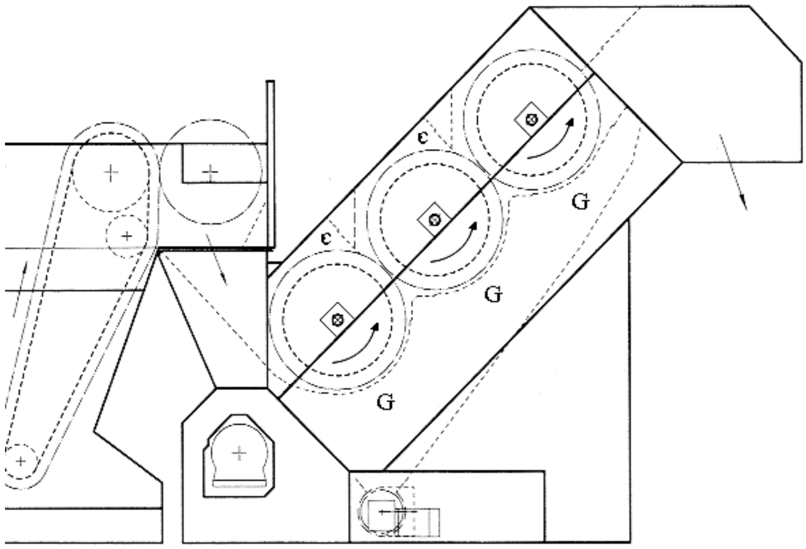



*Fig. 109  - Slant multiple opener-beater*

The wool passes into this opener-beater with no retaining device; the wool is conveyed from the entry to the end all through the machine only thanks to the thrust generated by the spikes covering the beater rollers. All along the path, the material is progressively opened and beaten as a consequence of the continuous shocks against the lattice bars.
In the horizontal 2-drum opener-beater, the feeding drums bring the fibres to a first drum covered with tapered spikes, which have round tips to minimise the tuft stay-time.
Wool is then opened and beaten by the spikes of a second drum similar to the first one.

The further opened and beaten wool is knocked off outside the machine by the centrifugal force and the air flow generated by the rotation of the second drum.
Under the drums, a mesh separates the wool from waste, which is then evacuated by means of a suction fan and conveyed to filters or to special storage compartments.
The spikes are big and have a frustrum shape with rounded-off rims; the spikes are fitted on bars screwed on the rollers to allow easy removal for cleaning and maintenance purposes.
Some machines feature a self-cleaning action carried out by the round bars of lattices, which (thanks to a pneumatic-control repeated cross motion) touches some inner containers and two series of guides on the machine sides.
The absence of wool retaining devices greatly helps preserve the dimensional stability of the fibres. Dust is eliminated by means of several special suction devices placed under the lattices, which convey heavier waste to a worm conveyor at the bottom of the machine for final evacuation.
The operating width and the output data are similar to the bale opener.

## Weight check

Since the liquor ratio of scouring vats must be constant, the weight of the material must be checked accurately before passing to the scouring operation.

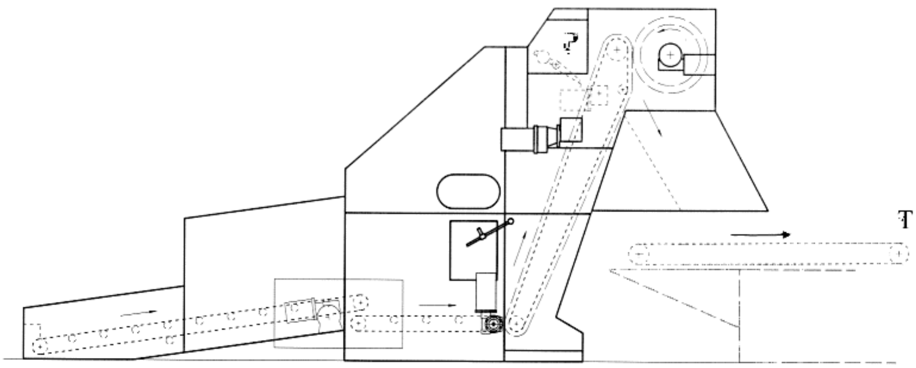



*Fig. 110 - Automatic feeder with weighing conveyor*

The machine used for checking weight includes:
- an automatic feeder similar to the previous one (“a3” in Figure 106),
- a “T” weighing conveyor (Figure 110 and “a4” in Figure 106), which weighs the wool at very short and regular intervals.

The desired wool weight is obtained by means of a weighing system; every time the weight varies, the system automatically sends an input command, which adjusts the speed of the feeder conveyors, as a result achieving the preset weight.

## Opening degree

Once the greasy wool has been opened and cleaned, it is necessary to find a correct proportion between the waste removed and the fibres lost during the successive scouring stage.
For example, an inadequate opening process with inefficient removal of broken fibres, fragments and brittle fibres from the inside the wool lumps, will generate a great quantity of dust in the carding room, where these materials are separated from fibres. A satisfactory degree of opening is reached only when wool is perfectly suitable for passing to the carding process, i.e. when the only fibres breaking are those that will certainly break during the carding process.

## Scouring

During the scouring stage, an appropriate stirring of the liquor is particularly important to allow an efficient removal of the “dirt” even if the stirring may lead to fibre entanglements and felting.
The main purpose of scouring is the removal of wax, suint and waste contained in the greasy wool; scouring should be carried out in such a way to prevent wool felting and the consequent breaking of fibres, to avoid the reduction of the fibre length, and to avoid an increase in the waste quantity during carding, drawing and combing operations.

The optimisation of the huge quantities of water necessary for scouring the greasy wool is obtained through the application of the principle that the bath can carry out a detergency action until the degree of “dirt” contained in the scouring liquor is lower than the degree of “dirt” contained in the material to be scoured.
The scouring of the greasy wool is carried out in 4 ÷ 5 successive scouring vats (b1.1 ÷ b1.5 in Figure 104) where correct circulation of the scouring liquor is maintained; thanks to this method, water consumption can be optimised in relation to the scoured/greasy wool yield (the water consumption ranges from 6 ÷ 8 litres of water per kg of greasy wool with yields exceeding 70%, to 12 ÷ 15 litres per kg for yields below 50%)

**Scouring vats**
Greasy wool is scoured inside special vats with the following features:

- the bottom of the first two scouring vats (b1.1 and b1.2 in Figure 106) has the shape of two truncated pyramids with rectangular base turned upside down and placed side by side. (Figure 114.). At the bottom of the vats there are two worm conveyors that take the sludge to the centre of the scouring vat, inside draining pits. At the bottom of these draining pits there is valve which constantly discharges sludge and solid contaminants without removing too much water. The rotary speed of the worm conveyor is variable and can be adjusted according to the type of wool and to the quantity of “dirt” to be removed;
- the lower part of the other three scouring vats (b1.3, b1.4 and b1.5 in Figure 106) has the shape of two pyramids turned upside down and placed side by side, with rectangular base (Figure 115); at the bottom of each scouring vat there is an open-flow drain valve with automatic timer control (for example 5 seconds every 4 minutes);

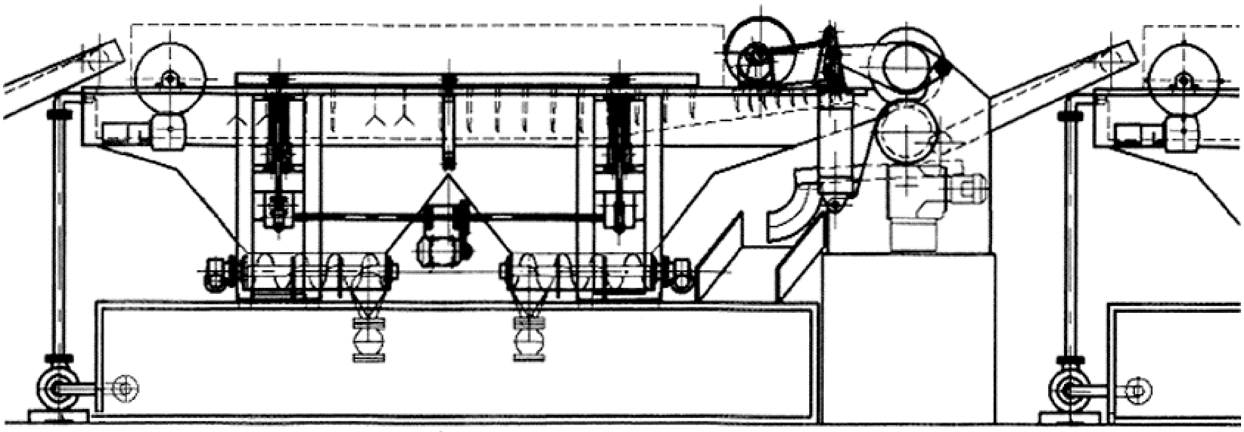


*Fig. 114 - Longitudinal section of the second scouring vat in the scouring range*

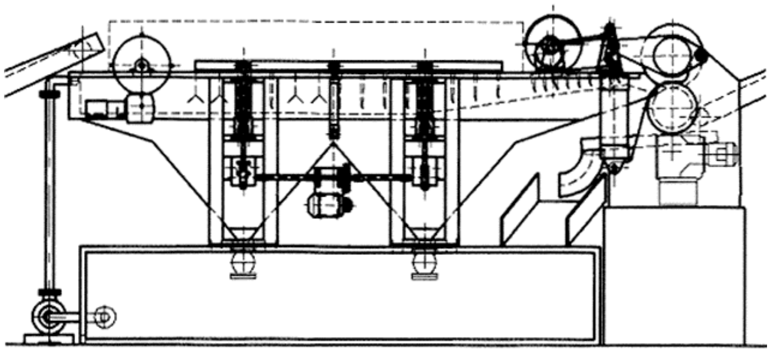


*Fig. 115 - Longitudinal section of the third scouring vat in the scouring range*

- in the first part of each unit there is a diving drum (the first cylinder on the left in Figures 114 and 115) which dips the wool into the scouring liquor and prevents it from floating on the liquor;
- in the upper section of each unit there is a mobile apron, with diving teeth and blades, featuring a reciprocating motion, and taking the material into and out of the liquor while feeding it through the process vat (Figures 114 and 115);
- in the final part of each scouring vat there is a small high-speed apron, taking the material into and out of the liquor, which allows a regular feeding of the squeezing press (the pair of cylinders shown on the right of Figures 114 and 115);
- in the middle of the scouring vats there is a perforated grid (the dotted line in Figures 114 and 115) separating the upper part of the vat (where the wool is scoured) from the lower side (where the sludge accumulates) to prevent "dirt" particles from being recirculated by the mobile apron;
- at the end of each scouring vat there is a squeezing press including a pair of cylinders (the lower cylinder is chromium-plated while the upper one is coated with a square rope made of nylon or rubber to grant the proper hardness) which exerts a pressure on the wool equal to 15,000 daN ("b3" in Figure 106). The squeezing of the fibre mass, passing from one unit to the other, improves the elimination of "dirt", prevents the contamination of the downstream liquor section and facilitates the soaking of the fibres when they plunge into it;
- on one side of each unit there is a settling tank for recovering the liquor from the overflow box of the scouring vat and the liquor squeezed by the press (Figure 116); each vessel is also equipped with an overflow box. A pump for recirculating the settled and pre-filtered liquor connects the vat to the initial section of the corresponding scouring vat and to another vat (described below).

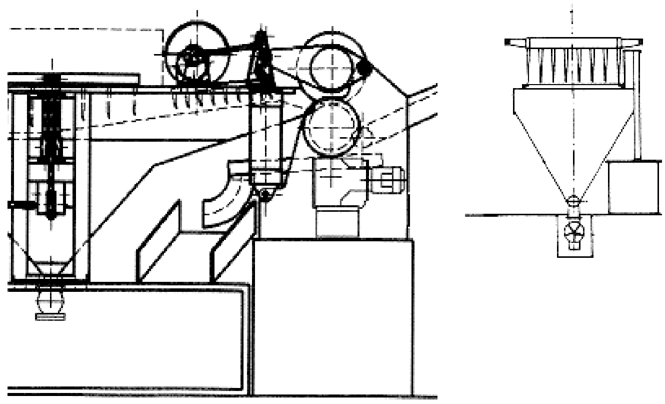


*Fig. 116 – Partial side view and front view of the settling trough of a scouring vat.*

## The scouring process

In the past, greasy wool was scoured by hand, near water courses (streams or rivers), by soaping and plunging it into the water inside a container where wool was stirred, by means of sticks, to generate the foam and the emulsion of non-soluble substances, without excessively powerful movements to prevent the felting effect. At more or less regular intervals, the wool was removed from the container and hand-squeezed to eliminate dirty water and foam.
The mechanisms of modern scouring vats reproduce the movements of hand scouring; in fact, the motion of the aprons has replaced the motion of the sticks and the presses that squeeze the wool replace the human hands.
Nowadays, a scouring range (Leviathan) includes 5 (sometimes 6) vats (Figure104); the first vat ("b1.1") is used for eliminating earth particles, the second and the third vats ("b1.2 and b1.3") for thoroughly scouring the wool; the fourth and the fifth vats ("b1.4 and b1.5") for rinsing the clean wool.
In the pre-scouring stage, the wool fibres are separated from earth particles and dung; the efficiency of this first stage also depends on the liquor temperature, which is kept at approximately 35 °C to avoid excessive temperature variations occurring when wool is transferred to the second scouring vat, which could lead to fibre entanglement or felting.
This pre-scouring stage, before the real scouring, entails the use of an additional vat but reduces the quantity of surfactants and alkali to be used in the subsequent vats.
In the second and in the third scouring stage, wool is actually scoured applying the scouring methods explained above, using surfactants and Solvay sodium carbonate.
These scouring stages must be performed at a temperature that liquefies (or almost liquefies) the yolk allowing its emulsification; a temperature of approximately 60 °C favours a quite fast formation of small spheres of yolk, around which surfactant molecules adhere.
It is worth remembering that an excessively low temperature does not allow a thorough scouring while an excessively high temperature can generate wool felting and/or formation of hardly recoverable fibre entanglements.
The quantity of sodium carbonate must be carefully controlled to avoid the deterioration of wool; in the second scouring stage the concentration can also slightly exceed 1% since a thin wax coat still protects the wool fibres.
The correct quantity of surfactant to be used is that which determines the required absorption level as well as the stability of the emulsion and the dispersion of particles.
By visually checking the foam it is possible to determine the optimum efficiency of the surface active agent and of sodium carbonate.
The "dirt" adhering to the wool fibres immersed in the scouring liquor (approximately 10 seconds) absorbs the water and swells quite rapidly, reaching a diameter three/four times bigger than the fibre (Figure 117). The dirt could spontaneously disperse and emulsify through a slow and unreliable process, which rarely ensures the desired effect. Conversely, dirt can be removed thoroughly through correct stirring and agitation of the liquor and a suitable speed of the press rollers.
A high efficiency of the "dirt" removal can be achieved with a stirring action determining a relative speed (ranging between 10 and 16 cm/s) of the liquor with respect to the wool, while the peripheral speed of the squeezer rollers (ranging between 4 and 12 cm/s) generates, in the roller nip area, a water flow favouring the removal of "dirt" from fibres.

From the second scouring stage, the greasy substances are recovered by heating the bath to approx. 90 °C to break the emulsion of grease and detergent, and by subsequent centrifugation. The clarified product (lanolin, primarily cholesterol esters of superior fatty acids) is used as a base for emollients in cosmetics and for medical purposes by the pharmaceutical industry.

In the fourth and fifth scouring stage, the temperature decreases, respectively to 55 °C and 45 °C to prevent fibre felting. Thoroughly scoured fibres are unprotected and can felt at higher bath temperatures. The higher the temperature of the water in the last vat, the faster and the more cost-efficient is the subsequent drying operation.

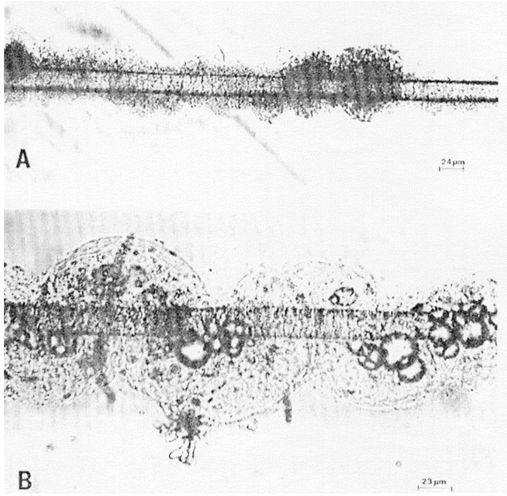



*Fig. 117 – Absorption and swelling of the "dirt".*

Figure 118 shows the liquor exchange between the scouring vats:

- the first vat receives the scouring liquor, suitably cooled down, from the fourth and fifth vats and drains it off through the overflow which eliminates the excess liquor from the settling trough; the liquor coming from the settling trough is partly recycled and sent to the scouring vat,
- the second vat receives the liquor from the third vat which drains and recycles the water like the other vat; the liquor from this vat is heated and sent to a centrifuge. The liquor from the centrifuge has lost its non-soluble fat (lanolin), separated by centrifugation,

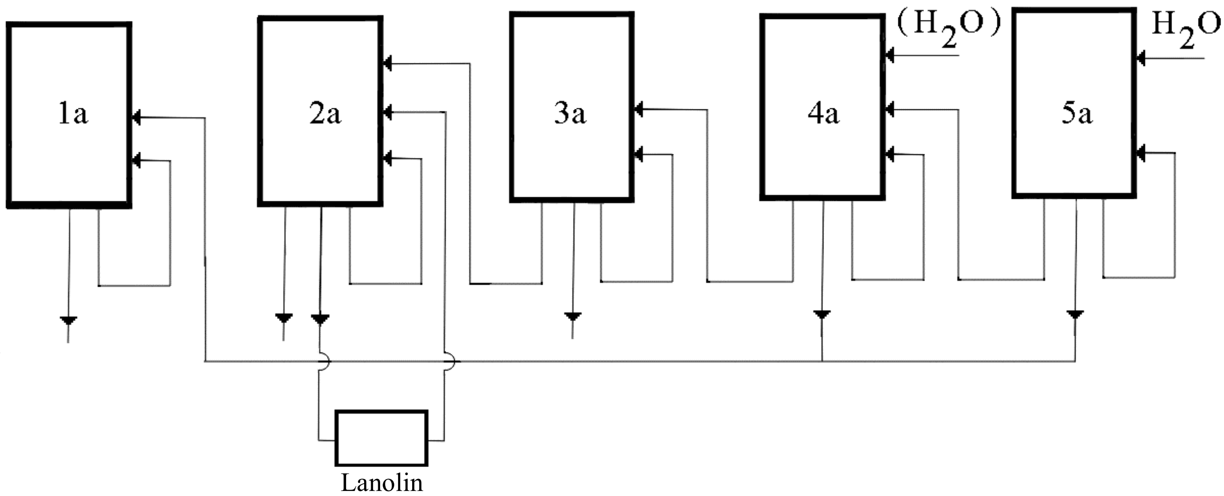



*Fig. 118 – Example of liquor circulation between the scouring vats*

- the third vat receives the liquor from the fourth vat, drains it through a drain valve and recycles it like the previous vat; the liquor taken from the settling trough of this vat flows into the second vat,

- the fourth vat receives the liquor from the fifth vat or fresh water (or both), and drains and recycles it like the previous vat; the liquor taken from the settling trough flows into the first vat,
- the fifth vat receives fresh liquor which is drained and recycled like the previous vat; the liquor of this vat flows into the first vat.

After the scouring process, the residual grease must not exceed 1%.
Some scouring groups have two settling troughs (Figure 119) placed at the sides of each scouring vat; these settling troughs have the same capacity as the scouring vat. A recirculation pump recycling the settled and roughly filtered liquor connects alternatively these troughs with the initial section of the corresponding scouring vat.
During the production cycle, when one vat is being prepared and is therefore by-passed, the other one receives the squeezing liquor from the presser and sends it again into the scouring vat after a rough filtration; when the "dirt" contained in this vat reaches the maximum acceptable level, the vat is by-passed and the second vat starts working.
When the liquor is recycled through the second vat, the first one is drained off, rinsed and filled with fresh liquor; this system therefore allows a non-stop scouring process also during liquor changes.

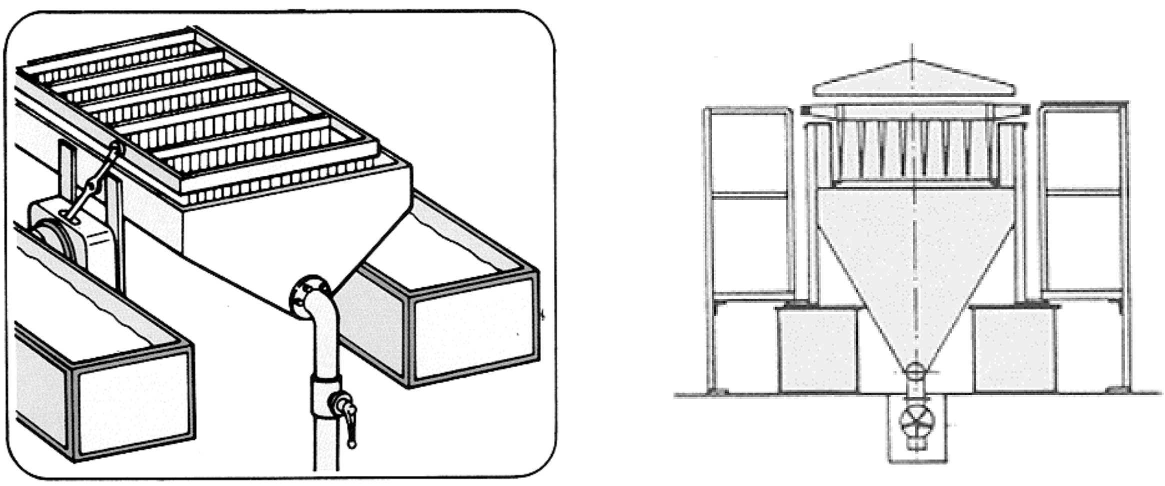


*Fig. 119 – Scouring vats with two side settling troughs*

## Drying

### Purpose of drying

On exiting the scouring range, the wool is wet (moisture content approx. 55% ÷ 60%) and must be dried so that:
- the lumps can take their natural swollen aspect (with fibres moderately attached or entangled) and pass through the carding process without breaking,
- the elimination of vegetal substances during the carding process can be facilitated since an excessive degree of moisture would make them softer and similar to the other fibres,
- optimal oiling could be obtained, by allowing the oil to spread uniformly over all the fibres.

The residual quantity of water contained in the material on exiting the dryer is generally 12 ÷ 15 % of the wool weight. The higher is the content of vegetal matters, the lower must be the quantity of water contained; for clean, fine and extra-fine wool, the water contained can reach the maximum value to ensure higher flexibility of the fibres during the carding process.

**Belt-type dryer**

The mostly used dryers are the belt dryers where water evaporates through the circulation of hot air, by suction or compression, forced perpendicularly through a fibre layer arranged on a horizontal conveyor belt.

The water content that can be evaporated inside these dryers is about 10 ÷ 15 kg per square meter per hour with an energy consumption of 250 kJ per kg.

The belt dryer (Figure 120) has an insulated metal compartment; inside the compartment a non-stop conveyor belt carries the material. The conveyor belt features perforated sheet metals for the passage of the hot forced air.

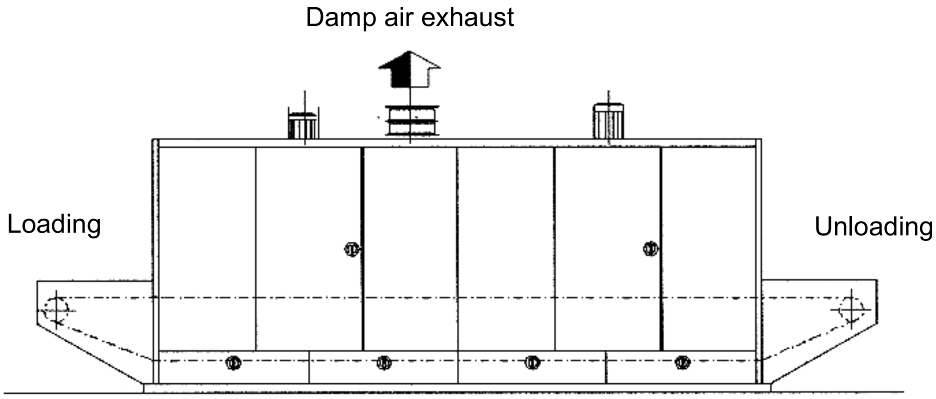



*Fig. 120 – Side view of a two-module belt dryer*

The air fed to the dryer is taken from outside through the material entry and delivery doors (Figure 121)

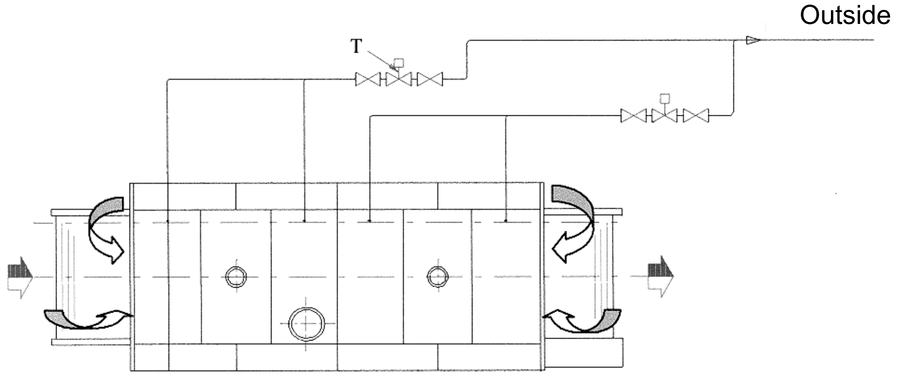



*Fig. 121 – Plan of the belt dryer: the arrows indicate the air inlet areas.*
*"T" stands for temperature controller.*

Inside the compartment, arranged on the sides, there are two metal walls making up the ducts for air recirculation and two air filters (Figure 122, “1”); the ventilation fan is positioned on top of the machine and the heating sets are arranged on the two sides of the aerothermal chamber to ensure the optimal balancing of the air circuit (Figure 122, “2”).

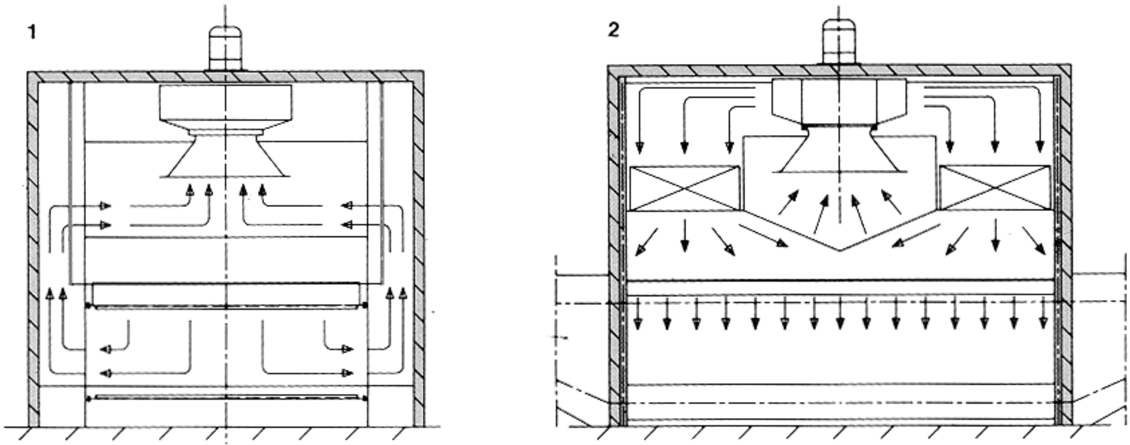



*Fig. 122 – Aerothermal chamber: cross section (1), longitudinal section (2)*

The recirculated air is filtered by a suction fan, heated through the heating sets and uniformly distributed on the material to be dried; the airflow from above prevents the formation of preferential paths.
With this operating method the hot air is homogeneously blown on the whole surface of the conveyor belt, taken symmetrically on the bottom and recirculated through two side tunnels; the slight vacuum on the surface of the conveyor belt ensures the stability of fibres on the belt despite the intense ventilation.
The air speed can be adjusted in order to allow easy passage of the lumps arranged on the conveyor belt.
To avoid saturation of the chamber air, some air is evacuated through the exhaust pipe while the suction air fed to the fan is sent onto the heating sets to reach the temperature level set on the temperature controller.
Thanks to the modular design of the dryer, the dimensions must be proportional to the required production capacity: each single module is 3,250 mm long while the conveyor belt is 1,300, 1,600, 2,000, 2,500 and 3,000 mm wide.

**Feeding the dryer**

Three aspects must be carefully considered to achieve proper drying and grant regular residual moisture of the fibre mass after drying:

a) quantity of water,
b) regular feeding,
c) non-stop feeding

a) The quantity of water
The press must eliminate most of the water included in the wool leaving the last vat of the scouring range; the dryer must only eliminate the residual water, since it is more cost-efficient to remove the water mechanically than by evaporation.
An increase in the pressure force of the squeezer cylinders of the press reduces the quantity of water to be evaporated, but the benefits beyond the values previously indicated are insignificant.
It has been verified that the temperature of the water affects the removal of a greater quantity of water during squeezing: the hotter the water, the greater the quantity of water eliminated by the press. Probably this is due to the reduction of the water viscosity following the temperature increase.
The evenness of the material to be processed is particularly important for ensuring the best possible working conditions for the press; in fact, the material on the edges of empty areas is wetter than the material in uniform areas.

b) Regular feeding
Besides the uniformity of the press feeding, also the condition of the wool layer fed to the dryer is very important; it must uniformly cover the conveyor belt at all the points. In fact, the air inside the dryer tends to pass through the empty areas with no coating or through thinner areas, thus decreasing efficiency and drying uniformity.

c) Non-stop feeding
The material fed to the dryer during a set period of time must have a uniform weight otherwise the drying could result in wool that is scarcely uniform (Figure 123) leaving the dryer with an unbalanced moisture content.

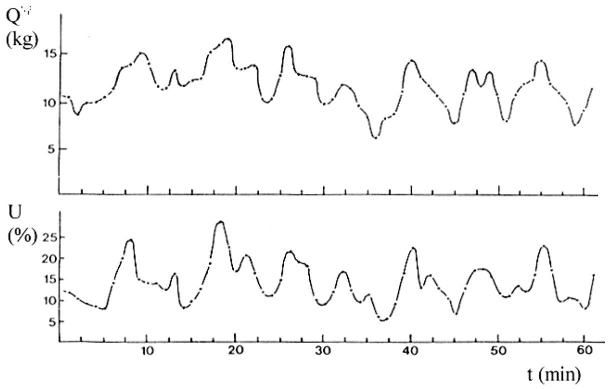



*Fig. 123 - Effect of feed variation on residual moisture*

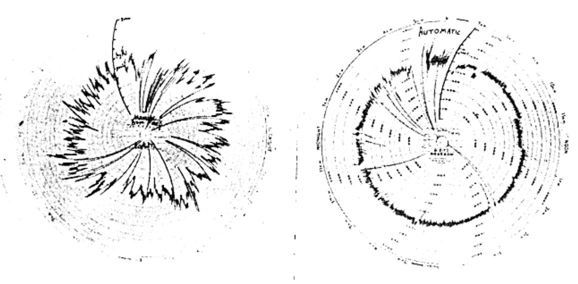


*Fig. 124 - Effect of the feed control on residual moisture;on the left: no control, on the right: with control*

The introduction of the “weighing belt” and checking the quantity of greasy wool fed into scouring range has generated a significant reduction of variability in the moisture content of the fibre mass leaving the dryer (for example, the CV% has passed from 10 to 23 % to a CV ranging between 2 ÷ 5 %; Figure 124)

## Control devices

Metal probes, placed on the delivery side of the drying unit, are used for controlling the dried wool moisture content (which must be uniform and predetermined); these probes measure the electrical capacity or resistance fluctuations, which vary according to the quantity of water contained in the fibres. It is however worth remembering that these measures are generally affected by the level of cleanness of the wool and by the possible presence of soluble salts.
The control device shown in Figure 125 (Moisture meter) calculates and determines the average moisture content in the material by means of four electrodes, each one carrying out 600 measurements per second, which determines the electrical resistance of the material when the current drops through the element. The measurement is carried out with a +/- 1% accuracy even when moisture values are very low (approaching zero).

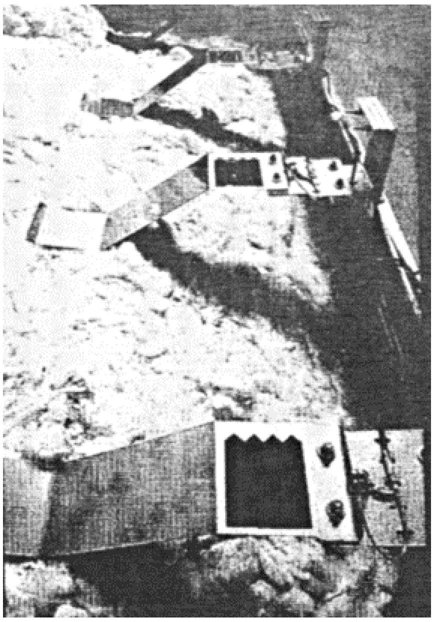


*Fig. 125 - Moisture meter*

A controller (Figure 126) can be added to the previous control device; the controller generates a signal that is used for checking one of the parameters affecting the process: the energy to be supplied to the dryer (through steam or gas valves) or the quantity of material fed (through the feeding speed).

## The drying process

The water is homogeneously eliminated from the fibre mass (Figure 106) starting with a first drying (pre-drying) stage carried out inside a “c1” dryer. The partially dried mass is then conveyed to a “c2” conveyor belt and exposed to the action of a “c3” automatic feeder, which blends again the layer of fibres fed. The wool is then further dried (final drying) in the second “c4” dryer, and open-beaten in a “d1” opener-beater.

A) Pre-drying
In a three-module dryer, the temperatures in the three different zones can be the following:

- approx. 80 °C in the first module,
- approx. 120 °C in the second module
- approx. 70 °C in the third module,

and the dwelling time of the wool inside the dryer should be about 90 seconds.

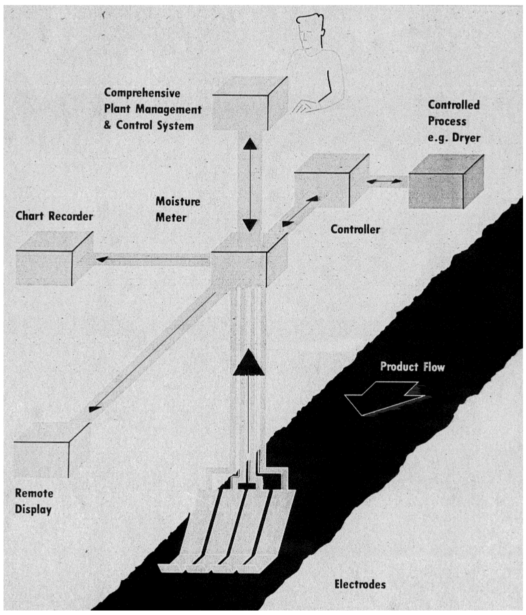



*Fig. 126 - Example of drying process control*

B) Opening and blending

The material leaving the pre-dryer is led to the feeder by a conveyor belt or by a pneumatic device, which slightly blends the more or less wet fibres.

The automatic feeder connecting the pre-dryer to the final dryer is similar to the ones already seen (Figure 127), i.e. it is characterised by an oscillating comb, which adjusts the evenness of the material fed and a large-diameter doffer roller, which prevents fibre winding.

C) Final drying

The final dryer is similar to the previous one but includes two modules where temperatures can be:

- approx. 45 °C in the first module,
- approx. 65 °C in the second one.

The dwelling time of the wool inside the dryer can be approx. 80 seconds while the air speed is adjusted in a similar way to the previous one.

A quality control to measure the moisture content of the wool must imperatively be carried out at the exit of this dryer (following the procedure previously indicated).

