Spinning

cotton and wool spinning

by Ezio Carissoni, Stefanno Dotti, Franco Fleiss, Luigi Petaccia, Lucia Pieri

REFERENCE BOOKS OF TEXTILE TECHNOLOGIES
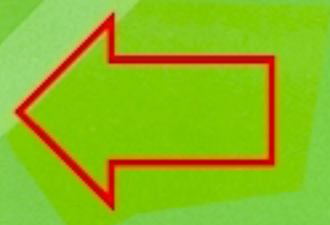
FONDAZIONE
ACIMIT

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Foreword

I am pleased to present the fourth handbook in the series on textile machinery technology that the ACIMIT Foundation is publishing for use in Italy's institutes of textile technology.

This handbook looks at the machinery, accessories, auxiliary equipment and technologies relating to "cotton and wool spinning", a further sector in which Italy boasts companies of international prominence and remarkable expertise.

This "spinning" handbook follows the ones on "weaving", "knitting" and "finishing", all of which have now reached their second edition, the 12,000 copies printed to date bearing witness to the interest generated by the series.

A fifth book, on "chemical fibres" is currently being produced to complete the series.

The need to publish these books emerged in the course of a series of meetings that ACIMIT had with principals and teachers in the context of various initiatives designed to promote relations between the industry and schools.

We were told that the textbooks currently in use do not reflect the continued and rapid technological evolution the sector has seen in recent years.

With the precise aim of publishing handbooks that respond, as far as possible, to students' learning needs, the ACIMIT Foundation decided, in agreement with the schools' principals, to entrust a group of teachers from the schools themselves with the task of realising the series of books. The teachers involved accepted this challenge enthusiastically.

Thanks therefore go, on behalf of Italy's textile machinery manufacturers, to the principals and teachers whose schools are source of valuable human resources, essential for the development of their industrial concerns.

Since no job is ever done to perfection the first time round, we will be grateful to anyone (students, teachers, company engineers and technicians, etc.) who sends us suggestions and corrections that might enable us to improve this publication and increase the value of the whole enterprise.

December 2002   *Alberto M. Sacchi, President of the ACIMIT Foundation*

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COTTON SPINNING

Since the beginning of civilisation, man has learned that following the harvest of the *cotton* fruit (or rather the fibre of the same name), he must separate the seed and the actual textile fibre. Using special equipment, he can obtain yarn, a resistant and uniform product that is also thin. Although the process is a difficult one, the most ancient findings related to cotton fabric reflect that the textile mastery of ancient Greeks included a remarkable operative capacity and achieved excellent levels of quality, even in the production of yarns and cotton fabrics.

Carded cotton spinning

Spinning cotton is also know as spinning short cut fibres, as the raw material comes in lengths of between 15 and 50 mm. For thousands of years, cotton processing has involved a single process, historically defined as carding, still used today in over half of the world's production.
The processing of cotton carded yarn is illustrated in the cycle shown below, where the following is described: processing stages, relative machinery used, the type of entry and delivery material of each stage, and the packaging form for the delivery material.

CYCLE OF CARDED COTTON

stage	machine	entry material	delivery material	package form
Opening and cleaning	bale plucker, opener, blender	raw cotton	lap	---
Carding	card	lap	card sliver	can
1st drawing	drawframe	card sliver	drawn sliver	sliver can
2nd drawing	drawframe	drawn sliver	drawn sliver	roving can
Roving	roving frame	drawn sliver	roving	roving bobbin
Spinning	ring spinning frame	roving	ring-spun yarn	bobbin / spool / cheese
Post-spinning processes	winding, doubling, singeing, reeling, twisting, winding-off machines	yarn	yarn	various (skein, bobbin, package)

The cotton arrives at the spinning stage pressed in special *bales* - these come in variable sizes and weights depending on where they come from - and it is put into storage in warehouses immediately following controls and checks on the technical properties requested of the raw part. The most common checks carried out on cotton on its arrival at the spinning mill include:
- determining the *moisture regain* (in order to define the quantity of water present in the material and therefore the commercial weight of the batch);
- analysis and quantification of all the impurities contained in the raw material;
- measurement of the *tensile strength*, the *count* and *length* of the fibre;
- checking the *colour*;
- checking of the *presence of organic substances* in the fibres;
- quantification of the content of *immature and dead fibres*;
- determination of the *stickiness*, *quantity of dust* and *elasticity* of the fibre.

The *conventional process of cotton spinning* can be considered broken down into four processing stages:
a) *opening, blending and cleaning* the fibre, carried out in order to permit the tufts to recovery their natural softness, which is lessened when the cotton is pressed into bales; blending the fibre must be as accurate as possible; a system of staves, batten reels and grids contribute to eliminating most of the natural impurities contained in cotton tufts; then puckers, openers and blenders are used;
b) *disentangling*, achieved by beating and carding, needed for increasing the relative parallelisation of the fibres, obtains a clean product free from fibres that are too short;
c) *doubling*, consists in drawing near and processing similar products (card and drawn sliver) from various machines, in order to improve the homogenous nature of semi-processed goods and consequentially the yarn, permitting any eventual irregular sections to be identified and homogenised;
d) *preparation for spinning and spinning*, this is actually the transformation of the semi-processed product to yarn with the desired properties (count, twist) and it is obtained using roving frames, followed by ring spinning frame;
e) *complementary processing*, supplementary operations necessary only for obtaining a certain packaging or a particular look for the final product; these operations are: doubling, twisting, winding, singeing, reeling and winding-off.

Combed cotton spinning

With the event of the industrial revolution, a need was born in England to diversify conventionally carded cotton yarn, introducing a thinner, but just as resistant, cotton yarn.
Numerous solutions were tried during the period, but the one that proved to have the longest staying power was the innovation introduced by the German Heilmann, who during the 19th Century studied, made and sold the *combing machine*, a machine capable of selecting the semi-processed sliver removing short fibres, permitting, therefore, finer and thinner yarns to be obtained, composed mainly of long fibres.
The notable diffusion of this machine, which over time received mechanical and technological perfecting, determined the birth of a second processing cycle, the *combed cotton cycle*.

CYCLE OF COMBED COTTON

stage	machine	entry material	delivery material	package form
Opening and cleaning	bale plucker, opener, blender	raw cotton	lap	---
Carding	card	lap	card sliver	drawn lap can
Pre-comber drawing	drawframe / lap drawing frame	card sliver	drawn lap	drawn lap can
Combing	combing machine	drawn lap	comb sliver	comb sliver can
Post-comber drawing	drawframe	comb sliver	drawn sliver	roving can
Roving	roving frame	drawn sliver	roving	roving bobbin
Spinning	ring spinning frame	roving	Ring-spun yarn	bobbin / spool / cheese
Post-spinning processes	Winding, doubling, singeing, reeling, twisting, winding-off machines	yarn	yarn	various (skein, bobbin, package)

Open-end cotton spinning

Finally, during the 1960's, technicians in what was then Czechoslovakia studied an original spinning system for cotton yarn, using a single passage going directly from drawn sliver to the yarn. This brought about *open-end spinning frame*, which would from the beginning of the following decade redefine the concept of quality of medium and coarse count yarns, as well as of a large number of fabrics that are today widespread. Below is a schematic representation of *the cycle of open-end cotton yarn*.

CYCLE OF OPEN-END COTTON YARN

stage	machine	entry material	delivery material	Package form
Opening and cleaning	bale plucker, opener, blender	raw cotton	lap	---
Carding	card	lap	card sliver	can
Drawing	drawframe	card sliver	drawn sliver	drawframe can
Spinning	open-end spinning frame	drawn sliver	(O-E) yarn	package

In simple terms, it must be remembered that virgin fibres (first processing), tough, long and fine, are employed to obtain combed yarns.

For carded yarns, virgin fibre with physically and mechanically inferior characteristics are used than for combed yarns, in addition to a small quantity of recovered and waste fibre from the combing cycle.

Finally, for open-end yarns, mainly very short fibres are used, both virgin as well as work waste. In this latter case recovered from the combing cycle (combing waste, noils) or from the carding cycle (waste, noils).

The general aspects of cotton spinning have been established, and now the stages of the processing cycle will be described, common to each of the three working cycles looked at, and these aspects are: opening and cleaning, carding, doubling and drawing.

Raw Stock Opening and Cleaning

Before entering into a specific description of opening, we must take a look at one of the most important concepts that characterises spinning in general and whose origin lies in the opening stage itself: the *concept of blending*.

Usually, the spinner possesses (in his storeroom) batches of bales from at least four diverse sources; the quantities of material can be very different from each other, as can be the purchase cost. For example, in a hypothetical storeroom there could be: 100 bales of type A, 150 of type B, 200 of type C and 300 of type D.

The blend obtained with cotton from different sources means that any eventual shortcomings in the supply of a particular type of cotton with definite characteristics can be overcome, substituting one type with one with similar characteristics but of another source.

From a quality point of view, the fibres that make up the same blend must necessarily possess the same staple length (average length of the fibre making up the batch), but also the fineness, resistance, degree of cleanliness and maturity must also be extremely similar. For this reason, a small sample of material is taken from each bale to undergo a series of technological analyses in order to arrive at a blend of optimal composition; this is made possible by the use of highly technological apparatus such as the HVI (High-Volume Instrument).

The blend is an important operation both for obtaining a good yarn as well as for reducing the price quality ratio to a minimum.

Independently from the processing cycle used in the mill (carded, combed, open-end), the raw cotton must be opened, meaning it must be extracted from the bale that was packed where it was cultivated. This is done with special machinery called a bale plucker. The spinning manager determines the quantity of bales that must be taken to the plucker and which will make up the so-called number of bales in the blend, meaning the number of bales being processed. Depending on the production type and the type of bales being processed, this number will range from 20 to 80 units. In order to obtain and permit long-lasting production homogeneity over time, it is a good idea to put together a blend in such a way that a number of bales proportional to the quantity of bales present in the storeroom exist. So, for example, if a blend made up of 45 bales were required, with a storeroom as described above, it would be possible to take to the plucker 6 bales of type A, 9 of type B, 12 of type C and 18 of type D, which will be lined up, or alternatively placed as described in Figure 1.
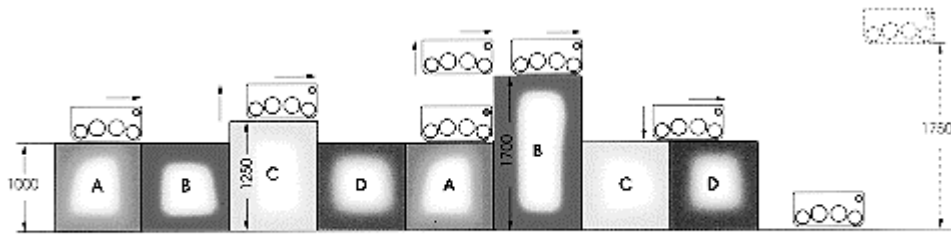
Fig. 1 Example diagram of the bales being blended by the plucker

The description is purely an example; in reality, a small number of variables capable of influencing the choice of type and quantity of bales being blended intervene, such as:
- the cost of fibre (depending on the source, with every other condition being similar, the difference of cost can vary even by some tenths of cents of dollars per pound);
- the total cost of the finished product and the relative sale price expected;
- the weight of the individual bale (depending on the source this could range between 120 and 270 kg);
- the intrinsic quality of each type of fibre compared to the others;
- how easy or difficult it is to find a raw cotton supply.

Thanks to the use of blends constituted from different sources, the mill can produce yarns with the same dyeing behaviour, or with the same mechanical features (like elasticity and resistance to traction) for long periods of time. This is good for the company as it means the business can have a serious and consistent reputation in the textile world, at least from the point of view of homogenous quality of the finished product.

The bales arrive at the tuft plucker (Figure 2 and 3) wrapped in metal supports or covered in a jute, cotton or polypropylene cover. They are opened by suitably trained workers and taken to the plucker area. This stage is extremely important, both from the point of view of personnel safety (risk of injury while the packing straps are cut) as well as the high risk of fire, caused by the presence of the metallic fragments that could be present inside the raw cotton, creating sparks during the processing and consequently posing a risk of combustion. In order to reduce the presence of metallic elements of raw cotton, spinners adopt various solutions such as sensors to detect metal, or the use of magnets, that identify metal and remove the mass of fibre that surrounds it.

The detrimental habits of cotton growers to cover bales with fabrics made of polypropylene, and using polypropylene sacks during the harvest of the fibres, leaves a presence of polluting fibre fragments that lurk between the cotton fibres and remain trapped in the yarn through the process until the fabric is made, causing serious quality problems. In actual fact, the uncoloured polypropylene fibres are often missed during controls because they cannot easily be identified by the equipment that uses special cameras located in the plucking line and see the cotton only on the basis of the fibre colour.

The tuft plucker is the only 'mobile' machine used in spinning; during the process, the main unit travels up a track in order to pluck the cotton laid out along its route, and this is the origin of its name.

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As the diagram (Figure 2) shows, the plucker has a control panel (1) on which the main machine operational functions are set. The plucker carriage (3), supported by a rotating tower (4), internally contains two plucker cylinders (6), covered with spikes made from a special tungsten-carbide alloy, capable of extracting raw cotton from the bales being processed (2). The high number of blades with spikes – up to 254 are located on both of the two plucker cylinders - allow the tufts to be opened to a certain degree when the bale is plucked, making the successive repeated untangling easier.
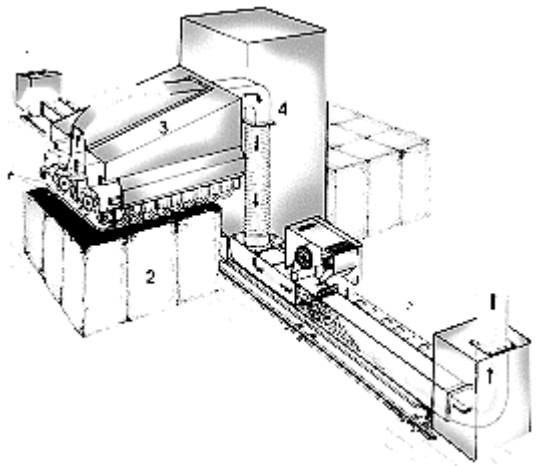

Fig. 2 Diagram of a bale plucker

As shown in the diagram below (Figure 4), the spikes of the plucker cylinders stick out from the grid, and as the distance between them and the surface of the bale can be adjusted, it is possible to adjust the amount of material plucked.

Fig. 3 Bale plucker
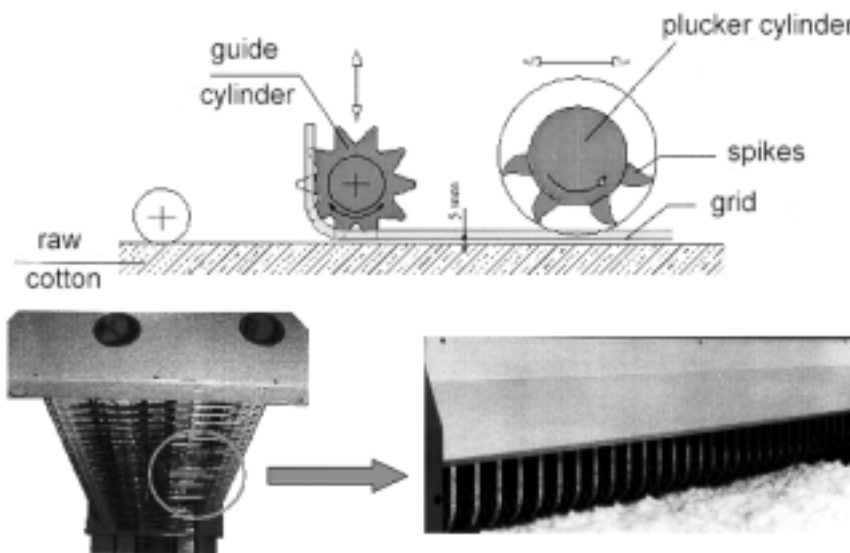
Fig. 4 Close up of the grid and blades with plucker spikes
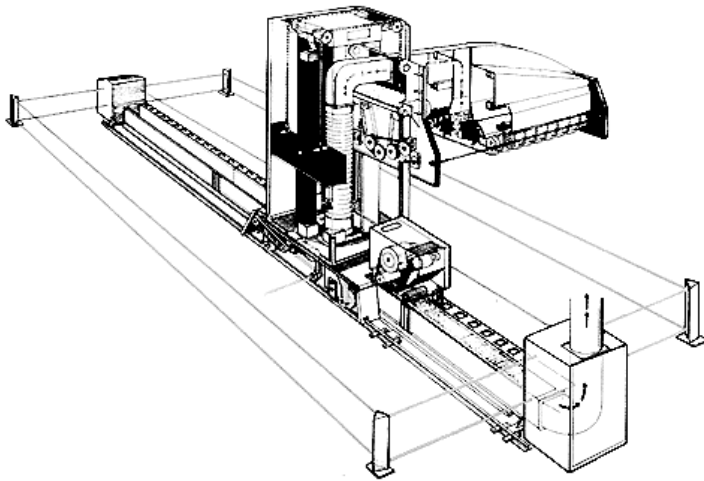
Fig. 5 A cut-away view of the bale plucker

Figure 2 shows how the transport conveyor (5) takes the cotton tufts to the aspiration conduit, which in turn takes them to the next machine.

We mentioned above that the blend often consists of bales of notable and irregular height and size, as they come from different locations of cultivation. The carriage is equipped with a device carrying a photocell that automatically raises or lowers the carriage when the profile of the bales being blended vary compared to the bales being processed (2), meaning the material is plucked in a regular and uniform manner, almost eliminating the quantity of residue raw cotton not collected from the ground.

The production rate limit, that can be obtained by a carriage of 1,700 mm deep, can reach 1,150 kg/h, while in the 2,250 mm version, the production rate rises up to 1,600 kg/h.

Work safety is guaranteed by a series of barrier photocells, places around the plucker operating range. See Figure 5, which shows (among other things) the light beam of the barrier photocells, located around the edges of the machine operating range.