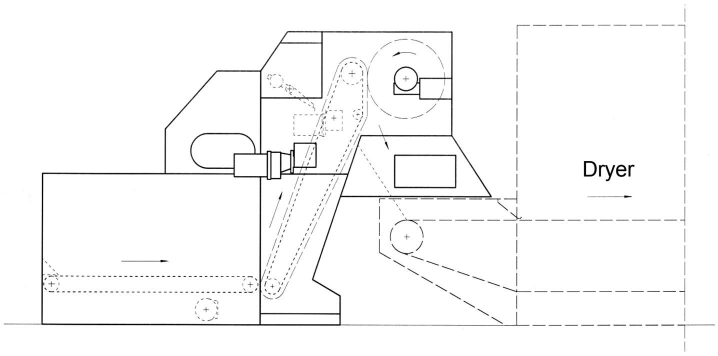



*Fig. 127 – Automatic feeder connecting the two dryers*

D) Final opening

Before passing the scoured and dried wool to the carding process, the material must be opened, beaten, dusted and blended by means of an opener-beater (Figure 128) equipped with 3 or 6 rollers (depending on quantity of impurities) operating at the speed of 300 revolutions per minute.

The rollers are covered with large-size cone spikes with rounded-off tips (these spikes are fixed since there is no need for cleaning them); the rollers are also equipped with doffer blades.

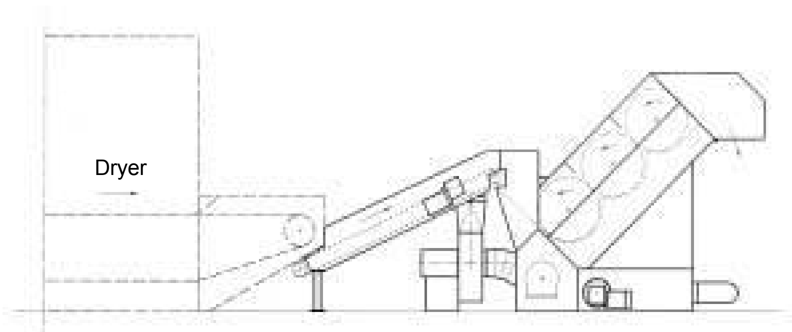



*Fig. 128- Multiple slant opener-beater*

Waste particles are separated by grids placed under the rollers, made of small bars with a very particular shape, for example triangular, easily adjustable from the outside by rotating them around their longitudinal axis, which allows the modification of the space between them (Figure 129); The grids can be cleaned by means of compressed air jets.

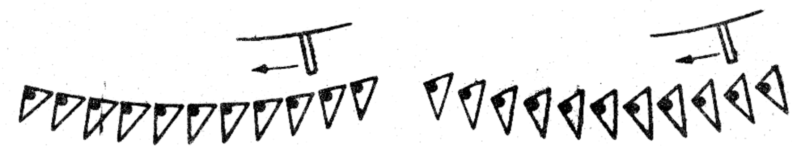



*Fig. 129 - Grid*

Dirt and waste falling below the grids is taken out by a worm screw and exhausted by means of a fan from the bottom of the grids

**Oiling**

At the exit of the opener-beater, fibres can condense and consolidate attracted by the scales now freed from the yolk; they can attract or reject each other depending on the electrostatic charges generated on their surface due to the friction between them or with other bodies.
To be rid of these problems, and therefore to facilitate the subsequent processes, the wool leaving the opener-beater undergoes the so-called "oiling" process, which lubricates the fibres by spraying on them an oily emulsion soluble in cold water.
The oiling device includes a number of nozzles, arranged next to each other along the whole operating width; each nozzle sprays a jet of emulsion on the dried wool that is proportional to the thickness of the fibre layer as indicated by a tracer.
The oil can be a blend of derivatives of natural fatty acids and polyoxyethylenates (anionic and compatible with anionic and non-ionic products) which, besides featuring a high fibre/fibre and fibre/metal lubricating power, can be easily eliminated with cold water.
The oil can be used alone or combined with another liquid featuring anti-static characteristics; in this case, the emulsion could be the following:

- 20 ÷ 25 % oil,
- 10 ÷ 15 % anti-static product,
- 70 ÷ 60 % water

to be sprayed on the wool (2 ÷ 3 % of the weight of the material to be oiled).

# Carding

## General remarks

Through the carding process, the washed, dried and oiled tufts of wool made of random and entangled fibres finally become a "card sliver" where fibres are straightened and aligned along the longitudinal axis of the sliver.
This operation is carried out with a "card", a machine which processes the fibres by means of a series of cylinders and rollers whose surface is covered with needles, i.e. the card clothing.
The interaction between the material and the needles of two opposite cylinders, rotating in opposite directions and at different speeds, takes place mainly according to the following scheme:

1. tufts are separated so that some fibres remain on the needles of one cylinder and some on the needles of the opposite one. The stretching of the tufts generates a reduction of their section and establishes the conditions for a certain quantity of fibres to be distributed on a greater surface; when this operation is carried out repeatedly, the fibres separate from one another;
2. fibres are transferred from the needles of one cylinder to the needles of the opposite one.

The formation of the card sliver is carried out through the following steps: first of all the fibre mass is disentangled (opened) so that each fibre can separate from the others. After that, the fibres are arranged (condensed) in the form of a thin continuous web, which is then transformed into a sliver. During these operations the material is selected and cleaned, i.e. very short fibres as well as foreign particles are eliminated from the fibre mass, which is then also partially blended.
The above mentioned processes must be carried out taking care that the fibre length is left unaltered.

## Interactions between clothing and fibres

To understand the behaviour of the fibres subject to the action of needles on two subsequent cylinders, and running in opposite directions and at different speeds, it is necessary to analyse carefully the various interactions between the needles and the fibres.
Interactions of the wool carding process prior to combing are mainly “carding” and “striping” and, in some particular cases, also “lifting”.
For the sake of straightforwardness, it is worth considering the following aspects concerning the geometrical shape and the motion of the needles:
- the needles can be simply inclined (a), or curved with a hook (b) or sawtooth-shaped (c) and for each needle we can determine a “convex” and a “concave” side (Figure 130);
- the needles are “inclined in the same direction as the roller” when the convex side comes before the concave side, with reference to the rotation direction (Figure 131);
- the needles are “inclined opposite to the roller direction” when the convex side follows the concave one, with respect to the direction of rotation (Figure 131);

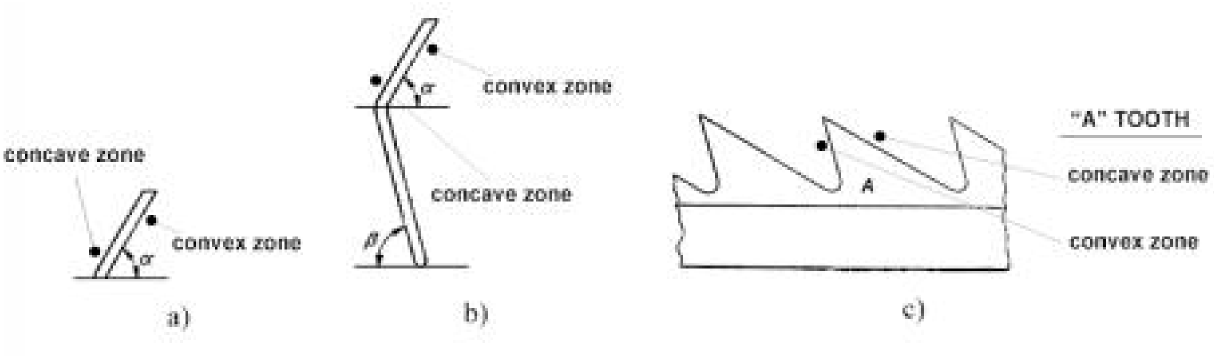



*Fig. 130 - Different types of clothing:*
*a) inclined needle   b) curved needle (flexible)   c) sawtoothlike wiring (rigid)*

- two needles (“AC” and “BD”) catch a lump of fibre by their respective C and D tips (Figure 134) and exert their action along the CD direction; the force exerted on the fibres by the tips generates a stretching effect; furthermore these fibres exert an “Af ” force on the needles, which at any instant is equal or contrary to the previous one, thus also subjecting the fibres to flexural stress.

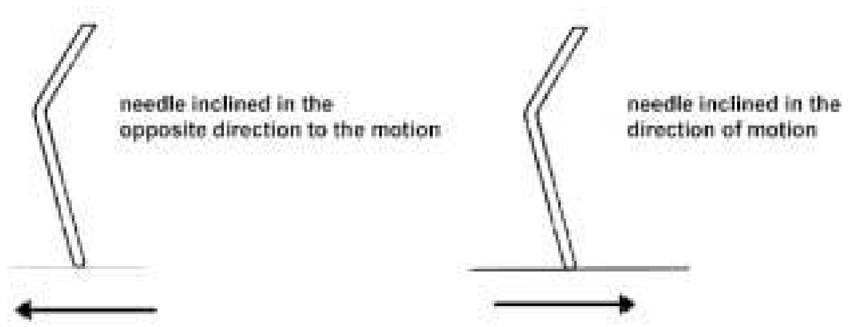
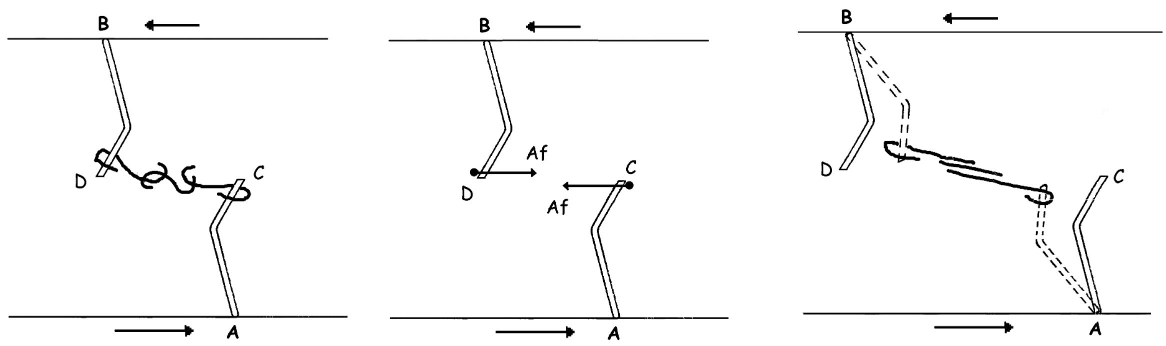



*Fig. 132 Interaction between the needles and the fibres*




a) b) c)

*Fig. 133 Inclination of the needles*

## The carding unit

Description

A carding unit is the smallest set of cylinders carrying out the actions previously explained.

The carding unit (with 4 carding points) includes the following elements (Figure 133a):

- “T”: the drum, covered with needles inclined in the direction of rotation. The drum is the carding device.
- “L1”, “L2”,“L3” and “L4”: worker cylinders, covered with needles inclined in a direction opposite to the rotation direction. The worker cylinders retain the material to allow the carding action.

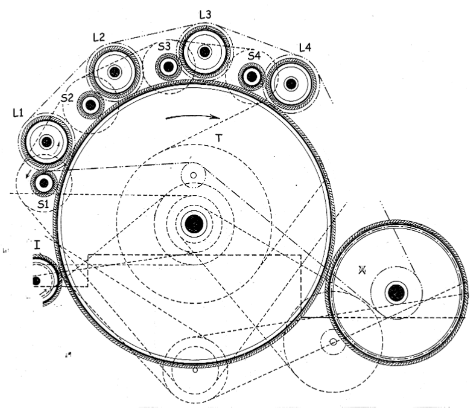



*Fig. 133a  Carding unit.*

- “S1”, “S2”, “S3” and “S4”: stripper roller, covered with needles inclined in the direction of the rotation. The stripper rollers pass material from the worker cylinders onto the drum. They partially blend the material.
- “I”: intermediate roller, covered with needles inclined in the direction of rotation. The intermediate roller transfers the fibres onto the drum.
- “X”: the comber roller, covered with needles that can be more or less inclined in the rotation direction. The comber roller moves slowly and, besides carrying out a further carding action, takes up the material coming from the drum and “condensed” on the roller clothing.

A card can include many carding units. Since a task of the carding process is to form the card sliver, the ultimate carding unit being the one used for forming the web (which becomes the sliver after a condensation process), it is equipped with (Figure 133b):

- “P”: comber roller, covered with needles inclined in the direction opposite to the rotation direction. The comber roller allows the formation of a web of fibres (besides being also a carding element),
- “p”: oscillating doffer comb, which detaches the web of fibres from the “P” comber roller.

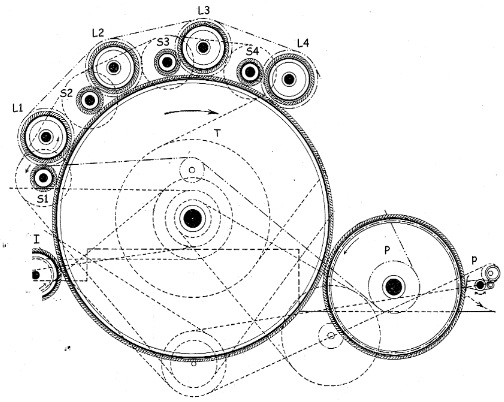



*Fig. 133b – Ultimate carding unit*

In some cases (Figure 133c), the ultimate carding unit can also include (between the last carding point and the comber roller):

- “V”: fly roller, covered with long and flexible needles, inclined in the direction opposite to the direction of rotation. The fly roller raises the fibres to the top of the needles of the “T” drum.

**Operation of the ultimate carding unit**

The interaction of the material with the needles (Figure 134)…

- of the “T” drum and of the “L1, …., L4” worker cylinders allows the “carding”, i.e. allows the opening of tufts down to single fibres and, as much as possible, the straightening and parallelisation of the fibres,
- of a worker cylinder and the corresponding fly roller allows the fibres to be transferred from the worker cylinder to the fly roller,

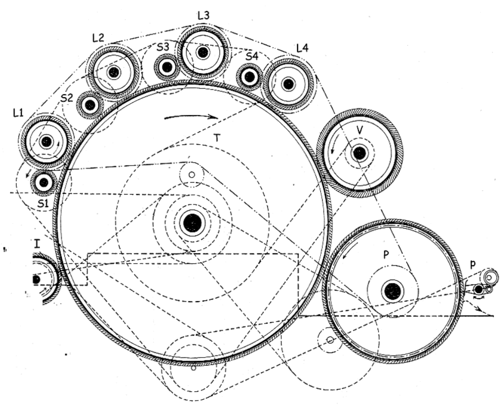



*Fig. 133c Ultimate carding unit with fly roller*

- of the stripper roller “S1, ……, S4” and of the “T” drum allows the fibres to be transferred from the stripper roller onto the drum,
- of the “T” drum and of the “P” comber roller allows the combing and “condensing” of the fibres, i.e. the overlapping of fibres. This leads to the formation, on the clothing of the comber roller, of a web that is consistent enough to be picked up and transformed into a sliver; the web is removed from the “P” comber roller by means of the “p” doffer comb.

When the carding unit is also equipped with a fly roller, the interaction of the material with the needles of the “T” drum and of the “V” fly roller allows the fibres to come to the surface of the drum needles; this movement is associated with an entanglement and a disarrangement of the fibres, which partly lose their parallelism.

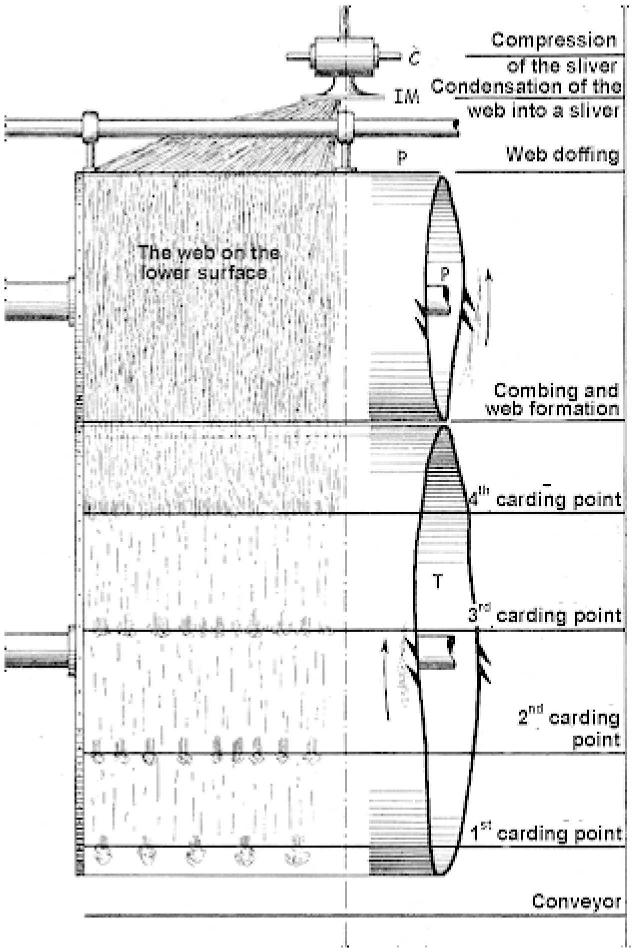



*Fig. 134 Operating principle of the ultimate carding unit*

For the sake of simplicity, in order to describe the interactions between the fibres and the needles of the clothing on the different cylinders, we will refer to the cross sections of the cylinders and to the typical needles found on the different card clothings.

A) Drum plus worker action

The drum and the worker cylinder rotate in opposite directions; in the zone where they interact with the material, the needles move in the same direction; the rigid needles of the drum move faster than the rigid needles (sometimes flexible) of the worker cylinder, VT > VL.

As a result, needles “1” and “2” (Figure 135) of the drum and of the worker cylinder turn in the same direction with such a speed that V1 > V2 and therefore needle “1” turn at the speed (V1 - V2) > 0 with respect to “2”. This means that the needles “1” and “2” after touching at position I-II continue to move rightward but, after some time, needle “1” precedes needle “2”.

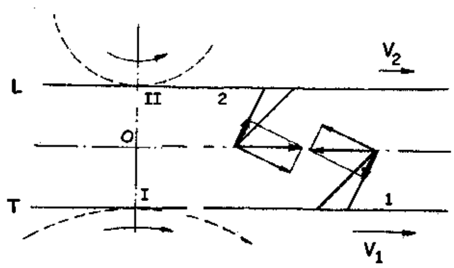



*Fig. 135 Carding action*

The needles of the drum are inclined in the direction of rotation while the needles of the worker cylinder are inclined in the opposite direction.

The tips of the needles of the two clothings are very close to each other so that the needles of the worker cylinder can retain the part of the material protruding from the drum clothing; in a few words, each tuft brought forward by the needles of the drum, is hooked and retained by the needles of the worker cylinder

The tuft is subjected to a stress force which overcomes the friction between the fibres and develops a reciprocal sliding of the fibres, as a result opening the tufts, which therefore disentangle and divide into smaller tufts; some of them pass onto the needles of the worker cylinder while others follow the motion of the drum.
During the opening of the tufts, the fibres are stretched and partially parallelised.
The repetition of these actions generates gradually smaller tufts until each single fibre is completely separated from the others (Figure 134). The action described above constitutes the "carding" process.
After a certain time, the clothing of the drum and of the worker cylinder are filled with fibres and must be cleaned.

B) Worker plus stripper action
Thanks to the interaction between the needles of the worker cylinder and the needles of the drum, the tufts on the needles of the worker cylinder are subject to the action of the rigid needles of the stripper roller.

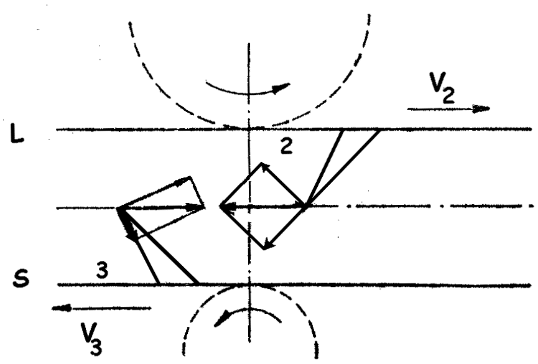


*Fig. 136 Fibre transfer*

The worker cylinder and the stripper roller turn in the opposite direction so that, in the zone where they interact with the material, their needles move in the opposite direction; the speed of the stripper roller is far higher than the speed of the needles of the worker cylinder, VS > VL.
Consequently, needle "2" of the worker cylinder and needle "3" of the stripper roller (Figure 136) move in opposite directions and the speed of needle "3" is much higher than the speed of needle "2", V3 > V2. The speed of needle "3" with respect to needle "2" is therefore equal to the sum of the two speeds: (V2 + V3).
The needles of the worker cylinder are inclined opposite to rotation direction while the needles of the stripper roller are inclined in the direction of rotation.
Thanks to the higher speed of the needles of the stripper roller and to their position converging towards the worker cylinder, the clothing of the stripper roller picks up the fibres from the clothing of the worker cylinder; in this way, the needles of the stripper roller "strip" the clothing of the worker cylinder.
Since the needles of the worker cylinder and of the stripper roller do not move along a linear path but along a circular one, the long tufts undergo an additional carding action since they are picked up by the needles of the stripper roller while they are still retained by the ones of the worker cylinder; therefore, the transfer of the fibres on the needles of the stripper roller is accompanied by a slight stretching and partial parallelisation

C) Stripper plus drum action
The tufts picked up by the stripper roller are fed to the drum.
The drum and the stripper roller rotate in opposite directions. As a result, in the zone where they interact with the material, the needles rotate in the same direction; furthermore, the speed of needles of the drum is higher than the speed of the needles of the stripper roller, VT > VS.
Consequently, needle "1" of the drum and needle "3" of the stripper roller rotate in the same direction (Figure 137) and the speed of needle "1" is higher than the speed of needle "3", V1 > V3.

The speed of needle "1" with respect to needle "3" is therefore e equal to: (V1–V3) > 0.
The needles of the drum and of the stripper roller are inclined in the direction of rotation. The needles of the drum hook and pick up the fibres that emerge from the needles of the stripper roller. Also during this transfer, the fibres are slightly straightened and partially parallelised.
The fibres picked up by the stripper roller from the worker cylinder and transferred onto the drum do not reappear on the drum exactly where they were picked up since in the meantime the drum has covered a greater distance than the one covered by the worker cylinder and by the stripper roller. For this reason, during the carding process fibres are alto partially reblended and tufts are further opened.

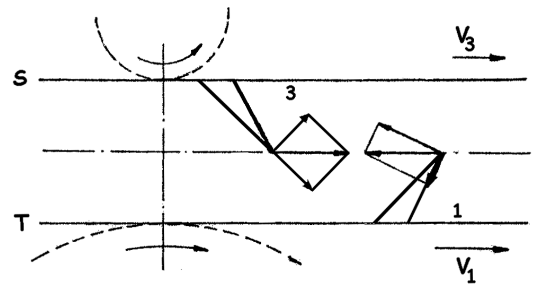


*Fig. 137 Fibre transfer*

After the first treatment carried out by the drum-worker-stripper, the fibres are conveyed to the other worker-stripper sets, whose needles are increasingly near the drum needles; the progressively more powerful carding process and the fibre transfer are carried out with the same methods as mentioned before (reference is made to the first worker-stripper set).
The number of worker-stripper sets varies from four to six.

D) Drum plus comber action
The comber roller rotates in opposite direction with respect to the drum, therefore, during interaction with the material, its rigid needles and the needles of the drum rotate in the same direction; the speed of the drum needles is remarkably higher than the comber roller needles, VT > VP.
AS a result, needle “1” of the drum and needle “5” of the comber roller rotate at such speeds that V1 > V5 (Figure 138) and, therefore, the speed of needle “1” with respect to the speed of needle “5” is equal to: (V1 – V5) > 0.
Needle “1” of the drum is inclined in the direction of rotation, on the contrary to needle “5” of the comber roller, which is inclined opposite to the direction of rotation; therefore the position of the fibres on the drum clothing, the directions and the speeds of the drum and of the comber roller are such that the needles of the comber roller hook up and drag the fibres seized by the needles of the drum, thus determining a carding action similar to the one occurring between the drum and the worker cylinder.
The fibres, which are not hooked up by the needles of the comber roller penetrate inside the drum clothing and, after a certain time, fill it up; for this reason, the clothing must be periodically cleaned.

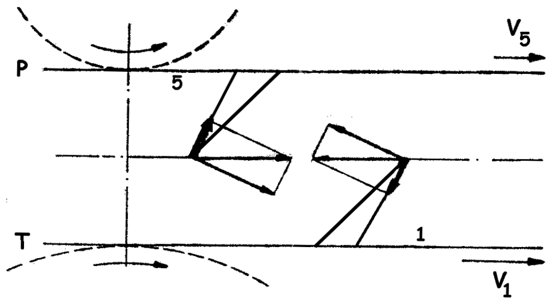


*Fig. 138 Carding action*

The wastes including short tufts and impurities falling under the comber roller and under the drum.

E) Comber plus doffer action

The fibres are removed from the needles of the comber roller, in the form of web using an oscillating doffer comb (Figure 139)

The needles of the comber roller move slowly while the doffer comb carries out a very quick oscillation touching the needles of the comber roller; the web is taken up as the comb moves downwards.

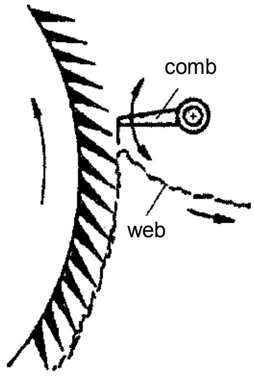



*Fig. 139 Doffer comb*

F) Special case: carding unit with fly roller

In the following, we describe the interaction between the drum and the fly roller on a carding unit equipped with a fly roller.

During the carding process, a part of each fibre on the drum penetrates inside the drum clothing; in order to allow transferring these fibres onto the clothing of the comber roller, the fibres are raised to the tips of the needles of the drum by the action of the fly roller whose flexible tips penetrate inside the drum clothing.

The direction of rotation of the fly roller is opposite to the drum, therefore in the whole area of interaction with the material, the two clothings move in the same direction (Figure 140); the speed of the fly roller is higher than that of the drum, VV > VT.

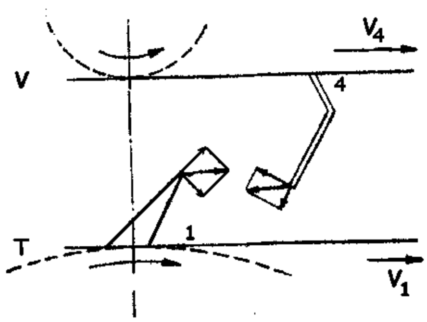



*Fig. 140 Fibre raising*

Consequently, needle “1” of the drum and needle “4” of the fly roller move in the same direction; the speed of needle “4” is higher than the speed of “1”, V4 > V1. The speed of needle “4” with respect to needle “1” is equal to (V4 – V1) > 0.

The needles of the fly roller are inclined in the direction opposite to rotation so that they can raise the fibres on the tips of the drum needles, without hooking them; in fact, the fibres raised by the needles of the fly roller cannot be transferred onto the clothing, which cannot retain them and, therefore, they remain on the tip of the drum needles, kept by adhesion with the fibres still partially inserted in the clothing.

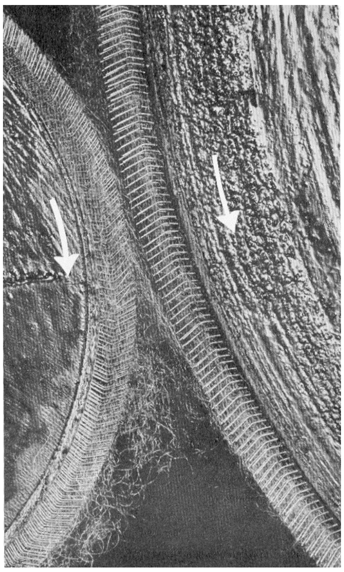


*Fig. 141 Formation of the fibre web*

The air vortex generated by the speed of the needles of the fly roller (up to 30% higher than the one of the drum needles) may scatter the fibres; to prevent this, a collector cylinder is placed under the fly roller (or sometimes above), whose needles seize the fibres and transfer them again onto the drum clothing.

After the fly roller, the fibres raised on the drum needles are subjected to the action of the needles of the comber roller (Figure 141). A special carding action takes place since the fibres are arranged on the tips of the drum clothing conveying them; fibres are therefore not firmly held by the needles, which retain them only thanks to the weak friction which is generated between them; these conditions only expose the longest tufts to the stretching action, which hook to the needles of the drum while the others transfer directly on the clothing of the comber roller, which retain the fibres by overcoming the weak friction stress contrasting the transfer.

Figure 139 shows the faster drum (on the right), whose needles are inclined in the direction of rotation, conveying the fibres arranged on the tips of its needles, without seizing them completely. These fibres are transferred onto the clothing (on the left) of the slower comber roller, whose needles are inclined in direction opposite to rotation, thus forming a web of fibres.

## Tandem card

### General remarks

The washed, beaten and oiled wool is sent to special carding rooms through a pneumatic system. It remains there for the time necessary to allow a proper distribution of the oiling substance into the fibres and also to meet the specific production schedule.
The efficiency of the carding operation strictly depends on the washing operation mode; in fact:
- a high moisture content of the material can generate undesired fibre winding on the clothing of the cylinders (“fibre bands”) with possible formation of hardly recoverable fibre entanglements (“neps”),
- an excessive residual quantity of grease dirties the clothing causing a consequent bad running,
- an excessive removal of grease increases the tendency of the fibres to take up static charges to such an extent that they cannot be neutralised completely by the anti-static agents added to the oiling substance.

### Composition

The so-called “tandem card”, which features 2 carding units, is used for fine or average-quality wool carding (up to 22 micron), whose vegetal substance content can even exceed 12%; the carding machine is completed by several devices to feed and open the material and by another carding unit, known as “pre-carding unit”, preceding the other two carding units and several “deburring” cylinders (Figure 142).
The additional 6 carding points on the pre-carding unit drum, are used for a preliminary disentangling of the wool lumps to improve the efficiency of the subsequent carding step and limit the wear of the clothing of the other carding units.
The deburring cylinders extract the substances of vegetal origin (“burrs”), i.e. the residues of wild thistles.
The card sequentially and simultaneously
- reduces the dimension of the tufts fed into the card,
- isolates and straightens the fibres of each single lump in the material feeding direction,
- separates the fibres from adhering vegetal substances,
- overlaps the fibres to form a web of even thickness,
- transforms the web into carded sliver.

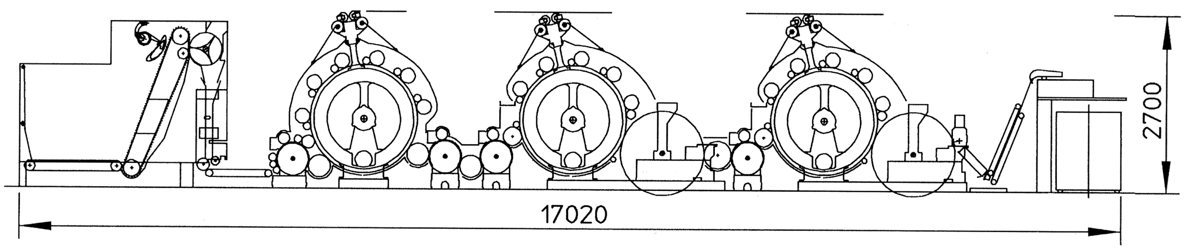



*Fig. 142 – Tandem card with pre-carding unit and deburring cylinders*

**Card operation**

In order to analyse the card operating principle thoroughly, a numerical value will be attributed to the tip speeds of the different cylinders; these values, referring to single specific cases, are therefore indicative and must be considered reference data only.

A) Formation of the web

The web is prepared by an automatic feeder which arranges, on an endless conveyor belt, a steady quantity of material per length unit, which is fundamental for a homogeneous distribution of fibres on the carding devices.

Figure 143 shows a (balanced) gravimetric feeder, suitable for processing longer fibres since the material is unloaded by means of special rakes avoiding potential winding problems.

The small material mass of constant weight, which is unloaded from the balance and dropped onto the endless conveyor belt, is then spread on the belt by means of a "compacting table" (in some cases it is also possible to use a cylinder) allowing the formation of a web of consistent thickness.

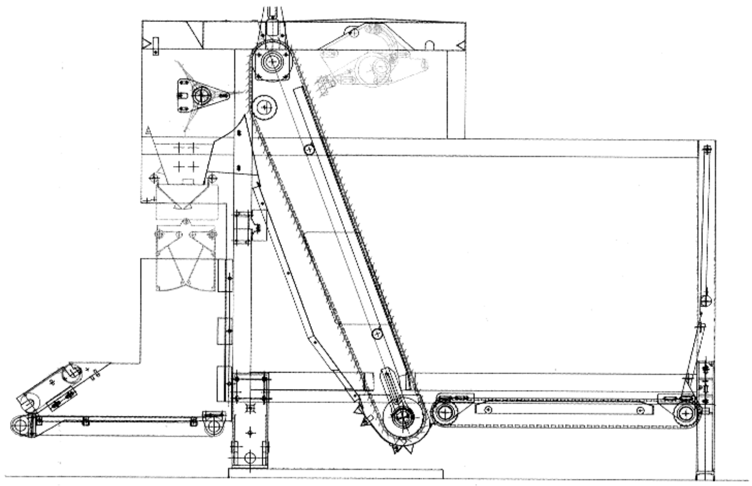


*Fig. 143 – Gravimetric feeder*

B) Web feeding

The endless conveyor belt, "F", pushes the web constantly to the feeder cylinders "A", which turn at the same speed (VF = 1.2 m/min) and take it to the opener roller "R" (Figure 144).

The “A” feeder rollers, covered with steel needles fixed on bronze rings or with a sawtooth wiring, with teeth inclined in the direction opposite to rotation, act as a gripping device and ensure a regular and controlled feeding of the card. They also act as a retaining device allowing the opener cylinder “R” to divide the material into smaller tufts without breaking the fibres.

C) Tuft opening

The inclination of the needles of “A” cylinders allows web retention while the rigid needles of the opener cylinder “R”, inclined in the rotation direction and turning at a speed higher than the “A” needles (VR = 11.8 m/min), penetrate the web and pick up the tufts; as a consequence of the stretching, the front free ends of the fibres (making up head of the tufts), straighten and become parallel (Figure 144).

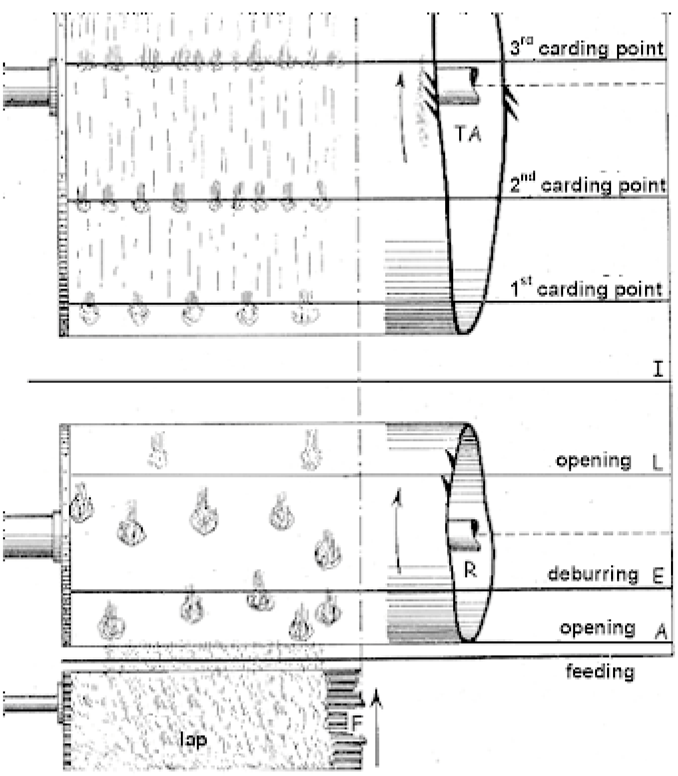



*Fig. 144 – Feeding and opening the web*

As soon as the tuft is released from needles “A”, it is dragged forward by the “R” opener cylinder. The “head” of the tuft is made up by the fibres having an end deeply inserted in the “R” needles while the remaining part (“body” or “tail” of the tuft) includes fibres, more or less entangled, floating on the “R” needles.

Figure 145 shows the solution adopted with the (previously illustrated) tandem card, to feed and divide the web. Worth noticing is that in the triangular space distance between the feeder cylinders and the opener, the “uncontrolled” fibres can be picked up by the needles of the opener (also irregularly) in “bunches” or “blocks”.

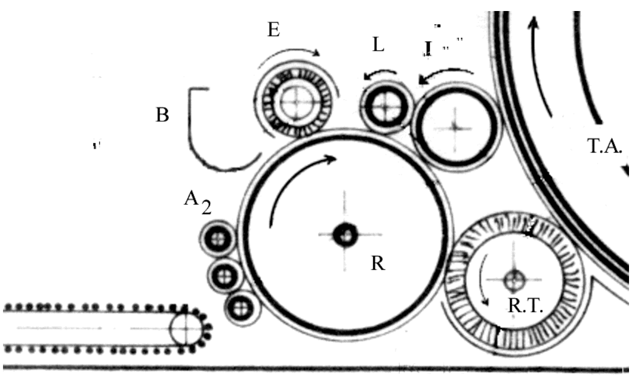



*Fig. 145 - Feeding and opening of the web (side view)*

To cope with this problem, the tufts are opened by a small “L” worker cylinder, covered with rigid needles inclined in the direction opposite to rotation which, turning at a speed of VL = 2.7 m/min, opens the eventual bunches or blocks of fibres and reduces their sizes. The “A2” cleaner roller includes a cylindrical brush (this type of clothing is called “Tampico”) rotating anticlockwise; the brush sends back on “R” any material eventually deposited on the needles of the upper feeder roller after being retained by the needles during the opening step.

The fibres on “L” and “R” are transferred onto the “T” intermediate roller, covered with rigid needles inclined in the direction of rotation and revolving at the speed VI = 27 m/min, which transfers the fibres on the “T.A.” pre-carding drum.
The “R.T.” collector-conveyor is a cylindrical brush, rotating at the speed VRT = 33 m/min, which recover the fibres dropped by the “T” intermediate roller that would be otherwise lost.

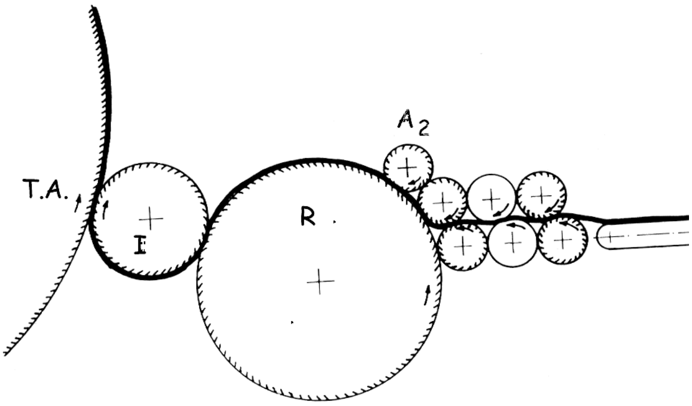


*Fig. 146 – Feeding and opening of the web (alternative solution)*

Figure 146 shows a solution adopted in the past to feed and open the web; the “R” opener roller, is followed by an “I” intermediate roller, as described above. The three pairs of feeder roller (the intermediate one is not covered with needles but has longitudinal grooves) ensure an excellent evenness of the material fed since they do not allow the “R” opener roller to pick up the fibres irregularly, i.e. in “bunches” or “blocks”; in fact, the second pair of cylinders, featuring a speed about 10 times higher than the speed of the previous pair of rollers, performs a remarkable drawing action on the fibre mass, which starts being opened straight away. The third pair of cylinders, similar to the first one, whose speed is about the two thirds of the second one, compact the web making it more even, and reduce the possibility that the opener roller picks up the fibres irregularly.
Whatever the solution adopted, the breaking of the web into tufts is carried out irregularly and at random; the result depends on the VR/VA ratio and on the thickness of the web on “F”.

D) Wool deburring
A partial deburring (elimination of the vegetal substances contaminating the fibres) can also be carried out inside the opener as well as the removal of other foreign matters contained in the fibre mass that could damage the clothing of card rollers; this operation can be carried out with a deburring roller provided with “E” tabs and the contiguous “B” collector (Figure 145).
The “E” deburring unit includes a roller covered with longitudinal blades (or radial tabs) rotating in a direction opposite to the “R” opener roller at such a speed that there is the passage of a tab per every 2 mm of revolution covered by the opener (1500 ÷ 2000 rpm).
Every time a tuft contaminated with vegetal impurities or other foreign matters reaches the web surface and passes near the longitudinal blades of the deburring roller (deburring point), it is repeatedly beaten by the blades. The particles stripped are taken to the “B” collector and conveyed outside the card by means of small blades driven by a belt running along the roller (across the machine) while fibres remain hooked on the needles and are therefore dragged further by the opener roller.

However, the elimination of vegetal substances through the deburrer on the opener roller (and of the comber rollers of the carding units) is not thorough enough; for this reason the card includes other rollers specially designed to eliminate burrs.

The most common solution is the use of rollers with Morel clothing. These rollers perform a powerful action on vegetal substances on sufficiently opened tufts, where fibres are not excessively entangled. Therefore, when using Morel clothings, the elimination of the burrs must be carried out after the tufts have been opened by pre-carding drum and/or a carding unit.

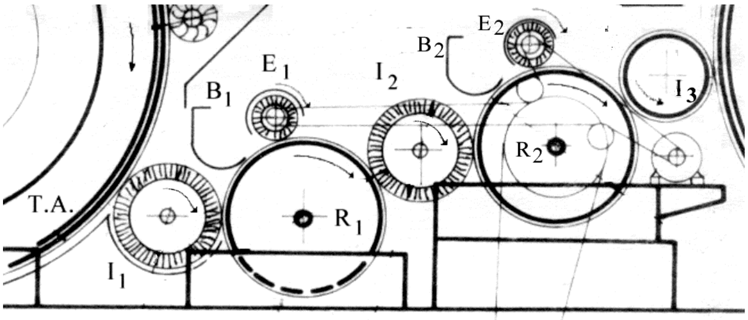


*Fig. 147 - Double deburring with Morel clothings*

A first deburring step (Figure 147) is carried out with the "R1" roller with Morel clothing, (VR1 = 165 m/min) and with the "E1" roller with radial tabs placed between the pre-carding unit and the first drum of the tandem card.

The needles of the "R1" roller have a trapezoidal shape and are arranged so that a gap of about 0.8 ÷ 1.0 mm is created between two adjacent needle rows; while the main part of the fibres pass between this space, bigger vegetal substances (whose height exceeds the gap width) do not pass over the rollers and float above them and above the needles.

The "I1" cylindrical brush, (a detail in Figure 147), which rotates at the speed VI1 = 99 m/min, transfers the fibres from the "T.A." roller (VTA = 49 m/min) to the "R1" roller while the "E1" finned roller strips the burrs from the web and takes them to the "B1" collector.

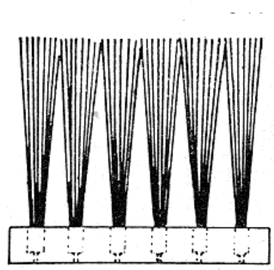


*Fig. 148 - Clothing of the cylindrical brush*

From the "R1" roller, the fibres are transferred to the needles of a second "R2" Morel roller, (VR2 = 329 m/min), with adjacent "E2" deburring roller, by means of another "I2" cylindrical brush (VI2 = 272 m/min) and finally are transferred onto the needles of the first drum, by means of an "I3" conveyor roller (VI3 = 456 m/min) covered with curved needles (flexible) inclined in the direction of rotation.

A last deburring operation can be carried out following the same method as before, between the first and the second drum (Figure 149), by means of the "R3" Morel roller, (VR3 = 240 m/min) , the "E3" deburring roller with its "B3" collector, the "I4" cylindrical brush, (VI4 = 158 m/min) and the "I5" conveyor roller (VI5 = 312 m/min), covered with curved (flexible) needles, inclined in the direction of rotation.

E) Carding

As previously said, the interaction of the material with the needles of the drum, of the worker cylinders and of the stripper rollers included in a carding unit, determines the separation and the drawing of the fibres.

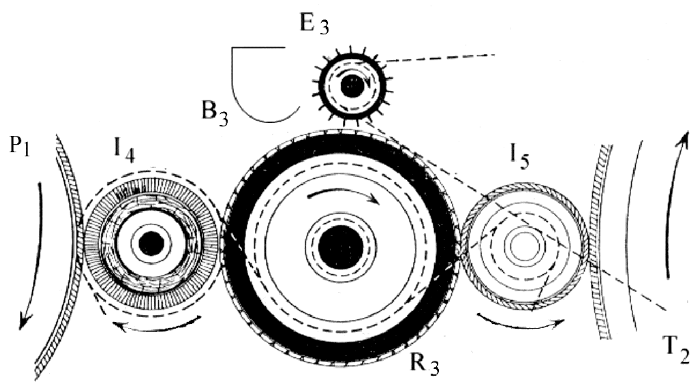


*Fig. 149 - Deburring with Morel clothings*

This operation, which starts in the carding points of the pre-carding drum and finishes in the last carding point of second drum (Figure 150 a, b, c), is carried out with the same methods illustrated for the carding unit.
The main role of the card is to subject the wool on the drum to the carding action of a certain number of worker cylinders; the other actions carried out by the machine are less important and mainly concern the loading and unloading of the material from the drum.

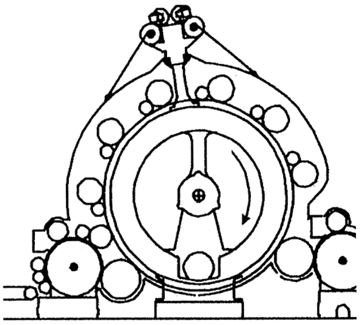


*Fig. 150a Pre-carding unit*

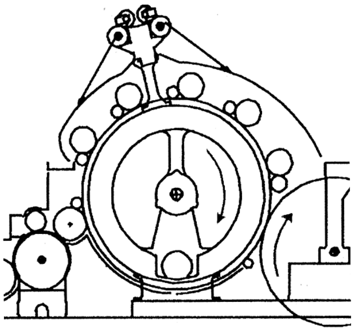


*Fig. 150b First drum*

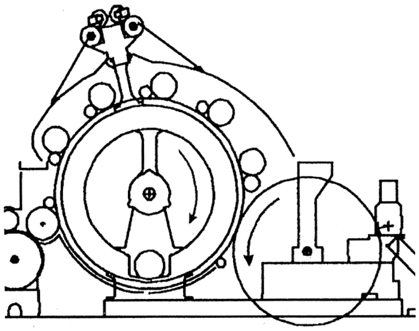


*Fig. 150c Second drum*

The carding process can be schematised as follows:

1 – when the fibres conveyed by the drum approach the stripper roller, they are part above it and part inserted in the needles of the drum inclined in the direction of rotation,

2 – when the fibres pass under the stripper roller, covered with needles inclined in the direction of rotation, they are pushed more deeply inside the clothing of the drum which rotates faster, but after having passed it, they protrude again beyond the needles with the fibres that have just been transferred from the stripper roller,

3 – in the contact area between the drum and the worker cylinder nothing happens since the fibres are only on the clothing of the drum because, if the stripper roller has correctly carried out its action, there are no fibres in the contact area on the worker cylinder,

4 – as soon as the fibres enter the contact area between the drum and the worker cylinder, they are pushed against the needles of the (slower) worker cylinder, that are inclined in a direction opposite to rotation, and seized in the same way as by the needles of the drum. As for the worker cylinder needles, it is worth noticing that:

• if they are correctly ground, they will penetrate the tuft and seize the fibres thus preventing them from winding on the clothing of the drum,

• if they are too far, only the ends of the tufts will be seized and the carding action is not carried out on all the fibres,

5 – the real carding action starts when the tuft is picked up by the needles of the worker cylinder; the part of tuft seized by the needles of the drum moves forward and the fibres are stretched. When fibres stretch, they tend to penetrate inside the needles of the drum and slip along the needles of the worker cylinder, until they hit an obstacle, for example one single fibre wound around the needle. As the stretching increases, the fibres slide around the needles until they are completely drawn; the tuft is separated into two parts whose dimensions depend on the structure and on the initial shape of the tuft. The fibres that cannot slide break; for this reason it is very important to protect the needles from the rust that remarkably increases friction with the fibres,

6 – immediately before the separation, the fibre ends of the part of tuft picked up by the clothing of the drum are powerfully and very quickly stretched through the needles of the worker cylinder. The fibres seized by the needles of the worker cylinder, turning at a lower speed, are subject to the action of the needles of the drum.

Considering all this, it is possible to say that the wool fibres picked up by the worker cylinder are carded more thoroughly than those retained by the drum.
Due to the drawing carried out by the drum, the fibres protrude from the needles of the worker cylinder, and are transferred on the clothing of the stripper roller, and additionally straightened before reaching the contact area of the two rollers.
In order to understand the function of the stripper roller, it is sufficient to see how the card would operate without it. The fibres, conveyed by the worker cylinder, are picked up by the drum before the contact area, thus the carding action would be anticipated, leading to fibre entanglement. The function of the stripper roller is therefore bring the fibres back onto the drum so that they can be subjected to the action of the worker cylinder without entangling.

E1) Analysis of drum-worker-stripper interactions
The clothings of drum, worker cylinders and stripper rollers of the three carding units (pre-carding, first and second units) can be:
- rigid,
- the stripper rollers of the pre-carding unit can be cylindrical brushes,
- the worker cylinders of the second drum can be covered with curved needles (flexible)
- etc.

For every solution adopted and apart from the carding unit considered, the tuft picked up by the "T" drum is conveyed to the first "carding point", near the first "L1" worker cylinder (Figure 151).

The carding points are the nip points on the paths of the tips of the needles of the worker cylinders and of the drum; the distance between the needles can be adjusted and ranges (in the forward direction) from some millimetres in the pre-carding unit to some tenths of a millimetre in the second drum, resulting in a gradual and regular carding.

The head of the tuft is deeply introduced among the needles of the "T" drum and, therefore, goes beyond the line of the carding points without being subject to the action of the needles of the worker cylinder while the body of the tufts, which protrudes from the needles of the drum, is retained by the needles of "L1". As a result, the body of the tuft is seized by the needles of the two clothings and the faster speed of the "T" drum with respect to the "L1" worker cylinder, makes it penetrate more and more deeply into the drum needles; the stretching exerted on the tuft disentangles and straightens the fibres in the direction of rotation of the "T" drum thus making them parallel and carding them.

From position "c" to position "c' " of the needles of the worker cylinder, the fibres of the body of the needle are disentangled and the ones whose end is introduced among the needles of the drum are unwound and straightened (Figure 150 shows the "sawtooth" wires of the worker cylinder sketched with a "curved shape" to better evidence the position of the "c" points).

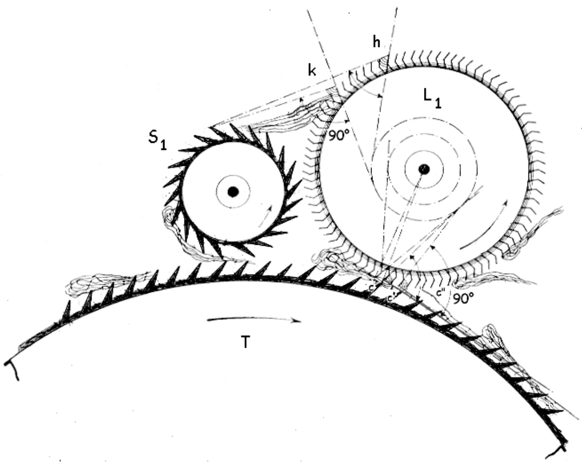



*Fig. 151 The drum-worker – stripper assembly on the 2nd drum*

The acute "retaining" angle, corresponding to "c", points out the capability of the needle of the worker cylinder to retain the fibres; the action terminates on position "c' ", where the angle becomes a 90° angle.
Beyond this position (for example, in c'' position), the needle is no longer capable of retaining any fibre.
The fibres are excessively entangled and their end has not yet introduced into the drum clothing or they are insufficiently introduced, they are seized by the needles of "L1" and brought back to the same carding point by the "S1" stripper roller.

Considering the faster speed of "S1" with respect to "L1", the stripper roller carries out a stretching action on the fibres, which, therefore, are straightened and partially made parallel.
The supplementary stretching is carried out when the fibres are positioned at points "h" and "k" of the worker cylinder (respectively found on the tangent to the trajectories of the needles of the two cylinders and on the retaining angle corresponding to 90°), which vary according to the "L1" and "S1" diameters; beyond the "k" point, the needle is no longer capable of retaining the fibres since the retaining angle is greater than 90° and there is no more stretching action.
The worker cylinders in the other carding points work like this and the more powerful the action, the smaller is the distance between the needles of the worker cylinder and the needles of the drum.

In the last carding point of the first and of the second drum, the worker cylinder has no corresponding stripper roller; in order to avoid poor carding results, the worker cylinder must be protected with a hood preventing it from picking up the fibres before they reach the interaction area of its needles with the needles of the drum. Furthermore, considering that this worker cylinder is placed near the vertical plane tangent to the drum surface, it must be necessarily followed by a cylinder that brings back on the drum the fibres which would certainly escape from its needles; the fibres therefore remain in the space between this cylinder, the worker cylinder and the drum.

During the carding action, the high speed and the huge quantity of needles of the drum entail a friction and a scoring of the fibres, which causes the separation of foreign particles, thus cleaning the material.
The centrifugal force and the ventilation generated by the rotation of the drum knock off a certain quantity of released impurities under the card; these impurities are mainly eliminated at the cylinder of the comber roller.
The partial blending of the fibres is carried out in the carding points where the tufts are fed in different blend steps; the more powerful the blending, the higher the number of carding points.
We can schematise the speeds of the drums (which generally do not exceed 1000 m/min), of the cylinders and of the stripper rollers of the different carding units as follows:

• pre-carding unit: VTA = 49 m/min VL = 6 m/min VS = 14 m/min
• 1st drum: VT1 = 750 m/min VL = 25.6 m/min VS = 143 m/min
• 2nd drum: VT2 = 750 m/min VL = 25.6 m/min VS = 149 m/min

E2) Analysis of drum-comber interactions

The straightened and parallel fibres leaving the last carding point are more or less deeply inserted into the needles of the drum; the direction of rotation and the slant of the needles of the first “T1” drum and of its “P1” comber roller (Figure 152) allows a powerful carding of the material.

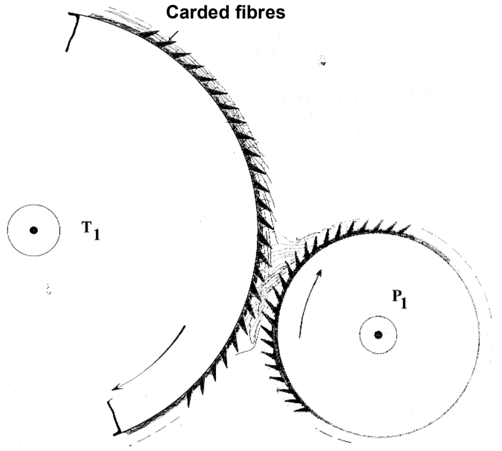



*Fig. 152 – 1st drum-comber roller*

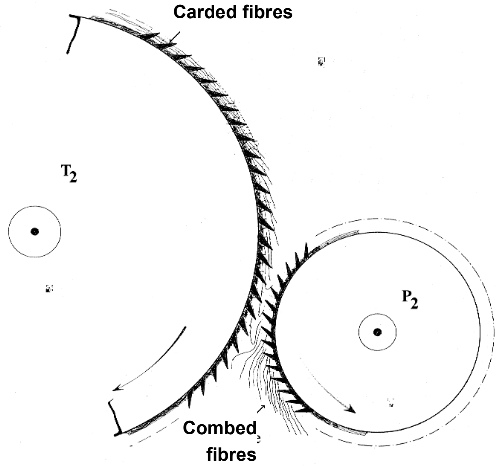



*Fig. 153 – 2nd drum-comber roller*

At the second drum, the carded fibres fed by “T2” hit the needles of the “P2” comber roller and pass onto its needles where, thanks to the speed difference, they gather and form web (Figure 153). Since the rotation of the cylinders is a non-stop rotation, the stacking and the overlapping of the fibres on P2”, i.e. the web formation, is carried out on a regular and non-stop base.

In order to allow the comber roller to regularly extract the fibres on the drum, the previous carding actions must have completely stretched and arranged the fibres as shown in position “f ” between the needles of the drum (Figure 154); each fibre must be therefore positioned in the space between two adjacent rows of needles so that the extraction from the clothing can be carried out without tear or break.

In fact, due to the high relative speed between “T” and “P” and also to the considerable size of the last one, as soon as the head of a fibre is retained by the “P” needles, the fibres turn upside down (Figure 155) positioned across many rows of “T” needles, as shown in position “f1” (Figure 154) i.e. the still hooked fibre cannot unwind rapidly and smoothly and is subject to a powerful stretching action which may break the fibre.

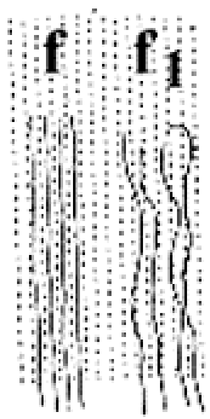



*Fig. 154 Fibres on the drum.*

The fibres that do not break on the “combing point” (which corresponds to the tangent point of the trajectories of the tips of the needles of the drum and of the comber roller) - after running off the “P” needles - pass again (folded) through the carding point where they wind around themselves or break for the same reason illustrated above. the loose impurities, or the impurities adhering to the fibres, escaped to the previous carding action; the eliminated impurities simply fall in the lower section of the card.

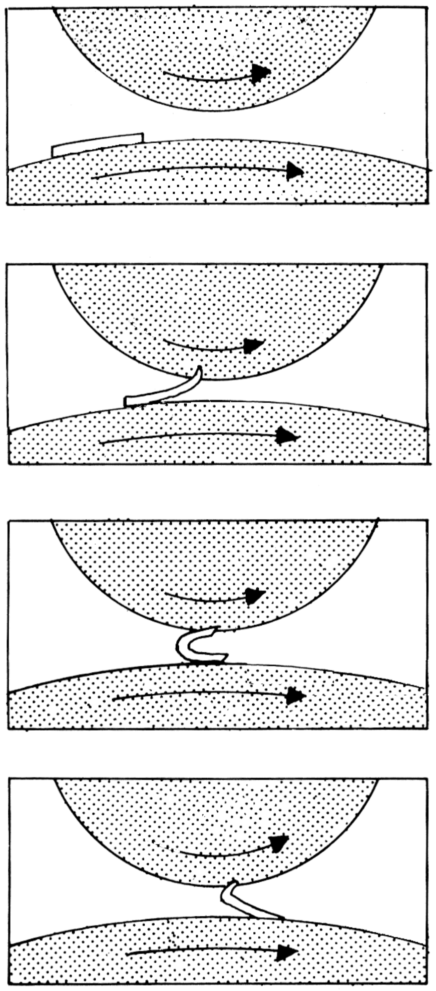


*Fig. 155 Turning a fibre upside down*

The speeds of the comber rollers (which generally do not exceed 80 m/min) of the two carding units, can be the following:

- 1st drum: VP1 = 69 m/min
- 2nd drum: VP2 = 50 m/min

E3) Special case: the effect of the fly roller

The action of the fly roller is necessary to convey the straightened and parallel fibres leaving the last carding point, which are more or less deeply inserted in the drum clothing, to the ends of the drum needles to facilitate their extraction by the needles of the comber roller.

The needles of the fly roller penetrate the spaces between the two rows of needles of the drum and raise the fibres, in the form of small “slivers”, up to the tips of the needles.

The hooking of the fibres by the comber roller is favoured by the airflow generated by the drum, which, running along the path between the fly roller and the comber roller, makes the front tips float and protrude outside the clothing.

Considering that the fibres are now on the tip of the clothing of the “T” clothing, by means of the “V” fly roller, the “P” comber roller powerfully combs the back tips of the fibres (Figure 156).

Here are the steps of the interaction between the fibres and the needles of the drum and of the fly roller:

- in the gap before the contact area between the fly roller and the drum, no action is carried out since the fibres lie among the needles of the drum,
- in the contact area, i.e. in the space where needles penetrate, the fibres are simply pushed forward since the speed of the fly roller is higher than the drum speed; the motion is not hindered until the fibre hits the needle of the drum in front of it and this must take place when the needles of the fly roller are leaving the needles of the drum and the fibres, which would otherwise be squeezed against the needles of the drum and knocked out of its clothing.

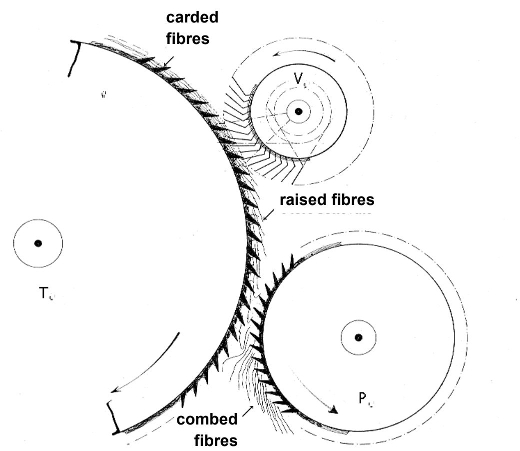



*Fig. 156 The effect of the fly roller*

The easier the release of the needles of the fly roller from the fibres, the smoother and better levelled their surface.
The complete effect of the action of the fly roller is therefore to drive the fibres on the backside of the preceding needles of the drum, and raise them to the needle tips.

The ratio between the speed of the fly roller and the speed of the drum must be accurately adjusted since if the speed of the fly roller is:

- slightly higher than the speed of the drum, its action could be insufficient to drive the fibres on the backside of the needles in front of it and, therefore, to raise them properly,
- too high with respect to the speed of the drum, the needles of the fly roller could drag the fibres and knock them out of the drum.

E4) Final remarks
The effectiveness of the comber roller action mainly depends on the accuracy of the fly roller action as well as on the grinding and on the inclination of its needles.

During the rotation, the last comber roller delivers the fibre web formed on its clothing to the action of the doffer comb which carries out a quick oscillatory movement, approx 2,000 ÷ 2,500 oscillations per min (generally they do not exceed 3,200 strokes/min) some centimetres wide. The teeth of the comb slightly touch the needles of the comber roller and remove the web formed on their tips. During the downward motion, the doffer comb with its fine teeth, drags the fibres downwards and far from the needles of the comber roller; this is possible since the friction with the fibres inserted in its teeth is sufficient to remove the part still inserted in the clothing of the comber roller.
During the raising motion, the fibres are left behind thanks to the gravity and to their adherence to the fibres making up the web; in the meantime, the comber roller moves away and therefore, during the following downward oscillation, the comb performs its action on another area of the surface.

A pair of reversing rollers, with the same speed of the last comber roller (or slightly higher), forces the web through a condensing funnel producing a sliver.

The most common operating widths available for tandem cards are 2,500, 3,000 and 3,500 mm; the production varies according to the count of the fibres making up the sliver and to the operating width, and ranges between 100 ÷ 1000 kg/h.

## Card with double comber

In order to increase the card output by 50 ÷ 100 %, with the same operating width, the following solutions have been implemented:
• unloading and formation of the web from the drum with two comber rollers of the same diameter, equipped with a collector device and with automatic introduction of the two webs effected by the two comber rollers, in the post-carding drawframe (Figure 156),
• increase of the operating speed of all the rollers, in particular increase of the drum speed, in order to reduce down to the minimum the presence of the fibres inside the card and therefore reduce the mass of fibres recirculated on the drum.

Here are the main technical features of the above-mentioned cards:

- operating width ranging between 2,500 and 3,500 mm,
- drum speed, up to 1,500 m/min,
- speed of the comber rollers, up to 100 m/min,
- doffer comb, 3,200 strokes per minute,
- deburring cylinders, 2,000 rev/min,
- count of the sliver produced (g/m),

| | 2500 mm | 3500 mm |
|---|---|---|
| without drawing unit | 20 ÷ 45 | 28 ÷ 65 |
| with drawing unit | 18 ÷ 30 | 22 ÷ 42 |

- output (kg/h)

| | 2,500 mm | 3,500 mm |
|---|---|---|
| 18 micron | 230 | 320 |
| 22 micron | 320 | 450 |

Temperature and moisture conditions in the carding rooms must be as follows:

| | |
|---|---|
| Moisture | 65 ÷ 75 % |
| Temperature | 22 ÷ 26 °C |

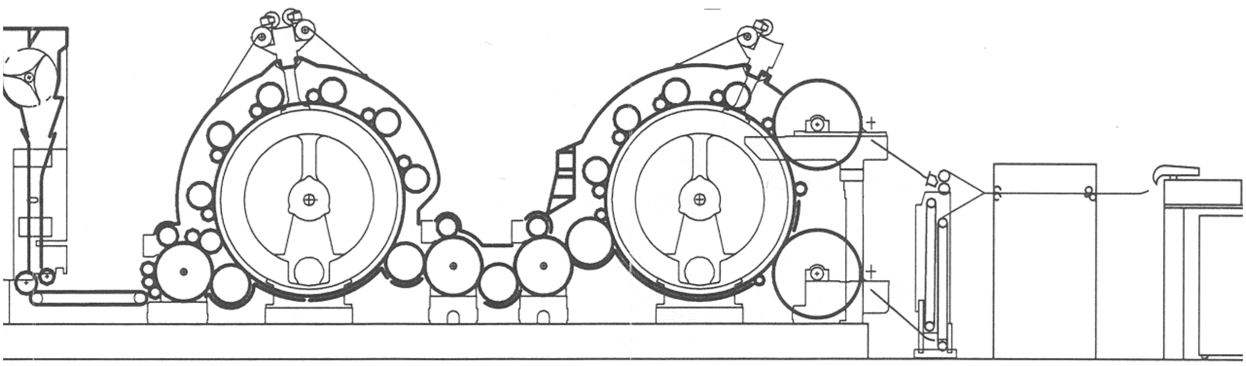


*Fig. 157 Card equipped with double comber roller*

## Post-carding lap drawing frame

### General remarks

The slivers released by different cards (4 ÷ 6) running in parallel (Figure 158) are usually doubled and drawn in a lap drawing frame, also called post-carding lap drawing frame.

*Fig. 158 Tandem cards working in parallel with post-carding drawframe*

In post-carding lap drawing frames the fibre web leaving each single card, after condensing in the funnel assembled before the reversing roller, is deviated by 90° by means of special guides; the fibre web is then conveyed onto a conveyor belt and arranged perpendicularly to the direction of the material flow, on which it overlaps the slivers coming from the other cards and is finally sent off to the drawing frame.
The use of the lap drawing frame offers a great advantage: an excellent reduction in the quantity of “curls” possibly forming on the tips of the fibres during the carding process; in fact, after the interaction between the drum and the comber roller of the card, many fibres making up the card sliver feature a “curl” end, or “tail” (along the direction of the forward movement of the sliver); the curl appears when the fibres conveyed by the drum are picked up and wound around the needles of the clothing of the comber roller and are thus transferred onto them.
This advantage is counterbalanced by a drawback: the running speed of the cards must be adjusted to a slower speed since all the slivers feeding the lap drawing frame must run at the same speed.
In order to ensure a uniform count of the sliver leaving the drawframe, at the exit of the cards, nearby the formation zone of the card sliver, there is a sensor signalling to the drawframe the presence of the corresponding sliver; when one of them is not present, due to a sliver break or card stop, the drawframe does not stop, but automatically changes the drawing values so as to keep the count of the sliver unchanged.
It is possible to reduce the production stops caused by the standby time of the cards, due to machine malfunctioning or maintenance of the drawframe by using two drawframes in the following way (Figure 159):

- the carded sliver, coming for example from 5 cards, is conveyed in groups of 2 and 3 to the two “A” and “B” drawframes respectively,
- should the “A” drawframe stop, the two slivers fed are sent to the “B” drawframe, which automatically changes the draw value,
- should the “B” drawframe stop, the conveyor belt, on which are arranged three slivers, reverts the direction of its motion and sends the slivers to the “A” drawframe, which changes the draw value.

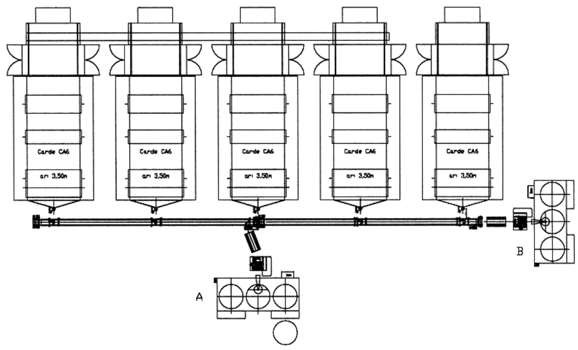


*Fig. 159 Double after-card drawing unit*

**Composition**

A lap drawing frame (Figure 160) includes the following components:

1. a conveyor belt with a bending device for each card (Figure 161),
2. a double belt inclined conveyor, which brings the card sliver to the height of the drawing head,

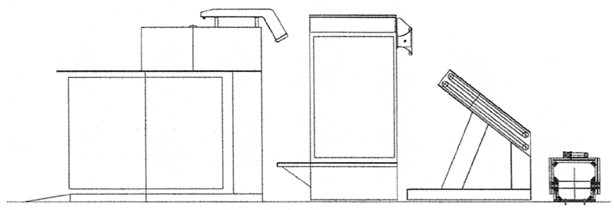


*Fig. 160 After-card lap drawing frame*

3. a condensing funnel, which contains the edges of the sliver and determines the width of the material entering the drawframe (Figure 162),
4. a drawing aggregate,
5. an automatic collecting can for the sliver produced.

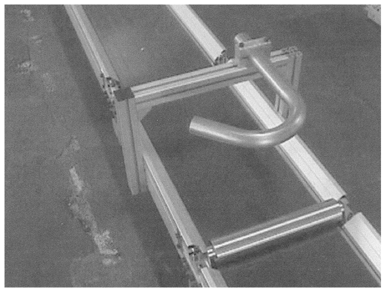


*Fig. 161 Sliver guide*

A) Drawing aggregate
The drawing aggregate of a lap drawing frame includes the following components (Figure 163):
- a feeder including a rubber-coated roller pressing two grooved rollers,
- a fibre control device including two pairs of toothed rollers (called “controllers”, Figure 164),
- a delivery device including a rubber-coated roller pressing on two grooved cylinders, one large and one small.

The “controllers” include a series of toothed plates arranged at an equal distance maintained by means of spacer rings (Figure 163); the accurate assembly of the toothed plates allows a perfect intersection of the teeth of each single cylinder with the teeth of the nearby cylinders

*Fig. 162 Condenser funnel*

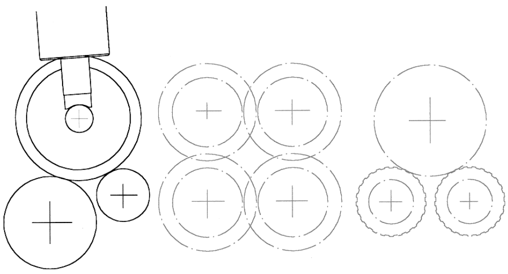


*Fig. 163 Drawing aggregate*

*Fig. 164 Controller*

The toothed plates are assembled on rollers with the teeth inclined in the direction opposite to the rotation and therefore in the direction opposite to the flow of the material which must be drawn.

# Combing

## General remarks

The carded sliver coming from the card or from the lap drawing frame undergoes the combing process in order to:
- eliminate short fibres,
- parallelise fibres,
- eliminate vegetal substances still contained in the fibre mass

The combing process is carried out in three different stages:
1. preparation for combing or pre-combing,
2 combing,
3. post-combing;
   The drawing frames are used for carrying out steps 1) and 3) while combing machines are used for step 2) for wools featuring for example a 21 micron count; in this case, the process shown on Figure 165 could technically be applied.