Although this section of the handbook focuses on the production of pure cotton yarn, it is necessary here to at least mention the production of yarns in *intimate blend*, meaning those processed in blends made up of between 2 and 4 types of fibre, with different fibrous composition, and consisting in:

• alternatively plucking each component from the relative bale and placing a high quantity on the respective blender;
• completing an intense opening stage (only for cotton fibre);
• placing the material on a special blender conveyor, in such a way that the quantity of each component is relative to the percentage desired;
• taking the multi-component material, first to the blender and then to the card, following the related processing cycles.

Where small batches of production are required, as opposed to the automatic plucker described above, plucking raw cotton from the bales is done manually and the rough untangling of tufts is done by a weighing feeder (Figure 6), a machine equipped with a feeding table (1) where the laps of raw cotton are deposited manually. The raw cotton is taken by the feeder table (3) to a blending chamber where a series of spikes arranged on the vertical apron (9), holds the material and takes it towards the delivery stage.
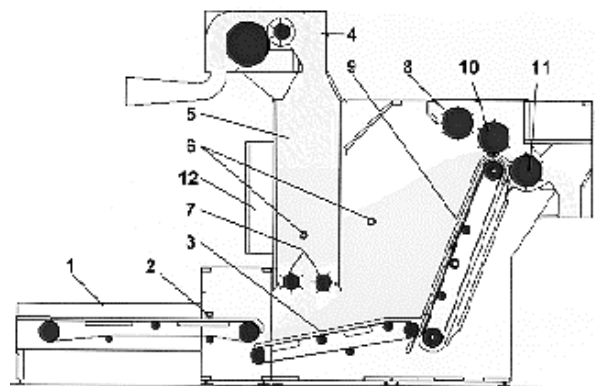
Fig. 6 Section of weighing feeder

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The equalising cylinder (10) rotating in the opposite direction to the advance of the apron, permits the passage of only those tufts held by the spikes, while returning the free tufts to the blending chamber. Finally, the removing cylinder (11), which rotates in the same direction as the apron but at a higher speed, removes the fibre from the spikes and unloads it in the weighing room, carrying out an initial rough disentangling.

This weighing feeder can be fed automatically, and in this case the material is returned by an aspiration cage (4), which deposits the material in a reserve hopper (5) at whose base there are two delivery rollers (7) which unload the material onto the feeder apron mentioned above (3).

From the first fibre processing steps and until the carding stage, the material is transported by an air flow, while inside the individual machines special aprons, cylinders, reels and fixed sectors are used, covered by steel spikes of various shapes and sizes. It is in fact this symbiosis in the use of the spikes and in the way they interact that the fibre tufts are disentangled and the fibres parallelised.

After the fibre tufts are plucked, they encounter the aspiration cage (Figure 7) which dedusts the tufts while taking them to the axial double flow opener; this is available both with incorporated motorised blower (6), as well as motorised blower installed separately, depending on the mill's needs. Through the entry mouth (1), the dusty material enters the feeding chamber (2) and is deposited on the perforated drum (3). The difference in specific weight between the fibres and the dust is such that the latter is separated from the raw material and a special doffer cylinder (4) takes care of dividing the dedusted tufts, which then go on to the next machine.

1 entry mouth
2 feeding chamber
3 perforated drum
4 doffer cylinder
5 material delivery
6 motorised blower
7 dusty air evacuation

dusty air
fibres
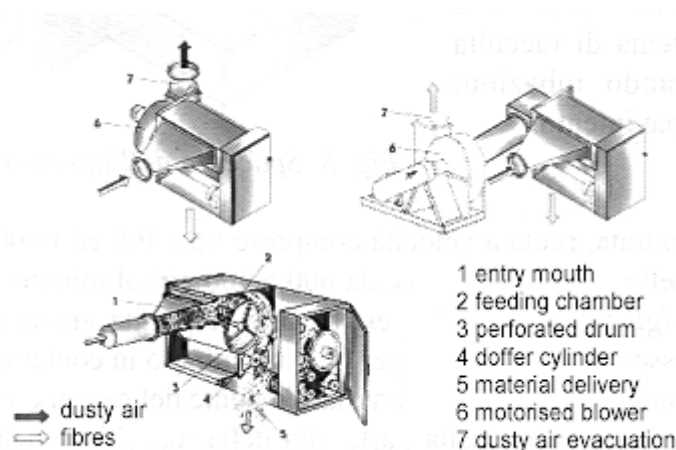
Fig. 7 Diagram and cut-away view of the aspiration cage

The dedusting effect is extremely useful both to improve the quality of the partially processed material, as well as for increasing the production rate of the preparation and spinning machines downstream. Furthermore, it reduces curling of the fibre while the material is being transported from one machine to another. In depth studies have shown that the presence of dust reduces the production output of open-end spinning frames, therefore in such lines a special dedusting machine for cotton being processed is included.

In consideration of the function carried out by the aspiration cages, these are used in various points of the processing line.

The roughly opened cotton - on exiting the plucker or feeder - is taken to the horizontal opener, whose main functions consist in:

.   the opening of raw cotton, in order to reduce the weight and volume of the fibre tufts and permitting the disentangling of the individual fibres;

.   cleaning of the raw cotton, by beating, with the elimination of foreign matter such as sand, dirt, vegetal fragments, dust (the waste material during the opening stage is generally referred to as *trash*).

The axial double flow opener (Figure 8), permits a delicate but efficient opening of the fibre tufts and at the same time dusts them, producing up to 1,250 kg/h of opened material.

Through two cleaner cylinders (1) and special automatically adjustable grids (2), the waste particles (vegetal residue, dirt, sand), but also fibre fragments, are separated from the fibrous tufts and delivered to the waste unloading cylinders (3), that lead to a central collection system that makes use of tubes running below the floor.
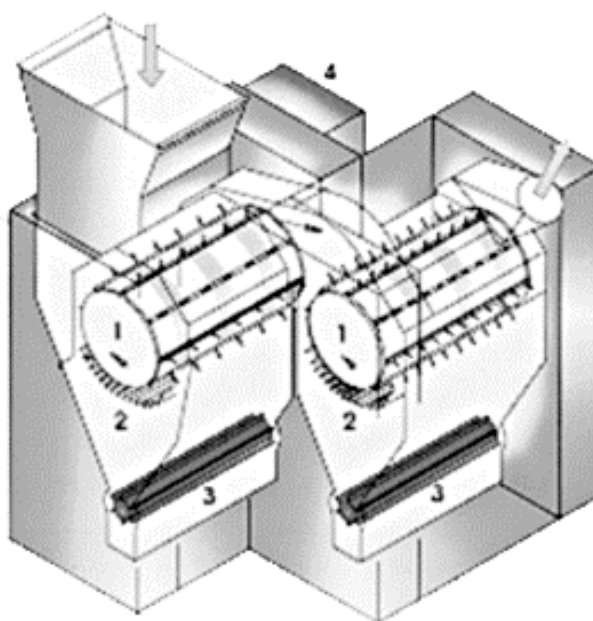
Fig. 8 Cut-away view of the axial double flow opener

The entry cleaner cylinder rotates at a speed of between 400 and 600 turns a minute, while the second cylinder (exit) turns at a rate of between 600 and 900 times a minute.

The formation of *neps* is drastically reduced by the absence of fibre gripping spikes. The fibre falls downwards thanks to gravity, it comes into contact with the spikes on the first cylinder, it is thrown against the grid, it encounters the spikes of the second cylinder, is beaten against the related grid and finally exits from the top end of the machine, drawn by the sufficient air flow.

The machine is equipped with a control panel, capable of saving all the adjustments that are step by step made and programming the ones to make, which are:

-   varying the speed of the two cleaner cylinders,
-   adjusting the degree of opening,
-   changing the angle of incidence of the grid knives, with respect to the tuft beating direction,
-   controlling the quantity of waste generated,
-   the option of working with two distinct blends, as the machine automatically adapts to the pre-selected processing positions.

The high speed of cylinder, together with the presence of pointed metal rods, determines a violent impact against the grid (formed by small triangular bars) and as a consequence of the highest specific weight of the foreign matter (as opposed to cotton) the trash separates from the fibre, passes through the grid and is taken towards a special container located away from the machine.

The *intensity of opening* is a fundamental factor above all in this stage, as it is necessary to disentangle the tufts and eliminate foreign matter, but at the same time any damage to the very delicate fibre must be prevented. This depends essentially on the following conditions:

1. *the opener feeding system*, which can be:

   . *free mass* when the tufts driven by the air flow come into contact with the cylinder rods, without being retained by feeding devices;

   . *in laps* when the tufts, on passing from the cleaner cylinder rules are retained by an apron (on the right of the diagram) and a feeder cylinder, and are delivered in the form of laps; the lap feeder can be either vertical or horizontal. In the first case, the tufts escape the action of the rods after having received just one beat; in the second case, after the first beat, the tuft rebounds on the grid and comes once again into contact with the cylinder rods, that beat it further. The vertical lap feed provides a higher degree of opening;
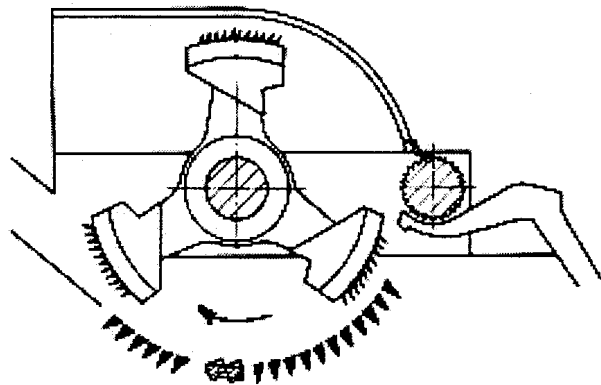
Fig. 9 Horizontal lap feeding

2. the *rods section*, that can be flat or round: the first type have a stronger hold on the tufts and therefore offer a higher degree of opening, but they risk defibrating the fibres even more; the above mentioned action is increased if the rods are sharp;
3. *the angular speed of the cylinder*, as this determines the number of beats that the fibre is subject to and the centrifugal force that they undergo as an effect of the rod beatings;
4. *the distance between the grid and the cylinder rods*: in fact with the minimum distance between them the highest degree of opening is achieved, as the tufts hit the grid at the top speed;
5. *the distance between the small bars of the grid*, which can be varied by rotating the bars on their longitudinal axis by a lever or a wheel: reducing the distance between the bars reduces the degree of opening and cleaning;
6. the *distance between the feeder cylinders and the cylinder rods*, which depend on the average length of the cotton being processed, generally this distance must increase proportionally to the length of the fibre, as the latter could get ruined or break under the beats from the rules;
7. *the air flow*: varying the air flow that accompanies the fibre during the processing cycle, the time the cotton remains in the machine changes and therefore so does the degree of opening.

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On exiting the horizontal opener, the tufts enter the blender (Figure 10), a machine of fundamental importance in the cotton processing cycle, which carries out the blending of the tufts by distributing the material inside special cells. There are between 4 and 8 cells and production as a consequence ranges between 800 and 1,200 kg/h. Thanks to the motorised blower (1), the fibre tufts are driven towards the feeder channel (2) and reach the distribution channel (3) after having come into contact with a pressure transducer (5) whose task is to control the quantity of cotton present in the blender cells and therefore command machine feeding acting on the previous machine. The tufts are deposited in the vertical cells known as blending cells (4); in this way the cotton forms layers made up of material from different bales being processed. The raw cotton is uniformly compacted by the weight of the tufts themselves and is collected by a pair of feeder rollers (6) and an opening cylinder (7), placed at the base of each cell. The angular speed of the feeder rollers is not identical for all cells but varies with the aim of maximising blending between fibrous tufts.
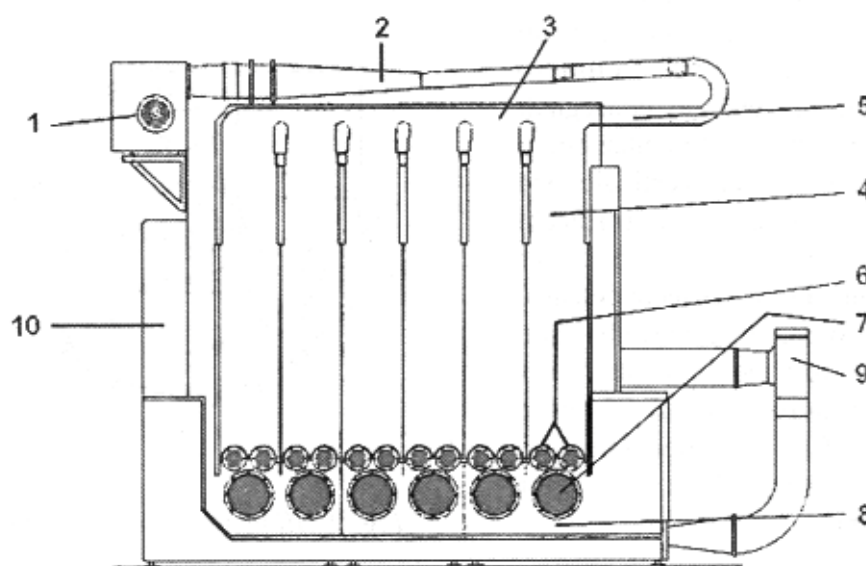
Fig. 10 Section view of six cell blender

The opening cylinder carries out further separation of the tufts and delivers them to the blender channel (8) where all the material extracted from the cells is gathered. An air current takes the cotton to the next machine. A by-pass valve acts in a transverse manner, capable of separating the process air from the material. Processing parameters can be set up on the control panel (10).
The importance of the role played by blending of fibre in the cotton spinning process cannot be stressed highly enough. Blending carried out by setting up the bales in process and the successive method used for plucking the laps continues in all the machines used in the opening process, but it materialises in the use of the blender, a machine of relatively recent conception, which took off as recently as the 1970's. Because of the construction form of the machine, the cells are gradually filled and above all they are not filled uniformly with one another, as lighter tufts are easily pushed to cells further away (on the left, see Figure 10). As will become evident below, the blending of tufts and fibres continues even in the machines that will be later described and especially in the card, the drawing machine, the lap drawing frame and the combing machine.

In order to increase the action of cotton cleaning, at the exit of the blender (where requested) there are one or more opening points, this time with horizontal lap. There are two technical solutions for this:
- the *single-cylinder opener*, which is suitable for 'roller' cottons (meaning fine and long fibre cottons) which have been subjected to cylinder ginning, and which therefore carries out an intensive but not aggressive action;
- the *three-cylinder opener*, designed on the other hand, for 'saw ginned' cottons (generally medium-short length fibre, with a characteristic high content of vegetal impurities), that carries out an extremely intense but still not aggressive action.
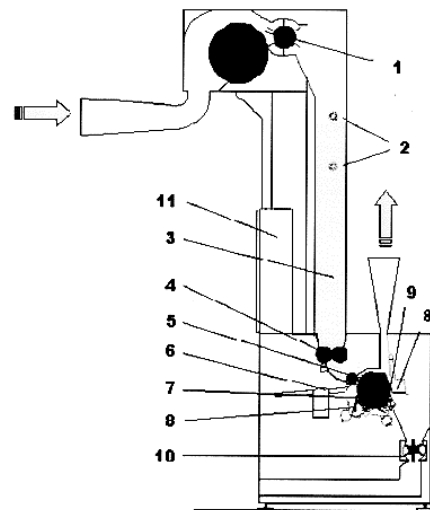
Fig. 11 Close up and section view of the single-cylinder horizontal opener

The single-cylinder opener (Figure 11) is defined as being horizontal because the feeder roller (5) carries out the lap of opened material in such a way that the opener cylinder (7) seizes it horizontally. The opener cylinder posses a process width of around 1,200 mm, a diameter of over 400 mm and an angular speed of between 600 and 1,100 turns a minute.

The machine permits an optimal degree of opening, dedusting is efficient and output can reach 600 kg/h. On the control panel (11), the necessary parameters for optimising the intensity of cleaning is set (a function of the rotation speed of the opening cylinder (7)), as well as the quantity of waste product is set (which is proportional to the distance between the opening cylinder and the small bars on the grid (8)). The heart of the machine is represented by the group that surrounds the opening cylinder: the presence of cleaning knives with aspiration mouths, the carding segments (9) as well as the option of adopting the cylinder covered with rigid clothing, with spikes or with needles, depending on the type of material being processed. A central aspiration system (10) sees to the continuous collection of waste product, while the fibrous tufts are pneumatically guided to the next machine.

Again with reference to Figure 11, the following can be seen: the aspiration cage (1), the photocells for controlling material flow (2), the reserve chamber or accumulation chamber for cotton tufts (3), the control rollers (4), and the feeder table (6).

The operative principle of the *three-cylinder horizontal opener* (Figure 12) is identical to that described for the single-cylinder horizontal opener, nevertheless the presence of three cylinders, all with a diameter of 275 mm and width of 1,200 mm, but with a different angular speed, that vary progressively from around 1,000 turns a minute for the first cylinder, to over 3,000 for the

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last. A pair of photocells (2) regulates the flow of accumulated material in the reserve chamber (3); the control rollers (4) release the right quantity of material and therefore influence the production weight and the degree of opening of the tufts.

It is the presence of three opening cylinders and the respective process speed together with the layout of knives on the grid (7), to the carding segments (8) and the deflectors, that permits an intense action even processing cotton containing a high level of trash.