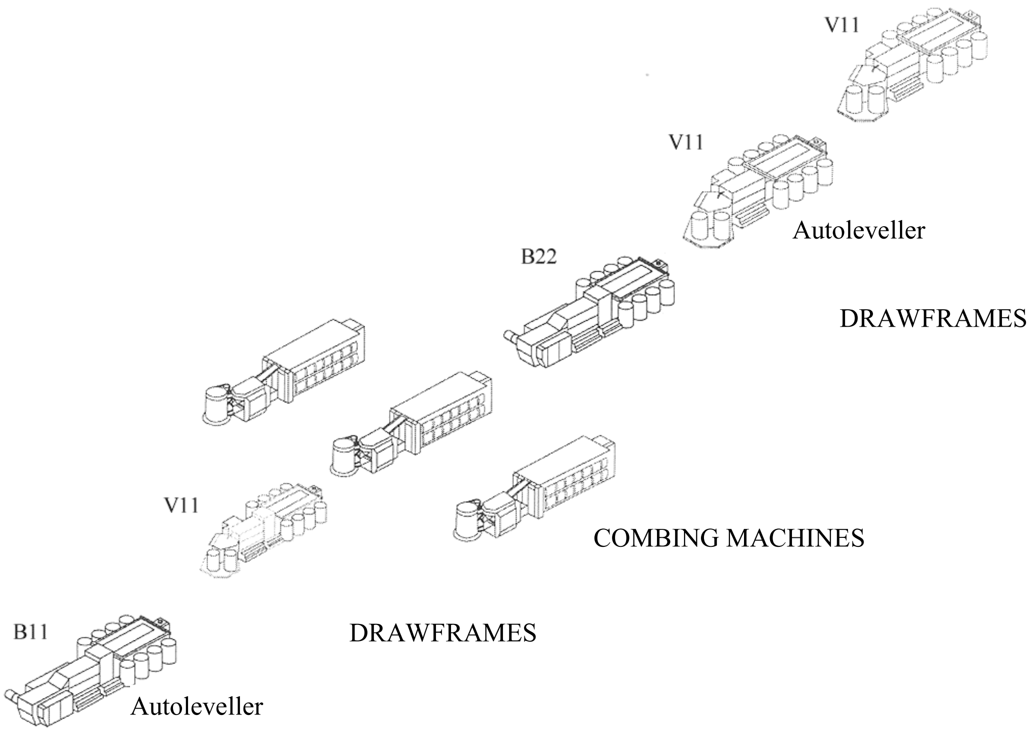



*Fig. 165 Combing cycle of 21-micron wool*

## Preparation for combing

Before passing the material to the combing machine, it is necessary to straighten and start parallelising the fibres to avoid the elimination of the "short" folded or curled fibres contained in the carded sliver, and to avoid the breakage of fibres produced by the powerful parallelisation action; all these actions are the objectives of the preparation stage for the combing process.
The drawing of the carded sliver carried out on the lap drawing frame after the card, reduces the quantity of curls generated on the "tail" of the fibres during the carding process; for their complete straightening, other drawing operations have to be carried out in sequence on the fibre tail and head alternately (with reference to the sliver leaving the card).
Everyday practice has shown that a correct compromise between the number of drawing operations to be carried out and the quantity of "blousse" generated inside the combing machine is reached after 3 drawing steps after the lap drawing frame; in this way two stretching and parallelising actions (drawing) are carried out on both fibre ends (tail and head) of the carded sliver (Figure 166).

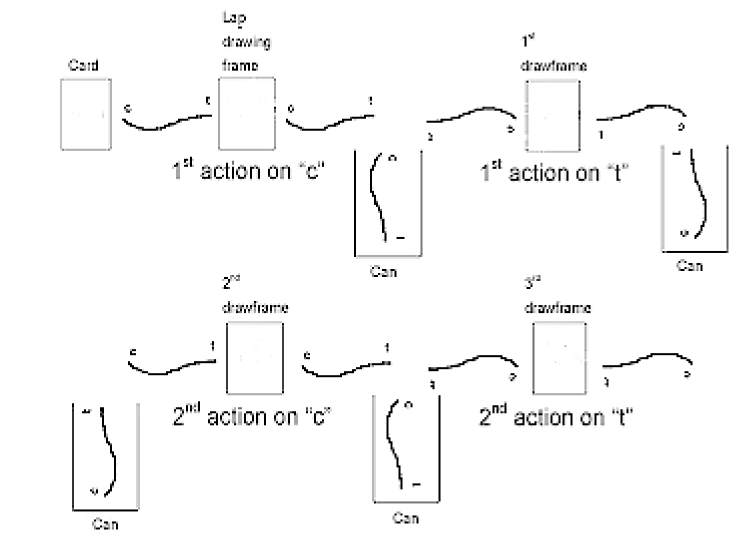



*Fig. 166 – Action of the fibres during the drawing operations*

Each single drawing step is accompanied by a suitable number of sliver doublings; this makes the portion of material fed to the drawframe more regular and makes up for the irregularities of each single sliver. The draft and doubling values are selected according to the characteristics of the material to be processed, the machines to be used and the production schedule.
Indicatively, the number of doublings ranges from 4 ÷ 8 while drafting vary from 4.5 ÷ 6.5; in this way the fibre mass behaves as a filter and allows a more efficient straightening of the fibres.

## Intersecting drawing frames

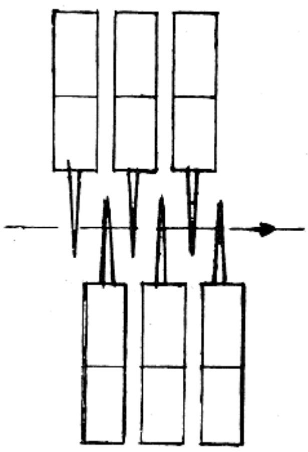


*Fig. 167 Comb needles*

The drawframes traditionally used for processing wool slivers and controlling the fibres in the draft range, include a bar with steel needles which, by intersecting, penetrate the fibre mass (from above and below) and drive it near the drafting cylinder. In this way, the distance between the needles, occupied by the fibres, is the same along the whole length of the needles (Figure 167) and this provides a steady pressure on the fibres and therefore a uniform control of the fibres subjected to drawing.
The above mentioned control device is called intersecting unit.
The needles are placed on steel bars forming the combs whose side ends (fins) are driven by the machine transmission (Figure 168).
The intersecting drawing frames most frequently used in this stage of the process are the single-head type, and their combs can be driven by a belt or by rotating flanges. Also traditional screw-type drawframes can be successfully used; they grant an excellent control of the fibres but a low production output due to the lower fibre feeding ratio.

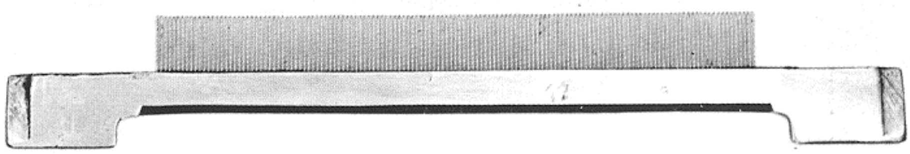


*Fig. 168 Comb with end tabs*

A) Composition

An intersecting drawframe includes the following components:

- a feed rack which arranges the slivers taken from the cans on a flat horizontal conveyor and sends them to the feeding cylinders of the drawing unit,
- a drawing unit including:
  a) two grooved feeding cylinders acting as fibre nipper,
  b) a double set of intersecting combs ("needle range") with the centre line positioned on the operating surface on the contact areas between the feed and the drafting cylinders. The combs are driven so that the higher needle range is separated from the lower one, on the feed side, to facilitate the entry of the material into the control device. The combs intersecting at the exit force the fibres through the needles with a consequent stretching and parallelisation action during the drawing,
  c) drawing cylinders, usually including 1 cylinder coated with rubber on 2 grooved cylinders,
- a device collecting the sliver in a can or reel. The drawframe used for carrying out the third drawing step collects the sliver on 1 or 2 reels per head (to limit the space needed to feed the combing machines, which require from 20 to 24 doublings each): the collection device imparts a false twist to the sliver in order to wind it with a suitable tension for proper winding onto a reel.

B) "Screw-type" drafting head (Figure 169)

Inside the "screw-type" drawframes the tabs of the combs engage in the threads of big worm screws ("screws", Figure 170) whose rotation allows the forward motion of the combs on a horizontal plane, one comb behind the other, towards the drafting cylinders.

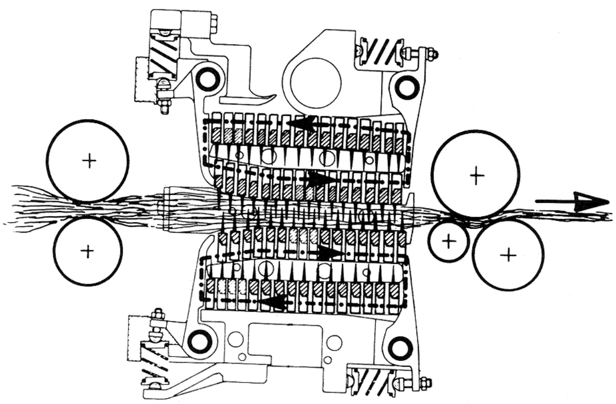


*Fig. 169 - Screw-type drafting head*

Every comb reaching the end of the stroke near the drawing cylinder, is lowered (if it belongs to the lower draft range) or raised (if it belongs to the higher draft range) driven by two rotating cams (Figure 170), fixed at the ends of the screws, which engage it into the threads of the two "return screws". The rotation of the return screws is such that the comb is driven back to the beginning of the needle range, where it is repositioned in the working area by two other cams, arranged at the ends of the return screws, which push it in the opposite direction.

The return screws usually have a pitch greater than the other screws so that, with the same number of revolutions, each comb can carry out the backstroke more rapidly; in this case, every second, the number of returning combs is lower than the working combs.

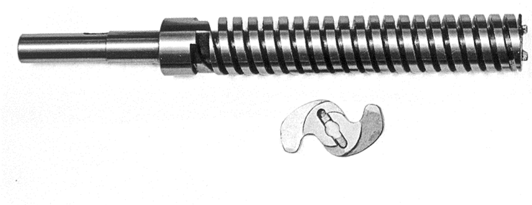


*Fig. 170 - Screw and cams*

During the whole cycle, the combs are kept parallel to each other and to the needles perpendicular to the direction of the material flow.
The efficiency of the fibre control is so high that, still today, the screw-type drawframe is considered a sort of benchmark for the other control systems; one of the limits of this machine is the low output capacity due to the impossibility the combs reaching high speeds due to the complicated motions and mechanical stresses.
To calculate the speed of the combs the following applies:

$$Vap\ (m/min) = Np/min * Dp\ (m)$$

where:

Vap = speed of the combs (m/min),
Np/min = number of combs passing through a certain point in a minute
Dp = distance (pitch) between one comb and the following one (m);

considering that near the screws, the combs are hit by the cams, the result is:

$$Vap = \frac{\dfrac{\text{comb nips}}{\text{min}} \times \dfrac{\text{pitch (mm) of the screws}}{\text{number of starts of screws}}}{1{,}000}\ (m/min)$$

The screw pitch is equal to 18 mm (occasionally 22 mm) and the thread has two starts; the screws feature maximum 1,000 revolutions per minute and considering that the cams hit the two combs at each revolution of the screw, the maximum number of comb nips per minute will be 2,000 (one nip every 0.03 seconds).

The maximum speed of the combs of the screw-type drawframes is 18 m/min (22 m/min with a 22 mm pitch), which is also the maximum peripheral speed of the feeding rollers.

C) Drafting head with rotating flanges (Figure 171)
In the drawframes equipped with rotating flanges, the motion of the combs is generated, for both needle ranges (lower and higher), by the rotation of two flanges provided with radial grooves which drive the combs by their end tabs; therefore, the combs follow the path of these grooves on two pairs of fixed side shoulders.
In this case, the non-stop horizontal displacement and the pulse vertical motion of the combs on the screw-type drafting head are replaced by a uniform rotation thanks to which the mechanical stresses of the involved devices are reduced to the bare minimum.

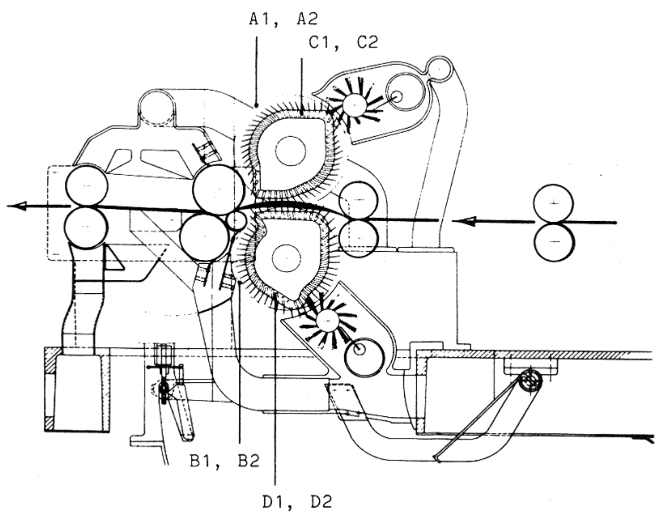



*Fig. 171 – Drafting head with rotating flanges (cross section).*

In these drawframes (Figures 171 and 172) the combs rotation is driven by means of two pairs of grooved flanges, “A1, A2” and “B1, B2”, featuring a uniform rotation while the two pairs of fixed cams, “C1, C2” and “D1, D2”, drive the combs and force them to carry out an almost linear motion in the working area as a result taking a position that determines the correct intersecting of the needles.

The bending of the material between the feeding rollers and the drawing cylinders favours the penetration of the comb needles and therefore increases fibre control.

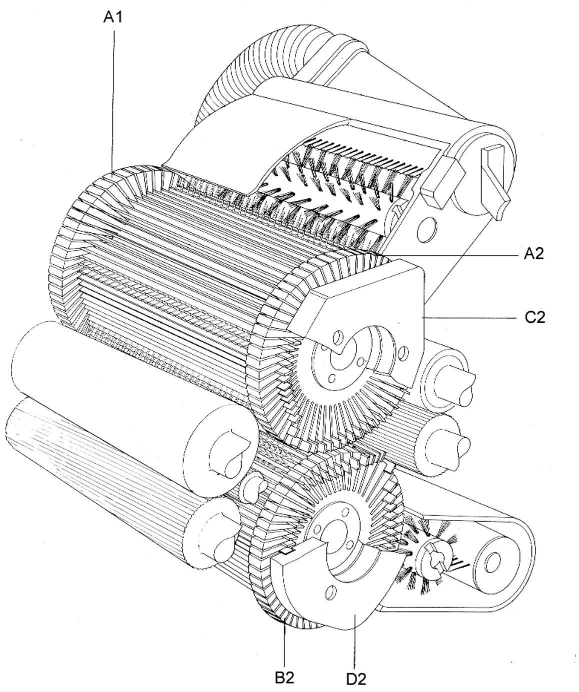



*Fig. 172 Rotating flanges drafting head*

D) Chain drafting head (Figure 173)

The same operating principles of rotating flanges drawframes also apply for chain type drawframes; the difference lies in the fact that in this case the combs are driven by two double chains arranged on the sides of the drawframes.

Both ends of the combs are provided with a pin engaging the chains (Figure 174), and profiled dogs jut out on the right and on the left end alternately; the profiled dogs are provided with bushes guiding the comb. The bushes follow the path created by two pairs of grooves on the sides of the drafting head, determining the orientation of the combs in the different positions taken during the combing cycle.

The three chains are the non-extensible type and feature special couplings for the pins of the combs; they are driven by means of a toothed wheel placed on the same side as the feeding cylinders, while a toothed driving pinion is arranged on the exit side; the draft is therefore generated by the return chain and not inside the working area, where the combs are driven in such a way that a steady pitch of 8 mm between them is guaranteed.

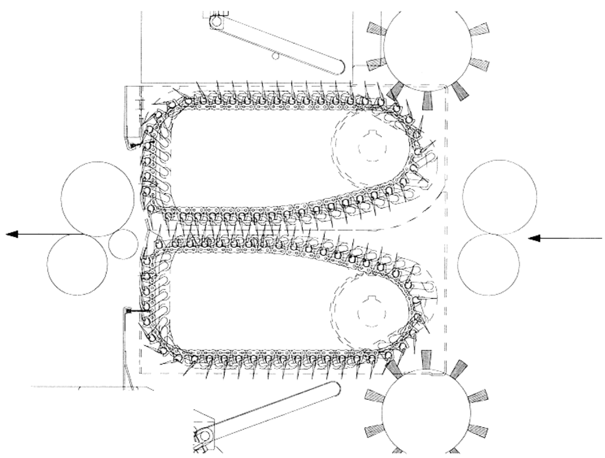


*Fig. 173 Chain drafting head*

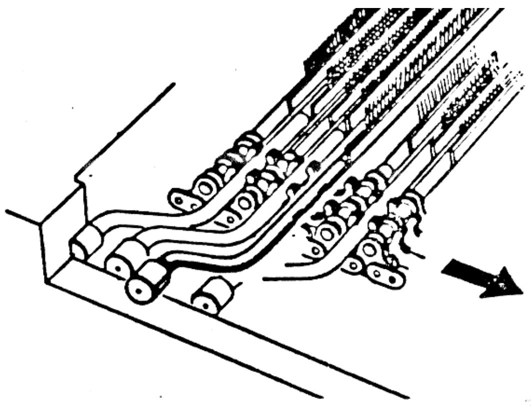


*Fig. 174 Comb motion control*

The inclination of the needles (Figure 175) allows the steady intersecting of the combs into the material for perfect and consistent control of the fibres processed, as well as a reduced distance between the last operating comb and the drawing unit for better control of short fibres.

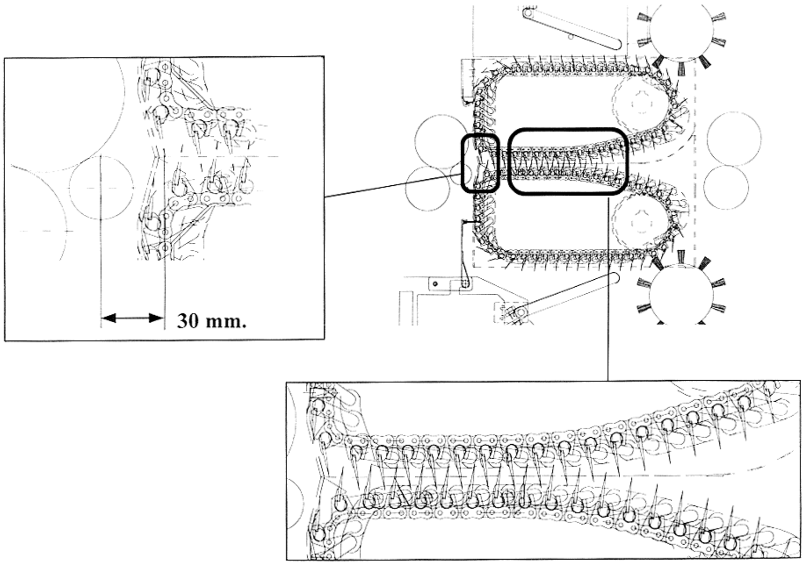



*Fig. 175 - Needle inclination*

E) Electronic autoleveller

Depending on the different cases, the first or the second preparation drawframe can be equipped with a draft autoleveller allowing the same count of the sliver also in case of possible variation of the material volume due for example to the sliver running out or to the splicing of a sliver with another.

The operation mode of the electronic autoleveller is quite simple (Figure 176):

- a mechanical feeler detects the volume oscillations of the material fed (Figure 177),
- a transducer sends the information received to an electronic memory,
- when, along its way to the machine exit, the material detected by the feeler enters the draft range, the memory sends the information to the feeding servomotor (to synchronise the draft correction with the sensing time),
- the motor changes the rotation speed according to the information received by changing the feeding rate and consequently the draft value.

The extreme intervention speed (equal to 0.002 sec) ensures a perfect adjustment also at very high drawframe feed rates.

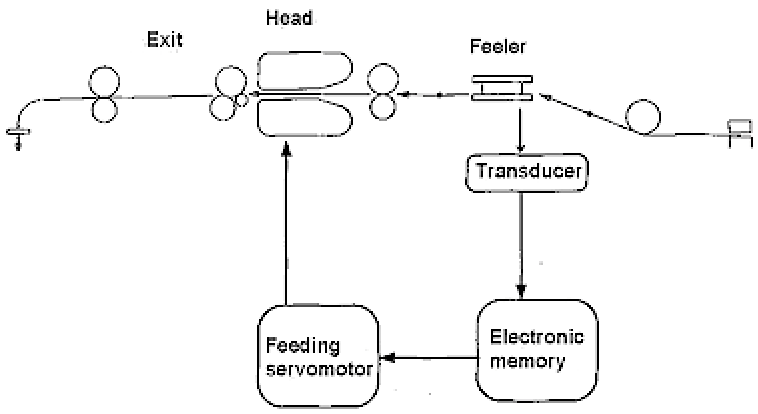



*Fig. 176 - Electronic autoleveller*

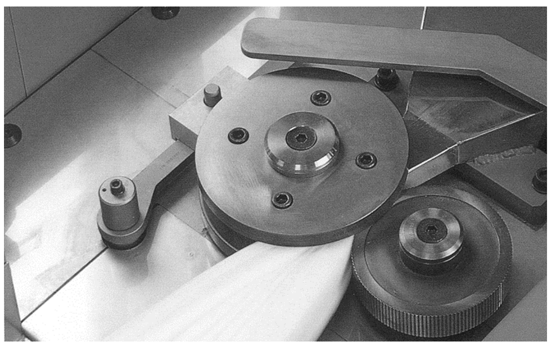


*Fig. 177 – Mechanical feeler*

F) Final considerations
In picture 165, the signs near the machines indicate how the material leaves the machine: “V11” stands for a sliver collected in a can, “B11” stands for a sliver wound on a reel; “B22” indicates that the two slivers are wound into two distinct reels.
The flow of the sliver leaving the unit is totally controlled to avoid possible false drawing.
The entry/exit side of the slivers into/from the drawframe may be also integrate oiling devices: the oiling devices at the exit side feature a nozzle drowned into the sliver while the oiling devices at the entry side feature a spraying compartment, between the feeding rack and the drafting head, where the slivers are overlapped before entering the machine.

# Combing

### General remarks

Through the combing process, the card sliver is stripped from residual foreign matter as well as from fibres shorter than a pre-set length. During this operation all the fibres are straightened and parallelised with respect to the longitudinal axis of the sliver, that at the end of the process is therefore called combed sliver.
The high degree of parallelism of the fibres and the reduction in the number of short fibres in the combed sliver remarkably reduce the bulkiness and the hairiness of the sliver, and increase the evenness of the yarn during the following processes.
The combing wool waste, called noils, is blended with other materials and used in the carded spinning cycle; the combing waste of inferior quality is instead destined for the felt industry.

### Hand combing

To thoroughly understand how combing machines carry out the combing process, it is worth mentioning how wool was manually combed in the past. This process included three main operations and precisely:
1. introduction of the fibre tuft in the comb;
2. combing of the head of the fibre tuft;
3. extraction and combing of the tail of the fibre tuft

1) Introduction of the fibre tuft in the comb (Figure 178). The “p” comb was fixed to a wall with the needles tips directed upwards; the comber took a tuft of fibres and inserted it on the comb so that the fibre tails protruded from the side of the comb in front of the wall.

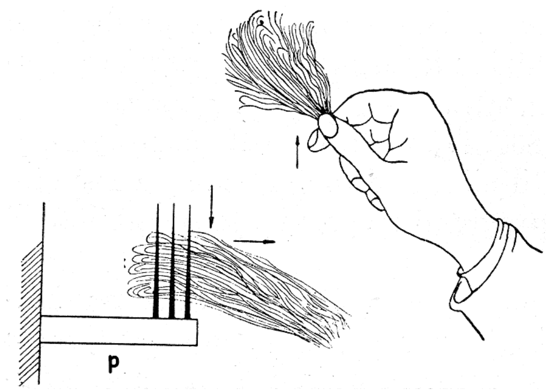



*Fig. 178 Introduction of the tuft*

2) Combing of the head of the fibre tuft (Figure 179). An “m” mobile comb was then repeatedly passed on the tuft retained by the “p” comb, taking care not to break the fibres. As a result, short fibres and impurities were separated from the “p” comb needles.

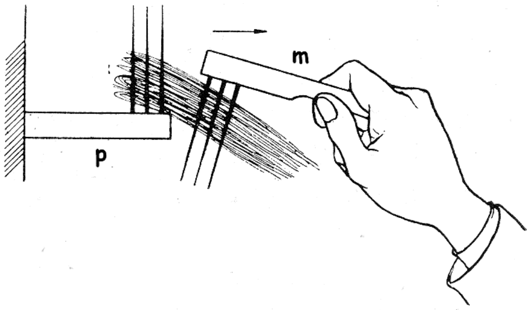



*Fig. 179 - Combing of the tuft head*

3) Extraction and combing of the tail of the fibre tuft (Figure 180). The comber, after seizing the head of the tuft, extracted it from the “p” comb forcing the fibres on the needles to slide. As a result, the short fibres and impurities of the tuft tail remained on the “p” comb needles.

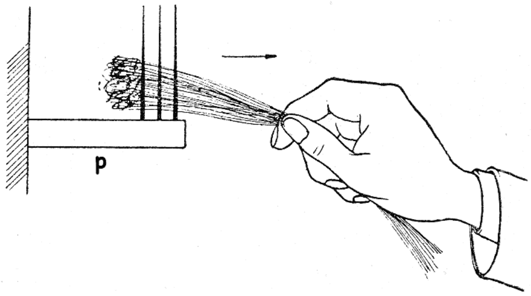



*Fig. 180 - Extraction and combing of the tuft tail*

The cleaning of the two “p” and “m” combs from noils was carried out manually.
The main problem of hand combing lies in the fact that the combed material still included some impurities due to a small area of the tuft not subject to the action of the comb needles. The front part of the tuft was combed by the “m” comb and the rear by the “p” comb. Even if the needles of both combs were extremely thin, there was always a small area of the tuft that the needles of the “m” comb could not penetrate since it was too near to the “p” comb; furthermore the “p” comb needles did not exert any action since they did not touch this area of the tuft during the extraction; as a consequence, this area was never combed and eventual impurities were not eliminated.

**Mechanical combing**

Three components were used in manual combing: the hand and two combs. The hand acts as a gripping means while the combs process the head and the tail of the tuft.
Mechanical combing is carried using linear combing machines which reproduce the actions of hand combing; the comb is still the combing means while the hand of the “combing roller” is replaced by different gripping means.
Linear combing machines work first the head and then the tail of the fibre tufts and include:
• a nipper, retaining the tuft,
• a circular comb, acting on the tuft head,

• a linear comb, acting on the tuft tail,
• a nipper, extracting the tuft from the machine

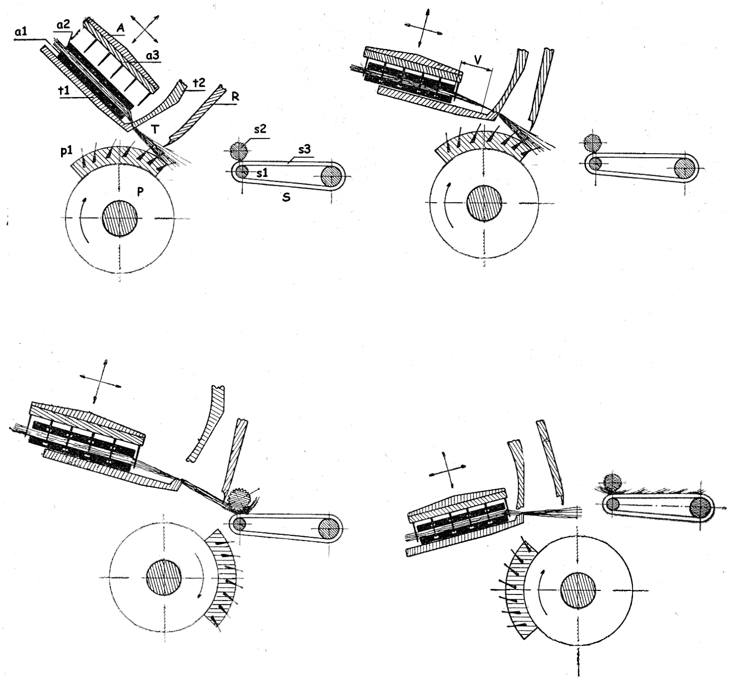



*Fig. 181 Combing of the head and of the tail of a tuft*

Figure 181 shows the four different positions assumed by the components of a linear wool combing machine.
The drawing on the top left side shows the closed nipper, made up of two jaws, and the circular comb, which starts operating on the head of the tuft. The drawing on the bottom left side shows the open nipper and the head of the combed tuft held by the other nipper (i.e. the extraction cylinders) leaving the combing machine while the lowered linear comb starts operating on the tail of the tuft.

In a few words, a linear combing machine operates as follows:
A lap of fibres, formed by 20-24 slivers partly arranged one beside the other and partly overlapped, is fed by the feeding cylinders (not shown in the pictures). The fibres are laid between the “a1” grooved plate and the “a2” separating apron, which, together with the “a3” needle bar make up the “A” feeding gill.
The head of the lap is retained between the “t1” and “t2” grippers of the “T” nipper. A certain length of the lap remains free and is penetrated by the needles of the combs on the “p1” sector of the “P” circular comb (Figure 180, top left).
While “P” rotates, the combs of the “p1” sector – whose needles which are thinner in the first rows (sorting area) and thicker in the last ones (finishing area) are inclined in the direction of the material flow – clean and comb the tuft (head) while the “A” gill carries out a return stroke of adjustable “V” width. During this motion, which prepares the feeding of the following tuft, the lap of fibres slides between “a1” and “a2” and stops since it is retained by the “T” closed nipper (Figure 181, top right).
When the “A” gill moves towards the open nipper, the fibre lap follows its motion and the following tuft is presented to the comb; the “a3” needle bar lowers and its needles penetrate the “a1” and “a2” spaces separating the short fibres.
After the last “p1” needle row has combed the head of the tuft, the “S” extraction cylinders (including the “s2” grooved cylinder and the “s3” sleeve sliding on the s1 grooved cylinder) which have approached the circular comb, catch the head of the tuft and the “R” linear comb lowers and penetrates it with its needles. At this moment, the “T” nipper opens, the “A” gill moves forward and the tuft tail, pulled by the extraction cylinders (which rotate and oscillate thus drawing back from “P”) is separated from the lap and combed by the needles of the “R” linear comb (Figure 181, below left).

The “s1” and “s2” cylinders are powerfully pressed one against the other to grant a perfect nipping of the tuft; furthermore, during the approaching oscillation of the circular comb, they rotate in the direction opposite to the material flow direction to draw back the previously combed tuft; this motion is necessary to overlap the tuft to the already combed one and ensure a good evenness of the combed sliver.

Once the tails of the tuft have been combed, the “T” nipper closes in order to retain the newly fed tuft, the “A” gill, which has moved completely forward, returns along the “V” section with the “a3” needle table raised, the “R” linear comb raises, the “S” extraction cylinders prepare to rotate (to draw back the material) and move (to approach “P”) and the circular comb, which has almost completed one revolution, approaches the tuft protruding from “T” with its first needle row (Figure 181, below right).
The tufts of combed fibres arranged on the “s3” sleeve, with the head overlapping the tail of the preceding tuft, form a thin web which, condensed into a sliver, is finally conveyed to a collection can.

### Linear combing machine with double combined motion

The linear combing machine (with double combined motion of the extraction rollers and of the nipper-holder carriage and the feeding gill) features a curvilinear oscillation to let the gripping point of the fibres run a path corresponding to an arc of circumference with its centre on the axis of the circular comb (Figure 182).
This motion takes place while the circular comb works on the tuft protruding from the nipper; this allows a more gradual action of needles on the fibres of the tuft head, with the same number of revolutions.
The stroke of the nipper determines a reduction of the stand-by times (a part of the approach movement to the extraction rollers takes place during the head combing) and this allows an increase in the speed of the circular comb, and therefore in the output rates, under the same operating conditions.
The parameter determining the length of the fibres to be eliminated is the “gauge” of the combing machine, which is the distance between the nipping point and the point where the extraction rollers grip the head of the tuft, i.e. the “minimum distance between the nipper and the extraction rollers”; the gauge also affects the output capacity of the machine since the quantity of noils produced during the process strictly depends on its value.

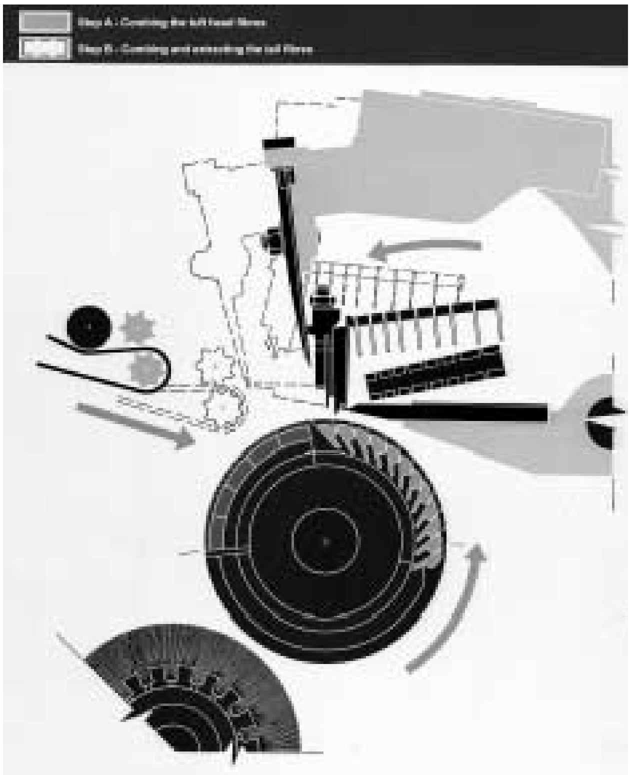


*Fig. 182 - Combing machine with double combined motion*

A) Operating principle

Figure 183 shows the positions of the main components of a double-motion linear combing machine during the two combing steps:

- 1st step; combing of the head of the tuft, carried out by the circular comb while the oscillation between the feed system and the extraction rollers is synchronised;
- 2nd step; extraction and combing of the head of the tuft, carried out by the extraction rollers and by the linear comb while the material is fed for the following operating cycle.

The combing machine works as follows:

a) – while the extraction cylinders are at their maximum distance from the nipper (Figure 183, top), the sorting section of the circular comb starts working on the material protruding from the closed nipper which oscillates towards the extraction rollers, together with the attached feeding gill (head combing); during the action of the two last needle rows of the circular comb (finishing sector) while the nipper continues its motion, the extraction rollers start their oscillating approach to the nipper which simultaneously opens,

b) – once the oscillation of the nipper and of the extraction rollers has come to an end, when the distance between them is equal to the gauge (Figure 183, below), the end of the fibres (tuft head) positions on the sleeve of the extraction device, above the end section of the previous tuft, and is captured by the extraction rollers; simultaneously, the linear comb oscillating together with the nipper lowers and its needles penetrate the material. At this point the nipper opens and two motions are started:

1) the extraction rollers rotate forward and withdraw from the nipper so to extract the fibres forcing them through the needles of the linear comb (tail combing),
2) the feeding gill moves forward in synchronism with the extraction rollers and feeds the material for the following cycle.

Towards the end of the rotation of the extraction rollers, the nipper starts the return stroke thus determining a further extraction of the tuft favouring the separation of longer fibres.

At the end of the two abovementioned motions (after combing the tail), during the backward oscillation, the nipper closes in the same opening position and takes a new tuft, starting a new cycle after the end of the oscillation.

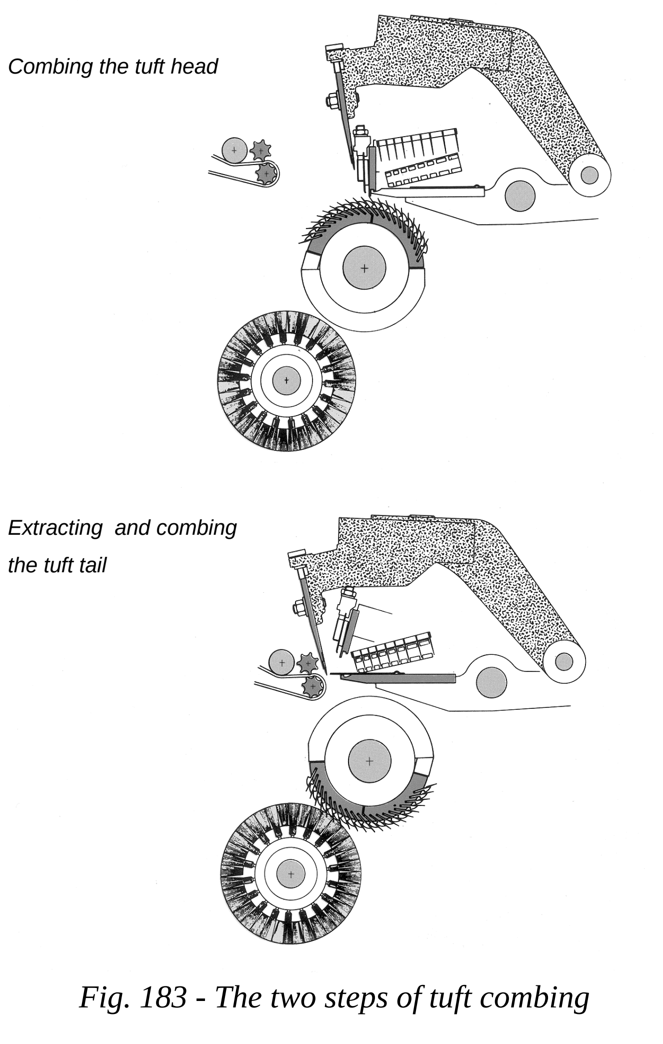



*Fig. 183 - The two steps of tuft combing*

While these motions are carried out, the extraction cylinders rotate in opposite direction and draw back a part of the combed tuft, which is made to adhere onto the sleeve thanks to a vacuum action; in this way, the head of the following combed tuft is positioned above the tail of the previous one granting an excellent bonding of the web as well as its uninterrupted consistency.

B) Feeding system

Before passing through the plates of the feeding gill, the lap goes through the pre-feeding system including a grooved cylinder with an upper roller coated with rubber to ensure the correct grip of the fibres also for sustaining greater loads.

The plates, through which the lap slides, converge towards the exit so that (by stepping towards the nipper) the material fed is compressed and progressively condensed.

The evenness of the material thickness, along the whole operating width of the linear comb, ensures a regular control of the fibres on the whole cross section of the lap, during the combing of the tuft tail with a consequent regular degree of parallelisation and cleanness of the material.

C) Nipper

The nipper, together with the feeding gill, carries out one oscillating motion towards the extraction cylinders to create a more favourable condition for processing the material.

The advantage of the forward motion of the nipper, in the direction of the circular comb, lies in the fact that it is carried out towards the end of the combing of the tuft head i.e. during the action of the last needle rows of the circular comb, which feature a higher needle density, and determine a combing speed (given by the peripheral speed of the circular comb minus the forward speed of the nipper) that is lower than the speed of the circular comb, with a consequent reduction of the “whiplash” of its needles on the fibres during the penetration stroke; as a result, the fibres are less subject to stress and strain.

In other words, we could say that the forward motion of the nipper accompanying the rotation of the last rows of needles of the circular comb determines an increase in the combing time giving a longer and more regular combing of the head of the tuft (as if the area of the circular comb covered with needles was greater, thus entailing a reduced break of the fibres and a better cleaning). The finer the count of the fibres to be combed, the more important this is.

To prevent fibres from escaping the nipper during the tuft head combing, the upper jaw of the nipper is equipped with two tooth-shaped tips in the fibre retaining area (Figure 184); the front one forces the tuft downward, towards the circular comb, and presses the fibres together with the rear bar on the head of the lower jaw. Furthermore the tension undergone by the fibres during the circular comb action favours their insertion between the nipper jaws, with a consequent improvement of the nipper grip, which prevents (also in case of big batches) the tearing of fibres by the circular comb, especially the finest ones.

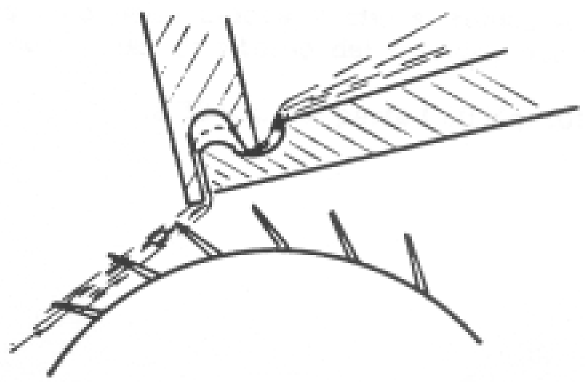


*Fig. 184 – The nipper jaws*

The pressure exerted on the whole length of the nipper must be uniform and its intensity must avoid a shearing effect on the fibres (for example 8-9 daN/cm)

To obtain good cleaning of the fibres, the distance between the nipper and the needles of the circular comb must be the shortest possible (usually, 0.5 ÷ 1.0 mm)
To prevent the fibres of the tuft head from escaping the needles of the circular comb, a small brush is fixed on the upper gripper of the nipper to force the tuft downwards (Figure 183).

D) Linear comb
The linear comb must lower one instant before the extraction rollers start their rotation; in case of delay, i.e. if the extraction has already started, the combing of the rear side of the tuft will be inadequate.
A nipper blade under the tuft head prevents the head from lowering during the downward stroke of the linear comb, due to the action of the very thick needles. During the circular comb action, the nipper blade is positioned just a little backward at the end of its operating area and steps forward to keep the head of the tuft raised, at the height of the nip point of the extraction rollers (Figure 183).
The linear comb is cleaned at every operating cycle by a special brush provided with two bristle rows to enlarge the operating surface.

E) Extractor
The extraction rollers carry out an oscillation towards the nipper in synchronism with the oscillation of the nipper.
The extraction rollers feature a helical groove, which allows a gradual grip of the tuft and a reduction of the pressure between them; this groove, besides preventing dangerous bending, grants a longer life of the sleeve on which the combed web is arranged.
To reduce the sleeve wearing, it is possible to adjust the operating time and the intensity of the pressure between the extraction rollers (the pressure should be maximum during the tuft extraction and minimum during the return of the rollers).
The pressure exerted on the extraction rollers is 1,600 N; due to the effect of the fibres wedging into the helical teeth, the force exerted on them during the extraction stage is equal to 2,200 N (during the backlash it is approximately of 600 N).
During the rotation of the extraction rollers determining the withdrawal of the combed tuft, an air suction opening retains the tuft tail to prepare the overlapping of the previous tuft with the next one. The vacuum must keep the tail of the tuft adherent but it should not be excessively high so as not to also attract noils.

F) Formation and collection of the combed sliver
On the sleeve of the extraction device, the outgoing fibre web is controlled by means of special blowers and collected into a vat for condensing; the sliver obtained is conveyed to the crimping device or to the double conveyor belt and sent to the coiler.

The double conveyor belt is generally used when operating on fine wools while the crimping device is used for improving the compactness of the fibres.

.

The crimping device includes two compacting rollers, a crimping compartment and a collection siphon. Inside the crimping compartment, featuring an adjustable 50-60 mm width, the material is compressed and the fibres are forced to take the preset waving, which increases the compactness.
The siphon acts as a receiver between the crimping device and the coiler and grants a non-stop collection of the sliver.

G) Noil discharging device
A circular brush removes the material accumulated among the needles of the circular comb and transfers it to the collection cylinder, coated with a card clothing, from which it is removed by means of an oscillating comb.
A vacuum device acts in the front area of the circular comb, with an opening placed between the circular comb and the circular brush, while a second opening allows vacuum dedusting in the rear side of the circular comb when it does not hold the tail of the tufts.
The dust is conveyed to a filtration box while the noils are collected into a special container on the same side of the collection area of the combed sliver (Figure 184).

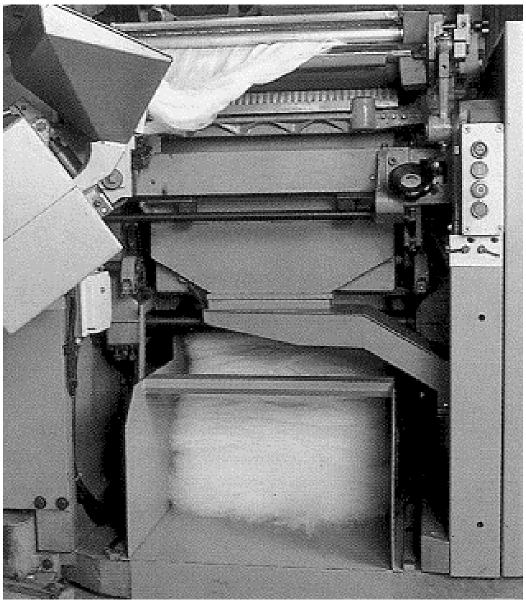


*Fig. 184 – Noil collection*

H) Feed and collection systems
The volume of material entering and leaving the combing machine should be enough to grant maximum autonomy to the machine; this is why the reels and the cans should be big enough to reduce the loading and unloading times to a minimum.

The feed racks of the reels allow maximum 24 doublings, and feature four pairs of longitudinal rollers arranged on two levels (two on each level) to unwind the reels (Figure 185).
Each pair of rollers is equipped with separate control to set a different rotation speed, which ensures a regular and complete unwinding of the reels with different diameters.
Also the can racks (2 slivers per can) allow max. 24 doublings (Table A).

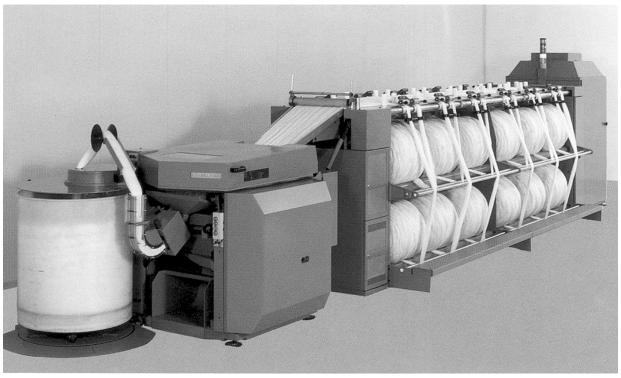


*Fig. 185 - Combing machine fed with reels of sliver*

# TABLE A

| Characteristics | | | Characteristics | | |
|---|---|---|---|---|---|
| doublings (cans or reels ) | n° | 24 | gill feeding | mm | 4 ÷ 10 |
| loading capacity | g/m | 500 ÷ 600 | nipper-circular comb  distance | mm | 0,2 ÷ 2.0 |
| throughput speed | nips/min | 200 | extraction rollers diameter | mm | 28/25 |
| circular comb operating range | mm | 440 | sleeve size | mm | 540x580x3,5 |
| linear comb operating range | mm | 460 | nipper oscillation | mm | 38 |
| gauge | mm | 28 ÷ 36 | extraction rollers oscillation | mm | 54 |

**Linear combing machine with fixed nipper**

Figure 186 (the arrows and the numbers indicate the directions, the orientations and the widths, in mm, of the motions of the different components) shows the complete schematic of a linear combing machine with fixed nipper where the linear comb does not oscillate towards the extraction rollers (for this reason, it will be also referred to as "fixed comb") but only perform the penetration and exit motion from the tail of the fibre tuft.

This means that every time the gauge is changed, the position of the fixed nipper must be adjusted and there is no need to adjust the linear comb, the cleaning brush, the nipper blade and the gill; in brief, near each position of the fixed comb, it is possible to operate in the maximum safety conditions also with minimum differences and therefore reach the maximum cleaning efficiency of the material.

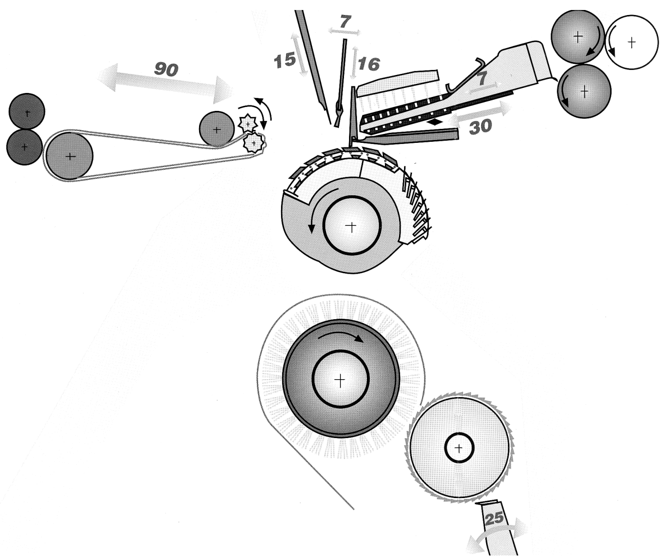



*Fig. 186 - Linear combing machine with fixed nipper*

A) Operating principle

The linear combing machine equipped with fixed nipper operates as follows:

a) the circular comb, with closed nipper and extraction rollers far from the nipper, combs the head of the tuft  while the gill moves backward (Figure 187),

b) the nipper opens and the gill moves forward, the extraction rollers approach the nipper and catch the head of the tuft, the linear comb lowers, the nipper blade moves forward (Figure 188)

The extraction rollers, drawing off the nipper, comb the tail of the tuft since the fibres are forced through the needles of the fixed comb.

When the extraction rollers grip the head of the tuft, they hold the tail of the previously combed tuft and extract the sliver, with the ends of two adjacent and overlapping tufts, through a rotation proportional to the feed length.

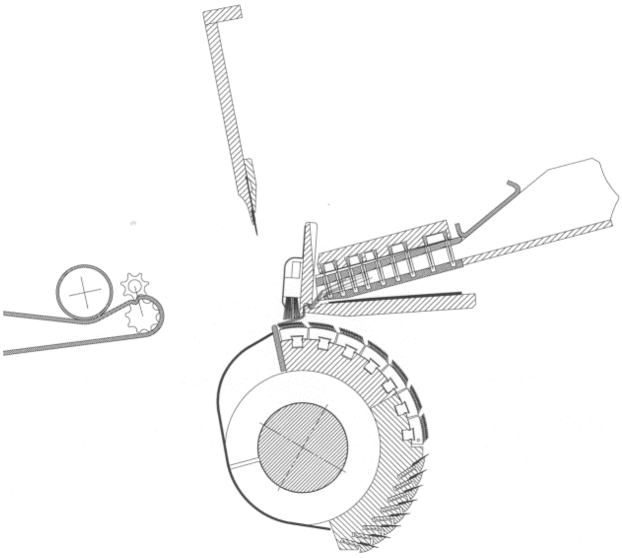


*Fig. 187 - Combing of the head of the tuft*

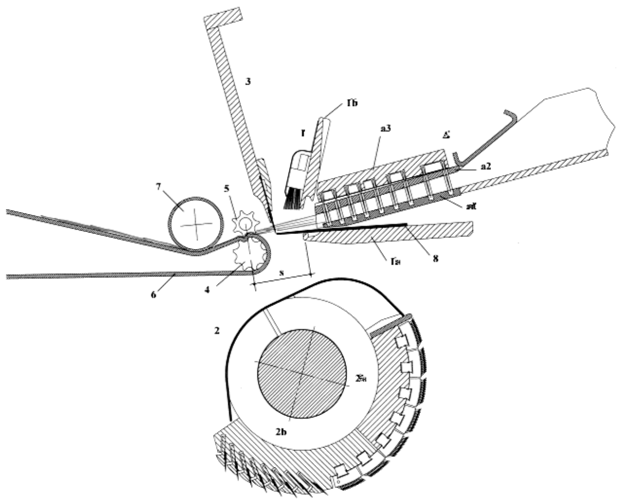


*Fig. 188 - Combing of the tail of the tuft*

B) Feeder

The adjacent and overlapped wool slivers forming a compact lap with uniform thickness, are pushed forward by means of a pre-feeding device including 3 rollers, one pressure roller and two feeding rollers, rotating uniformly, which ensure a steady control of the material (Figure 186).

The V-shaped gill grants a regular condensation of the lap and ensures a uniform feed (Figure 189).

During the feeding step (Figure 188), the “a3” needle table is lowered so that the fibre lap moves together with the “A” gill towards the nipper; when “A” starts the backstroke, “a3” raises and separates from the fibre mass which, held by the closed nipper, stands still while the two “a1” and “a2” plates slide on it. Once “A” has come back, the “a3” table lowers and the lap is ready for the next tuft feeding.

C) Nipper

The nipper is in a fixed position, perfectly aligned with the circular comb and keeps a steady combing angle for any gauge value; this grants a good impact evenness of the circular comb with respect to the tuft.

To avoid possible floating of the fibres on the circular comb, the nipper is equipped with a special brush which sinks into the tuft.

Nipper “1” has a lower “1a” jaw; the material is squeezed on the tip of the lower jaw by means of the upper “1b” jaw. The distance between the tip of the “1b” jaw and the needles of the 2” circular comb is adjustable.

After being fed, the lap protrudes beyond the nipper by a distance equal to the gauge (represented by the distance between the nip point of the nipper and the nip point of the extraction cylinders, Figure 188)

With the same feed (load), the quantity of noils generated by the combing machine change according to the number of slivers forming the lap; to be precise, it can increase (decrease) in an inversely proportional manner with respect to the number of slivers fed.

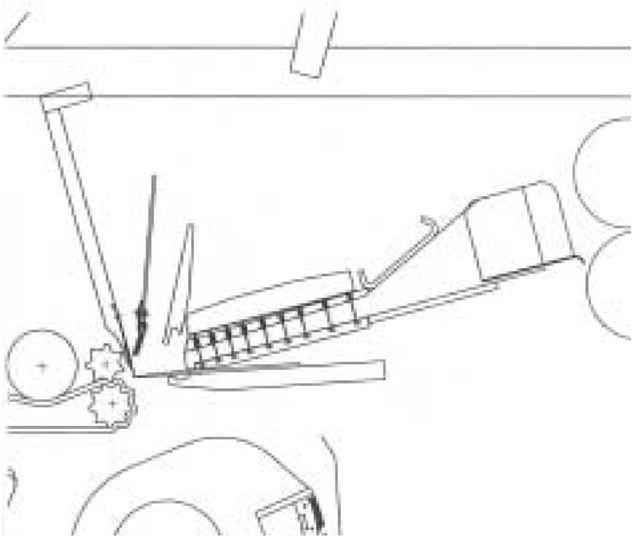


Fig. 189 -Feed gill

In case of small quantity of slivers fed, the arrangement could result in a non-uniform organization and the nipper could exert different pressures on the whole surface of the lap; in this way, some fibres (also the long ones) could slip off under the action of the circular comb and reach the other noils.

D) Circular comb
The “2” circular comb, featuring a non-stop rotation, acts on the section of material protruding from the nipper; the circular comb is provided with a certain quantity of combs with different needle density. The first thin rows of needles (the “2a” sorting section in Figure 188) which is almost the same for any type of wool combing, pre-open and separate the material while the other denser needle rows (“2b” finishing section) are interchangeable for combing different types of wool and parallelising the fibres. The small bars with needles are arranged on a 264 mm arc.

The material treatment starts when the nipper catches the lap by its “1a” and “1b” grippers; the “2a” and “2b” needles of the comb are introduced into the part of lap protruding from the nipper, they parallelise the fibres retained by the nipper and remove short fibres, which can move freely, and impurities.

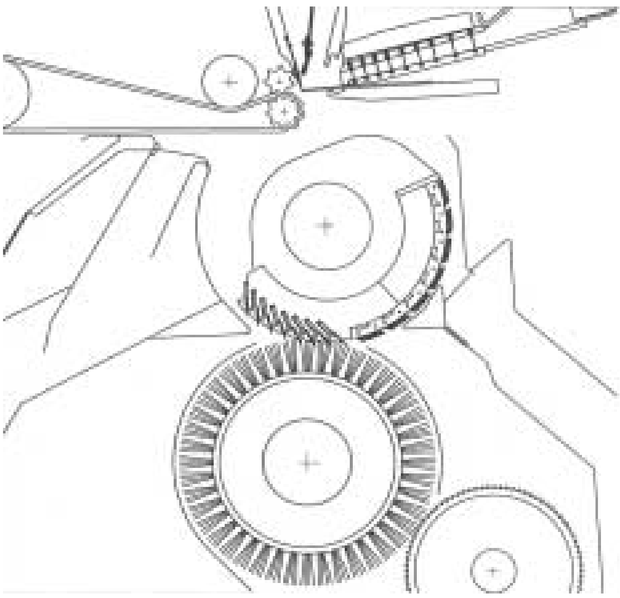


Fig. 190 - Circular comb with brush

The circular comb carries out one entire revolution per each combing cycle of a tuft (tail and head).
To obtain maximum efficiency from the action of the circular comb, the tip of the “1b” gripper of the nipper must be positioned as near as possible to its needles; furthermore, both the number of combs and the needle thickness must be the greatest possible.
A big circular brush cleans the circular comb to prepare the biggest possible contact surface between the needles and the fibres and facilitate the comb cleaning (Figure 190). The action of the big brush can be synchronised through a timer to generate the control function with variable frequency according to the cleaning level required.

The head of the fibre tuft sinks into the needles of circular comb by means of a special sinking brush (Figure 187).

E) Linear comb

The “3” linear comb oscillates only vertically with no other horizontal motion since it is not attached to the nipper nor to the feed gill; for this reason it is imperative that the “3” linear comb starts working at the end of the feed gill forward motion, just one instant before the extraction rollers start moving and combing the head of the tuft to be processed.

A special brush featuring a continuous forward and backward motion cleans the linear comb (Figure 186).

The needles of the linear comb act as a filter for the material which, therefore, releases short fibres and impurities which separate from the material also because they (caught and drawn by the extraction cylinders) slip off the lap and powerfully adhere to other fibres on which the impurities and the short fibres are left.

The “8” nipper blade ensures regular combing of the tail of the tuft; it is positioned very near to the row of needles of the linear comb (Figure 188) to prevent the fibres from lowering during the downward motion and escaping the action of the needles.

The nipper blade also drives the tuft end to the nip line of the extraction cylinders.

F) Extractor

The extractor (Figure 188) includes a “4” lower grooved roller which moves the “6” sleeve on which the “5” upper grooved roller exerts a certain pressure (extraction rollers); the already processed tufts (making up the combed web) are laid evenly on the sleeve. The “7” roller features a smooth surface and by exerting a certain pressure, it arranges the fibres and discharges the static electricity acquired by friction during the process.

The extraction rollers have two different rotation modes:

1. one rotation is direct and contributes to the stretching and to the removal of the tuft from the lap,
2. the other one is opposite to the direct one and drives back the tuft, to eliminate the free space between the combed tufts, whose ends overlap, like roof slates.

While the nipper opens, the extractor oscillates and takes the extraction cylinders near the left end of the gauge.

The inverse rotation of the extraction cylinders slightly withdraw the combed tuft; in fact, the oscillation of the extractor creates some free space between the tuft and the combed tuft and it is consequentially impossible to collect the web; the inverse rotation of the extraction cylinders determines the overlapping of the ends of the combed tufts and the formation of a continuous web.

G) Formation and collection of the combed sliver

An adjustable-compression crimping device granting the right consistency and tensile strength facilitates the next processes (Figure 191): two rollers feed the compression room and the fibre rolling can be adjusted by means of the pressure table of the crimping device; a detecting system controls the level of the receiving tank and stops the machine in case of break of the outcoming sliver.

Figure 192 shows the linear combing machine equipped with fixed nipper and can feed-system (two slivers per can). Table B contains the main technical data.

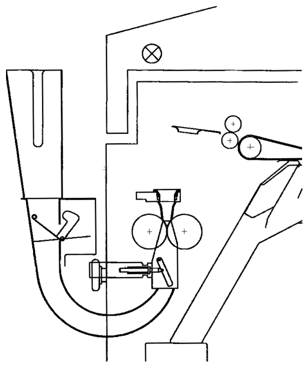


*Fig. 191 - Crimping device*

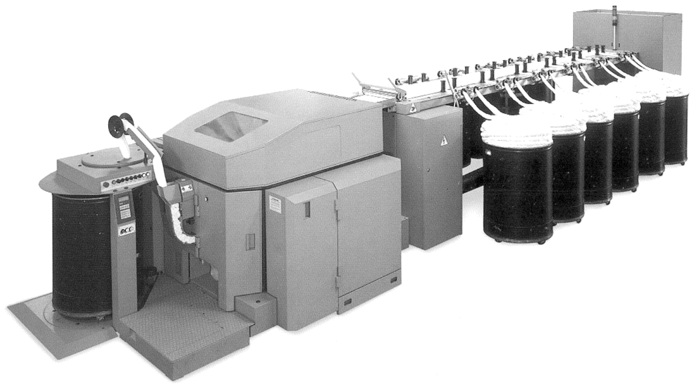


*Fig. 192 - Linear combing machine with can feed-system (two slivers per can)*

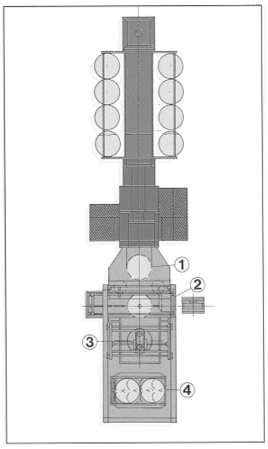
## TABLE B

| Characteristics | | | Characteristics | | |
|---|---|---|---|---|---|
| Doublings (cans or reels) | no | 24 | gill feed | mm | 4 ÷ 10 |
| Gill lattice width | mm | 400 | feed-nipper distance | mm | 280 |
| throughput speed | nips/min | 260 | extraction rollers diameter | mm | 28/25 |
| circular comb operating range | mm | 460 | circular comb diameter | mm | 195 |
| circular comb needle arc | mm | 264 | circular brush diameter | mm | 200 |
| gauge | mm | 25 ÷ 40 | extraction rollers oscillation | mm | 90 |
| 1 of 2 pre-feed (diam.) | mm | 66 | nipper-gill-blade | | fixed |

## Post-combing

The slivers emerging from the linear combing machines are made of tufts whose fibres are tied to the fibres of the tufts nearby only by means of the friction existing between their overlapping ends; for this reason, these slivers:
• are poorly compacted (despite the crimping device of the combing machines),
• the section is highly irregular, due to the manner they are worked by the combing machines

To find a solution to these problems, the sliver coming from the combing machines must undergo two doubling and drawing steps inside two intersecting drawing frames called "can emptier drawframe" and "finisher drawframe"; the latter is generally equipped with an autoleveller.
The finisher drawframe includes a device to collect the combed sliver, the "tops", in reels or bumps (the content of a can, vertically squeezed and reduced to the dimensions of a reel).
It is possible to carry out the automatic change of cans with the formation and the "parallelisation" of the bumps (Figure 193): the cans are changed by means of a rotary platform which takes a full can and replaces it with an empty one, transferring the full can from the working position to the press to form and the bind the bump. The cans can also be changed using a conveyor serving several machines (Figure 194). The conveyor removes the full can, positions the empty one without stopping the operating cycle, and takes the full cans to a single press, which presses and binds the bumps.



1. Drawframe exit side
2. Rotary platform
3. Bump pressing
4. Bump conveyors.

*Fig. 193 - Bump delivery*

1. Empty can loading
2. Full can unloading
3. Conveyor
4. Bump press
5. Hoist for bump unloading
6. Conveyor for bump bales

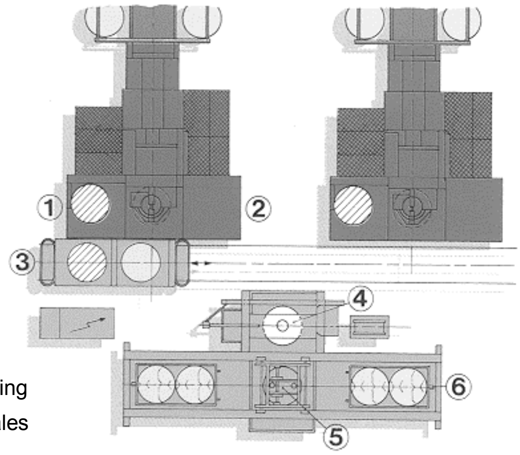


*Fig. 194 - Bump delivery with mobile conveyor*

Table C shows all the technical data of the drawframes with the different drawing heads

# TABLE C

| Characteristics | | Chain | Rotating Flanges | Screws |
|---|---|---|---|---|
| Feed rack | positions | 12 | 12 | 12 |
| Incoming load max | g/m | | 200 ÷ 300 | |
| Heads per machine | no° | 1 | 1 | 1 |
| Automatic delivery: cans or reels | n° | 1–2 | 1–2 | 1-2 |
| Slivers per can | n° | 1–2 | 1–2 | 1-2 |
| Slivers per reel | n° | 1 | 1 | 1 |
| Combs per head | n° | 88 | 52 + 52 | 82 o 66 |
| Width with needles | mm | 200 ÷ 270 | 275 | 200 |
| Length with needles | mm | 200 | 130 | 185 |
| Needles intersecting in the operating range | mm | 11,6 ÷ 13,6 | | |
| Needles protruding from the combs | mm | | | 18,5 o 16,5 |
| Drawing rollers – pressure roller | mm | 32/66-80 | 30/62,5-75 | 30/66-80 |
| Free drawing range (feed roll. – first comb) | mm | | 35 ÷ 110 | |
| Free drawing range (last comb – drawing roller) | mm | 30 ÷ 50 | 27 ÷ 42 | 24/27 ÷ 85 |
| Feed ratio | m/min | 100 | 80 | 18 o 22 |
| Max. throughput speed with can exit | m/min | | 500 (350) | 230 |
| Without autoleveller | m/min | 500 | | |
| With autoleveller | m/min | 450 | | |
| Max throughput speed of reel exit | m/min | 400 | | 230 |
| single | m/min | | 400 | |
| double | m/min | | 350 | |
| Drawing | | 3,24 ÷ 12,00 | 3,84 ÷ 12,16 | 4,20 ÷ 11,50 |
| Max outgoing load | g/m | | 30 ÷ 50 | |
| Pitch between the operating combs | mm | 8 | | 9 o 11 |
| Head feeding rollers | mm | 66 | 30/62,5 | |
| Feed pressure roller | mm | 80 | 75 | |

TABLE D shows the values of the main adjusting parameters of the combing cycle units. A +/- 5% max tolerance for the combed sliver count ("top") is allowed.

**TABLE D**

| Unit | Te g/m | A | Ce g/m | S | Tu g/m | Vu m/min | N° of Exit Elem. | Pt kg/h | η % | N° of Units | $P_p$ kg/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Card | | | | | 20 | | | | | | |
| 1° step | 20 | 8 | 160 | 5,0 | 32 | 450 | 1 | 864 | 75 | 1 | 648 |
| 2° step | 32 | 6 | 192 | 6,0 | 32 | 450 | 1 | 864 | 75 | 1 | 648 |
| 3° step | 32 | 4x2 | 128x2 | 6,4 | 20 | 385 | 2 | 924 | 70 | 1 | 647 |
| Combing machine | 20 | 24 | 480 | | 30 | 260* | 1 | 45** | 90 | 14 | 567 |
| Can emptier | 30 | 6 | 180 | 6,0 | 30 | 450 | 1 | 810 | 70 | 1 | 567 |
| Comb. Finisher | 30 | 5 | 150 | 6,0 | 25 | 275 | 1 | 413 | 70 | 2 | 578 |

* nips/min

** Theoretical reference production with 9 % of noils

# Blending and Recombing

## General remarks

The blending process is carried out when processing slivers made of:
- grey wool of different origin or materials of different nature (wool-acrylic, wool-polyester, etc) to homogenise the mix,
- material dyed with the same colour, to harmonize the colour shades,
- materials dyed with different colours, to obtain the so-called mélangé colours
- different materials dyed with different colours, for special applications.

The recombing process is necessary to:
- eliminate the colour clusters and the fibre entanglements from the slivers, formed during the dyeing process,
- blend fibres of different more deeply origin, even raw fibres, to improve the elimination of short fibres still contained but above all to eliminate impurities from synthetic or man-made fibres to be blended with the wool.

This process, which is very expensive and carried out only on materials to be used for high-quality products, features four different stages (Figure 195) and precisely:
1. blending
2. preparation to recombing
3. recombing
4. post-recombing

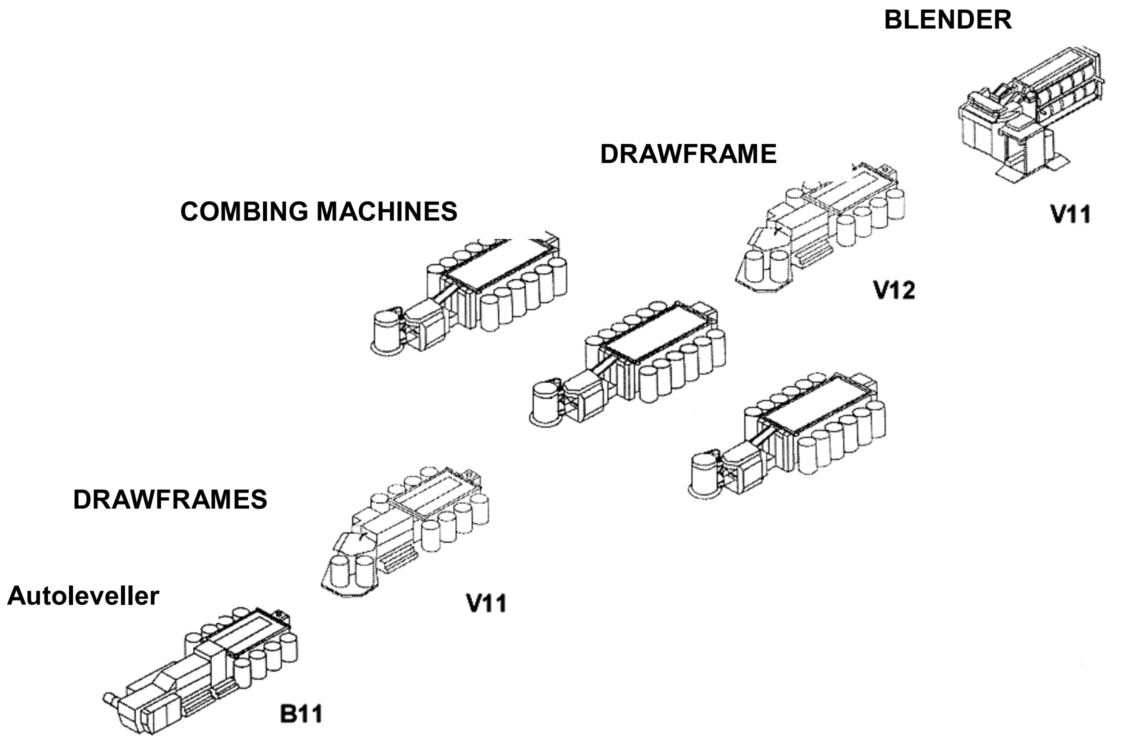



*Fig. 195 – Recombing cycle of 19-micron wool*

The blending process is carried out by blenders.
The recombing preparation usually includes only one drawing step carried out inside an intersecting drawframe since the fibres are already parallelised.
The recombing process is carried out with combing machines similar to the machines used during the combing stage; in this case a smaller quantity of noils (2% ÷ 10%) are generated.
Post-recombing consists of two drawing steps: one is carried out with the can-emptier drawframe and the other one with the recombing finisher drawframe, which features the same functions as explained in the combing chapter.

## Sliver blending

The combed sliver packed in reels or bumps is subjected to the blending process, which prepares an homogeneous mixture by eliminating the differences of the characteristics unavoidably existing between different batches of similar materials (and, in some cases, also in the same batch).
When blending fibres made of different materials, the operation is often repeated many times to obtain a sliver with homogeneously distributed components; the same happens when blending combed slivers dyed with two or more colours to obtain the "mélange" effect.

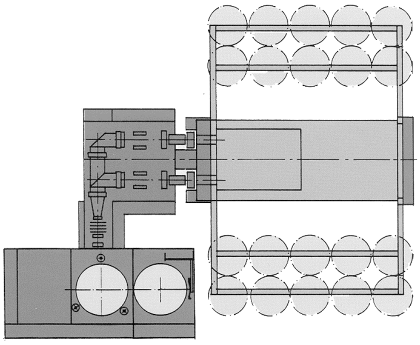


*Fig. 196 - Blender*

The blenders is a special type of drawframe made of two parallel drawing heads and of a third drawing head, the so-called “reducer”, arranged perpendicularly to the previous ones (Figure 196).
The operation is carried out in two different steps: first of all the material is pre-drawn in separated masses by means of two defelting parallel heads; the two webs exiting the two drawing heads, are deviated by 90°, overlapped or further drawn by the reducing head.

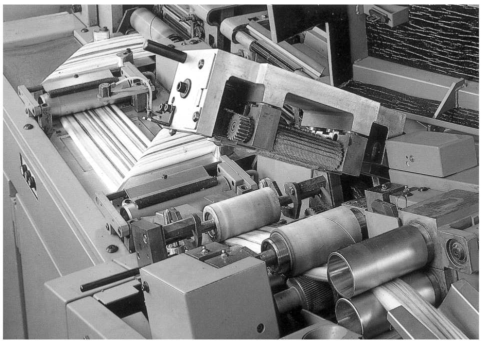


*Fig. 197 – Reducing head*

The two defelting (drawing) heads are of the “intersecting” screw-type (distance between the combs: 11 mm) while the reducing head features a drawing range controlled by rotating and intersecting disks (Figure 197)
From a technical point of view, the screw-type head is the most suitable one to carry out the pre-drawing since it allows reduced free drawing ranges and features excellent defelting properties.

As far as the output rate is concerned, the presence of the screw-type head does not reduce the potential productivity of the machine since, by effect of the double consecutive drawing, it is possible to work with the maximum delivery speed (300 m/min) of the blended sliver without going beyond the maximum feeding rate of the screw head.