Other elements indicated in the figure are: the aspiration cage (1), the control panel (9), the feeder roller (5), the first opening cylinder (6).
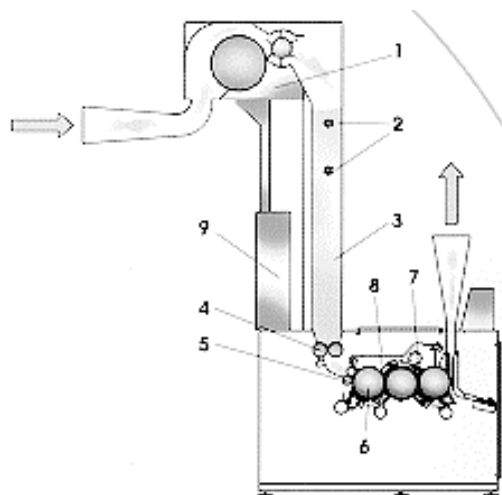
Fig. 12 Section view of three-cylinder opener

The production rate per hour of this opener can reach 600 kg of opened material and the delivery to the feeder hoppers of the card is carried out by a control system, capable of feeding a line of 12 cards (with one or even two blends in process).
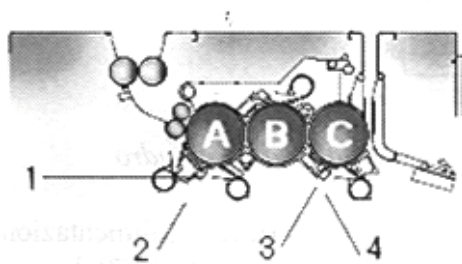
In the detailed figure on the left (Figure 13), the flow of material happens from left to right, therefore the following are shown: the three opening cylinders (A is the entry, C is the exit), the knives (1), the aspiration mouths (2), the carding segments (3) and the deflectors (4).

Fig. 13 Detail of the three-cylinder set

Once past the opening and beating stages (Figure 14), the cotton reaches the feeder hopper of the card (8), whose function is to receive the opened material from the opener and deliver it to the card in the form of a regular bulky web, producing at the most 150 kg/h of lap.
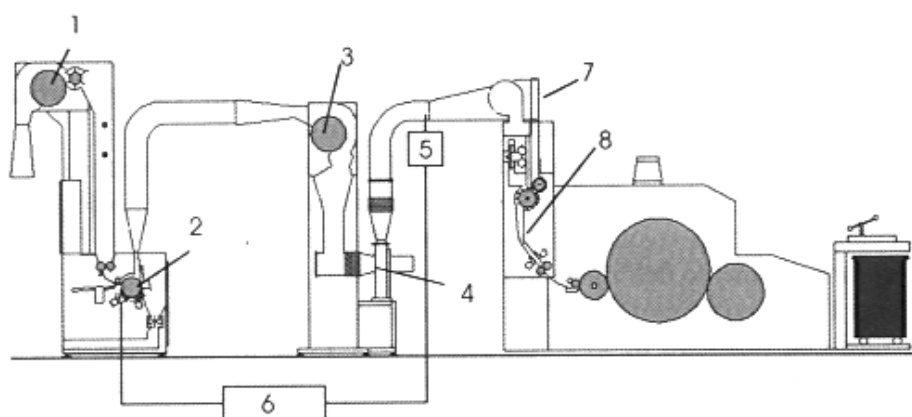
Fig. 14 The linkage between opener and card

The following can be seen in the above diagram: the aspiration cage (1) of the horizontal opener with one cylinder (2), the aspiration cage (3) of the motorised blower (4), the pressure transducer (5) located at the entrance to the feeder hopper (8) of the card, the control unit (6), and the hopper feeder channel (7).

As an alternative to using a conventional motorised blower, above all in the open-end spinning cycle, the use of a specific *dust separator* (Figure 15) is recommended. This is an actual machine that is inserted after the last point of opening and before the card feeder (Figure 16), capable of producing up to 600 kg/h of opened material free from dust and micro-dust. The opened cotton, driven by the motorised blower (1) is taken through the feeder conduit (2) to a special chamber lined with perforated sheet metal (4), which is employed to extract the dust (7) and the waste (8) and it then eliminates the waste through a removal conduit (9). The aspiration funnel (5) gathers the dusted tufts, which thanks to the drive from a second motorised blower (6), again using air pipes are taken to a card feeder hopper. Figure 16 shows the connection between the opener (2) and the card feeder hopper (8), through dusting (4).
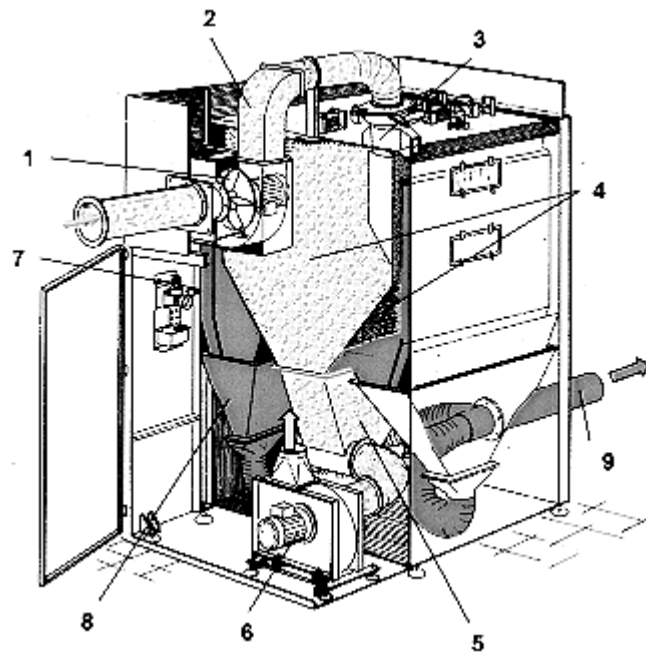
Fig. 15 Cut-away view of the dust separator.
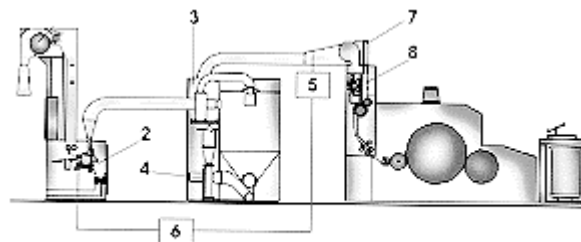
Fig. 16 Linkage between the opener and the card using a dust separator.

The presence of the pressure transducer (5) and the control unit (6) can be seen in Figure 16. The role played by these instruments consists in regulating the flow of material entering the card feeder channel. If the pressure transmitter detects an increase in pressure, it means that the feeder channel is saturated, therefore it commands the production of the opener to slow down or even stop. On the contrary, once normal processing pressure is resumed, the control unit triggers the production of the opener to start up again.

The transportation of the cotton tufts in the air pipe areas of the card feeder system makes use of a two chamber system, with continuous control and regulation of the material contained in the reserve chamber, therefore from the diagram of *card feeder hopper* (Figure 17) it can be seen that in the feeder channel (1) the material is pushed by an adequate air flow and falls (upon request) into the hopper of each individual card incorporated in the carding set.

A special feeder roller (5) takes the cotton tufts from the upper reserve chamber (4) to the opening cylinder (6) where they are suitably thinned out and then transferred to the lower chamber (9), where the lap is formed on exiting the hopper and therefore the count of the lap entering the card is configured.

A transducer (12) regulates the speed of the feeder roller, on the basis of the pressure detected in the accumulation channel (8); the air discharged into the upper hopper chamber (4) goes to a dust extraction channel (2), while the air in the lower chamber is recovered and recycled by the motorised blower (7).

In the figure, the following are also shown: the breaker cylinder (6), the lower air recovery channel (10), the lap plucker rollers (11), and the control unit (13).
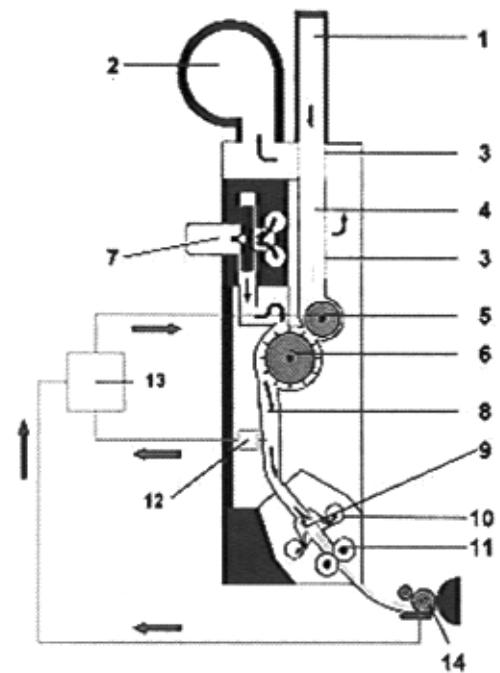
Fig. 17 Section view of feeder hopper

The lap exiting the hopper is taken to the feeder roller (14) which is the first (in order of appearance) mechanical element of the card.

Carding

General remarks

Carding is one of the most important operations in the spinning process as it directly determines the final features of the yarn, above all as far as the content of neps and husks are concerned. There are many objectives of the carding process and these can be summarised as:
• opening the tufts into individual fibres;
• eliminating all the impurities contained in the fibre that were not eliminated in the previous cleaning operations;
• selecting the fibres on the basis of length, removing the shortest ones;
• removal of neps;
• parallelising and stretching of the fibre;
• transformation of the lap into a sliver, therefore into a regular mass of untwisted fibre.

1 feeder hopper
2 licker-in cylinder
3 drum
4 carding flats
5 doffer
6 drawing unit
7 coiler
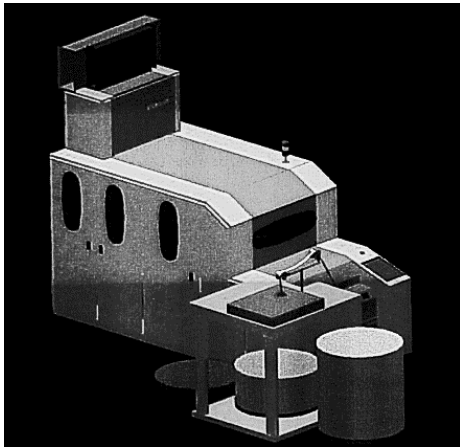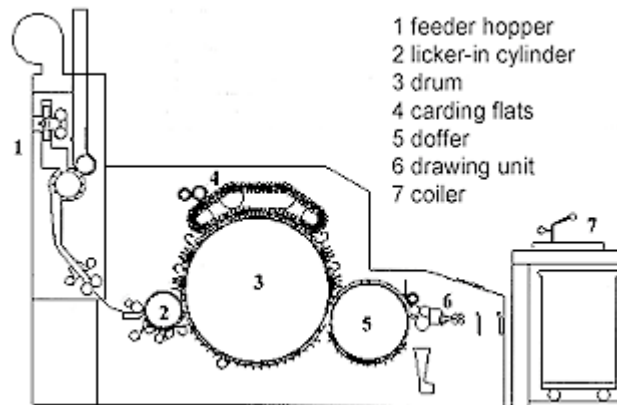
Fig. 18 Card   *Fig. 19 Section view of the card with hopper*

The carding operation is carried out by the *card* (Figure 18 and 19), a machine that in practice is a system of rotating organs, mobile and fixed flats, covered with steel spikes that go by the name of wiring. It is a good idea to know what the wiring and its functions are before going onto a description of the card.

Wiring and clothing

There are different types of cylinder wiring, in particular:
• rigid wiring, for rotating parts;
• elastic clothing, for mobile flats;
• clothing for fixed flats.
The most common on the machine are the wiring type. They are made up of a steel wire with sharp cutting teeth, the sawtoothlike edge of the wiring is hardened in order to better resist wear caused by the abrasive action of the fibres. The base of the wiring is thicker than the toothed parts, both to guarantee support to keep the teeth in a vertical position, as well as to prevent lateral contact between the teeth and to permit the necessary momentary penetration of fibre into the wiring.

The sizes of the teeth vary notably and depend on how compact the material is, on the quantity and on the fineness of the fibre. The parameters which permit one type of wiring to be distinguished from another are:

- concentration, meaning the number of teeth in a square inch of the wiring (for the various devices of the card the concentration is different and is strictly linked to the type of fibre used; for fine fibre, for example, wiring with a high concentration is used);
- the height of the teeth, which can vary according to the wired element;
- he angle between the teeth and the base in a longitudinal sense.

It is a known fact that a wired element moves in:

- a positive way when it moves in the same direction as the inclination of the teeth;
- a negative way when it moves in the opposite direction to the inclination of the teeth

The fibrous material is found between the two wired elements which, by moving, act on the fibre in an alternate manner: first they trap it then they remove it.

Depending on the layout of the teeth, the direction travelled and the speed of the devices, two conditions are possible, called:

- *carding* position (Figure 20) which is obtained when the teeth of the wired elements are inclined in an opposite direction and their movement occurs with a certain speed and in a direction that permits a reciprocal grasp of the fibre and then the disentangling of the neps and elimination of trash and dust.
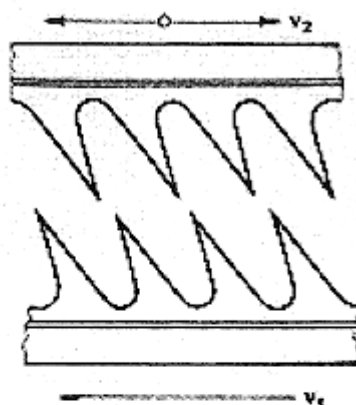
Fig. 20 The carding stage

- position of cleaning or brushing (Figure 21), which is obtained, on the other hand, when the devices have converging teeth and their movement occurs with such a speed and in such a direction to permit the passing of fibre from one organ to another.
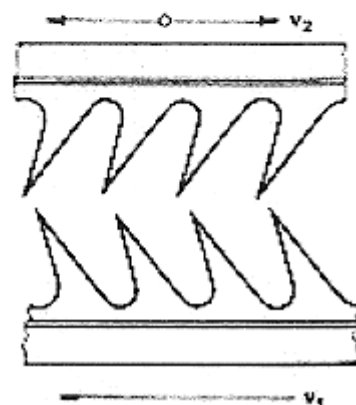
Fig. 21The brushing stage

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Card

The lap, turned slowly by the conveyor cylinders of the feeder hopper described in the previous pages, is stretched out (Figure 22) onto the feeder table (4), at the end of which is the feeder cylinder (1). The feeder table is made of well polished metal so the fibre is not caught and at the end of it there is a particular spout shape to permit the tooth holding the fibre to get as near as possible to the feeder cylinder.
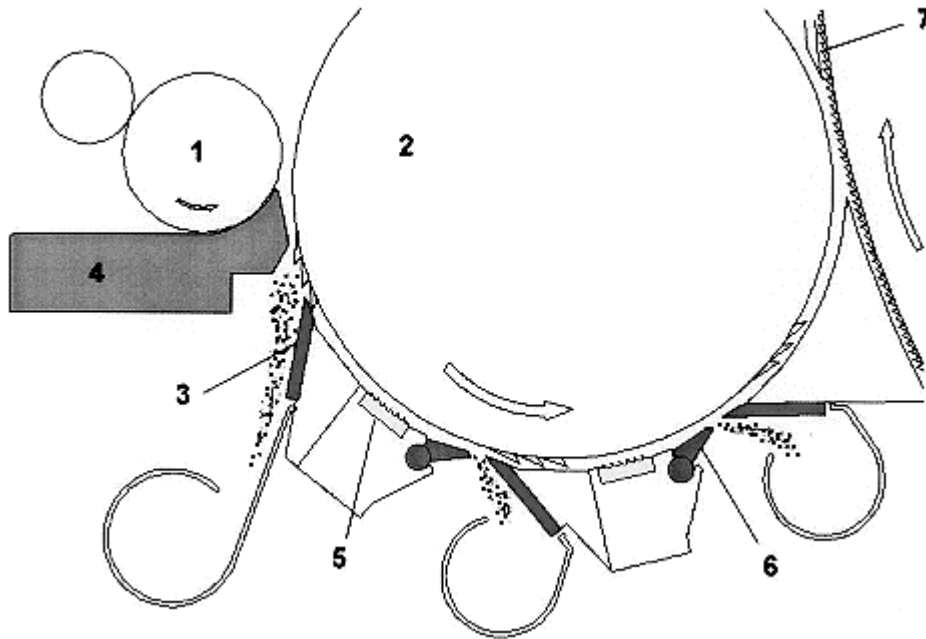
Fig. 22 Detail of the licker-in cylinder

The feeder cylinder, which has a diameter of around 10 cm, is equipped with a slow motor and delivers the fibre to the licker-in cylinder (2) made of light metal with a diameter of between 25 and 35 cm, which rotates in a positive way at high speed, from 400 to 1,300 turns a minute.

The drawing between the feeder cylinder and the licker-in cylinder is around 2,000 times, meaning that a metre of lap fed by the feeder cylinder, becomes 2,000 m on the surface of the licker-in cylinder. The material in this stage reaches a high degree of opening while trash and neps are eliminated. To obtain sufficient opening, it is necessary to respect a theoretical condition, according to which the number of teeth in the entry cylinder which pass in front of the feeder table, must equal the number of fibres fed at the same time. The ratio between these two sizes, in the unit of time, is defined as the *intensity of carding*. Therefore, to increase the intensity of carding, the quantity of fibre entering and vice versa must be reduced. The licker-in cylinder is equipped with rigid wiring with large and resistant teeth.

The grill and knives on entry are very important factors for obtaining good opening and cleaning of the material. As evident in Figure 22, the grill is made up of three parts: an initial plate with knife 93), a section with triangular section teeth (5), making up the fixed flat, finally, a third section with a continuous plate (6). As well as helping clean and select the fibre, it permits the recovery of tufts of good fibre that eventually come away from the licker-in cylinder, and it moves them nearer to the exit; in particular when the amount of waste is determined by the position of the continuous plate compared to the cylinder teeth.

The function of the licker-in knives is to eliminate any large impurities that the cylinder has brought with it. They are made up of steel rods with trapezoidal section with sharp tips, inclined in the opposite direction to the licker-in cylinder teeth, in order to force the material through a violent impact and therefore release foreign matter and neps which usually, being heavier than the fibre, protrude more than the wiring, and they collect the material left protruding from the continuous plate. Immediately after the entry cylinder there is a drum (7). This consists in a large-diameter cylinder, around 130 cm, in cast iron and generally cast in a single piece for better solidity and to prevent deforming. After the casting, the drum is stress-relieved in an oven or left to harden outside for some months, and then it is turned, ground and balanced. The drum is equipped with rigid and thick wiring, it turns positively with a peripheral speed which is almost double that of the licker-in cylinder (therefore between the two elements there is a two times the drawing action) and it follows the same cleaning phase as it.