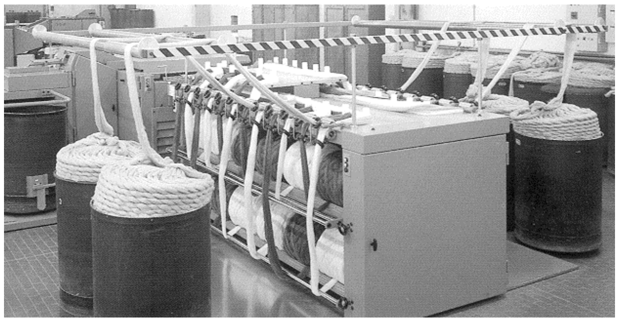


*Fig. 198 – Feed rack*

A) Feed rack
The blender is fed with reels while the unwinding stage is carried out through adjustable-speed unwinding rollers with non-stop speed changers (Figure 198).
The rack allows 24 doublings and each position features a ”knot-stop” ring; when the sliver breaks, the machine stops by mass contact of the rollers which convey the slivers to the rack conveyor. By adding a “bower-type” structure, the blender can be fed also with cans or bumps (Figure 198).

B) Web-guide conveyor
The webs coming out of the two defelting heads are deviated by two special web-guide conveyors onto the delivery conveyor, which is perpendicular to the defelting heads; the two webs overlaps and feed the reduction head (Figure 197).

C) Oiling device
There are three spray-oiling points: one is near the feed of the two defelting heads and the third one is between the two webs on the delivery conveyor (Figure 197); in this last oiling point the oil quantity spread on the material ranges between 1% and 4% of the weight.
The way the oil is spread on the material is crucial since any drip from the spraying nozzle must imperatively be avoided to prevent sliver areas possibly generating thick places.

## Preparation to recombing

Before subjecting the slivers coming out of the blender to the combing action of the combing machines further doubling and drawing operations are carried out to improve the fibre blending as well as the evenness of the slivers and reduce their count to the most suitable value for feeding the combing machine.
The drawframe used is the “chain” or “rotating flanges” intersecting drawframe equipped with a two-sliver exit per each can (usually, this is called “reducing” drawframe).

## Recombing

The recombing operation entails a further combing step, which is similar to the one carried out after carding. The operation in this case is less powerful than the previous one and determines a reduced formation of noils (which, anyway, depends on the gauge).

The recombing process is necessary when the transfer and package (in reels or bumps) as well as the action of the dyeing liquor of the tops has damaged or felted the material; in this case the fibrous diagram needs to be regularized to avoid irregularities or difficulties during the spinning stage.

## Post-recombing

The sliver comes out of the combing machines with “tail on head” overlapped tufts, i.e. characterized by great section irregularity.
To avoid this inconvenience two doubling and drawing operations are carried out through intersecting “chain” or “rotating flanges” drawframes, called “can-emptier” and “recombing finisher” respectively.
The finishing drawframe is often provided with autoleveller to grant the evenness of the sliver count also when the draw or the feed load changes within a certain time.
Table E shows the main adjusting parameters of the machines of the recombing cycle.

## TABLE E

| Unit | Te g/m | A | Ce g/m | S | Tu g/m | Vu m/min | N° of Exit Elem. | Pt kg/h | η % | N° of Units | $P_p$ kg/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Blender | 25 | 24 | 600 | 20 | 30 | 350 | 1 | 630 | 60 | 1 | 378 |
| Reducer | 30 | 6 | 180 | 12 | 15 | 280 | 2 | 504 | 75 | 1 | 378 |
| Combing machine | 15 | 24 | 360 | | 30 | 260* | 1 | 48** | 94 | 8 | 361 |
| Can emptier | 30 | 6 | 180 | 6 | 30 | 290 | 1 | 522 | 70 | 1 | 365 |
| Recomb. Finisher | 30 | 5 | 150 | 6 | 25 | 350* | 1 | 525 | 70 | 1 | 368 |

* nips/min

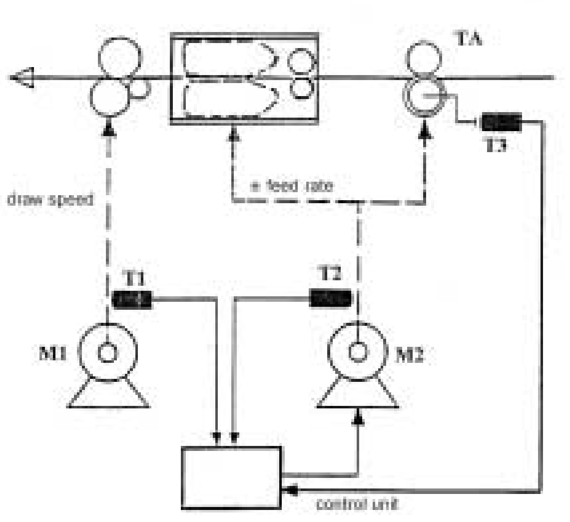
** Theoretical reference production with 9 % of noils

## Electronic autoleveller

This system is used for achieving an automatic adjustment with two different criteria of speed variation:

- feed rate variation, for all autolevelling standard applications
- variation of the delivery speed when the machine requires steady feed rate like in case of linkage with other machines with the same throughput speed (for example, in the after-card drawframe combined with a set of cards).

The first system, previously analysed, is most frequently used in this process stage. Its operation is schematised in Figure 199: a mechanic feeler detects the thickness of the material fed, the variations are transformed into electric signals and sent to a control unit which, with a suitable delay corresponding to the passage of the material from the feeler to the drawframe, determines the variation of the feed rate and therefore of the draft.




T1: Delivery speed transducer
T2: Feed rate transducer
T3: Detecting transducer
TA: Feed feeler
M1: Motor of the draw cyl.
M2: Motor of the feed cyl.

*Fig. 199 – Electronic autoleveller*

The electronic autoleveller does not set definite limits to the possibility of adjustment but in relation to the correct detection and to the speed limit of the intersecting comb head, the suitable adjusting range applicable varies between – 25% and + 25%.
It is also possible to store the maximum and minimum drawing limits beyond which the machine no longer complies with the technological operating conditions allowed for each material.

# Spinning

## General remarks

The spinning process includes all the operations necessary to transform the combed sliver ("tops"), blended and/or recombed, into a yarn of the desired count and twist.

Spinning includes the following processing stages:
1. preparation for spinning,
2. spinning.

The preparation for spinning stage can be divided into two different cycles:
- low preparation,
- high preparation.

The machines used for carrying out the low preparation progressively reduce the sliver count and improve the evenness through a series of doubling and drawing operations.
This process includes 4 drawing steps on drawframes (which can be reduced to three for yarns ≤ Nm 40).
Surveys of production control in spinning departments reveal that the number of yarn breaks on looms decreases when the pre-spinning stage also integrates a fourth drawing step.

The machines performing the high preparation for the spinning process transform the sliver, obtained with doubling and drawing operations, into a roving through combined drawing and rubbing-finishing actions. This process stage is carried out on a rubbing-finishing machine.

## Preparation for spinning

### Low preparation

For the low preparation stage, it is possible to use all the intersecting drawing frames analysed previously (screw, chain and rotating-flange types); these machines are further integrated with drawframes whose draft range is controlled by:
- intersecting rotating disks,
- Herisson /barrel cylinders with elastic nip,
- cylinders with elastic nip

The control system which is best suited can be established by carefully analysing the characteristics of the fibres but above all, the quantity of fibre to be processed, i.e. the number of fibres, which, during the drawing step remain in the draft range.
The drawframes featuring a drawing control system equipped with Herisson cylinders combined with barrel cylinders and elastic nip are particularly suitable for the fourth pre-spinning step when yarns finer than Nm 40 have to be produced. The main technological characteristic of this drawframe is the possibility of carrying out a delicate but powerful control of the fibres by distributing them and achieving the best sliver evenness, thus remarkably reducing the number of thin places during spinning.

A) Drawframe equipped with intersecting rotating disks

The drawing head equipped with intersecting rotating disks (Figure 200) includes three pairs of rollers ("controllers") coated with teeth inclined in the direction opposite to rotation, which intersect and rotate in the same direction as the material flow; the disks are self-cleaned by the intersecting action.

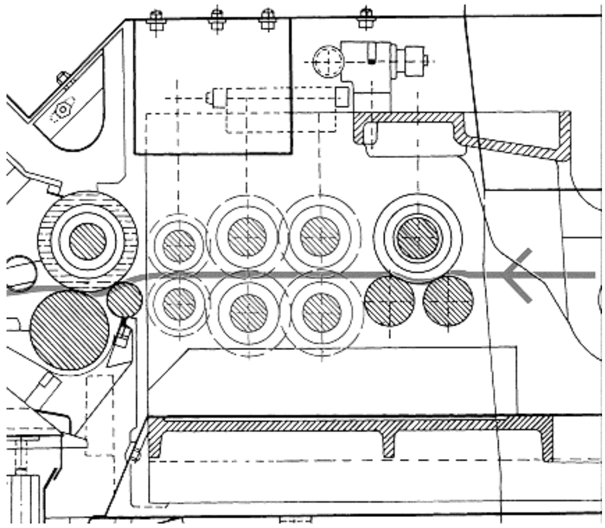


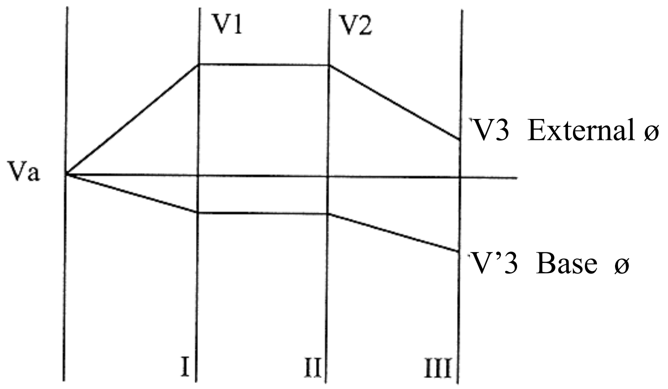
*Fig. 200 – Disk-type drawing head*

The structure of the controllers excellently affects the fibres and grants a good feeding capacity of the drawframe as well as no limits for the maximum length of fibres; the first two pairs of rollers of this drawframe have large and identical diameters while the third pair, next to the drawing rollers, has a smaller diameter.

Differently from the comb system where the material, in the draft range, is controlled by means of spikes moving at the same feed speed of the head equipped with disks, the speed of the teeth tips of the controllers is higher than the base speed; this allows the speed of the control device to be varied within a certain range.

To check the fibres without causing eventual problems to the material, the different points of the teeth of the controllers must operate at speed values within the feed and draft (exit) values.

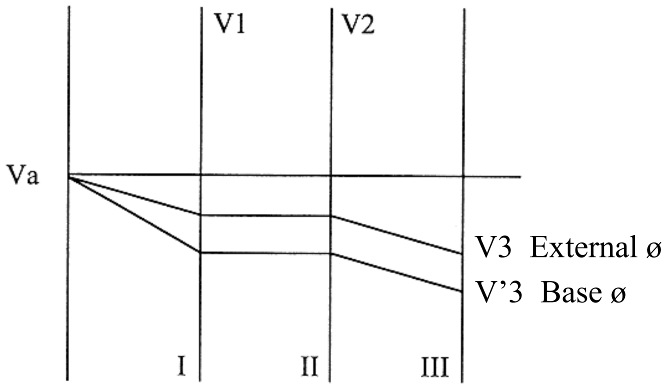
Usually the standard quality diagram of the peripheral speeds of the controllers in the different positions is the following:




Positions of the draft controllers

1.05 ÷ 1.15 between the V1 speed (the speed of the first pair of controllers) and the Va speed (the speed of the feeding cylinders) favours a good evenness; a ratio ranging from 0.90 to 0.92 between V2 and V3 (the speeds of the other pairs of controllers) provides an anti-rolling effect since it allows good relaxation of the fibres making it consequentially easier for the teeth to release the material.

In special cases, for very long fibres and/or for fibres that tend to wind around the cylinders, the quality diagram could be represented as follows:




Positions of the draft controllers

The peripheral speed of the teeth, which is lower than the feed speed, determines the relaxation of fibres that decreases their compression at the base of the teeth of the controllers and exerts an anti-rolling action, which should be applied as much as possible near the draft rollers.
The drawframes equipped with intersecting rotating disks used during the pre-spinning stages are "multihead" drawframes and precisely:

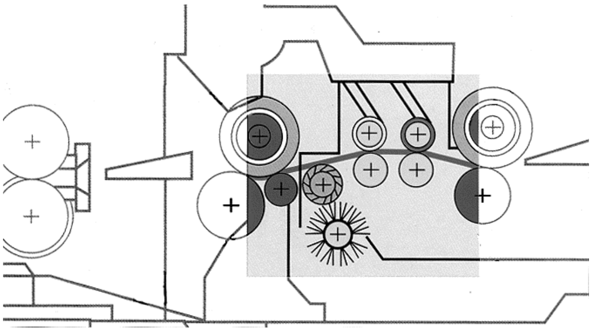
- 2-head drawframe: to process 2 slivers (one sliver per head) collected in 2 cans (one sliver per can),
- 4-head drawframe: to process 4 slivers (one sliver per head) collected in 2 cans (two slivers per can)

Table F indicates the technical data of the single-head or multi-head drawframes equipped with intersecting rotating disks.

# TABLE F

| Characteristics | | | Intersecting rotating disks | | |
|---|---|---|---|---|---|
| Heads per machine | | n° | 1 | 2 | 4 |
| Automatic exits: cans or reels | | n° | 1-2 | 2 cans | 2 cans |
| Slivers per can | | n° | 1-2 | 1 | 2 |
| Slivers per reel | | n° | 1 | - | - |
| Controllers per head | | n° | 6 | 6 | 6 |
| Width coated with teeth | | mm | 255 | 103-170-200 | 110-130 |
| Pitch of the controllers | | mm | | 3 | 2.6 |
| Projection of the teeth | | mm | 5/7/9 | | |
| Feed twin-rollers | | mm | | 40/40 | 40/40 |
| Draft rollers – pressure roller | a) | mm | 30/66 ; 80 | 25/66 ; 75 | 25/66 ; 75 |
| | b) | mm | 40/66 ; 95 | 30/66 ; 80 | 30/66 ; 80 |
| Gauge | | mm | 220 | 230-270 | 230-270 |
| Free draft range (last tooth – draft roll.) | a) | mm | 30/33 ÷ 70 | 28-70 | 28-70 |
| | b) | mm | | 33-70 | 33-70 |
| Max mechanical feed rate | | m/min | 100 | 75 | 75 |
| Max mechanical delivery speed | a) | m/min | 320 ÷ 400 | 300 | 300 |
| | b) | mm | | 400 | 400 |
| Draft | | | 3 ÷ 12 | 5.73 ÷ 12.07 | 5.73 ÷ 12.07 |

B) Drawframe with draft control through Herisson/barrel cylinders with elastic nip
This drawframe, used only when the fourth passage of preparation-to-spinning is required, features a draft range (Figure 201) controlled by two pairs of cylinders with elastic nip and a Herisson cylinder featuring needles or toothed disks (Figure 202), arranged near the draft rollers.



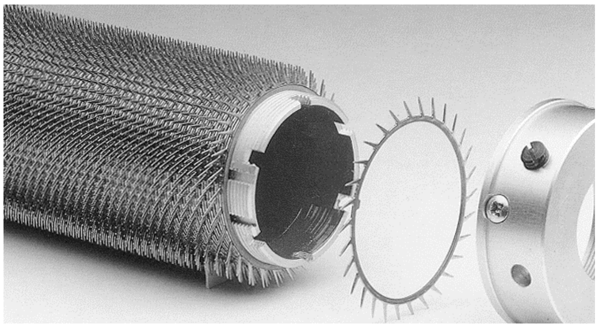


*Fig. 201 - Drawing head with Herisson/barrel cylinder control with elastic nip*

*Fig. 202 –Herisson cylinder with toothed disks*

Fibre control during the drawing stage is carried out by means of a linear/curvilinear system: the former by means of elastic nip of long fibres and the latter by means of the action of the needles or of the spikes on short fibres near the draft rollers.
The elastic nip from the barrel cylinders between the feed and the Herisson cylinder prepares and retains the material during the action of the Herisson cylinder.
The assembly of the barrel cylinders must allow the sliding of long fibres already retained by the draft rollers but also the retention of the material to make the fibres sink into the spikes of the Herisson cylinder.

Considering the operating conditions of the barrel cylinders with elastic nip (Figure 203), for correct fibre control the material must run perfectly aligned within the elastic zone of the rubber to grant the uniform distribution of the fibres (as explained hereinafter).
The hardness and the elasticity of the rubber of the barrel cylinders affect the fibre nip, which - in turn - determines a variation of the material tension between the barrel cylinders and the Herisson cylinders thus modifying the sinking of the fibres into the spikes of the latter.

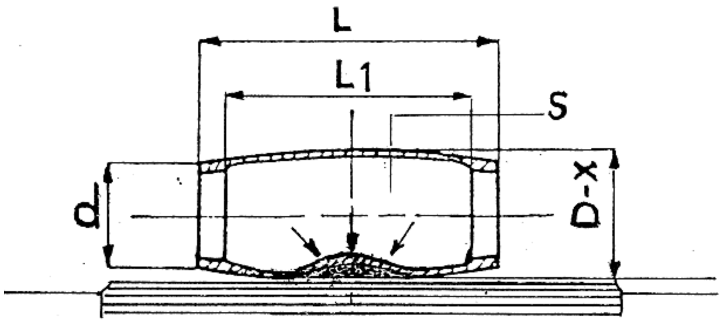



*Fig. 203 – Fibre control systems with barrel cylinders with elastic nip*

The sinking degree of the material determines the fibre control, which must be suitably adjusted; in the case of short fibres, the control must be improved to generate a deeper sinking (and on the contrary reduced in the case of long fibres).
A greater tension of the material creates deeper sinking and favours the control and the evenness of the sliver delivered while a slighter tension remarkably reduces the possibility generating windings. The fibres must not float above the spikes of the Herisson cylinder; they must sink deeply into the roller.
The Herisson cylinder divides the material into as many smaller slivers as the number of spikes (minus one) all along the production scheme; this condition facilitates the staggering of the fibres between one sliver and the other one but, at the same time, makes their sliding difficult.

The larger the quantity of spikes, the more regular the draft and the smaller the slivers into which the material is divided; basically, the need for a high number of spikes is reduced quite substantially by staggering the spike rows of the controllers, so that the fibres do not run along a linear pattern but are forced to slide between them.

The fibre control exerted by the Herisson cylinder improves in proportion to the number of spikes on its circumference due to the reduction of the nip between the fibre retaining point and the next one in the drawing stage.

The diameter of the Herisson cylinder affects the good performance of the system since it reduces the free draft ranges with no winding risk for the material.

Two different types of clothing are available for Herisson cylinders:
• the standard clothing with round needles,
• the spiked disks clothing, which gives the same technological results.
The second solution is the most frequently used since it allows easier cleaning and simpler replacement of the damaged spikes.

C) Drawframe with draft control by means of elastic nip rollers.
This drawframe, used only when a fourth preparation step is required, features a draft range controlled by means of two rollers with elastic nip and an apron on the bottom guide rollers (Figure 204).
The apron grants the uniform feeding of fibres and represents an efficient solution to prevent possible fibre winding in the case of direct contact with the cylinders.

While in the previous system the performance of the elastic nip only affects long fibres and lets the fibre mass sink into the Herisson cylinder, in this case the elastic control is essentially based on the autolevelling of the fibres, which starts with the deformation of the rubber cot of the barrel cylinder when the material passes onto it.
This deformation exerts a reaction pressure that compresses the material, modifying the bonding friction between the fibres, more or less powerfully, according to the elastic degree of the rubber; this ensures a smooth feeding of the fibres also with the sliding of the longest fibres already gripped by the draft rollers.

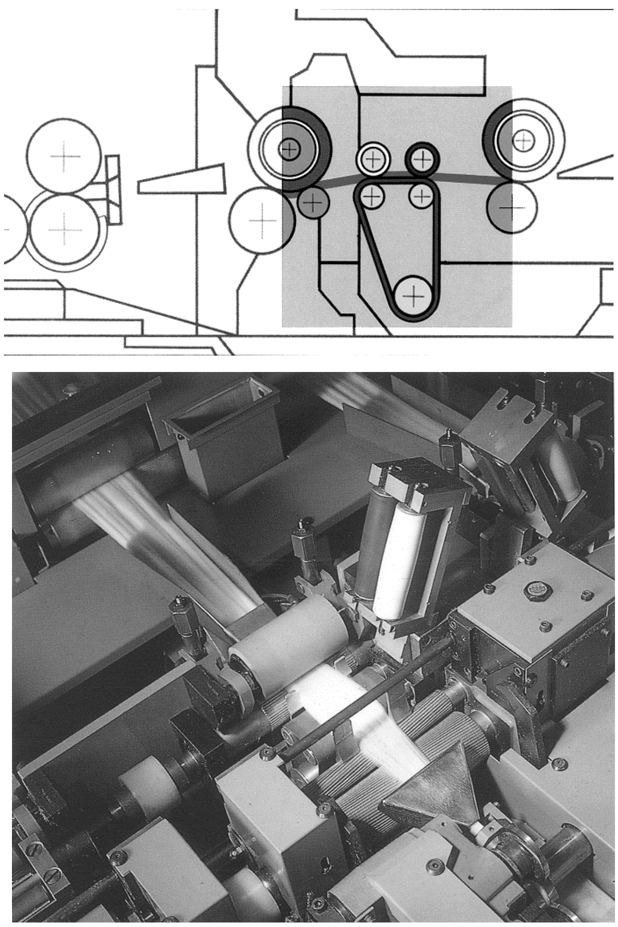


*Fig. 204 - Drawing head featuring barrel cylinders with elastic nip*

The rubber section of the barrel cylinders with elastic nip is thinner in the middle so that the reaction forcing intensity is proportional to the “x” thickness of the cross section of the material, as a result compressing the material (Figure 203).

The use of rubber cots of different hardness and elasticity allows an adjustment of the fibre compression proportional to the fibre diagram and to the free draft ranges applied.
Table G shows the main technical data of the drawframes used for the fourth pre-spinning step with two different draft control systems.

# TABLE G

| Characteristics | | Herisson-small barrel cylinders | small barrel cylinders/apron |
|---|---|---|---|
| Heads per machine | n° | 4 | 4 |
| Can automatic exits | n° | 2 | 2 |
| Slivers per head | n° | 1 | 1 |
| Slivers per can | n° | 2 | 2 |
| Thickness with Herisson needle roller | needles per square cm | 27/32 | |
| Herisson clothed width | mm | 100 | |
| Thickness with Herisson disk roller | spikes per square cm | 14 | |
| Barrel sleeve for elastic control | mm ø | ø 36 x 125 | ø 36 x 125 |
| Feed load | g/m | | 25 30 |
| Feeding cylinder | mm | 50 | |
| Draft roller – pressure roller | mm | 25/66-75 | 30/66-80 |
| Gauge | mm | 175-265 | 135-270 |
| Free draft range (last spike /grip – draft roller) | mm | 23 ÷ 113 | 38 ÷ 60 |
| Mechanical feed rate | max m/min | 40 | 50 |
| Mechanical delivery speed | max m/min | 300 | 350 |
| Draft | | 3.55-7.96 | 7.91-11.72 |

**The mechanical draft autoleveller**
Generally, one of the drawframes used for low preparation to spinning features a mechanical autoleveller for the draft.

Placed between the drawing head and the feed creel, the mechanical autoleveller applies the mechanical feedback principle, i.e. the draft is adjusted (as for electronic autolevellers) according to the incoming count variations, as detected through the variation of the feeding speed.

The adjustment range vary from –20% and +20% with a tolerance of +/- 1.5% with respect to the weight of five meters of delivered sliver.

The mechanical autoleveller has a feeler at the entry side and is connected to a lever system that amplifies the variations, which - through a mechanic memory - sends the feeler data to a double-cone variable-speed drive.

The feeler is made of a pair of vertical-axes pulleys; one pulley features a fixed groove while the other one has a mobile groove. The movable roller is pressed against the fixed roller by applying a force of about 2000 N.
The feeler is interchangeable and can be adjusted in relation to the different depths of the groove with respect to the feed loads and to the type of material, in order to translate the weight discrepancies into a variation of thickness.

The mechanical memory is a disk in constant rotation with special threaded pegs on its edge; the pegs can move into and out of the disk, as a result storing the weight variations detected by the feeler.

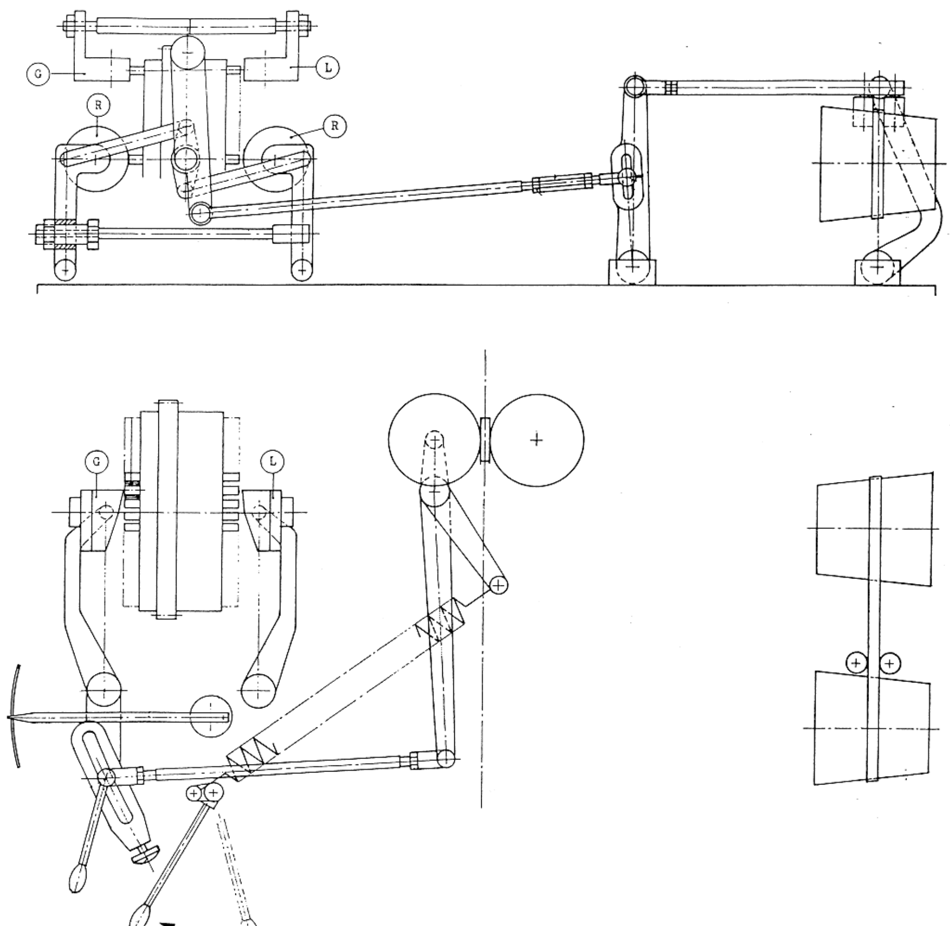
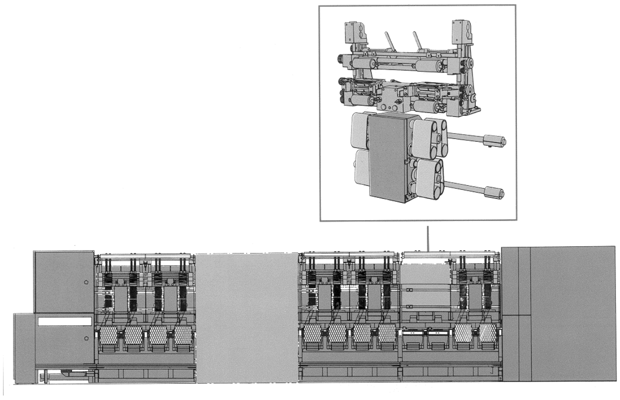



*Fig. 205 - Mechanical draft autoleveller*

The operating mode of the mechanical autoleveller is the following (Figure 205): the mobile pulley moves right or leftward depending on the material mass that can be smaller or greater than the reference stored value. The movement, driven through "G" and "L" sliding blocks connected to the lever mechanism of the feeler, pushes the pegs into or pulls them out of the mechanical memory. When the material passes from the feeler to the drawing, the mechanical memory rotates by three-fourths of a turn; the "R" detection rollers, with reference to the position of the pegs, shift the apron on the variable-speed drive thus generating a variation of the feed speed that is perfectly synchronised with the feeler and the drawing operation.

The memory speed, which sets the operating time of the drawing process, can be adjusted according to the machine gauge.
When the speed increases, the system tends to influence the detection intervals, thus reducing the feeler accuracy proportionally.
The maximum feeding speed allows a correct operating mode of the mechanical autoleveller, which can range between 40 ÷ 45 m/min; in case of higher speed, more efficient systems are preferably employed to improve accuracy and rapidity.

**High preparation**
High preparation equipment includes a finisher rubbing frame, which gives the sliver its size and the cohesion suitable for the optimum execution of the following spinning operation.
In the most common finisher rubbing frames, the drafting components are positioned on a vertical axis to keep the material as aligned as possible during the process, which, consequently, can be carried out at higher speed to grant the same product quality.



The vertical finisher rubbing frame features a modular structure with 2 drafting units and double rubbing action (Figure 206) working separately and autonomously; the modularity grants the machine non-stop operation also when one or more units are not working. Since a rubbing drafting unit works on 2 rovings simultaneously, each module produces 4 rovings, which are collected, in pairs, on 2 bobbins.

*Fig. 206 - Vertical finisher rubbing frame*

The winding and cross distribution of 2 parallel rovings for each bobbin tube is carried out by a fixed bobbin holder rail and two oscillating roving-guide twisters (performing a false twisting) (Figure 207).
The system applies the following operating principle: a drafting unit featuring an elastic nip control system reduces the size of the sliver fed after the fibre bonding and after the transformation of the sliver into a roving. The sliver is transformed into a roving by means of a double rubbing drafting system made of two couples of elastic sleeves, which feature an alternated cross movement (simulating hand friction) as well as a rotation in the direction of the material flow.

The difference between the various vertical finisher rubbing frames mainly lies in the different assembly of the drafting unit and the formation of the bobbins with deposition strokes and winding cross passages of the roving on small tubes suitable for the different counts.

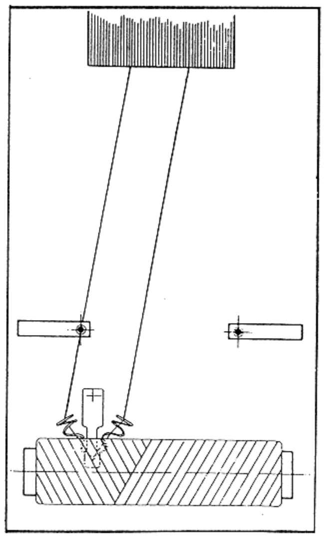


*Fig. 207 - Bobbin formation*

A) Drafting unit

The elastic nip control of the fibres inside the drafting unit can be carried out through two different systems and precisely:

a) an apron driven by the guiding rollers, with cylinders respectively coated with barrel or cylinder-shaped rubber cots ensuring elastic control, and small cylinders to create small free draft ranges suitable for processing short fibres (Figure 208). This system is employed to prepare Nm 2 ÷ 6 fine and extra-fine rovings and for processing fine counts;
b) two guiding rollers coated with barrel or cylinder-shape rubber cots for elastic control (Figure 209). This system is used for processing rovings of all counts but in particular for coarse Nm 0.8 ÷ 4.5 ones as well as for greater feed loads (up to 18 g/m).

The driving gear of the a) drafting unit involves a 1.05 pre-draft between the feed and the intermediate control rollers, which relaxes and stretches the material for the drawing process carried out by the draft rollers.

During the drawing step, the fibres are controlled in two intermediate zones (Figure 210): in the first zone, only long and medium-length fibres are controlled (approx 40 ÷ 50 % of all fibres) with a powerful retaining action of the fibre mass. The second zone controls all the fibres and grants, thanks to the higher elasticity of the rubber cot, easier slide to the fibres already retained by the drafting rollers.

Thanks to the possibility of reducing the free draft range to a minimum, the number of floating fibres is remarkably reduced (less than 10% of the fibre diagram); this ensures good results of evenness for materials with short fibres.

On the basis of the operating conditions of the straight and barrel rubber cots with elastic nip, we can see that (Figure 211):

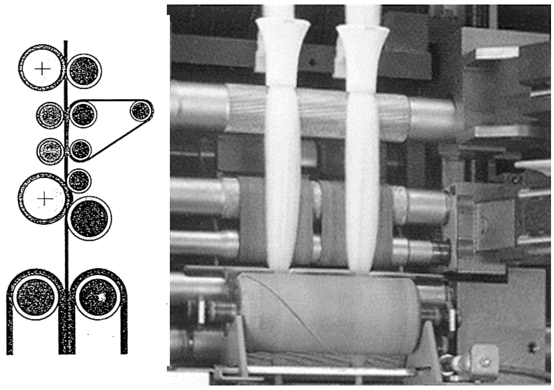


*Fig. 208 – Control with barrel elastic-control rubber cots*

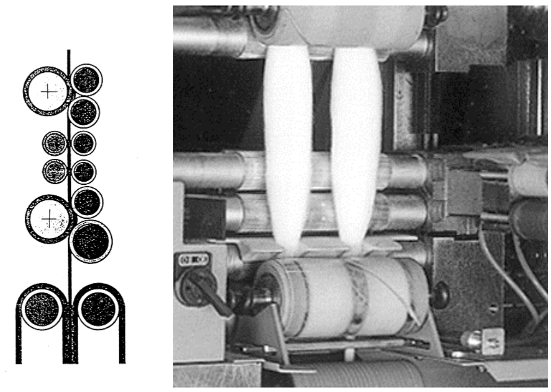


*Fig. 209 – Control with straight elastic-control rubber cots*

- the deformation of the straight rubber cot with elastic control occurs by relaxing the rubber retained at the edges of its bush with respect to the thickness of the material processed; it slightly envelops the material on the edges (with a lower intensity with respect to the Sampre rubber) and therefore the evenness of the control greatly depends on condensation degree and on the cross section of the material,

- the deformation of the barrel rubber cot with elastic control allows the rubber to wind the material; therefore, with the same number of rubber cots, this system ensures better control of the fibres with respect to the straight rubber cot system with elastic control,

- the rotation of the elastic-control roller with straight rubber cot is effected by the pressure applied on the edges of the bush on the relevant roller; the motion is therefore independent from the material and interferes very little with its cross section,

- the rotation of the elastic-control barrel cylinder which takes place thanks to the contribution of the fibre mass and with reduced contact with the relevant driving roller.

Considering the operating conditions detailed above, as well as the process applied, we can state that the barrel cylinder exerts a greater control in the case of small feeding loads (the "a" type is more suitable) and fine counts, while the straight roller is more suitable for greater feeding loads (the "b" type is more suitable) and, therefore, for coarse and medium counts and for conventional process.
The maximum loads, with medium count fibres (21÷23 micron), are the following:
1- 8 g/m for the a) type,
2- 15 g/m, with proportional reduction of the fibre count for b) type.

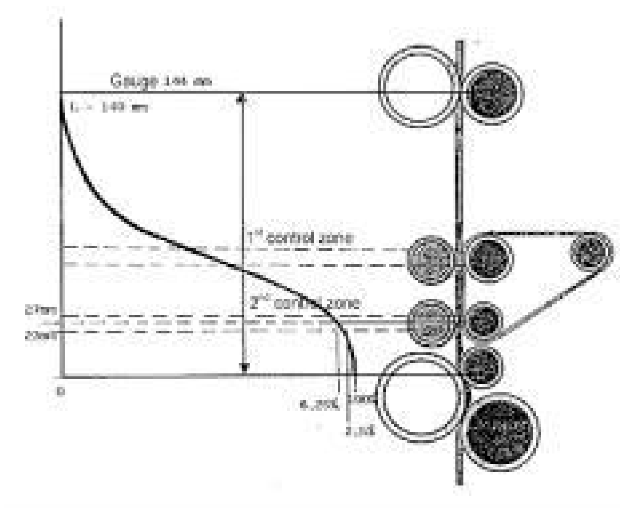
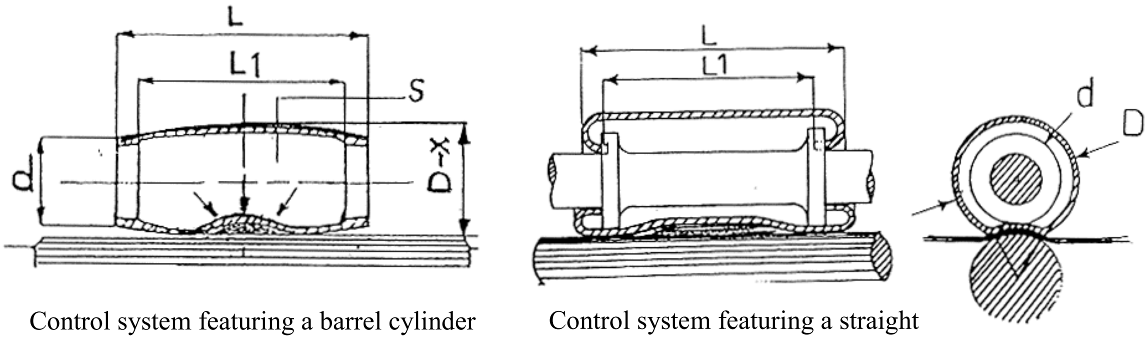



*Fig. 210 – Fibre control zones*




Control system featuring a barrel cylinder with elastic control

Control system featuring a straight cylinder with elastic control

*Fig. 211 – Comparison between fibre control systems within the draft range*

B) Double rubbing unit
The rubbing sleeves are driven by two shafts: one for rotation and the other one for alternated oscillation.