There is a grill beneath the drum to help eliminate the short fibre and prevent the fibres generated by the high centrifugal force as well as air currents caused by the rotary action of the drum from being dispersed. In order to complete its function, the grill is eccentrically positioned, with a higher distance at the entry. The grill can be made up of small bars or in some cases perforated sheet metal. The drum can reach a speed of 500-600 rpm. It is also possible to verify that with the increased speed of the drum, the particles of trash in the card sliver are reduced. Nevertheless, it has been noted during laboratory tests that this correlation has an asymptotic trend towards a maximum value, meaning a further increase in speed, for example an increase from 400 to 500 rpm does not lead to any significant progress in cleaning the card sliver.

The drum speed is important also as it concerns another two parameters: the number of fibres present in the drum and the defibration of these. As far as the first is concerned, with other conditions on a par, the higher the increase in speed, the more the fibre density is reduced. While for defibration, on the other hand, it increases to an extent that is more proportional to the increase in drum speed. Above the drum there is a series of plates called mobile flats, whose depth is equal to that of the drum.

Flats

In the past, mobile flats (Figure 23) were made up of cast iron bars, with a T-shaped section providing a robust rib in the centre in a longitudinal direction, to prevent deformation. Nowadays, the rib is made from an aluminium alloy, that increases resistance to deformation and is lighter. Semi-rigid clothings are fixed at the base of the flats; these are connected to each other by special chains (Figure 24-2) and their extremities rest on special arches fixed to the shoulder of the machine. The distance between flats and the drum is reduced towards the exit (on the right looking at the diagrams in Fig 23 and 24), in order to gradually disentangle the fibres; their motion can be either positive or negative (depending on the solution chosen by the manufacturer) but it is, however, a very slow process depending on the intensity of carding desired; if the speed is increased, the quantity of waste rises too.
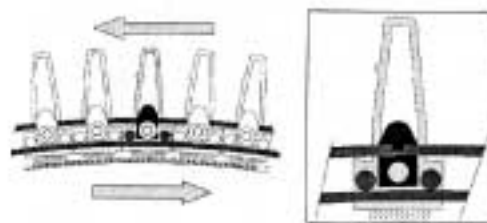
Fig. 23 Detail of the flats

The level of the needles on the flats is not parallel to that of the drum, but it forms an angle of around 1.5 degrees, as the fibres would be gripped almost exclusively by the front rows of flats, resulting in a reduction of the carding surface and rapid wear on the needles. Therefore, the inclined positioning of each flat permits uniform working by all the needles and a gradual hold on the fibres that are raised by the centrifugal action between one flat and another.
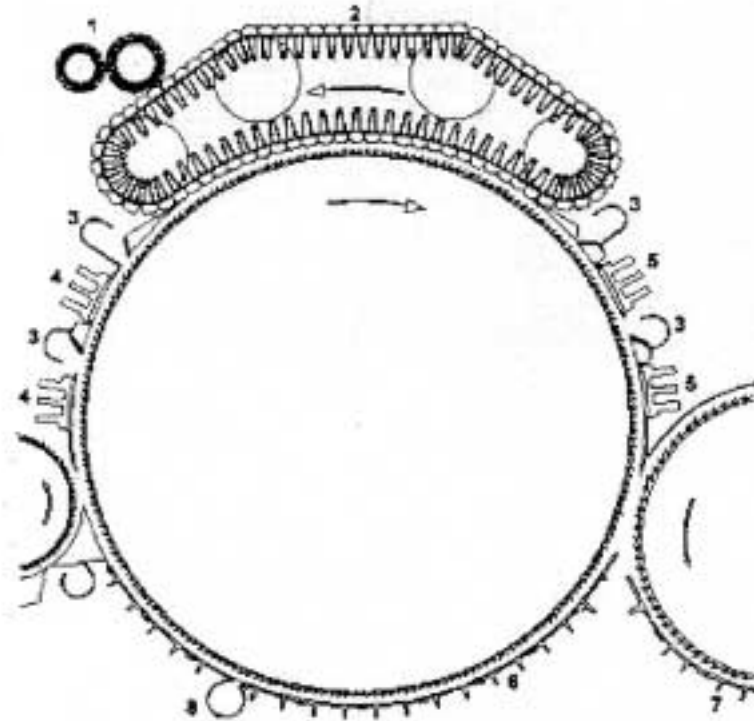
Fig. 24 Detail of the drum area

It can be noted from Figure 24 how each flat can be in a work or rest state. In the first case, the drum teeth and the flat needles face opposite directions and therefore this is the true carding stage, while in the second case the flats have needles pointing upwards.

An oscillating comb is employed to clean the flats removing the waste accumulated on the flats needles, and the comb is aided by a rotating brush (1) covered by very long curved needles, which penetrates into the wiring of the flats carrying out thorough cleaning of residue waste.

Between the licker-in cylinder and the entry to and delivery of the flats and the doffer cylinder, there are some fixed flats (4 and 5) and respective cleaning units composed of cleaning knives (3) with a mouth for continuous aspiration, which provides a good dedusting effect. The fixed flats have the function of increasing the carding action, so improving the quality of the card sliver. In modern cards, in order to obtain a trouble-free working even with sticky cotton, special aluminium plates are used (6 and 7) as is direct aspiration of the card waste (8). All the carded fibres from the drum then pass to a doffer cylinder, which is covered with wiring similar to the drum, being very dense. The peripheral speed of the doffer cylinder is lower than that of the drum, therefore between the two a process of condensation occurs. To permit the fibre to be collected as a uniform web, the doffer motor rotation is negative while between it and the drum a carding action takes place.

From what has been described, the passage of the fibre from the drum to the doffer cannot take place. It is, on the other hand, possible for the following reasons:
• the teeth in the doffer cylinder are always clean and therefore the passage of the fibre from the drum to the doffer can easily take place;
• the closeness between the drum teeth and the doffer permit the latter to get a grasp on the fibres;
• the centrifugal force, generated by the high speed of the drum and the air current, tends to remove the fibres from the drum teeth, taking them towards the surface of the doffer;
• the longer length of the doffer teeth compared to the drum teeth means that fibres are gripped by the first;
• two organs in a carding position in relation to each other operate a reciprocal exchange of fibre.

During the passage of fibre from the drum to the doffer cylinder, various fibres curl and behave like short fibres. These curls can be at the tail end if the fibre is folded in a direction opposite to the movement of the material, or at the tip if the opposite is true. This defect will be eliminated later, by drawing and eventually by combing. Analysis of laboratory trials show that mainly tail curls emerge from the card.
The web that forms on the doffer is removed in a continuous manner, by wired extractor cylinders which, rotating in an opposite direction to the doffer cylinder, are able to pluck the fibres and condense them in a web.
The latter is picked up, passed through a pair of smooth steel cylinders and through two flat belts, and accompanied into a conveyor funnel, which condenses the web turning it into a sliver. The sliver is pulled by a pair of cylinders. The lower ones are steel and have longitudinal furrows, while the upper ones are covered with rubber and are maintained pressed against the lower ones. With this pair of cylinders, the drawing operation takes place, increasing the parallelisation of fibres. The fibres are drawn no more than two times in this area. On delivery from the drawing unit, there is a system to control the presence of the sliver, and this system will stop the machine immediately if no sliver is detected.
The next sliver passes through another funnel and is distributed in a can by a special device called a coiler, composed of a pair of rollers (necessary for pulling and moving the material forward), of a condensation funnel carried by a plate equipped with a rotary motor (to distribute the sliver in the can in overlapping coils). Inside the can there is an aluminium or plastic plate, supported by a spring which serves to maintain the distance between the distribution plate and the sliver delivery point constant, in order to reduce the occurrence of false drafts in the section of sliver between its delivery from the coiler and the bottom of the can. In fact, as the material is deposited on the plate, the spring is compressed. While the sliver is unwinding from the card, the spring carries out the same function described, but in the opposite way, thus supporting the sliver upwards.

Automatic cleaning of the card

As the card produces a notable quantity of dust, it is necessary for aspiration by a pneumatic system to be continuous, equipped with recovery mouths, which can suck out contaminated air from various points of the machine and take it to the central conditioning system.
The main air removal points are:
• between the cylinder and feeder table and the licker-in cylinder;

- between the working flats;
- between the doffer and the removal cylinder;
- beneath the licker-in cylinder, the drum and the doffer.

As far as the discharge of impurities is concerned, this procedure is carried out regularly by the machine's central aspiration system both beneath the licker-in cylinder as well as in the flats.
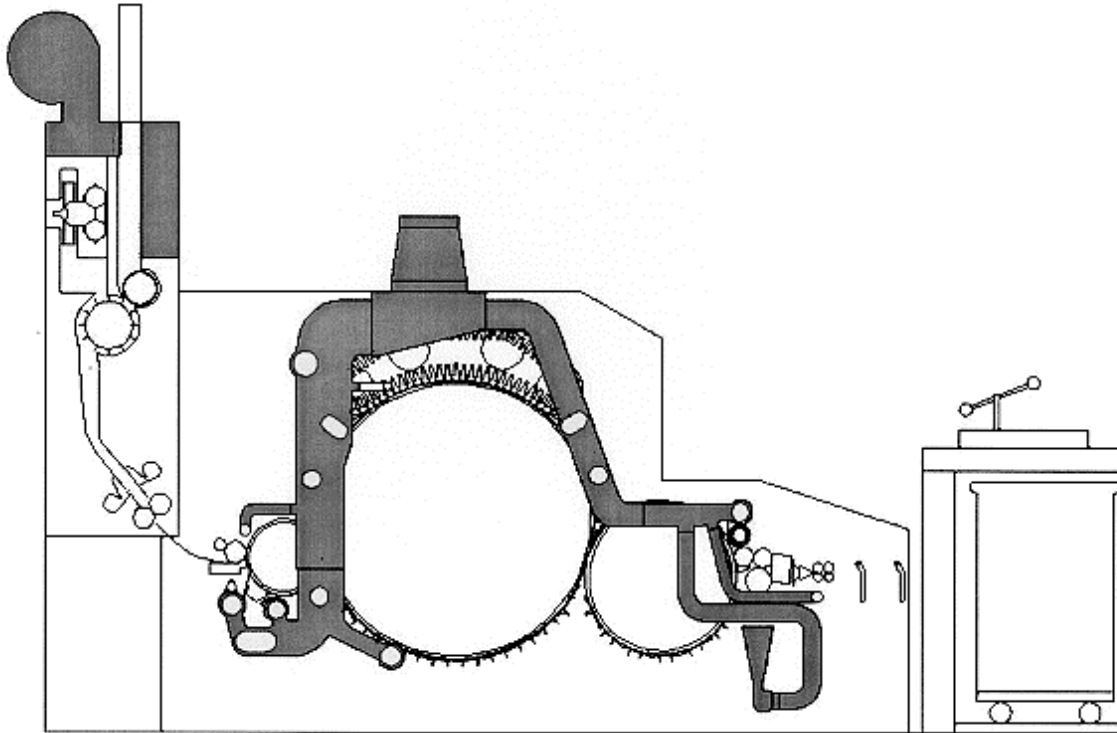
Fig. 25 The automatic cleaning system.

Sliver count autolevelling

The card sliver usually presents some variations in count (long-term irregularities) due mainly to the section of entry lap. Less frequently, sectional irregularities on short lengths of sliver are generated (the so-called short-term irregularities).
These are eliminated by the doubling of slivers on the drawframe.
A device called a self-regulator is used (Figure 26) to highlight the variations in count on the card. By varying the drawing action of the machine on the basis of the variations in the section of material, the device permits slivers to be obtained with maximum evenness.
The autoleveller is composed of:
- a measuring device which controls, on entry or on delivery, the section of fibrous mass being worked and sends signals with proportional intensity to the measured section;
- an electronic apparatus that processes and recognises the data sent by the measuring device and, if the difference between the measured value and the desired value is greater than the preset tolerance level, it sends electrical impulses to the draft variator;

- a speed variator controlling the movement of the autoleveller, that carries out the variation of the machine draft on the basis of the section of material controlled.

Depending on the position of the measuring and levelling devices, there are closed loop autolevellers when the measuring device is placed before the autoleveller or on open loop autoleveller when the contrary occurs.
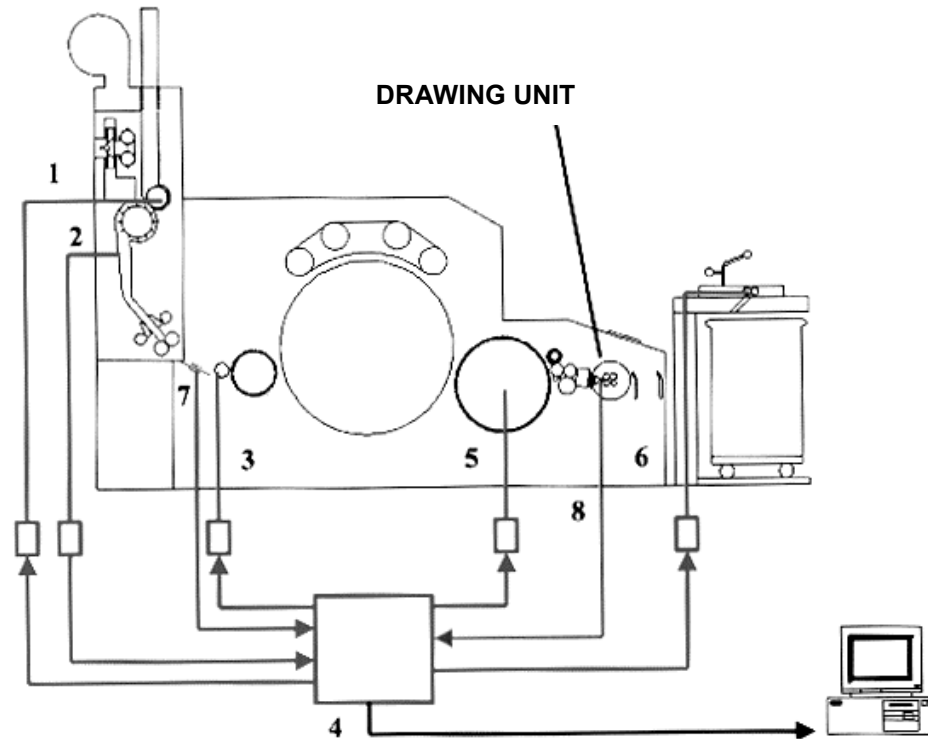
Fig. 26 An autoleveller for medium-period defects

1 Hopper feeder cylinder
2 Analogue pressure switch
3 Card feeder cylinder
4 Microcomputer
5 Doffer
6 Coiler
7 Lap thickness sensor
8 Funnel with monitoring sensor for quantity of sliver.

Recycling process waste

As a consequence of the spinning, weaving and knitting of the cotton and short-staple fibre being carded, combed or open-end spun, working of regenerated fibre has sprung up where regenerated fibre is intended as knitting waste, sub-products derived from the spinning cycle (flying fibres), the waste, the scraps from weaving (cut selvedges and so on).
Since the 1980's, this type of fibre has been recycled thanks to the conventional carded spinning system: they were in fact worked in sets of two or three cards and then spun on conventional ring spinning frames).

With the diffusion of open-end spinning frames, these fibres are now worked with the new technology that in just a few years has completely replaced conventional carded spinning.

The work stages of the cotton scraps have therefore become:
- unravelling of the hardest materials (knitted scraps, cut selvedges, flying fibres)
- beating of waste
- blending with virgin materials
- carding with a system dedicated to cotton fibres with the need to parallelise and open the fibres that are much shorter and opened to a much lesser degree with the lowest amount of waste possible.
- doubling and drawing (cotton drawframe). Essential for obtaining finer counts, this is inevitable in the case of coarser counts through the application of an autoleveller on the card and direct passage to the spinning frame.
- open-end spinning frame, fed directly by the card or the drawframe depending on the finished product.

The cards for regenerated cotton and for very dirty cotton must open and clean what cannot be opened in the preparation stage and must lead to the lowest percentage possible of waste, this type of fibre being extremely difficult to recycle a second time.

As can be seen from the diagram attached (Figure 27), these cards are equipped with a pre-opening unit made up of a pre-carding cylinder (diameter 700 mm) with a series of fixed flats with ordinary clothing. It is the task of this cylinder to pre-card the fibres.
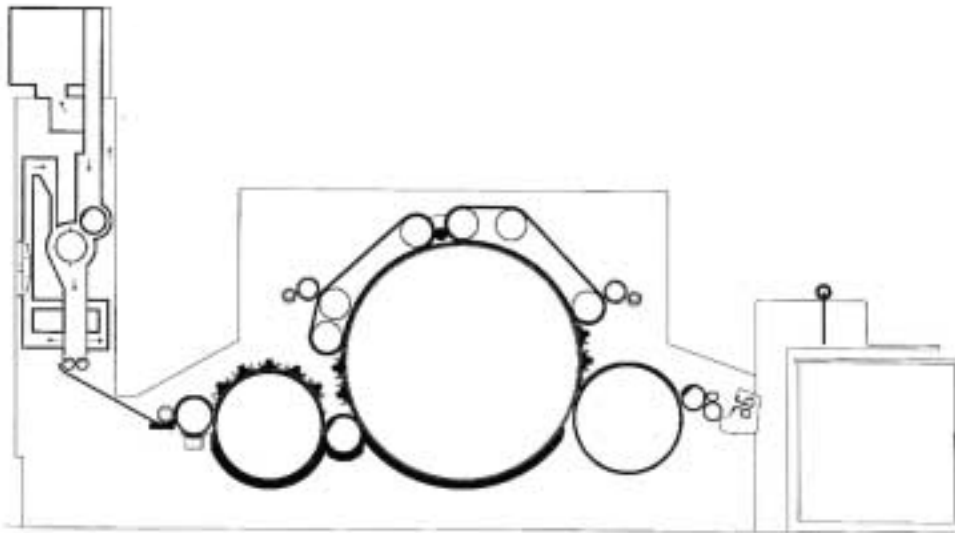
Fig. 27 Card for regenerated cotton

These cards have a main cylinder with a diameter wider than that of a conventional cotton card (1500 mm) which permits the application of a double set of flats (64 flats on drum entry side and 70 on delivery side) which permits a high carding action and improves the cleanliness of material on exit.

The drum speed varies from 300 to 450 rpm, while the flats vary from 100 to 400 mm a minute.

The speed of both the drum as well as the flats are variable to make developing the carding in function of the type of the materials used easier, bearing in mind that the fibres in this sector are very inhomogeneous. Machine aspiration is only employed to evacuate the dust that is generated during operation.

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A single waste knife for coarse material is applied on entry to the licker-in cylinder.

Flats fixed on the drum both on the entry as well as delivery make parallelisation of the fibres distributed on the drum easier and as a consequence permit them to be cleaned and opened.

Once the material is carded, it is condensed on the combing machine and it is conveyed by two transversal belts (indispensable for this type of working) that transport the web coming out of the web doffer in a funnel.

For carding operations immediately preceding the open-end spinning stage, on each card a sliver autoleveller is applied which, acting on the delivery speed of the sliver, and eventually on the material entry speed, means the variations in count on the sliver can be reduced.

In working materials involving passage through the drawframe (not possible with very short fibres or ones that are difficult to draw in a uniform manner) the evenness of the sliver fed to the spinning frame comes from both doubling the slivers from different cards as well as the autoleveller of the drawframe itself.

The passage through one drawframe (when possible) also permits the doubling of slivers from different cards and guarantees on the final sliver a perfect homogeneity not possible in the case of a direct passage.

On the basis of these considerations, open-end spinning of regenerated fibre permits a yarn to be obtained that reaches a maximum count of Ne 5 in the case of direct spinning after carding and yarns up to a count of Ne 20 in the case of passage through the drawframe.

When working with very dirty cottons and cotton waste, the card (having the structure that has been indicated) is equipped with additional aspiration points (under the licker-in cylinder and the main drum) so that it can remove as many impurities as possible from the material.

Doubling and Drawing

In preparing the fibre tufts for spinning, doubling and drawing represent two essential operations and their combined effect permits a sliver with a more regular section to be obtained (through doubling) equipped with parallel fibres (through drawing) as well as the count requested by the spinning plan.

The drawing operation done with the machine called the drawframe (Figure 28), permits a homogeneous blend both with fibres of the same nature as well as fibres with a different nature; the doubling steps are usually between four and eight.

On a par with fibre characteristics such as length and fineness, a sliver with parallel fibres permits a yarn with better regularity and resistance. The drawing depends on some factors such as the number of doublings carried out and the value of the count of the entry sliver and delivery sliver. With drawing, curls are also eliminated, meaning the fibres folded in on themselves, present in the carded sliver.
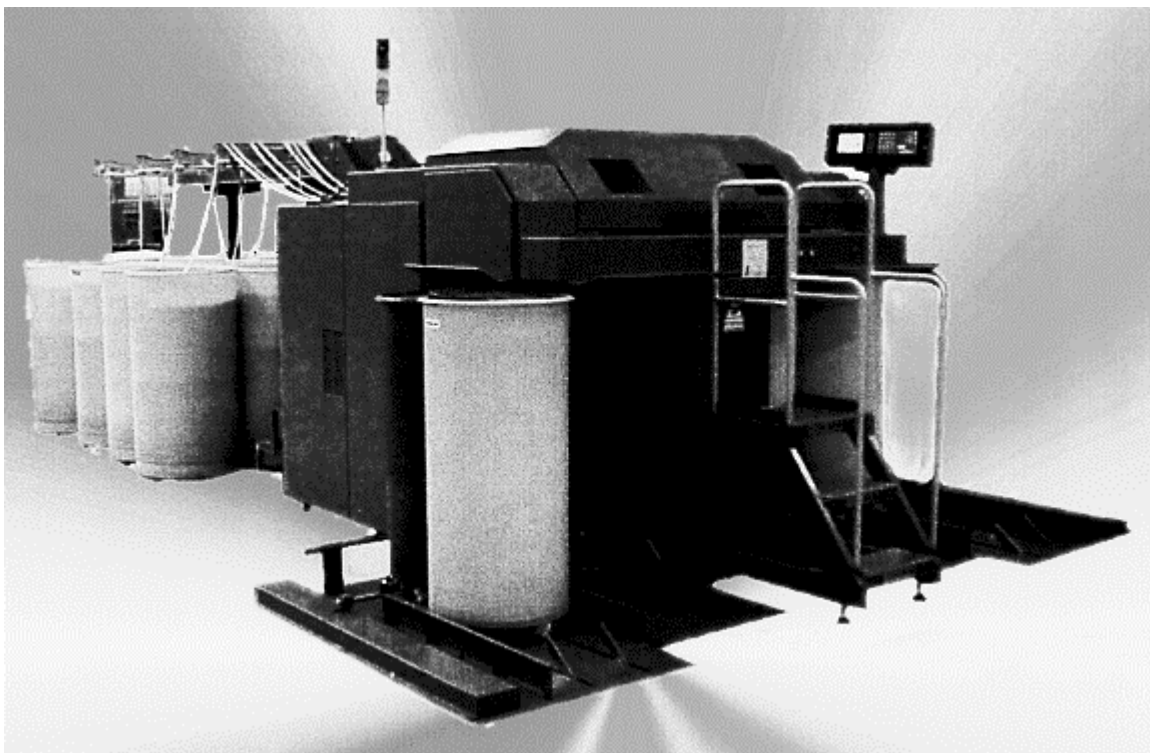

Fig. 28 Drawframe

Drawframe

The cans that contain the sliver are placed along the drawframe feeder rack, usually including eight pairs of cylinders (each pair is above the space occupied by a can): the lower cylinder is commanded positively, while the upper one rests on the lower one in order to ensure movement of the relative sliver that runs between the two.

Supported by the feeder rack, the slivers are pulled by the drawframe entry cylinders, which they join guided to lay beside each other on a well polished table. The system described notably reduces the so-called false drafts, which the slivers can be subject to. The false drafts occur when material of little consistency, such as the sliver or roving, is lengthened and is subject to excessive friction or unusual tension during the passage from one machine to another (but also on the same machine). The occurrence of false drafts depends therefore on the distance between the delivery or unwinding point and the material pull point, as well as on the smoothness or fluidity of the support and guiding parts.

Another important action taken to avoid false drafts, as mentioned above, is the use of cans with spring plates, using which it is possible to maintain a minimal and constant distance between the point the sliver unwinds and the pull cylinders.

Drawing aggregate

The *drawing aggregate* is composed of a series of lower cylinders called draft cylinders, below a series of upper cylinders with rubber sleeves called pressure cylinders.

The draft cylinders consist of single-piece steel bars or bars made up of perfect fitting sections; they must be perfectly cylindrical and have longitudinal grooves, so that the fibres can be grasped in the tangent point with the pressure cylinders and later come away easily, without getting tangled up.

The grooves can be either of two types: parallel or helical.

The draft cylinders have various support points in order to prevent them from or limit their bending and they glide on rolling bearings on the supports. It is important that the right diameter is chosen, as when the diameter is increased, the following occurs:

1) the lower cylinders travel at a slower angular speed and consequently there are fewer vibrations and less wear on the bearings;
2) the gripping arch of the cylinders is increased, permitting better control of the fibres;
3) the pressure of the upper cylinders is reduced and therefore there is a lesser load on the draft cylinders providing for a longer life of the covering, less wear on the bearings and a lower energy consumption.

The pressure cylinders are also made in steel and are covered with rubber sleeve; they have support pivots at their ends that fit into the special guides, establishing the position of the cylinders and providing the connection with the relative loading devices. The rubber sleeve must:

- provide excellent grip on the fibres, but at the same time it must offer a long life;
- resist the abrasion effect produced by the fibre and the draft cylinder;
- be elastic to the point of being able to recovery its original form after having been crushed on the draft cylinder;
- be non-adhesive in order to repel substances such as enzymes, wax, and sugar which tend to remain on the surface of the cylinder, interfering with the normal working process;

On the cylinder pivots, a certain load is applied, which permits a harder or less hard crush against the corresponding draft cylinders. The so-called load is exerted by air or spring pressure devices.

The pressure conferred can be subdivided into absolute or relative.

The former is obtained when maximum pressure is exerted on all the fibres that are between the cylinders, so the fibres assume the peripheral speed of the relative draft cylinder. The second is actuated when a simple control is carried out on the fibres being drawn, so that they can glide between the pair of cylinders without breaking, they are guided and accompanied and therefore do not float.

The uniformity of the drawn sliver also depends on the gauge between cylinders, meaning the distance between two adjacent cylinders on a drawframe. An incorrect gauge leads to a great quantity of floating fibres and therefore irregular sections. The gauge will depend on some factors such as: fibre length, the quantity of fibre to draw, the entity of the draft in the relative area (called partial draft), the degree of pressure from the cylinders in question, and the degree of parallelisation of the fibres. Generally the gauge increases as these values do.

As far as floating fibres are concerned, it is important to emphasise how the draft value essentially depends on the number of fibres present in the fibrous mass to be drawn.

In a draft zone, the fibres can be found in three positions:
- held by the pair of entry cylinders and then advanced slowly;
- held by the pair of delivery cylinders and then made to travel faster;
- loose, meaning fibres that are in the central part of the draft zone which shorter than others and not parallel, these are not held by either pair of cylinders.

If the loose fibres follow those held, problems will be avoided as they will then be gripped by the pair of delivery cylinders and then drawn accordingly. If the loose fibres follow those held by the pair of delivery cylinders, the fibres will float, meaning that the fibres will travel through the draft zone at a higher speed than the speed required for a normal draft, taking them further forward than where they should be. Therefore, with their irregular and periodical movement, these loose fibres give rise to what are known as draft waves.

Floating fibres cause lengths of sliver with variations of section that can be fine (referred to also as cuts) or coarse. The number of these defects is proportional to the number of floating fibres and the frequency of the waves.

The drafting set mounted on the drawframe can be divided into two categories:
- systems composed of three pressure and four draft cylinders;
- systems composed of four pressure cylinders on five draft cylinders, with an intermediate draft cylinder with a smaller diameter than the others and with pressure bar.
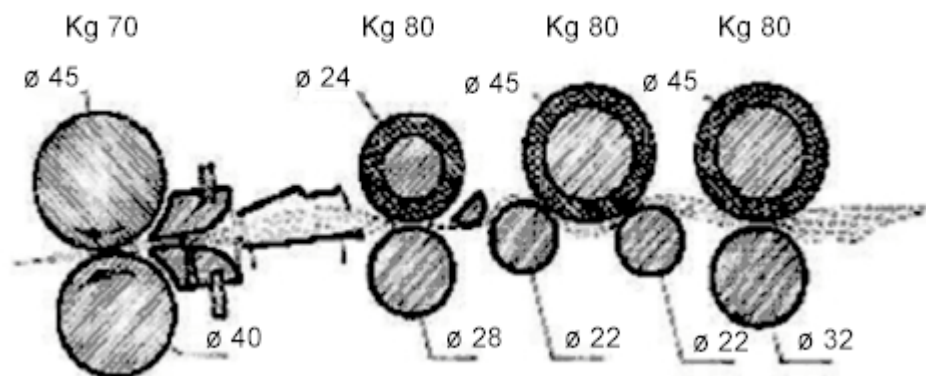

Fig. 29 Three- cylinder drafting unit on top of 4, with pressure bar

Pressure bar systems (Figure 29), used essentially when working with blends made up of fibres of different lengths, have a 3 pressure and draft cylinder unit and a cylindrical bar that does not roll called the pressure bar, located between the first and second pressure cylinder and connected directly to the latter by small arms at the ends. Therefore, it is located above the fibre band and it presses down while the fibre is travelling through the delivery area (area where maximum draft pressure is applied), forcing the fibres to adhere to one another. In this way the fibres are checked and well distributed during the draft, creating even slivers even at high speeds.
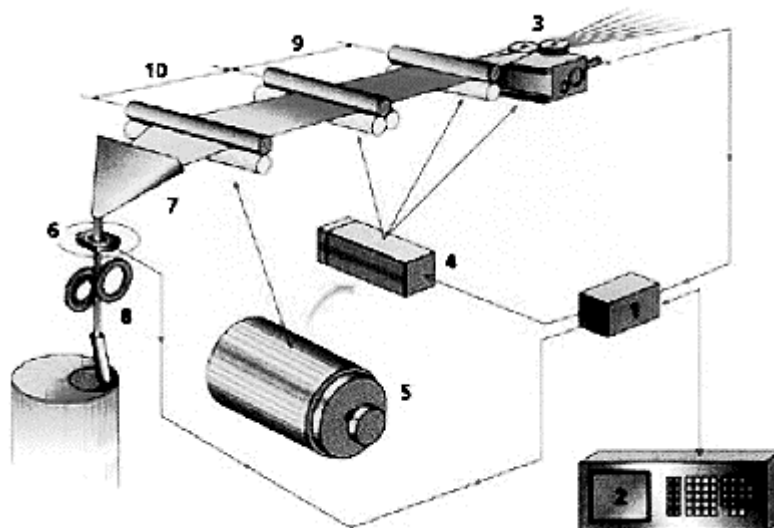
Fig. 30 Drawframe autoleveller

1 Autoleveller module	6 Monitoring sensor
2 On-board computer	7 Web condenser
3 Measurement unit	8 Delivery rollers
4 Servomotor	9 Pre-drawing
5 Main motor	10 Main draft

Like on the card, there are also autolevellers on the drawframes (Figure 30), whose job it is to correct the draft in function of variations in the fibrous mass, to maintain the section of sliver as even as possible and therefore reduce the frequency of breaking threads in spinning and in successive operations.

On the drawframe, the variations in sliver mass are detected by a measurement device (3) composed of scanning cylinders, and they are compensated for by a variable draft driven by a digital processor and a speed variator which drives some draft cylinders.

It is possible to obtain the following values on the drawframes:

- total machine draft, this can vary from around 6 to 9 times and usually affects the delivery area, where a partial draft of between 4 and 7 times is completed;
- partial entry draft, this can vary from around 1.2 to 1.8 times and affects the entry area between the last and next to last cylinder;
- the tension draft for slivers entering the pull cylinders and the entry cylinders of the drafting unit oscillate between 0.9 and 1;
- the web tension draft, between the delivery cylinders of the drafting unit and the pressure rollers, can vary between 0.9 and 1.

Combing

Fig. 31 Combing machine

The combing process is carried out in order to improve the quality of the sliver coming out of the card. The process eliminates short fibres, it achieves better parallelisation of fibres, it stra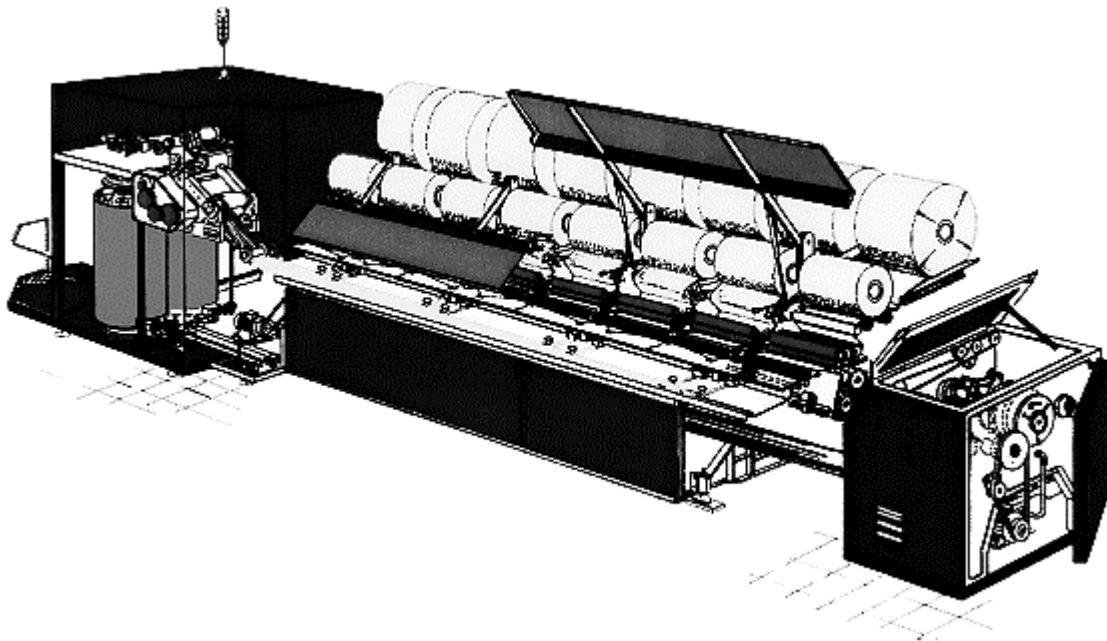ightens curls, and it removes neps and residue impurities. It is clear from these functions that the combing process is essentially aimed at obtaining excellent quality yarns and to fulfil this objective raw materials with above average physical and mechanical features must be used from the very beginning of the spinning process. Depending on what is being produced, waste from combing varies from 12% to 25%, and this can be employed to obtain yarns with a medium-coarse count using the open-end process.

As far as parallelisation of curls is concerned, when curls are combed they tend to behave in a very similar way to short fibres and therefore if they do not straighten they are removed, and this produces a notable amount of waste fibres; it is therefore necessary to reduce the curls before the combing stage. Some of the "curls" straighten when drawn in the combing preparation stage. Furthermore, it is a good idea for the curls to be presented head first to the combing machine, as the latter are to a large extent straightened by devices on the combing machine. The direction of the curls depends on the number of passages the material is subject to following carding, as between one passage and another the direction of the material is inverted and consequentially the curls are too. Therefore, considering that mainly tail curls come out of the card, in order for them to arrive at the combing machine as head curls, it is fundamental to carry out an even number of preparation passages, usually two, one to the drawframe and one to the lap drawing frame.