The double rubbing process is carried out by means of two pairs of sleeves, assembled in series on the vertical roving path and synchronised. The gauge between the two rubbing ranges is crucial since the rovings must move forward so that the nips of the first and of the second range are summed and the maximum action of the second range coincides with the action of first range; the travel of the second range must not be reversed on the rubbing point of the first range (Figure 212).

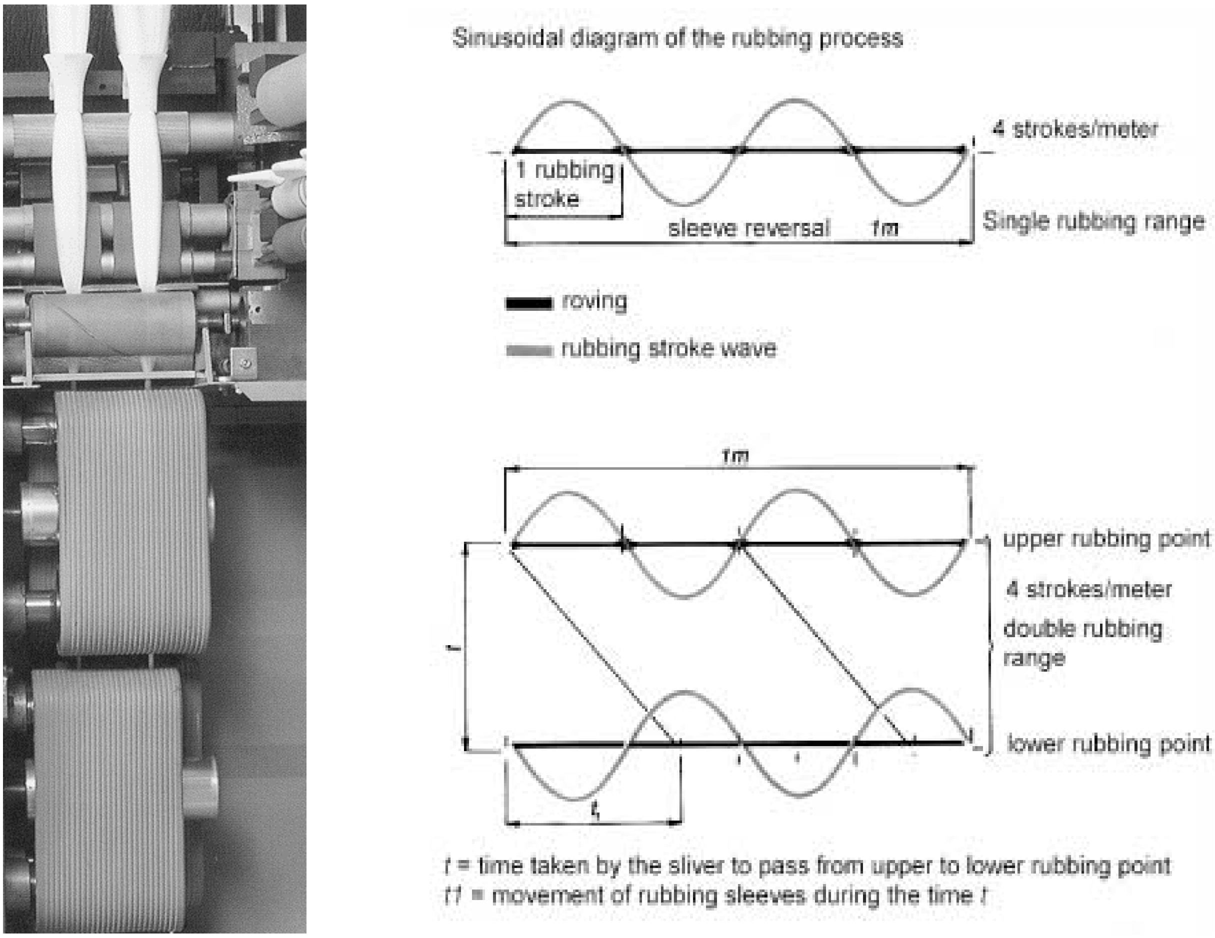



*Fig. 212 - Phasing of the two rubbing ranges*

The following diagram represents the relation between the feed speed of the material (m/min) and the rubbing per meter (strokes/m) and the oscillation speed of the sleeves (strokes/min):

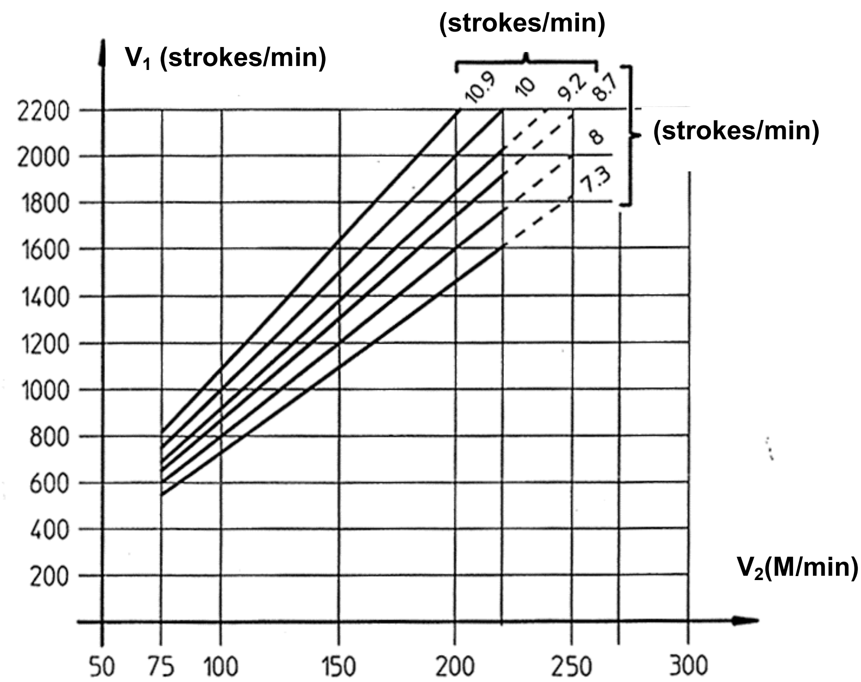


Table H shows the technical data referring to a finisher rubbing frame equipped with different elastic stroke systems of the fibres during the drawing process.

# TABLE H

| Characteristics | | Apron | Two rollers |
|---|---|---|---|
| Drafting and rubbing modules | n° | 6 – 8 – 10 – 12 | 6 – 8 – 10 – 12 |
| Bobbins per unit | n° | 12 – 16 – 20 – 24 | 12 – 16 – 20 – 24 |
| Rovings per unit | n° | 24 – 32 – 40 – 48 | 24 – 32 – 40 – 48 |
| Max. rubbing strokes | strokes/min | 2200 | 2200 |
| Total rubbing strokes | mm | 23 | 23 |
| Recommended counts | | up to Nm 6 | from Nm 0.8 |
| Max. mechanical spee | m/min | 250 | 295 |
| Max bobbin weight | daN | 5 | 6.8 |
| Feeding cylinder – pressure cylinder | mm | 35 – 45 | 32/32 – 60 |
| Drawing cylinder – pressure cylinder | mm | 25/45 - 55 | 30.32/48.15 – 60 |
| Gauge | mm | 100 ÷ 190 | 115 ÷ 220 |
| Free draft range (last. nip – draft cylinders) | mm | 25 ÷ 45 | 33 ÷ 58 |
| Draft ratio | | 5.28 ÷ 25.14 | 6.22 ÷ 29.64 |

## Ring spinning

The objectives of ring spinning are
- to thin out the roving and give it the desired count,
- to impart a specific twist to the yarn so as to give the yarn the desired resistance
- to collect the yarn into a package (i.e. the bobbin) for simpler storage and handling.

### The working principle of the ring spinning frame

The ring spinning frame operates as follows (Figure 213):
1. the bobbins ("1"), coming from the finisher rubbing frame, are suspended on the feeding rack above the spinning frame, one bobbin for each two spindles,
2. the rovings ("2"), unwound tangentially from the bobbins, are pulled by the feeding cylinders of the drafting unit ("3") where they are thinned out,
3. once the fibres leave the exit rollers of the drawframe, the forming yarn ("4"), pulled by the revolving spindle, passes through the yarn guide ("5"), inside the anti-balloon ring ("6") and inside the traveller ("7"), then is twisted and wound on the tube ("8") placed on the spindle ("9").

The yarn twists since, when winding on the small tube on the rotating spindle, it makes the traveller ("7") rotate around the ring ("10"), with a movement concentric to the spindle (Figure 214); at each turn of the traveller around the ring, the yarn makes a twist in the segment of yarn between the drafting cylinders and the traveller.
The winding of the yarn on the tube can be achieved since the traveller movement is helped and driven by the yarn; the rotation speed of the traveller is lower than the tube (spindle) speed due to the frictional force generated when sliding on the ring (and, to some extent, also to the resistance of the air to the motion of the yarn between the yarn guide and the traveller).

The distribution of the yarn on the tube, allowing the formation of the bobbin, takes place by means of the alternated vertical stroke of the rings, arranged on a horizontal rail; the stroke reversal points are not fixed but move continuously upward.
The travel of the rail is always steady; the rail begins to move near the base of the tube and stops after reaching (through the continuous upward shift of its stroke reversal points) the top edge of the tube.

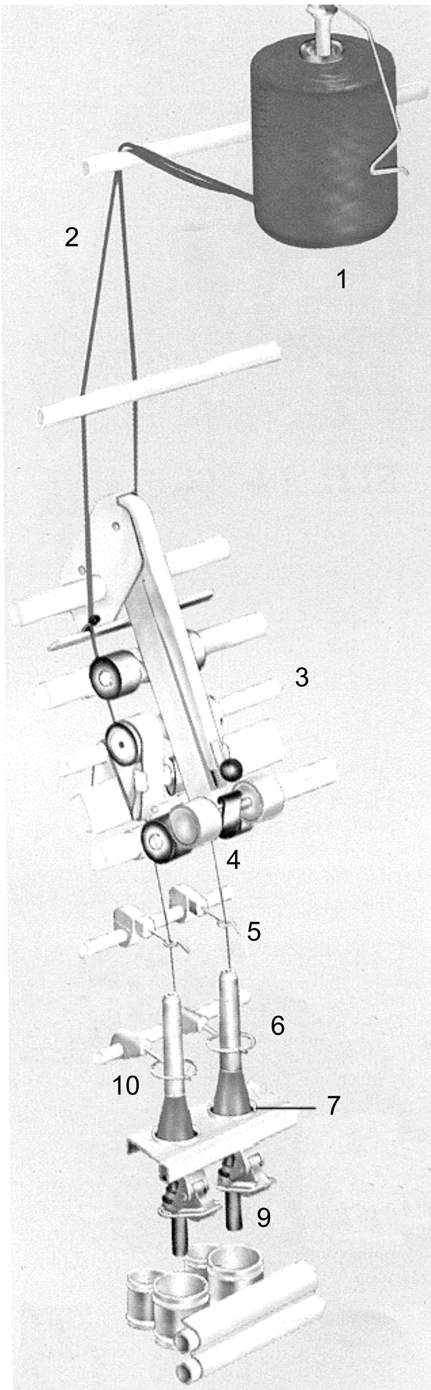


*Fig. 213 - Ring spinning diagram*

A) Roving feeding
The roving feeding system, though being a quite simple device, can greatly affect the number of defects of the yarn; in particular, if the roving unwinds incorrectly, possible "cuts" or even breakage could occur.
The structures used (Figure 215) consist of equipped with supports hanging on rails, one behind the other, along the whole length of the spinning frame; they are equipped with a braking device, which prevents the bobbin from rotating too quickly.

B) Drafting unit
The drafting unit can be equipped with different types of fibre control devices and precisely:

- three-cylinder fibre control device with double apron (Figure 216, top) for yarns with medium and medium-fine counts,
- four-cylinder fibre control device with double apron (Figure 216, bottom) for yarns with fine and very fine counts with high evenness, resistance and elastic properties.

The fibre mass entering the draft range is made of a slightly resistant fibre sliver since it contains only few fibres; for this reason the friction is reduced to a minimum. Two rotating aprons grant a suitable control; the upper apron compresses the material against the lower apron.

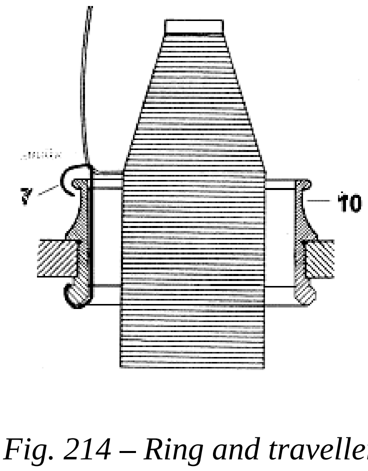


*Fig. 214 – Ring and traveller*

Usually, the upper delivery cylinder is some millimetres ahead with respect to the lower one; as a result the fibre nip point is moved slightly ahead and the size of the spinning triangle (as detailed hereinafter) is reduced, along with the number of breakages of the forming yarn.

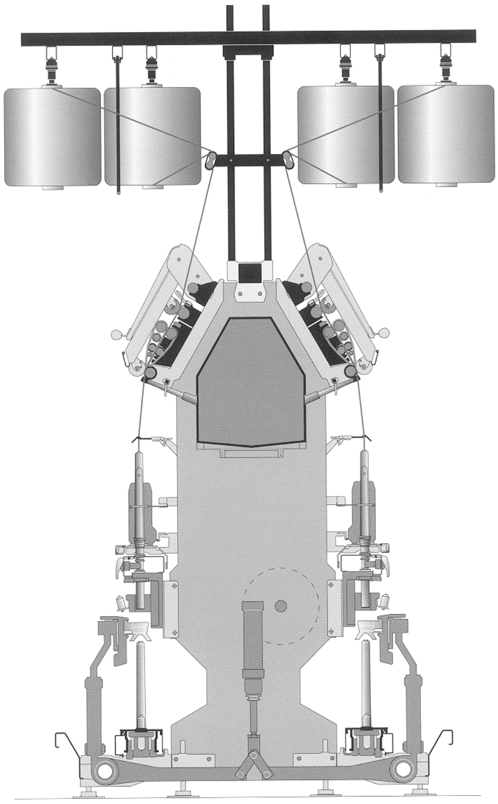


*Fig. 215 - Single control ring spinning frame*

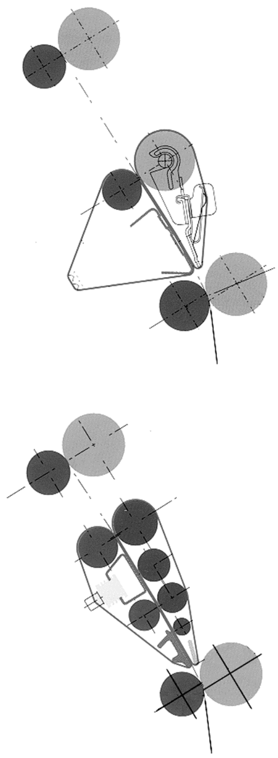


*Fig. 216 – Drafting unit*

C) The spindle drive system

The spindle can be driven using one of these three systems:
• by means of small belts,
• by means of a tangential belt,
• by means of a sectional tangential belt

The small belts drive ensures the uniformity of the number of revolutions of the spindles and, therefore, the twisting evenness. Furthermore, in case of belt break, the replacement is more rapid.
With respect to the tangential belt, the use of belts driving groups of spindles (sections) represents an advantage: it generates less noise, requires less energy and allows an easier replacement of the belts. The benefit of the tangential belt lies in the fact that there are no cylinders and pulleys under the machine; this creates less air turbulence, generally associated with less maintenance.

In the small belts drive system, a belt drives 4 spindles on each side of the spinning frame; the belt therefore commands 8 spindles (Figure 217) driven by a pulley.
On a tangential belt system, a belt driven by the machine motor slides tangentially on the internal part of the spindles of both the machine sides (Figure 218A); a great quantity of tensioners are therefore necessary to ensure that the belt has the same tension on each spindle.

It is also possible to use two belts, one for each side of the spinning frame (Figure 218B); this grants a better rotation uniformity of the spindles, above all on spinning machines incorporating a great number of spindles.

On the tangential sectional belt system, one belt usually drives 24 spindles on each side of the spinning machine; the belt then moves 48 spindles (Figure 219A) driven by a pulley in case of single-control spinning machines (one single shaft drives the spindles of both sides) or 48 spindles (Figure 219B) driven by two rotating pulleys in case of double-control spinning frame (two shafts, each one driving the spindles of a single side).
In all cases, a suitable number of tensioners must be provided to keep the belts tight.

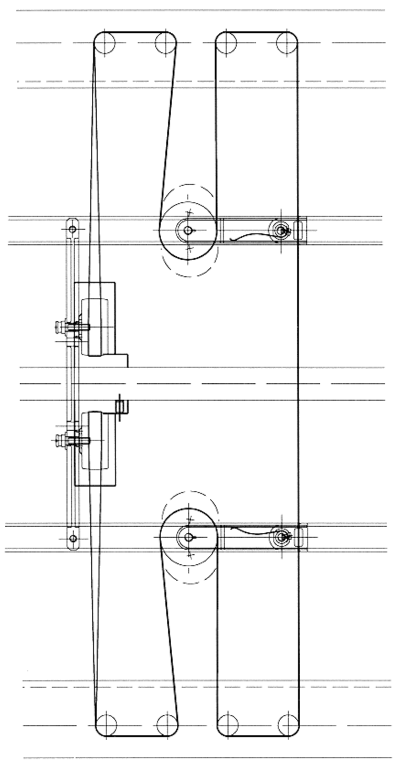


*Fig. 217 – Small drive belts*

D) Yarn guide
The yarn guide is exactly placed above the spindle, lying on the spindle axis line; it must grant the most suitable distribution of the twists on the yarn so as to limit possible breakages during the spinning process.
When the yarn is wound on the bobbin, the yarn guide moves together with the ring rail, yet with a shorter travel; as shown in Figure 220, the motion of the yarn guide guarantees that the balloon formed by the yarn while twisting is kept under control. An excessive variation of yarn tension would lead to poor evenness and an increased number of breaks.

E) The balloon control ring (anti-balloon ring)
The distance between the ring and the yarn guide could cause the formation of:
- a large balloon, with consequent space problems,
- a long balloon, which could change its shape and create consequent unevenness (collapse of the balloon) leading to possible yarn breakage.

These problems could be reduced by increasing the winding tension of the yarn through a heavier traveller; this is not the best solution since the increase in the yarn tension is directly proportional to the increase in the number of breaks.
The best solution could be the installation of a balloon control ring (Figure 221) allowing a division in smaller parts, thus giving more stability and reduced yarn tensions.

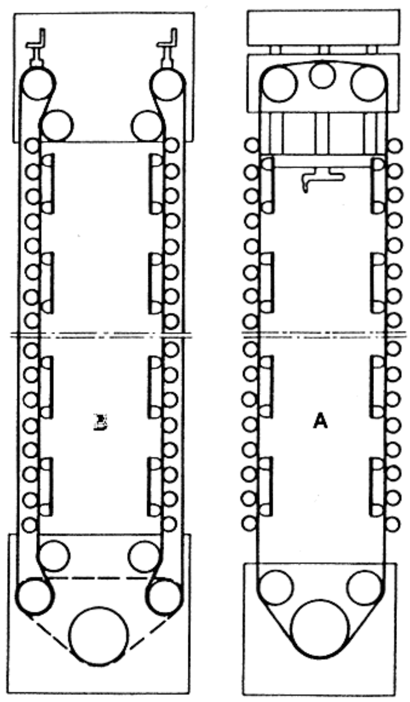



*Fig. 218 – Tangential drive belt*

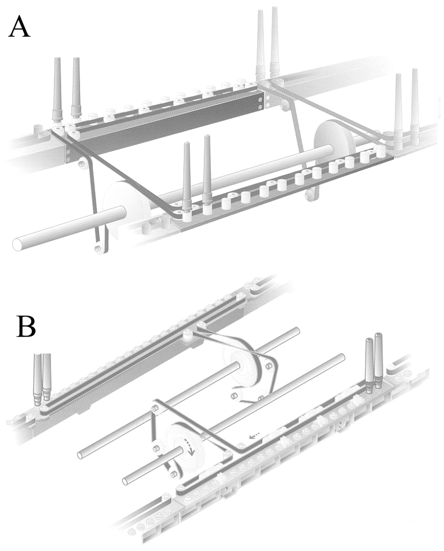



*Fig. 219 - Sectional tangential belt*

Clearly the anti-balloon rings allow high speeds with long spindles by keeping the yarn tension within acceptable limits; the friction of the yarn on the ring surface can cause the formation of unwanted hairiness and the loss of short fibres (flying fibres).

When the yarn is wound on the bobbin, the anti-balloon ring carries out the same (but shorter) travel on the ring rail; the synchronised motion between the ring rail, the anti-balloon ring and the yarn guide grants a steady control of the balloon during the whole bobbin formation process (Figure 222).

F) The control system of the ring rail

The control system of the ring rail can be:

- a gravitational control system: when only the rail upward motion is controlled by the system while the downward motion is by gravity (usually this system is applied on single-control spinning machines, Figure 223A),
- a positive control system: when both the upward and downward motion of the rail are controlled (Figure 223B).

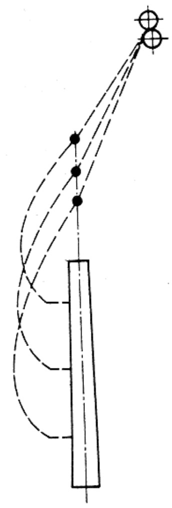


*Fig. 220 - Yarn guide*

G) Dividers

Yarn breakage mainly occurs in the spinning triangle where the material - made of a few fibres still loosely bound - is powerfully stretched.

In case of breakage in this zone, the free part of the yarn winding around the spindle can interfere with the neighbour spindles and cause further breakages; this problem can be eliminated by inserting between the spindles some dividers made of plastic or aluminium sheet, which are fixed to the rail and therefore follow its travel.

H) Fibre suction after the drafting unit

Considering that, in case of yarn break, the roving feeding does not stop, a special air suction system is placed at the exit side of the draft cylinders. This suction system, (called "Pneumafil") performs the following tasks:

- picks up the fibre sliver from the drafting system and avoids possible entanglements with yarns or possible further breakages,
- prevents fibres from scattering in the spinning room,
- limits the winding of the outgoing material on the draft rollers.

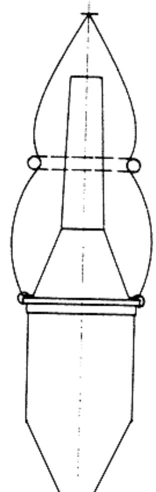


*Fig. 221*
*Antiballoon ring*

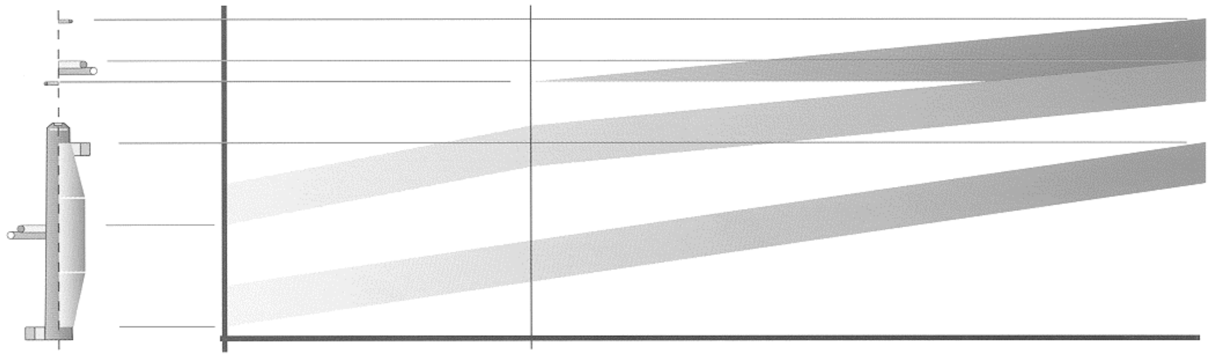


*Fig. 222 – Synchronised motion diagrams of the ring rail, of the anti-balloon ring and of the yarn guide.*

I) The traveller

The traveller allows the twisting and the correct delivery of the yarn on the bobbin.

The take up speed of the yarn, which corresponds to the difference between the peripheral speed of the bobbin and the peripheral speed of the traveller, is equal to the peripheral speed of the delivery cylinders of the drafting unit.

The difference between spindle rpm and the traveller rpm, within a specific unit of time, gives the number of coils deposited on the bobbin within a specific unit of time. Therefore, with the same spindle speed, the traveller rpm increases along with the bobbin diameter while the number of coils wound on the bobbin decreases.

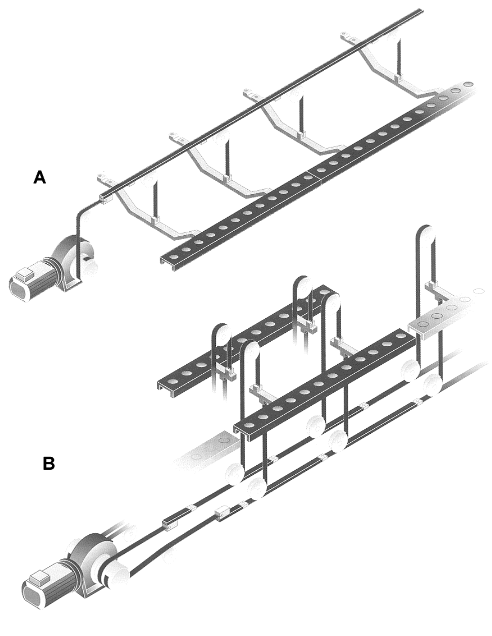



*Fig. 223 - Driving system of the ring rail*

Thanks to the centrifugal force generated, when the traveller rotates the high contact pressure between the ring and the traveller creates huge friction forces that generate heat; the traveller can reach temperatures exceeding 200 ÷ 300 °C since its small mass does not allow a quick transfer of the heat to the air or to the ring. For this reason, significant improvements in ring spinning can be hardly achieved with the materials currently available, since the speed of the traveller has apparently reached its maximum limit (approx. 33 ÷ 35 m/sec for steel travellers and 45 ÷ 47 m/s for nylon-glass fibre travellers).

This is why the traveller used for producing a specific type of yarn must feature the most suitable shape, mass, material, finish and cross section.

To reach the highest speeds, the shape of the traveller must correspond to the shape of the ring. This creates a very large contact surface, which facilitates heat transfer; the surface must also be very smooth to grant a low barycentre. The flat profile must allow space enough for the yarn since the friction between the yarn and the ring could increase the yarn hairiness and consequently the formation of flying fibres.

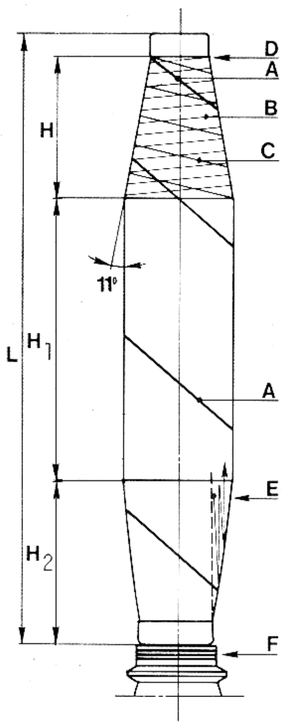
The mass of the traveller determines the friction force between the ring and the traveller, the balloon size and consequently the take up tension of the yarn.
If the mass of the traveller is very small, the balloon will be sufficiently large, the take up tension will be limited and the bobbin will be soft; on the contrary, a heavy traveller will determine an increase in the take up tension and a greater number of breaks. In a few words, the mass of the traveller must be strictly proportional to the yarn mass (count and resistance) and to the speed of the spindle.

**The structure of the bobbin**

A) The shape of the bobbin
The tube is usually made of paperboard, plastics and has a conical shape similar to the spindle tip; the yarn is wound on the tube leaving a free space (10 ÷ 13 mm) at both ends. A full bobbin (Figure 224) consists of three different parts:

- the "H2" tapered base (kernel),
- the "H1"cylindrical part at the centre (yarn package or build-up),
- the "H" cone-shape upper end

A bobbin is wound starting from the base to the tip by overlapping the various yarn layers frustrum-like; except for the kernel, this gives a conical shape to the material from the edge of the kernel to the tip of the bobbin.




KEY
A - Bobbin tying thread (0.5 m)
B - Windings wound when the ring rail raises (2.95 m)
C - Windings wound when the ring rail lowers (1.18 m)
D - Tying start
E - Bobbin formation start
F - Reserve on the spindle
H – Bobbin cone = 60 mm
L – Tube length = 260-280 mm

MACHINE TECHNICAL DATA
Ring diameter : 51-55 mm
Run-out length : 4.14 mm
Winding ratio 1:2.5

*Fig. 224 – Bobbin structure*

Each step of the bobbin formation consists essentially of the overlapping of a main yarn layer with a cross-wound tying layer.
The main layer is wound during the slow upward travel of the ring rail; the yarn coils laid one next to the other provide the bobbin build-up. The cross layer, made of distant coils inclined downwards, is formed during the quick downward travel of the rail. This system keeps the main layers separated, in order to prevent them from being pressed one inside the other (thus resulting in a quite difficult or almost impossible unwinding of the yarn).
The ratio between the number of yarn coils wound on the bobbin during the upward travel of the rail and the number of yarn coils wound during the downward travel usually range between 2:1 and 2.5:1 (Figure 225); for this reason the rail must raise slowly (A) and lower quite quickly (B). When unwinding the bobbin at high speed (D) the simultaneous unwinding of many coils could lead to entanglements of the yarn (this does not occur in "C" case).

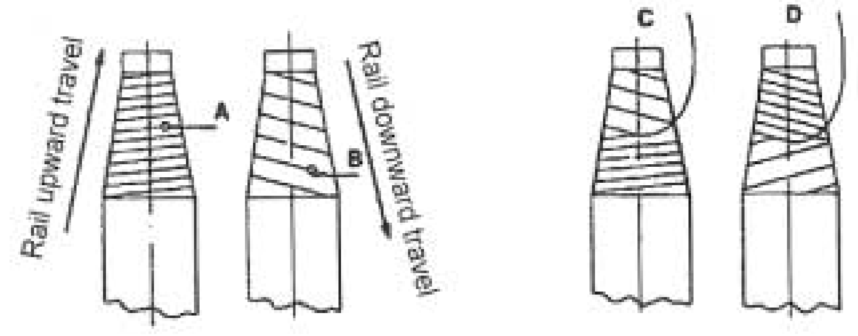



*Fig. 225 – Effects of the cross-winding ratio*

The yarn wound on the bobbin during each upward and downward travel of the ring rail is called "run-out"; to facilitate successive unwinding, the length of the run-out ranges from 3 to 5 m and is smaller for coarse yarns and greater for finer ones.

The travel of the rail is considered sufficient when it is 15÷18% larger than the ring diameter.

The structure of the bobbin is the result of the continuous motion of the winding point of the yarn on the bobbin affected by the ring rail. The rail travels up and down along the vertical axis to form the main layers, and on the cross axis (with an upward progressive increment) to homogeneously distribute the yarn on the bobbin (Figure 226).

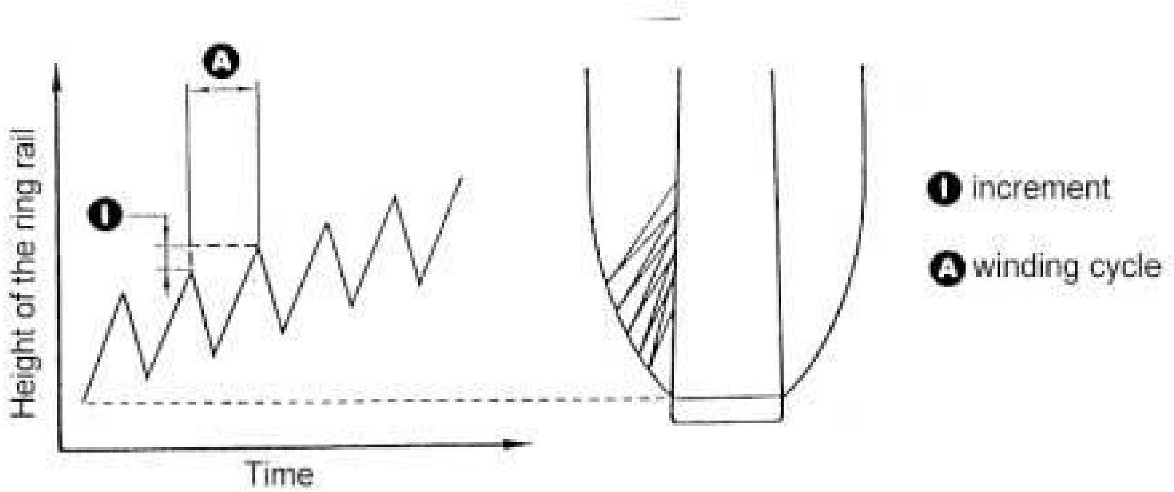



*Fig. 226 - Diagram of the ring rail motion*

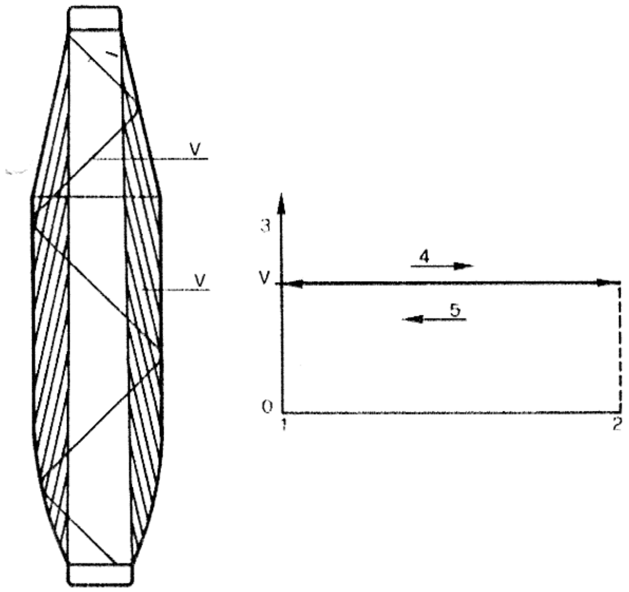
The increment value, i.e. the space between the two subsequent upward travels of the ring rail (winding cycles), determines the forming bobbin diameter with respect to two different parameters: the run-out and the yarn count.

To obtain bobbins of a given diameter it is necessary to consider that the increment is inversely proportional to the yarn count (Nm) and directly proportional to the length of the run-out; in other words, after establishing the diameter of the bobbin, with the same yarn count, when doubling the run-out length, the increment must also be doubled or, with the same run-out length, when doubling the yarn count (Nm) the increment value must be halved.

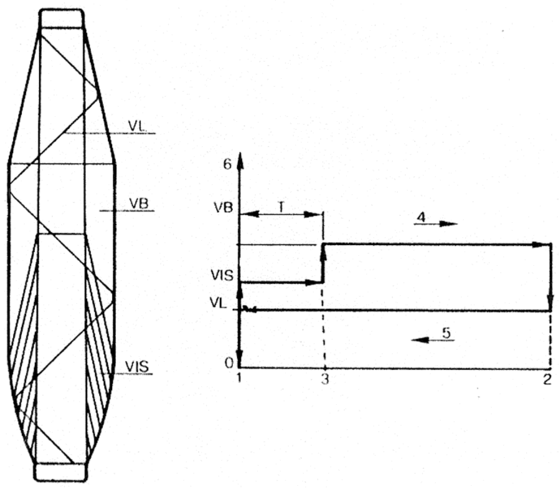
## The spindle speed

The yarn tension, during the bobbin formation, increases during the upward travel of the rail i.e. when the bobbin diameter decreases; the increase is quite remarkable (almost doubled) and heavily affects the number of breakages.
To grant a steady tension of the yarn and reduce the number of breakages to a minimum, the spindle speed during the upward travel should be reduced (and increased at during the downward travel).