The lap drawing frame has, furthermore, the task of forming the interfacing, which is employed to feed the combing machine. The interfacing is obtained by doubling a certain number of slivers (from 16 to 32) previously subject to a drawing passage. In the lap drawing frame, the material undergoes a light draft of around 1.5 to 2 times one a drawing aggregate of the type 2 on top of 3 cylinders.

40

Combing machine

The combing machine is composed of eight combing heads which produce slivers which, later, are doubled four on four by a drawing aggregate of four on top of five cylinders to make two slivers which are taken to the collection cans. Each combing head is composed of feeder rollers which hold the web and rotate it perfectly, without varying the structure. The rollers rotate slowly with continuous drive and bring the web forward to a combing unit made up of special nippers (Figure 32) which must hold the fibres during the combing stage and take them to the device which gathers the tufts.
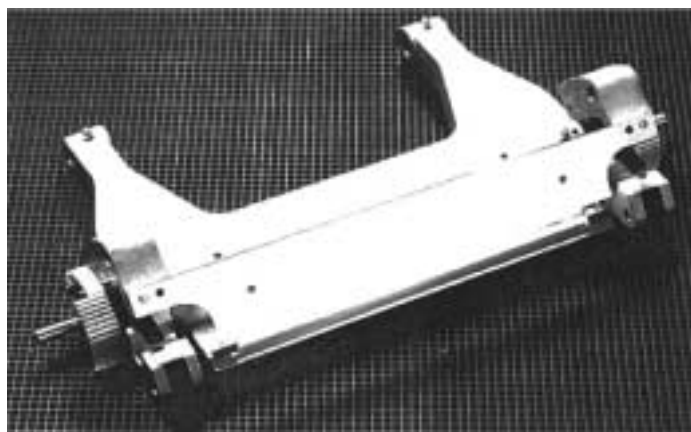
Fig. 32 Combing machine nipper

The nippers are formed of two square aluminium plates, called "lower jaw" and "upper jaw". The first acts as a feeder table for the web, while the second holds the tuft. During the combing cycle, the nipper has an alternating movement, it can be all the way back and closed to hold the fibres during combing or in an all-forward open position to favour the separation between the combed tuft and the advancing web. The feeder cylinder is located above the "lower jaw". It follows the movements of the "lower jaw", it rotates intermittently, drawing the web forward a certain distance at each stroke of the combing device. The feeding can take place in one of two ways: feed with nipper moving forward or backward. From empirical trials, it has been established that backward feeding offers better benefits in terms of separating waste and in the combing effect.
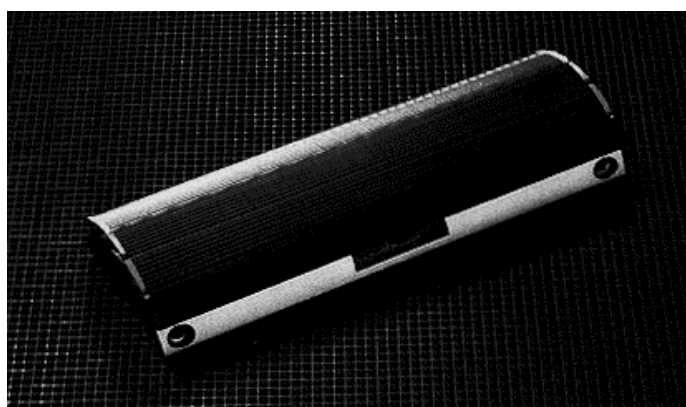
Fig. 33 Circular comb

The combing element takes the name of circular comb (Figure 33). It is without a doubt the most important device on the machine, it is composed of a circular sector covered with needles covering around a quarter of its circumference and the density of its needles differ from the first lines to the last. The circular comb turns quickly in a positive direction and the needles, penetrating the tuft of fibre to comb, remove the fibres that are not clasped by the nippers, and parallelise the others. The circular comb completes around 200-250 rpm. To eliminate the fibres caught, a cylindrical brush penetrates the needles on the circular comb removing all the waste and an air current removes it, taking it towards the collection bins before the next combing stage begins.
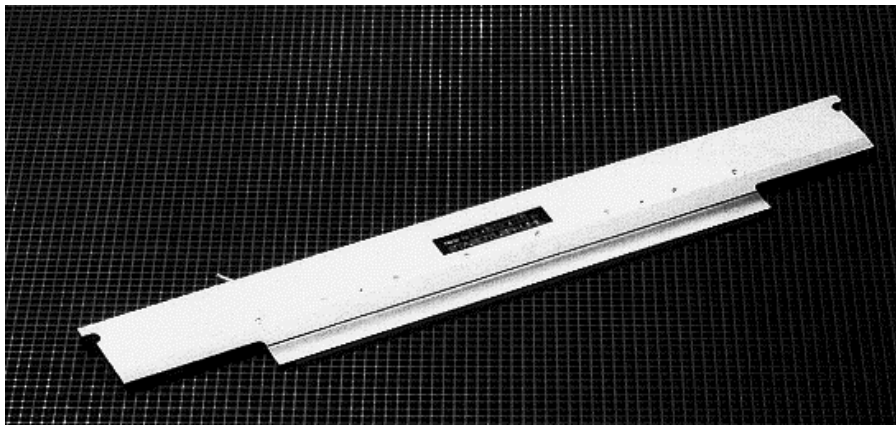

Fig. 34 Linear comb

The fibres which are clasped in the nipper following the passage through the circular comb, are again combed by the linear comb (Figure 34). This is made up of a bar covered with very dense needles positioned almost vertically between the nipper and the device that allow the tuft to travel forward.

The task of the linear comb is to straighten and therefore parallelise the fibres folded towards their tail ends and pick out the folded fibres, letting past those successfully combed and holding back the others which will later be combed. The device that takes the combed tufts forward is made up of two pairs of small diameter cylinders which are called drawing off cylinders. The upper cylinders are covered with rubber, the lower ones are grooved metal.

They rotate alternatively and intermittently in the two directions, in order to remove the combed tuft from the small lap and condense it with the previous one, giving rise to a continuous fibre web. Initially they rotate in a negative direction bringing back a section of the previous tuft, then in a positive sense overlapping the latter with a part of the tuft, which is then drawn off by the small lap, drawn and brought forward a certain degree.
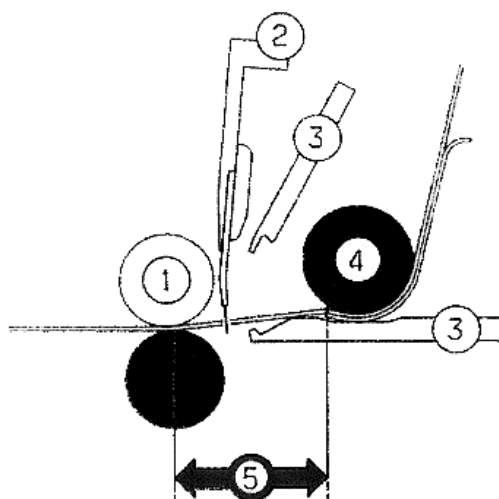
Fig. 35 Detail of a combing machine
    1 Drawing off cylinders
    2 Linear comb
    3 Nipper (upper-lower jaw)
    4 Feeder cylinder
    5 Tuft.

The fibrous material comes out of the drawing off cylinders in the form of a web, and this passes between one pair of cylinders, whose task is to provide the necessary consistency, to then pass into a condensation funnel and the small rollers which transform the web into a sliver. The latter is dragged on a very smooth table to prevent any friction, it turns ninety degrees and is taken next to the slivers coming out of the other heads of the combing machine.

At the end of the table the slivers enter a drafting unit, very similar to the one on the drawframe, and are doubled and drawn to obtain the combed sliver, which is then taken by the rollers and the distribution plate to the collection can.
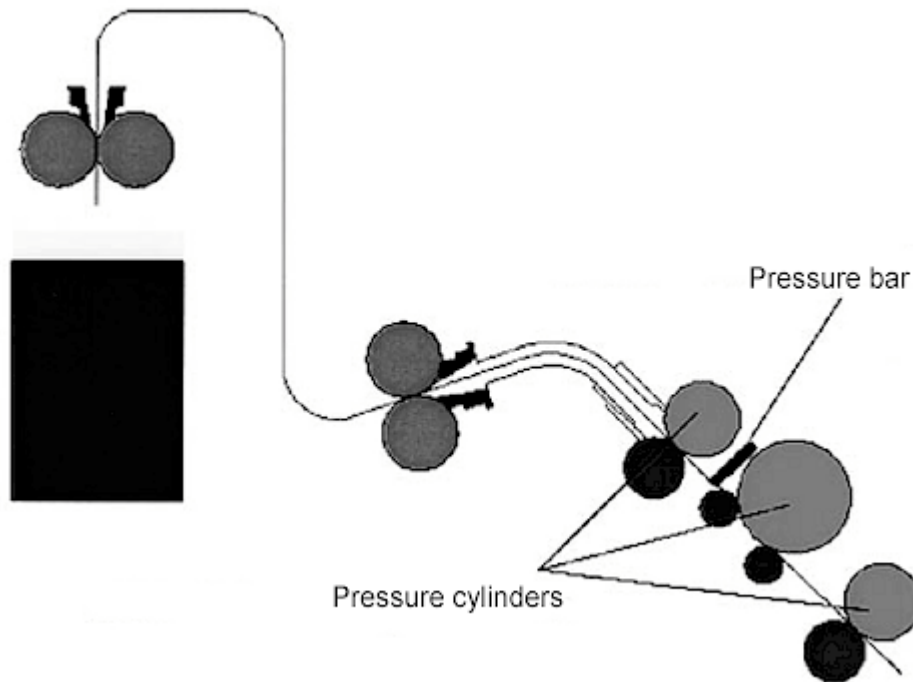
Fig. 36 Detail of the drawing aggregate

Combing stages

The devices on the combing machine are well synchronised with each other and a combing cycle is completed in the time it takes the circular comb to complete one turn. This cycle is divided into three stages:

1) combing of the tuft
2) backward motion of the previous tuft
3) condensing of the tufts.

The movements of the devices on the combing machine are as follows:

1st stage: the tuft is combed
The nipper moves backwards and closes, leaving a section of fibrous material protruding and this is the tuft to comb. The length of the tuft is around 10-15 mm and is given by the minimal distance between the nipper and the drawing off cylinders plus the section fed. The circular comb penetrates the tuft with its needles and removes the fibres which are not held by the nippers along with the neps and foreign matter. The feeder cylinder, the linear comb and the drawing off cylinders remain still.
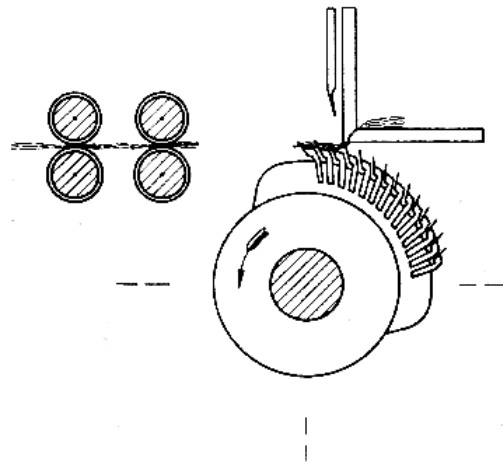
Fig. 37 Combing action

2nd stage: the previous tufts move backwards.
As the last needles on the circular comb leave the tuft, the drawing off cylinders rotate in a negative direction taking a section of the fibrous web back by around 5 cm. The nipper advances towards the drawing off cylinders and opens. The feeder cylinder, the circular and linear combs and the stripper cylinders remain idle.
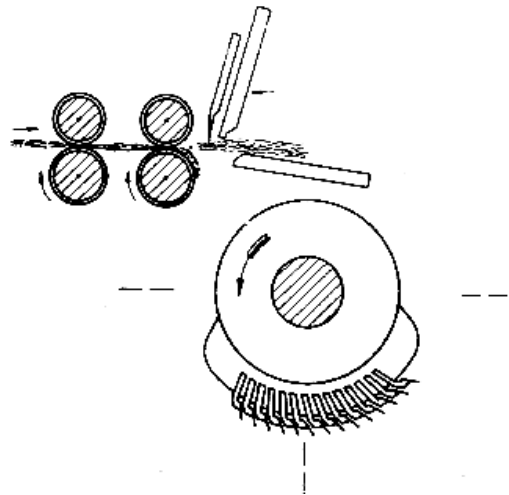
Fig. 38 Moving backwards

3rd stage: condensation of the tufts
The drawing off cylinders rotate in a positive direction, bringing forward the fibres towards the exit of around 8-9 cm. The linear comb sinks its needles into the tuft, preventing the uncombed fibres from advancing. The nipper, completely open, reaches the minimal distance from the drawing off cylinders and then reverses its direction. While the nipper moves backwards, the feeder cylinder rotates, taking the small lap forward by around 4-6 mm. The circular comb is not in action.
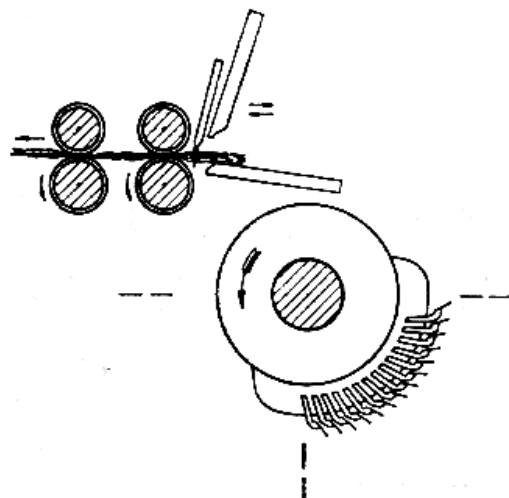
Fig. 39 Condensation

Spinning

Following the drawframe stage, the slivers undergo the final passages towards being transformed into yarn, which are the following:

Cycle of carded cotton

Spinning	Roving frame
	Ring spinning

Cycle of combed cotton

Roving frame
Ring spinning
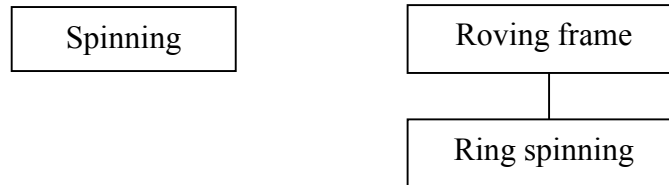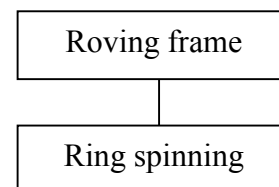
In both types of spinning, the yarn undergoes the following packaging and finishing operations, not necessarily carried out in the order given.

      Winding

      Waxing

      Singeing

      Doubling and twisting

      Reeling and winding off

These steps do not necessarily apply to all yarns, therefore the order is only indicative. As the individual machines are described, the function and eventual combination of various operations will be stated.

Roving frame

The task of this machine is to transform the sliver coming from the drawframe into roving.
It is present in the carded ring spinning cycle and in the combed ring spinning cycle, in the first case it is found following the post-carding drawframe (one or two drawing steps), while in the second case after the post-combing drawframe.
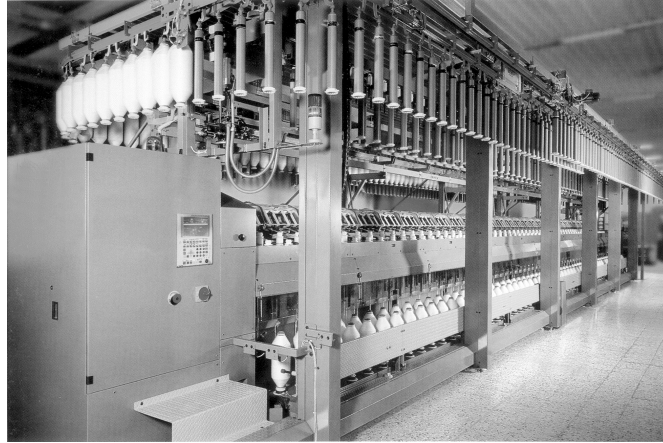
Fig. 40 Roving frame with automatic doffer

Transforming the sliver into roving occurs in a continuous manner through three stages:
* drawing
* twisting
* winding

Drawing is generally carried out by a draft system with 3-cylinder weighing arm with double apron capable of working with entering sliver counts of 4900 tex to 2460 tex (0.12 Ne to 0.24 Ne) and counts of the delivered roving of 2200 tex to 200 tex (0.27 Ne to 3 Ne).

The draw value that can be achieved has a range of between 4 and 20 and can work fibres of a length up to 60 mm.
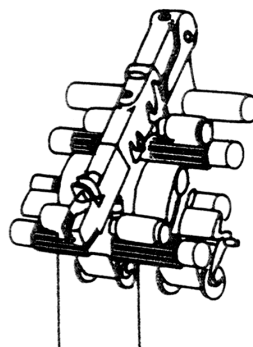
Fig. 41 The drafting system

It can be seen in the figure that the drafting system has a normally low preliminary draft of between 1.2 and 2, while the more consistent draft comes from the main draft area given by the action of the aprons, permitting better control over the movement of the fibres.

Overall drawing can also reach values of 20, but generally the process is carried out with lower values for better final results.

The twist is given by the rotation of the flyer located on the spindles, in fact the exit roving coming from the draft cylinders enters in the higher hole of the flyer, passing through the hollow arm and then winding on the bobbin.

The twist value is given by the following equation:

$$\text{No. twists} = \frac{\text{Revolutions of the spindle (flyer)}}{\text{Exit length 1st cylinder}}$$
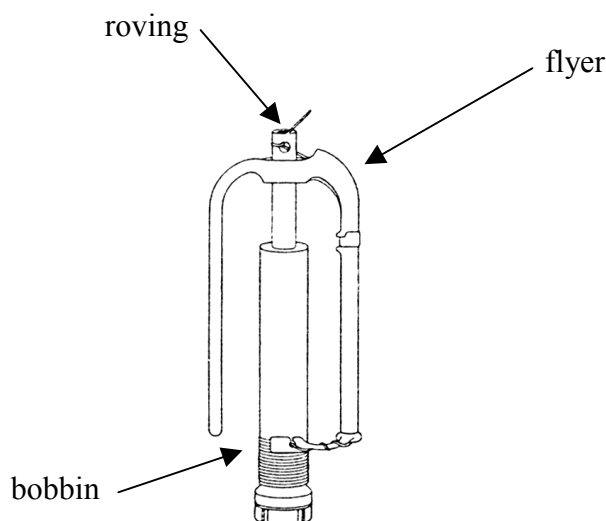
Fig. 42 Flyer and bobbin

The number of revolutions of the spindle can reach up to a maximum value of 1500 rpm. The twist rate given by the roving has a value of between 10 – 100 T/m (0.25 T/inch).

It should be noted that the twist value to give the roving, this being an intermediate product, has a fundamental practical importance for the next processing stage.

The minimal value limit must guarantee even working of the roving during feeding to the spinning frame, while the maximum value must not impede the draft action of the fibre gliding to the spinning frame.

The thread is wound by the action of the bobbin rotating at a higher speed than the flyer (spindle), in order that on every turn the bobbin makes in addition to the spindle, a coil of roving is wound on the bobbin. The length of coil is shorter for the first layers and longer for the last.

To keep the length of the wound roving and the number of spindle revolutions constant in the unit of time, it is necessary for the bobbin to gradually reduce its rotation speed as layers are formed over layers, and this must be inversely proportional to the winding diameter for all the successive layers of roving added to the bobbin.

The distribution of the roving along the bobbin is given, on the other hand, by the upward and downward movement of the carriage; because of the frustrum shape of the bobbin on each layer wound the distribution height is reduced, but the winding diameter increases with a consequential increase in the coil length of the roving wound and the time taken to wind the coil.

Even the translation speed of the carriage must be reduced in order to maintain the same pitch of the winding helix for all layers.

In conclusion, bearing in mind the fact that the feed to the roving from the draft cylinders is always constant, at each layer there is a progressive reduction in the number of revolutions the bobbin makes and the translation speed of the carriage is diminished, which reduces its travel at every layer.

These variations occurred in conventional machines through speed variators (eg pairs of cones) for the carriage translation speed and the variator plus a differential for the bobbin rotation speed.

In modern roving frames, the commands for the various functions carried out are given by various motors (see Figure 43) independently coordinated by a central machine control system, permitting better functioning and a reduction of energy consumption and noise level.
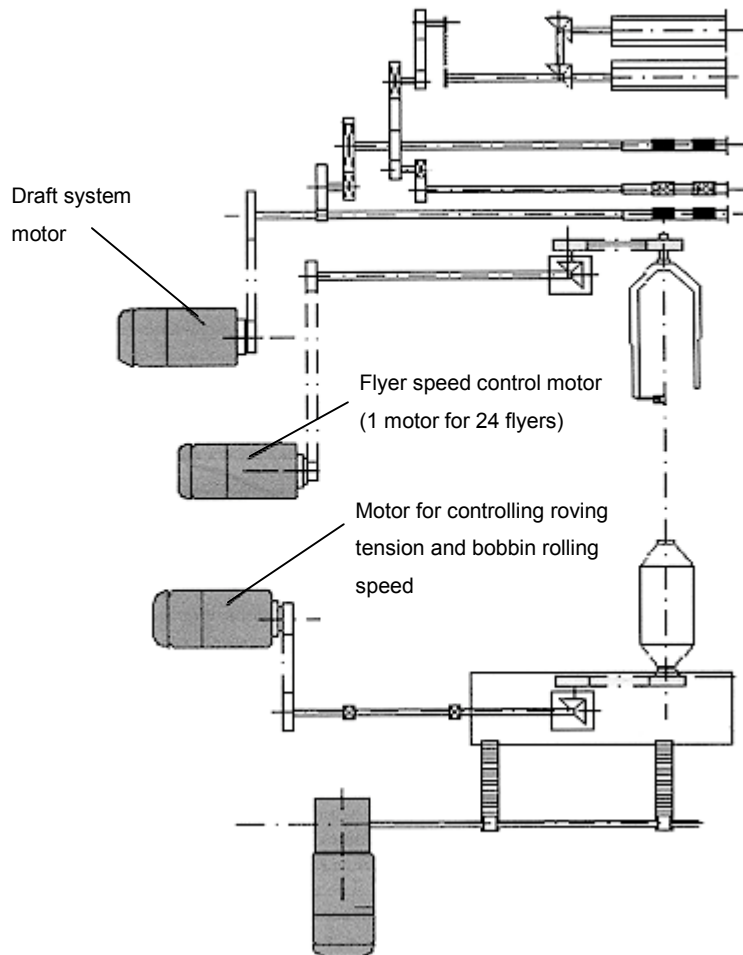
Fig. 43 Roving frame motors

Furthermore, the central machine control system is capable of maintaining control over all technical parameters, all data is stored and can be recalled immediately upon demand.
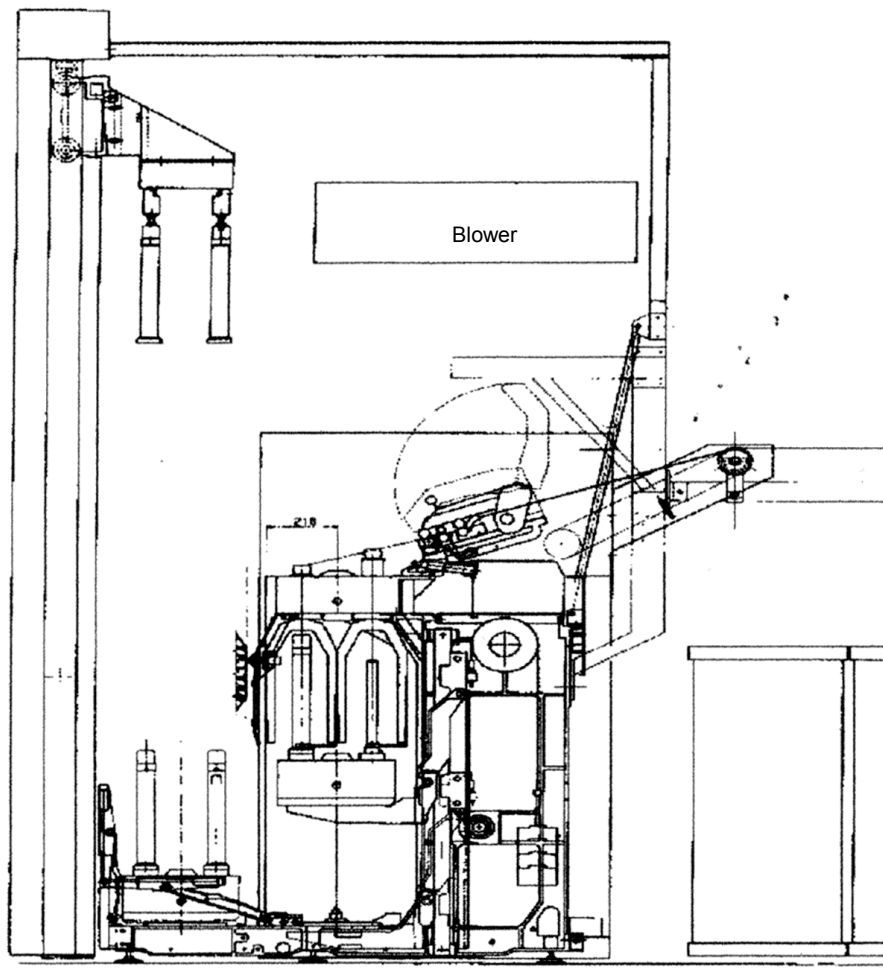
Fig. 44 Functional diagram of a roving frame

A modern roving frame can normally carry up to 120 spindles.

The roving frame can be unloaded of bobbins manually or an integrated automatic removal system can be used which provides an automatic suspended link between the roving and spinning frames.

Electronic apparatus is used for quality control of the roving from the frame by controlling the count, twist and evenness of the section.

Calculating output

An example of calculating machine output:
Count delivered Ne 1, twist 47.24 T/m, spindle speed 1200 rpm, No. of spindles 96.
Theoretical linear production = 1200/47.24 x 96 x 60 = 146,316.68 m/h.
Pondered theoretical production = 146,316.68 x 0.59/1 = 86,326.84 g/h
Real production with performance equal to 92%: 86,326.84 x 0.92 = 79,420.69 g/h.

Ultimate spinning

This term describes final operation needed to obtain yarn.

In cotton spinning, the following machines are used:

- **cycle of carded cotton: ring spinning frame, open-end spinning frame**
- **cycle of combed cotton: ring spinning frame**

Ring spinning frame

The ring spinning frame, commonly called the ring, is the conventional spinning system and it transforms the roving from the roving frame into spun yarn using the operations of:
- Drawing
- Twisting
- Winding
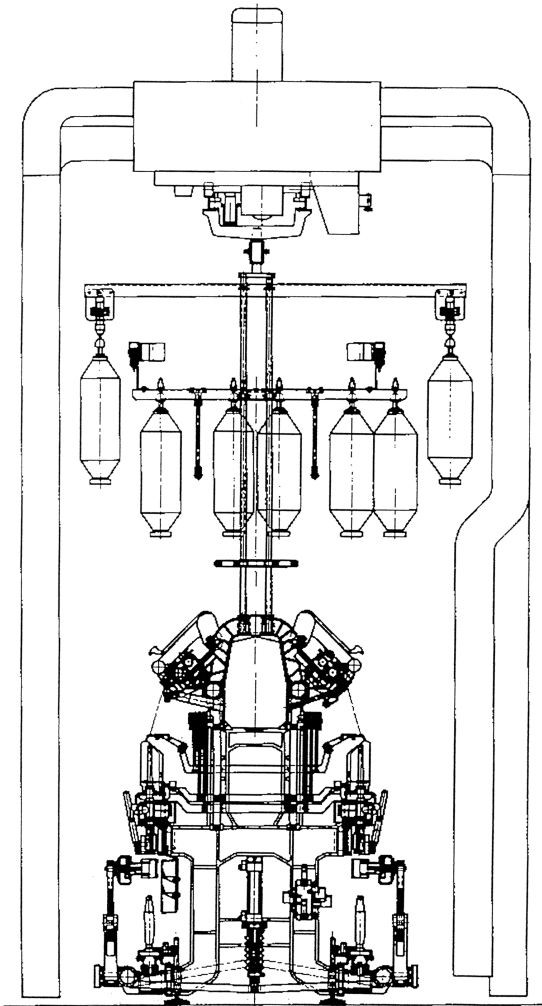
The following figure shows a functional diagram of a ring spinning frame.

As can be seen in Figure 45, the fixing area for the roving bobbin of the machine is in the upper part, the draft is imparted is made in the central area and the lower part is home to the bobbin rail.

A modern spinning frame can hold a high number of spindles, which generally vary in blocks of 24 spindles from 384 to a maximum of 1080 with a gauge of 70 mm and 1008 for a gauge of 75 mm.

Fig. 45 Ring spinning frame

The draw is made with a "3 on 3" system with double-apron drafting system with pressure generated by a weighing arm system. The drafting unit is in an inclined position compared to the ground in order for the twisting to be started the moment the fibre leaves the first draft cylinder where twisting is avoided to prevent the yarn from breaking.

The drafting unit system is capable of working fibres of up to 60 mm (carded and combed cotton, blends and chemical fibres) with draw values of between 10 and 80.
The roving is first subject to a preliminary draft with values of between 1.5 and 2 and successively a main draft in the apron area until the desired count is achieved.
The spinning counts are between Ne 5 and Ne 150 (118 – 4 Tex).
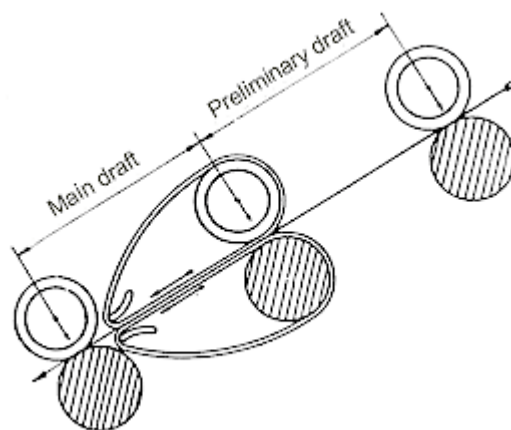
Fig. 46 Scheme of the drafting unit

On conventional spinning frames, when the fibre comes out of the draft cylinders, the so-called "spinning triangle" is formed, which is a cause of breakage, unevenness and yarn hairiness. To eliminate the spinning triangle, the fibres must be condensed before they leave the draft cylinders.

Now, compact spinning systems have been developed, also called condensation systems, which are able to compact the fibre before twisting eliminating the spinning triangle and integrating all the fibres including short ones. Compacting has a notable influence on the structure of the yarn and it consequentially improves physical and mechanical properties leading to better evenness and strength of the yarn. These factors have provided a fundamental contribution to progress in the spinning and weaving process.

The compact spinning system, represented in Figure 47, is made up of a pair of 4-4' entry cylinders, a pair of 3-3'cylinders with apron, the pair of 2-2' delivery cylinders from the aspiration tube A with latex apron G and 1 delivery cylinder. The first two draft ranges are in common with those of normal spinning with the same problems faced during operation (waste, pressure and so on). The S tube, subject to depression, presents a opening between A and B, the fibre bundle previously drawn is then subject to depression and condensed between point A and point B of final gripping. The pressure cylinder 1 is moved by a toothed wheel on the pressure cylinder 2'.

In the section A – B, condensation occurs, helped also by the opening in the aspiration tube which is at an angle compared to the direction the fibre is moving in order to give the bundle of fibres the desired twisting on their axis, an important factor in working short fibres.
Condensation occurs until the final exit point and this reduces the spinning triangle to a minimum.
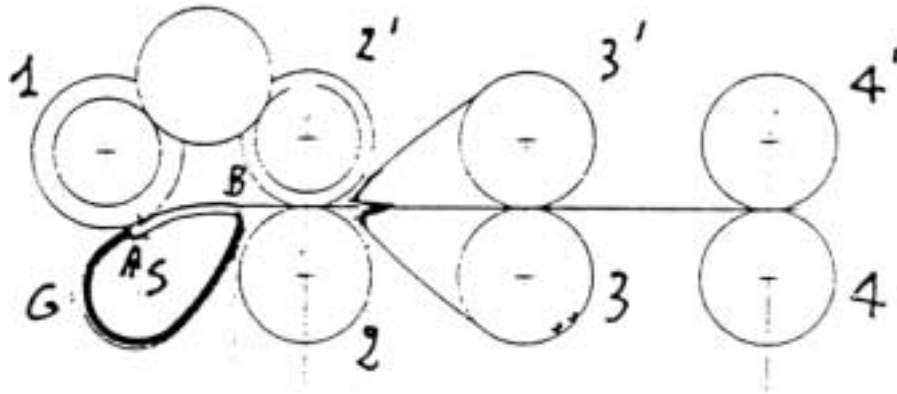
Fig. 47 Model of compact spinning

Fibre can be condensed by systems different from the one illustrated. However, all systems require the presence, at the exit from the main draw field, of a cylinder with aspiration capabilities for condensing the fibres eliminating the formation of the spinning triangle.

A   B
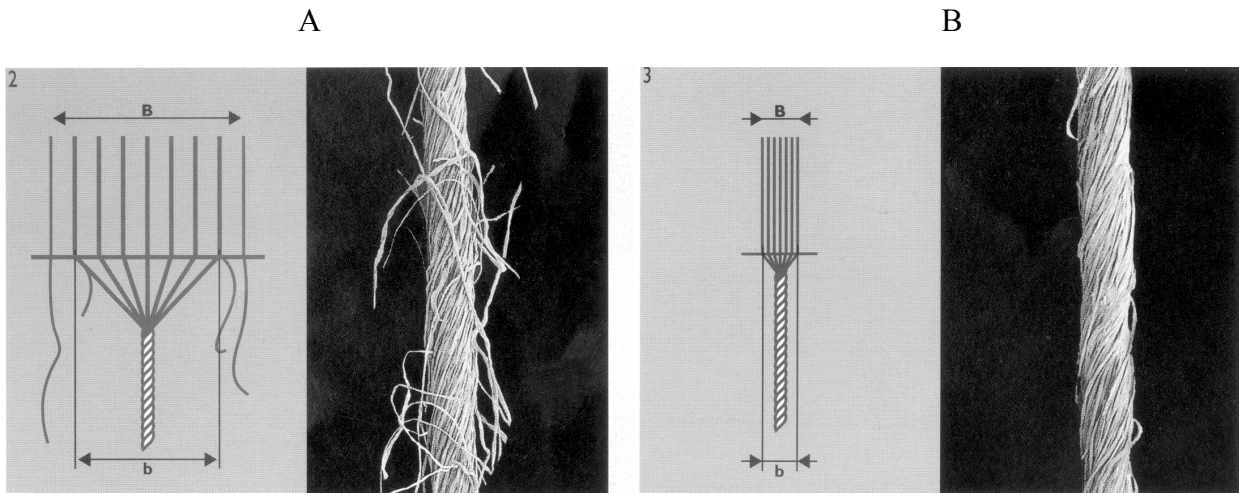
Fig. 48 Comparison between a normal ring-spun yarn (A) and a yarn produced (B) with the condensation technique

A modern ring spinning frame adopts two separate commands using brushless motors for the draft cylinders. With this system, the draw parameters necessary for changing the count are set on the command panel without requiring any equipment to be changed.

The yarn, on delivery from the draft cylinders, passes through a yarn guide and then through a traveller, and then it is wound on the tube fitted on the spindle.