The following diagrams show the various possibilities for controlling the spindle speed with respect to the bobbin structure; they range from a total lack of control (always the same spindle speed) to a steady control (variable spindle speed). The most suitable choice is given by the best proportion between the higher cost and the greatest benefits obtained in terms of total breaks



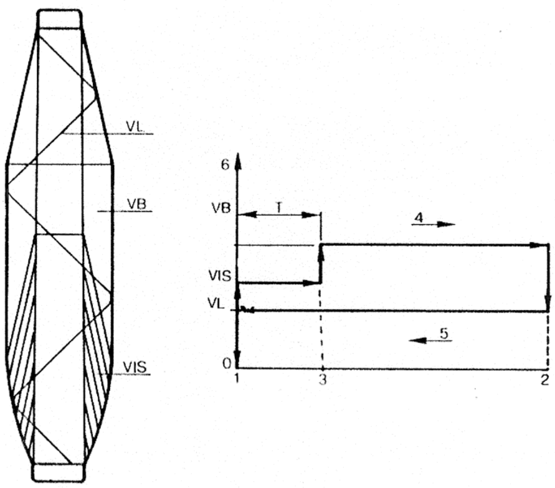

KEY
1 - Bobbin start
2 - Bobbin end
3 - Speed of the spindles
4 – Bobbin build-up
5 - Bobbin tying
V – Operating speed




KEY
1 - Bobbin start
2 - Bobbin end
3 – End of kernel formation
4 - Bobbin build-up
5 - Bobbin tying
VR – Bobbin build-up speed
VIS – Kernel formation speed (bobbin start).

| | | | |
|---|---|---|---|
| V.Fin. | 13000 | 240 | |
| 8° | 13000 | 210 | 80% |
| 7° | 13200 | 190 | 70% |
| 6° | 13300 | 180 | 64% |
| 5° | 13500 | 150 | 46% |
| 4° | 13200 | 115 | 26% |
| 3° | 13000 | 100 | 18% |
| 2° | 12700 | 90 | 11% |
| 1° | 12300 | 80 | 8% |
| V.In. | 12000 | 60 | |

**Average take up speed (18 m/min)**




KEY
1 – Bobbin start
2 – Bobbin end
3 – Kernel end
4 – Bobbin build-up
5 – Bobbin tying
6 – Speed of the spindles
VR – Bobbin build-up speed
VIS – Kernel formation speed (bobbin start).

## The spinning geometry

After leaving the drafting unit, the material assumes different inclination angles when passing through the yarn guide, the anti-balloon ring and the traveller, that are placed far from each other and are not aligned; this path determines the spinning geometry, which greatly affects the yarn structure.
The parameters that mainly affect the spinning geometry are the number of breakages and the evenness of the yarn, the binding of the fibres and the hairiness. To obtain the maximum spinning yield, the positions of the various components of the spinning unit must be carefully defined (Figure 227).

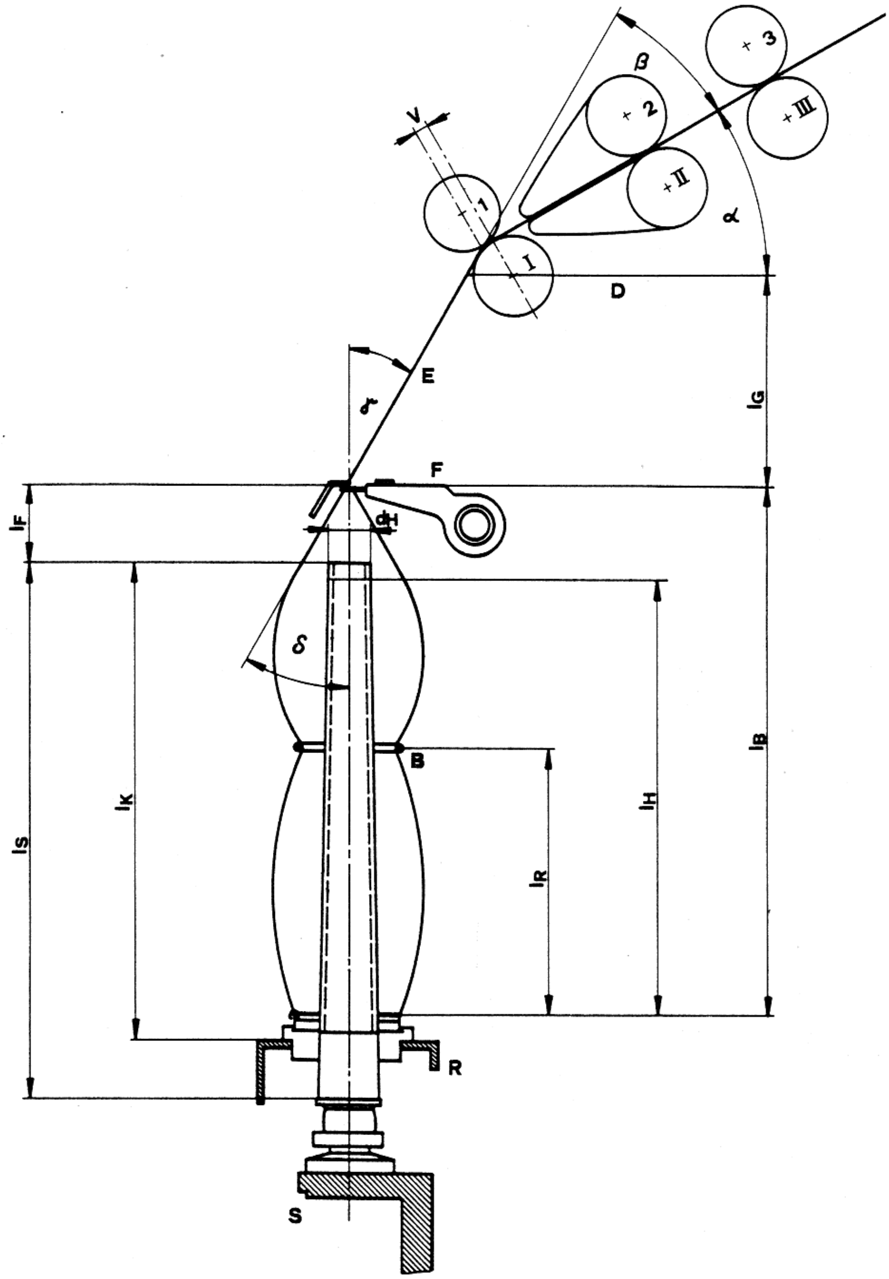



*Fig. 227 – Values determining the spinning geometry*

A) The spinning triangle

The yarn twists, generated by the traveller, climb up the yarn, in the direction opposite to its motion, to the nip point of the draft cylinders. However, the twists never reach this point since the fibres of the sliver, at the exit of the drafting unit, must unite and only afterward they can get the twist. For this reason, after the drafting unit delivery rollers, the fibre mass takes the shape of a triangle ("spinning triangle") where fibres are still untwisted.
The greatest number of breaks occur in this weak zone, where fibres do not adhere to one another because of the tension transmitted by the balloon.

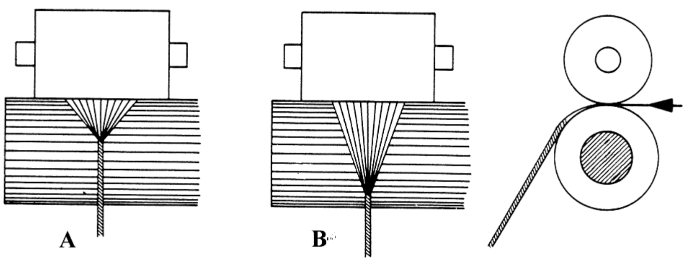



*Fig. 228 - Spinning triangle*

The size of the spinning triangle depends on the spinning geometry and on the position reached by the twists on the yarn; a short spinning triangle (Figure 228A) has a smaller weak zone and will provoke fewer breaks; the fibres at the sides of the triangle are more inclined.
All the fibres move but it happens that some fibres on the sides do not twist with others and get lost (flying fibres) or adhere to the other fibres only by one end, while the other end extends from the yarn body thus generating the so-called hairiness.
On the contrary, a long spinning triangle (Figure 228B) generates a larger weak zone and consequently a higher number of breaks, yet it allows the side fibres of the triangle to better adhere to one another thus generating a softer yarn with reduced hairiness.

B) The inclination of the drafting unit
The angle of the drafting unit determines the sizes of the spinning triangle:
• a small angle (Figure 229A) corresponds to a longer section of the fibre sliver adhering on the draft cylinder and, consequently, a "long" spinning triangle,
• a wide angle (Figure 229B) corresponds to a shorter section of the fibre sliver adhering on the draft cylinder and, consequently, a "short" spinning triangle.

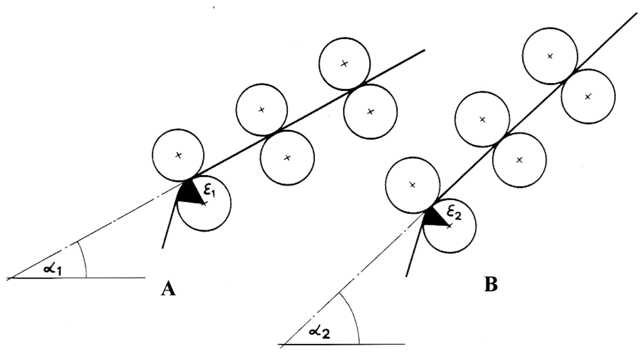



*Fig. 229 - Inclination of the drafting unit*

C) The inclination of the yarn with reference to the yarn guide
The yarn guide acts as a brake in relation to the twist transfer and to the tension generated on the yarn; the first is a negative effect that hinders the twists from reaching the spinning triangle with a consequent increase in breaks and a reduction of the twists on the yarn (resulting in a less condensed and resistant yarn), while the second effect is positive as it reduces the tensile stress on the weak zone of the spinning triangle.

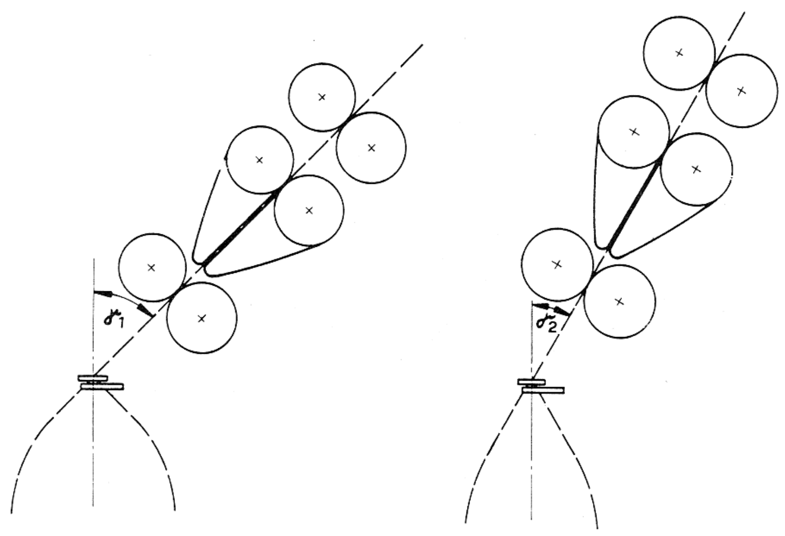


*Fig. 230 - Inclination of the yarn with reference to the yarn guide*

Furthermore, the yarn guide acts as a limiter of the vibrations generated by the balloon, which rarely moves in a regular manner.

A reduced yarn angle with reference to the yarn guide (Figure 230) allows the twist to reach the spinning triangle more often but also with a more powerful tension, which limits the positive effect of the twist; also vibrations reach the spinning triangle more easily.
A wider yarn angle with reference to the yarn guide allows the elimination of all the above-mentioned problems.

**Ring spinning with controlled-balloon spindles**

The main feature of controlled-balloon spinning (Figure 231) is the particular shape of the spindle tip which, having the yarn wound on it for a given length, reduces the balloon and limits the tension of the yarn near the spinning triangle.
The decrease in the spinning tension reduces the number of yarn breakages, or allows higher spinning speeds with the same number of breakages.
In case of spinning machines equipped with a balloon control device, the yarn guide is always placed along the spindle axis and its position is fixed to allow the correct functioning of the spindle.
The yarn tension can be modified between the draft cylinder and the spindle tip by varying the inclination of the spinfinger; the more inclined the spinfinger, the smaller the tension of the yarn between the yarn guide and the draft cylinders.

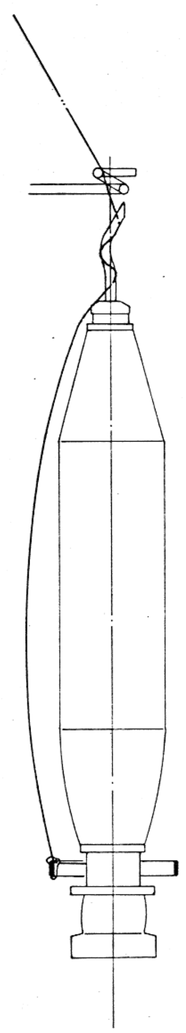


*Fig. 231 - Spindle with spinfinger*

## Condensation spinning

The condensation principle is based on the airstream used for parallelising and condensing the fibres to reduce the size of the spinning triangle and obtain a yarn with reduced hairiness and improved evenness and strength.
The fibre condensation process is carried out on the draft cylinder; the vacuum created inside the perforated draft cylinder allows the generated airstream flowing from outside into the cylinder thus condensing the fibres on its surface without modifying the geometry (Figure 232).

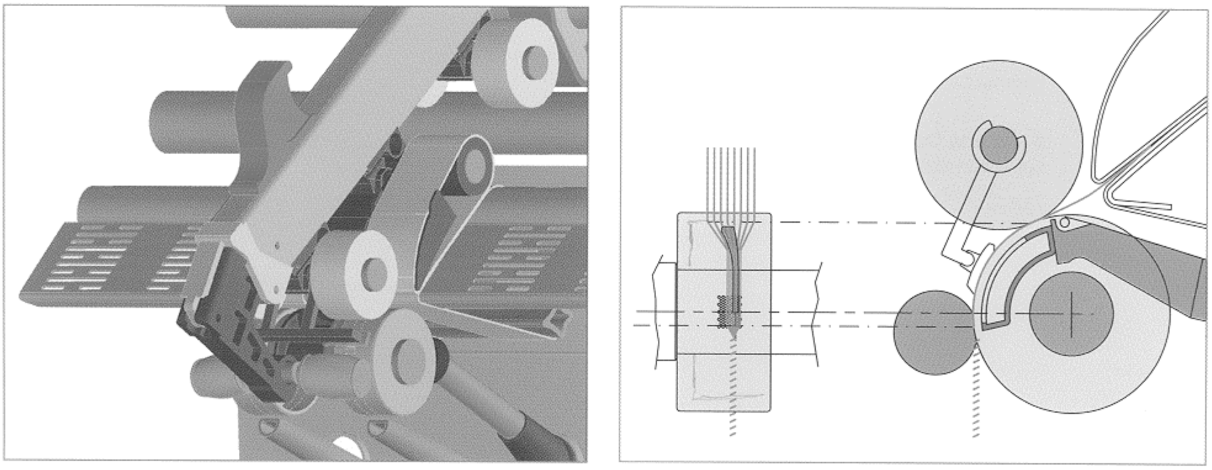


*Fig. 232 – Condensation ring spinning frame*

The weighing arms carrying the pressure cylinders also include a extension consisting of two Sampre barrel cylinders with elastic nip, whose axes are inclined with respect to the material feed axis (Figure 233).

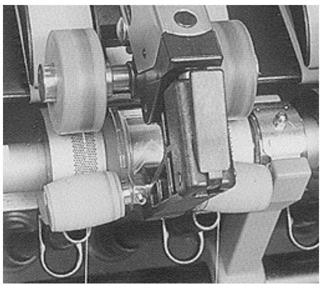


*Fig. 233 - Sampre rollers with inclined axes*

In brief, a pressure roller and a front roller with inclined axes act on each perforated cylinder; the nip area makes up the condensation zone where the fibres are condensed by the airstream. Drawn by the fixed suction devices inside the perforated cylinder, the air stream penetrates into the cylinder.
A special air conveyor (Figure 234) above the condensation path of the fibres (optional) and the particular shape of the slot of the vacuum insert (Figure 235) drive the airstream and produce a shift on the lateral fibres that favours their condensation with the central ones.
The elastic-nip rollers stretch the long fibres which remain in contact with their surface, retained by the draft cylinders since the bundle of parallel and condensed fibres must rotate continuously around its axis (in other words, along the condensation path, the vacuum action must always be more powerful than the fibre tension).

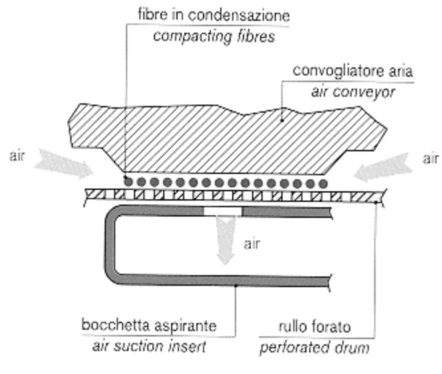



*Fig. 234 - Air conveyor*

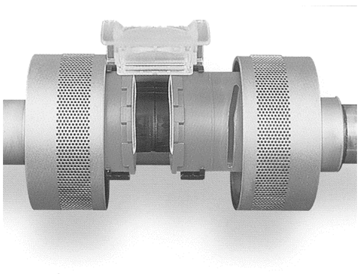


*Fig. 235 – Vacuum insert with slot*

Fibres are thus condensed, i.e. gathered in a smaller section, which, besides reducing the size of the spinning triangle, keeps all the fibres parallel one to the other before twisting (Figure 236).

Technical features of the ring spinning frame
Table I shows the main technical features of a ring spinning frame

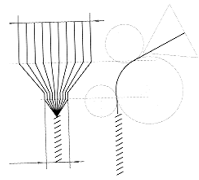


*Fig. 236 – Spinning triangle*

## TABLE I

| Characteristic | | single-control | | double-control | |
|---|---|---|---|---|---|
| Automatic unloading | | yes | | | |
| Drafting unit | | 3 or 4 rollers | | | |
| Draft | | more than 26 | | | |
| Max gauge | mm | max 222 | | | |
| Free draft range (cont-deliv. roller) | | | | | |
| 3 rollers | mm | 26 | | | |
| 4 rollers | mm | 19 | | | |
| Free draft range (feed cyl. -cont) | | | | | |
| 3 rollers | mm | 117 | | | |
| 4 rollers | mm | 88 | | | |
| Draft cylinders/pressure roller | | | | | |
| 3 rollers | mm | 40/50 | | | |
| 4 rollers | mm | 35/50 | | | |
| Spindle gauge | mm | 75 | 82.5 | 75 | 82.5 |
| Rings | mm | 42 ÷ 51 | 48 ÷55 | 42 ÷ 51 | 48 ÷ 55 |
| Spindles | n° | up to 1056 | up to 960 | up to 672 | up to 624 |
| Tube length | mm | 220 ÷ 260 | 240 ÷ 280 | 220 ÷ 260 | 240 ÷ 260 |
| Yarn count | Nm | 40 ÷ 140 | 30 ÷ 60 | 40 ÷ 140 | 30 ÷ 60 |
| Max. spindle speed | rpm | 16,000 | 16,000 | 16,000 | 16,000 |

**Flow diagrams for preparation for spinning and spinning processes**

When defining the flow diagram of preparation for spinning processes, two crucial objectives must be carefully considered:

1st – the sliver evenness,
2nd – the drastic condensation of slivers according to the final count.

For fine (Nm 40 ÷ 70) and extra fine (> Nm70) yarn production, the equipment should include a drawframe for the fourth pre-spinning step in preparation of the

3rd objective – setting of the sliver evenness in consideration of the subsequent fine adjustments without doubling stage.

Valuable raw materials are used in the preparation stage; the processed slivers feature fine counts and a few fibres per segment; for this reason the operations must be carried out with utmost precision and uniformity; the fourth drawing step allows intimate control of the fibres, a high number of doublings and a better sequencing of the various drawing steps.

Flow diagram no.1 – Output rate: 500 kg/h of Nm 40 wool yarn (Table J)
The third drawing step with disk head, after two drawing steps with chain head, grant good results as well as minimum maintenance interventions and high operating speeds (Figure 237).

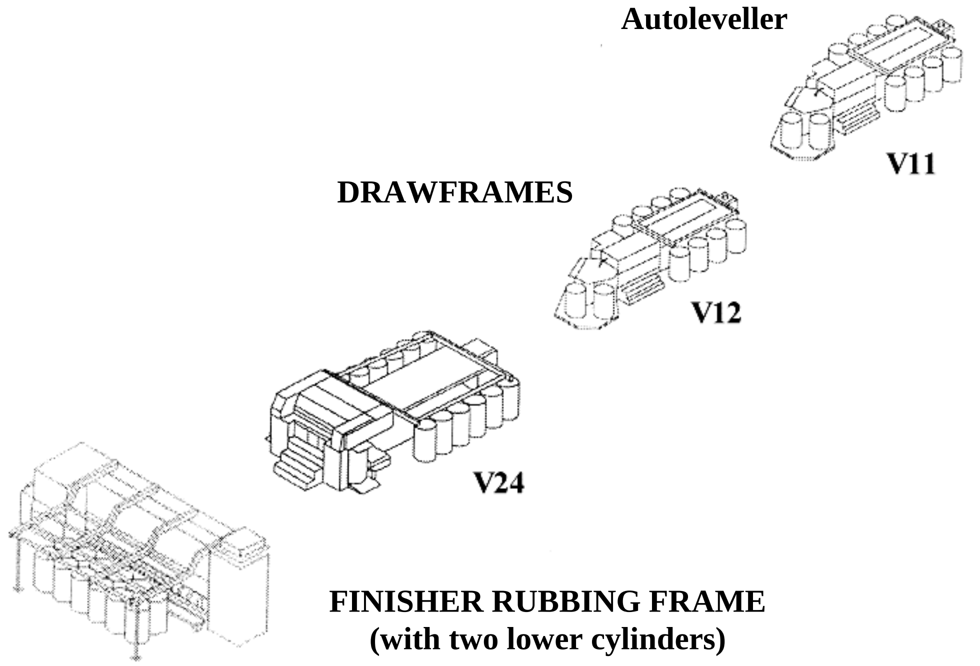



*Fig. 237 – Preparation for the spinning cycle of medium-coarse wool yarns*

## TABLE J

| Unit | Te g/m | A | Ce g/m | S | Tu g/m | N° of Exit Elem. | Vu m/min | Pt kg/h | η % | N° of Units | $P_p$ kg/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st step<br>1 sliver in 1can | 25 | 8 | 200 | 7.14 | 28 | 1 | 400 | 672 | 75 | 1 | 504 |
| 2nd step<br>2 slivers in 1 can | 28 | 4x2 | 112x2 | 8,0 | 14 | 2 | 400 | 672 | 75 | 1 | 504 |
| 3rd step<br>4 slivers in 2 cans | 14 | 4x4 | 56x4 | 8,0 | 7 | 4 | 375 | 630 | 80 | 1 | 504 |
| Finisher rubbing frame<br>2 rovings in 1 bobbin | 7 | 1 | 7 | 13,31 | 0.526 | 2x24 | 231 | 349.9 | 72 | 2 | 503.9 |
| Spinning frame<br>Yarn wound on bobbin | Nm 1.9 | 1 | Nm 1.9 | 21 | Nm 40 | 1x576 | 23.8 | 20.6 | 94 | 26 | 502.6 |

Finisher rubbing frame: 24 heads
Spinning machine: 576 spindles

This flow diagram can be also prepared with a 2-head chain drawframe, with an electronic autoleveller on each head (Figure 238), suitable for processing medium and light weight slivers.
The autoleveller on the drawframe that carries out the second drawing step for the preparation to spinning (Figure 239) allows:

- a good control of the evenness of the slivers during a process closer to spinning,
- the autolevelling of slivers draft with fewer fibres and therefore more accurately.

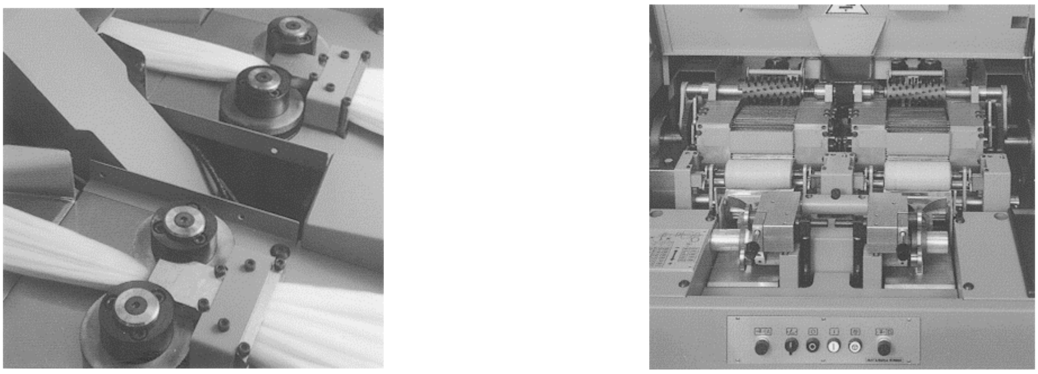


*Fig. 238 – Two-head chain drawframe with electronic autoleveller*

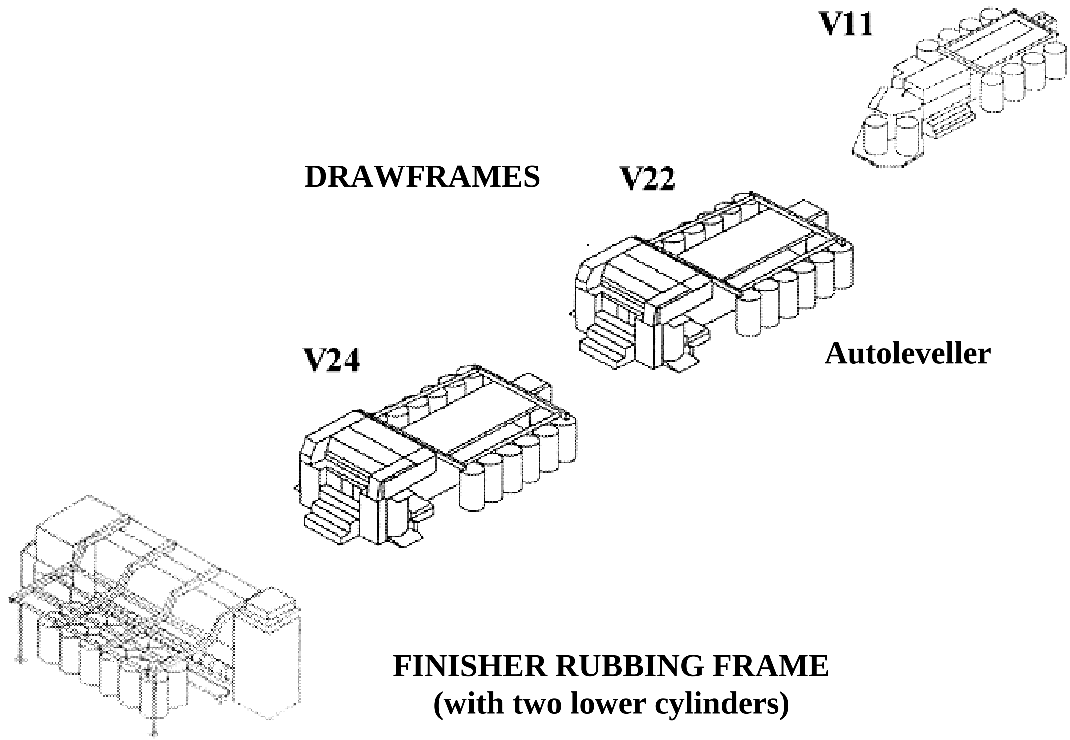



*Fig. 239 – Preparation for the spinning cycle of medium-coarse wool yarns (with autoleveller in the 2nd drawing step)*

Flow diagram no.2 (Figure 240)
Output rate: 315 kg/h Nm 70 wool yarn (Table K)

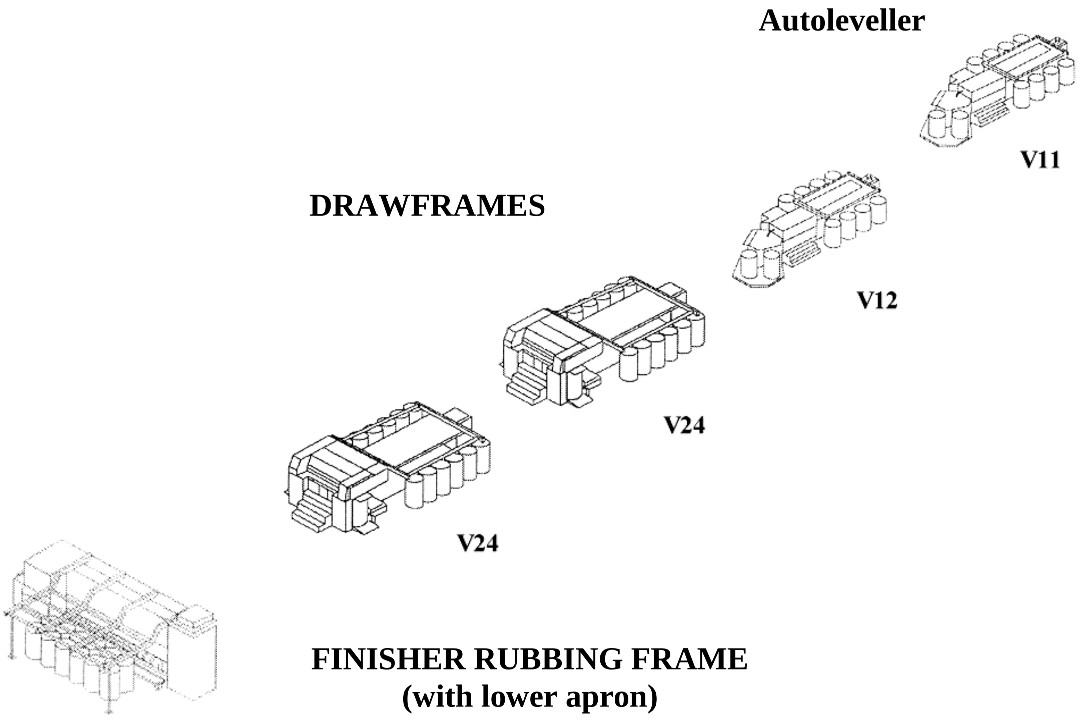



*Fig. 240 – Preparation for the spinning cycle for fine and extra-fine count wool yarns*

## TABLE K

| Unit | Te g/m | A | Ce g/m | S | Tu g/m | N° of Exit Elem. | Vu m/min | Pt kg/h | η % | N° of Units | $P_p$ kg/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st step<br>1 sliver in 1can | 25 | 7 | 175 | 7.95 | 22 | 1 | 320 | 422.4 | 75 | 1 | 316.8 |
| 2nd step<br>2 slivers in 1 can | 22 | 4x2 | 88x2 | 8 | 11 | 2 | 320 | 422.4 | 75 | 1 | 316.8 |
| 3rd step<br>4 slivers in 2 cans | 11 | 4x4 | 44x4 | 8 | 5.5 | 4 | 300 | 396 | 80 | 1 | 316.8 |
| 4th step<br>4 slivers in 2 cans | 5.5 | 6x4 | 33x4 | 8.25 | 4 | 4 | 206 | 197.8 | 80 | 2 | 316.4 |
| Finisher rubbing frame<br>2 rovings in 1 bobbin | 4 | 1 | 4 | 12 | 0.333 | 2x24 | 229 | 219.6 | 72 | 2 | 316.3 |
| Spinning frame<br>Yarn wound on bobbin | Nm 3 | 1 | Nm 3 | 23.33 | Nm 70 | 1x576 | 17.8 | 8.8 | 97 | 37 | 315.4 |

Finisher rubbing frame: 24 heads
Spinning machine: 576 spindles;

In the case of standard output rates, this diagram could include a screw-head drawframe for the first two drawing steps (Figure 241); in this case, the control of the evenness of the slivers is carried out by a mechanical autoleveller (Table L)

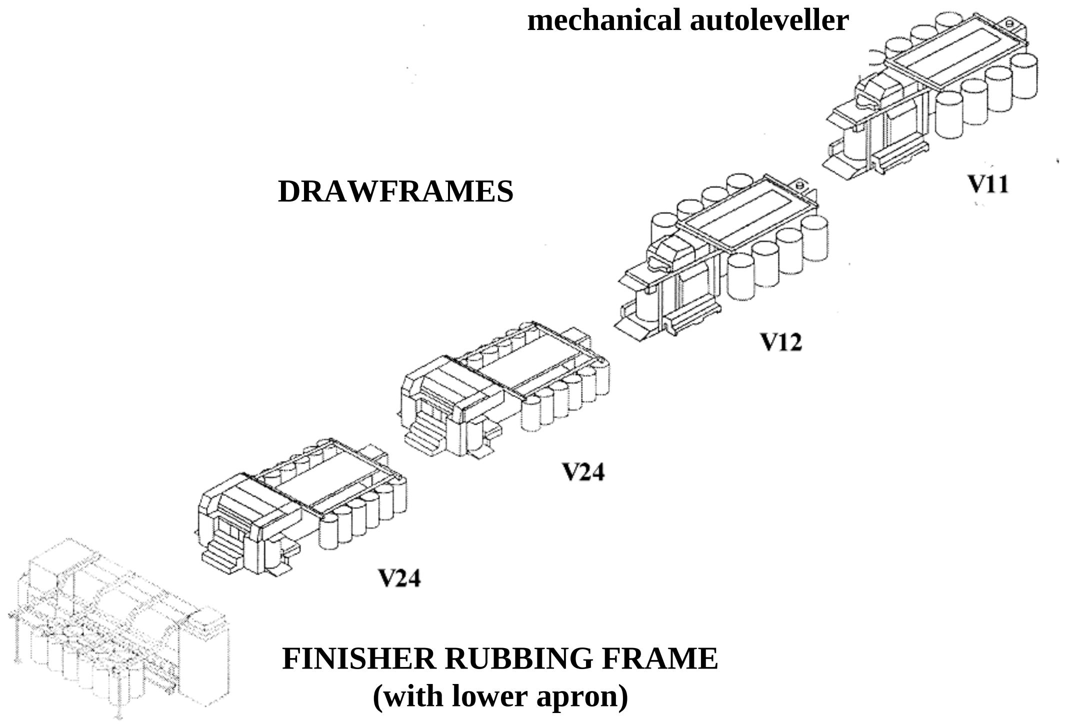



*Figure 241 – Preparation for the spinning cycles for fine or extra-fine wool yarns with screw-head drawframes*

## TABLE L

| Unit | Te g/m | A | Ce g/m | S | Tu g/m | N° of Exit Elem. | Vu m/min | Pt kg/h | η % | N° of Units | $P_p$ kg/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1$^{st}$ step<br>1 sliver in 1can | 25 | 7 | 175 | 7.95 | 22 | 1 | 107 | 141.2 | 75 | 3 | 317.8 |
| 2$^{nd}$ step<br>2 slivers in 1 can | 22 | 4x2 | 88x2 | 8 | 11 | 2 | 107 | 141.2 | 75 | 3 | 317.8 |
| 3$^{rd}$ step<br>4 slivers in 2 cans | 11 | 3x4 | 33x4 | 6 | 5.5 | 4 | 150 | 198 | 80 | 2 | 316.8 |
| 4$^{th}$ step<br>4 slivers in 2 cans | 5.5 | 4x4 | 22x4 | 5.5 | 4 | 4 | 206 | 197.8 | 80 | 2 | 316.4 |
| Finisher rubbing frame<br>2 rovings in 1 bobbin | 4 | 1 | 4 | 12 | 0.333 | 2x24 | 229 | 219.6 | 72 | 2 | 316.3 |
| Spinning frame<br>Yarn wound on bobbin | Nm 3 | 1 | Nm 3 | 23.33 | Nm 70 | 1x576 | 17.08 | 8.8 | 97 | 37 | 315.4 |

Finisher rubbing frame: 24 heads
Spinning machine: 576 spindles;