The effective twist is that given by the number of rotations made by the traveller, whose rotation is caused by a dragging action and which is subject to variations in speed depending on the winding diameter, varying during the formation of each individual layer of yarn on the bobbin due to the effect of the vertical movement of the rail. These differences in twist are in part compensated for in the axial rewinding of the yarn, because as the diameter of the bobbin varies coils are added or removed with a criteria opposed to what previously happened in function of the different speed of the traveller.

In practice, the twist is conventionally taken from this formula:

$$\text{No. twists} = \frac{\text{Number of spindle revolutions}}{\text{Exit length 1st cylinder}}$$

The direction of twist S (left) or Z (right) depends on the direction of spindle rotation.

The number of twists is measured in twists per metre (T/m); for cotton yarns, the T/inch is also used as a measurement.
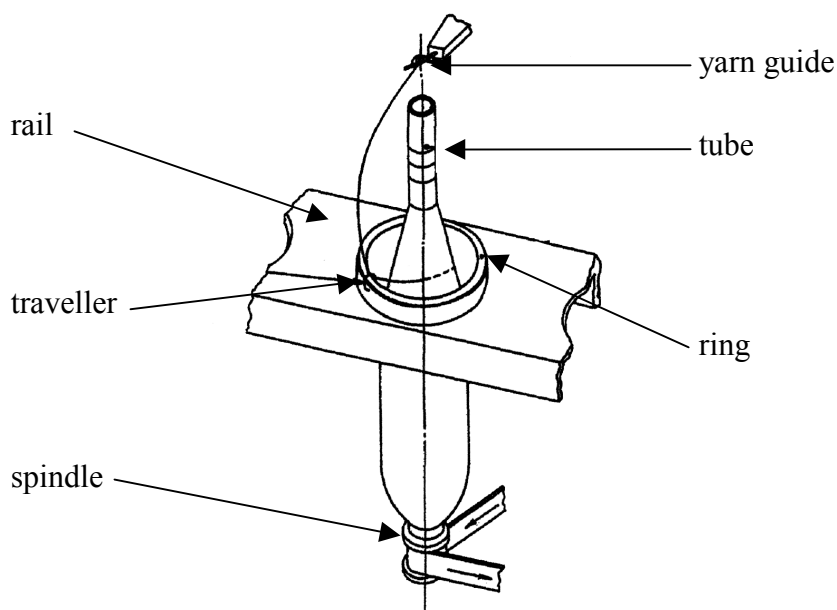
Fig. 49 Ring and traveller system

The spindle speed on a modern spinning frame reaches 25,000 rpm, with the possibility of giving the yarn a twist of between 4 and 80 revolutions/inch (158 – 3150 revolutions/m). The movement of spindles on the spinning frame is driven by a tangential double belt drive system, saving much energy.
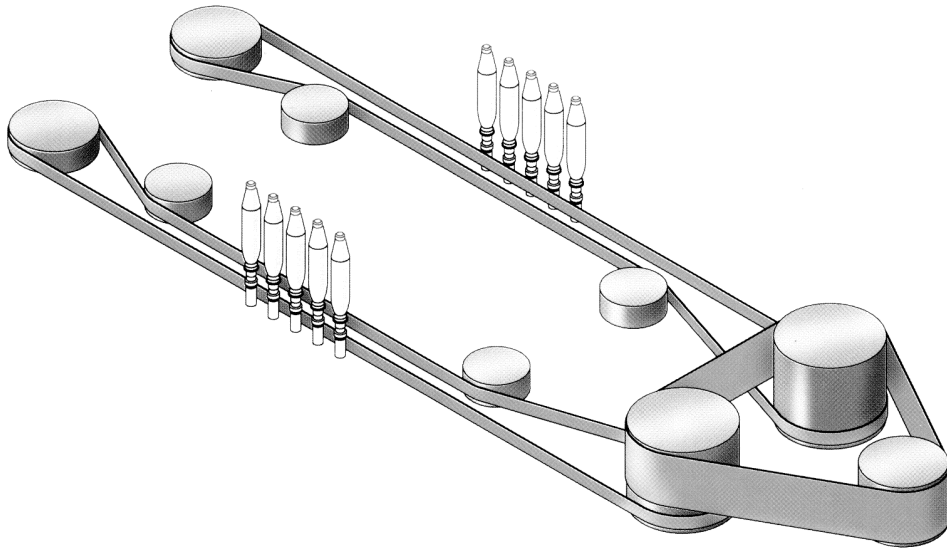
Fig. 50 Tangential spindle drive system

The twist number (T/m) and direction (S or Z) to attribute to yarns depends on the type of fibre and features required by the yarn according to its application.
The calculation of the number of twists is given by the following formulae:

$$T/m = km \cdot \sqrt{Nm}$$
where: Km coefficient of twists in rpm.
Nm Metric yarn count

$$T/inch = Ke \cdot \sqrt{Ne}$$
where: Ke coefficient of twists in twists/inch
Ne English yarn count

$$T/m = \frac{Ktex}{\sqrt{Tex}}$$
where: Ktex: Tex coefficient of twist in T/m
Tex: Tex count of yarn

The twist coefficients are determined practically in relation to the characteristics of the cotton being used and the type of yarn, depending on the use for which it is destined.

The traveller, traditionally in steel, is the most delicate part of the machine, as it is not able to support high speeds. When the spindle travels at high speeds, friction is created that could cause the traveller to heat up and get damaged.

Therefore, as the traveller speed determines the revolutions of the spindle and the diameter of the ring, for fast spindle speeds the diameter of the ring must be contained and as a consequence, so must the bobbin.

For example, a spinning frame can have ring diameters that vary between 36 and 54 mm with spindle gauge of 70 – 75 mm and a tube height of between 180 and 260 mm.
There are three fundamental shapes of the travellers, called C or M or elliptical

54

The figure below represents the three types.

"C"　　　　**"M"**　　　　**"Elliptical"**　　　　**"Oval"**
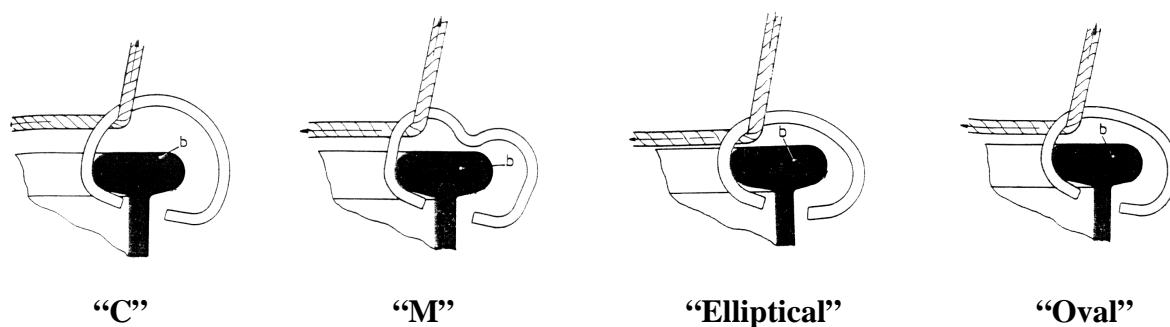
Fig. 51 Travellers

The "C" type ring guarantees space for the passage to thread, but it presents a high barycentre (b), the "M" type has a low barycentre to guarantee the passage of the yarn, the elliptical type ring has a low barycentre, but offers less space for the passage of the thread.

The latter is preferred because it has the lowest centre of gravity in the point of contact with the ring, establishing a position of equilibrium so that the contact with the ring is determined in a single point of the internal flange, making friction minimal to guarantee passage of the yarn. Combining the type "C" with the elliptical one, a type of traveller known as "oval" is formed which maintains the advantages of the elliptical traveller but provides a larger space for the yarn to pass. The section of yarn that goes from the traveller to the fixed thread guide in its rapid motor driven motion around the ring is subject to a combined action of centrifugal force and air resistance, so it swells forming a particular curve called "balloon". An excessive balloon effect leads to a maximum size, larger than which the balloon becomes plaited causing the thread to break.
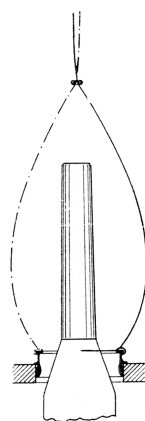
Fig. 52 "Balloon" effect

It is important therefore to limit the diameter of the balloon by reducing the distance between the thread guide and the traveller using special limiter rings.

Another efficient system, used for coarse yarns, uses cutting edge spindles to collapse the balloon effect.

Winding occurs with the winding of the yarn on the tube forming the bobbin, the dimensions of this vary from machine to machine depending on the diameter of the ring and the height of the tube. The distribution of yarn on the bobbin is given by the up and down movement of the ring rail. The rise time is about three times longer than the descent time, in order to provide better compactness for the bobbin when the coils of wound yarn cross.

In addition, the rail travel (an equal width on each layer) is progressively moved upwards by a particular device, the extent of the movement must depend on the yarn count. For coarse yarn the upward movement of the rail must be more rapid as it winds a shorter length of yarn on a par with the weight of the bobbin, and the opposite happens for a finer yarn.

The length of yarn wound on each rise and descent travel of the rail is called run-out.

The weight of the bobbin can vary from around 50 to 100 grams.

In order to maintain a clean yarn, the spinning frames used nowadays are equipped with systems capable of removing dust and fibre residue that can form during processing. If the yarn should break, a particular aspirator tube collects the fibre as it leaves the draft range. There are special cleaning systems for the draft cylinders, while a travelling cleaning system made up of flexible tubes mounted on suspended tracks takes care of general machine cleaning.

One manufacturer has designed and made a system called Wondercleaner made up of a travelling cleaner and reserve yarn cleaner. The cleaner at the base of the spindles is hooked to a travelling blower between the two doffers only when it is needed to be used. This cleaner cuts the coils of yarn wound around the base of the spindle and the blower sucks them up rather than leaving them fall to the ground. With this system, efficient for every count, the actual cutting yarn blades are removed and a cleaner room results.
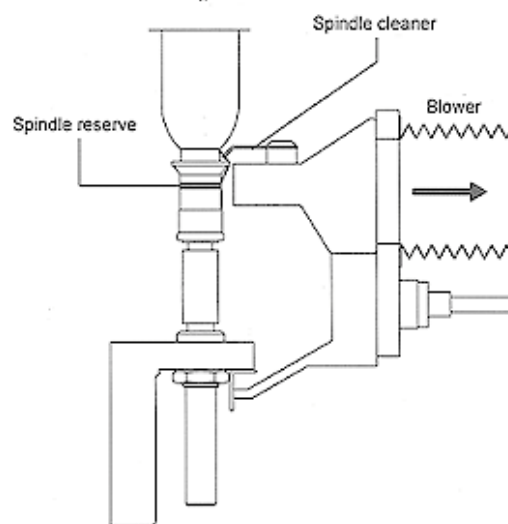
Fig. 53 Detail of the Wondercleaner system

The spinning frame is equipped with a control panel where the parameters needed for the spindle speed, main draft, yarn twist and formation of bobbins can be set without requiring any change to equipment. Special software also permits the production of iridescent yarns.

In order to reduce operator intervention, modern spinning frames are equipped with devices that carry out doffing of full bobbins completely automatically as well as inserting empty tubes.

The time needed for doffing is around 2 – 2.5 minutes.

There are also systems to provide a direct connection between the spinning frame and winding machine.

To state the quality of the yarn, the checks normally carried out are as follows:
- evenness of count
- evenness of twisting
- evenness of the section
- hairiness
- tensile strength

Open-end spinning

This is normally used in cotton carded spinning. The frame is fed with slivers from the drawframes which transform the yarn directly into packages, eliminating the passage on the roving frame and, in many cases, further packaging operations.
The figure below represents an example of rotor (or open-end) spinning frame.
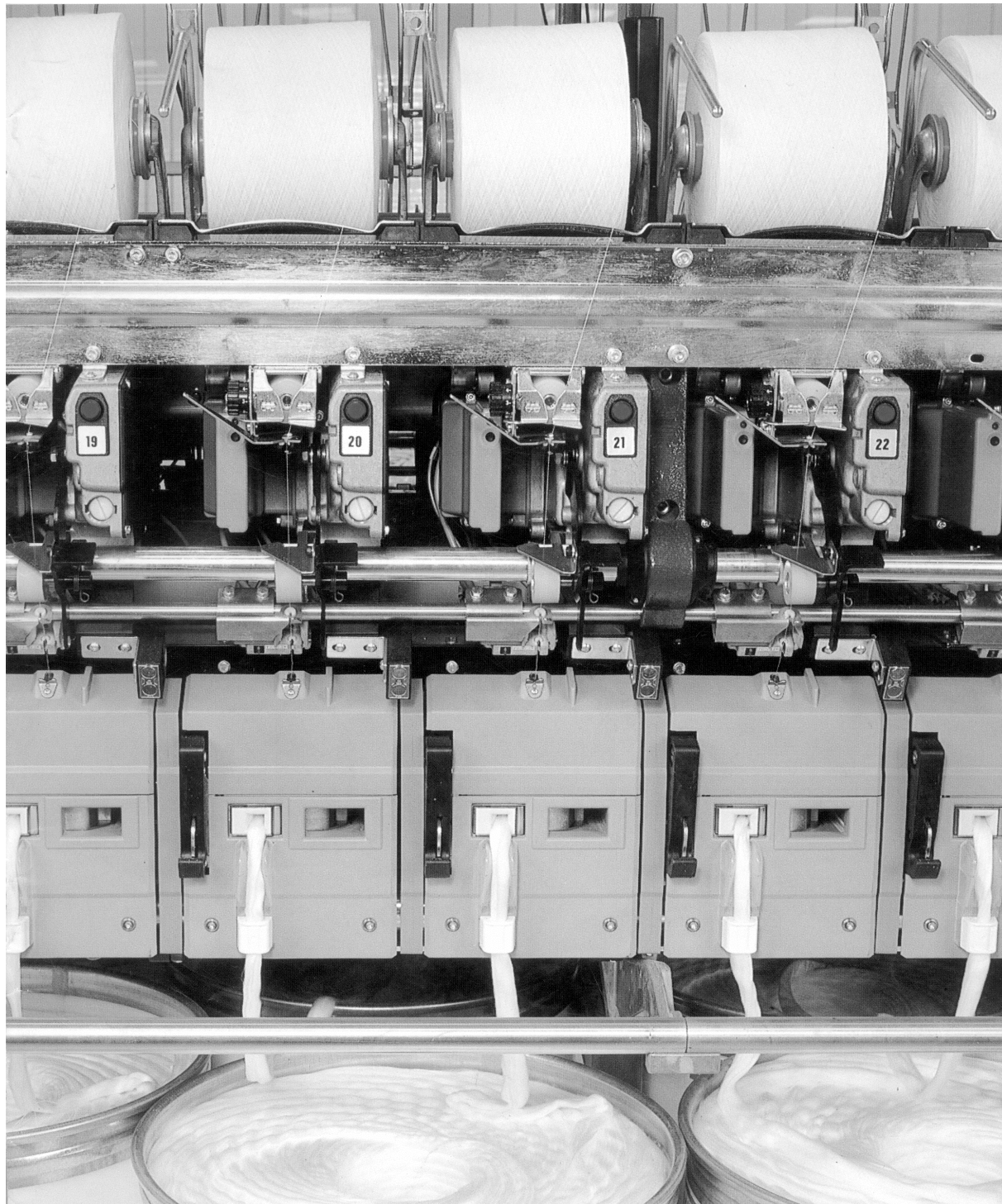
Fig. 54 Rotor spinning frame

The main function of the spinning unit is as follows. The sliver from the drawframe is introduced by a feeder cylinder and is subject to the action of an opener with saw-toothed wiring which rotates at a speed of between 6000 and 9000 rpm, separating the sliver into single fibres, then the fibres are sent to the rotor through a vacuum channel. The rotor, whose diameter is between 32.5 and 54 mm, rotates at a very high speed over 100,000 rpm, and compacts the fibres partly thanks to its special shape, twisting the fibres at the same time.

The processing data of an open-end frame for cotton are normally as follows:
- sliver count Ne 0,10 – Ne 0,27 (Tex 5900 – Tex 2180)
- yarn count Ne 5 – Ne 40 (Tex 120 – Tex 15)
- draft range 16 – 250
- twists 300 – 1500 T/m.

The yarn formed in this way then passes to the winding unit which makes the packages, that are either cylindrical or conical. The cylindrical packages can have a diameter of 300 x 152 mm and the conical ones a diameter of 270 x 152 mm.
The winding speed can reach up to 200 m/min.
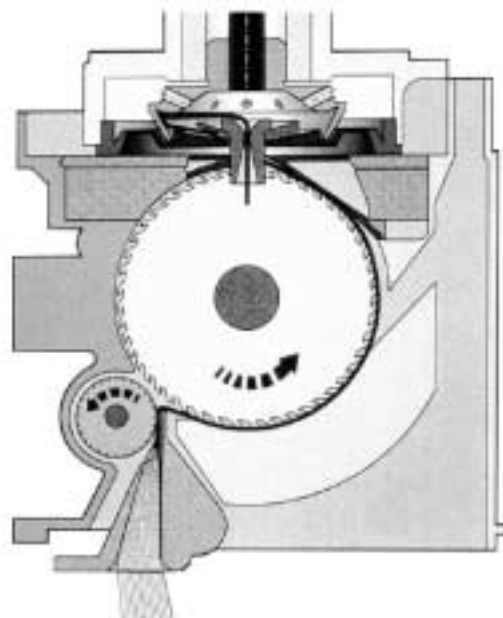
Fig. 55 Diagram of rotor spinning frame

The yarn produced by the rotor spinning frame presents different features from the conventional ring yarns, as the fibres tend to be arranged around the edges of the rotor in a casual manner, rather than as a result of the length of the fibres themselves or with a preferential migration of fibres.
It follows that a regular yarn is formed but with the presence of longer fibres in the yarn that also hold other fibres, giving the yarn a characteristic look and a higher degree of hairiness.

Modern rotor spinning frames, due to some technical improvements such as more efficient cleaning, thanks to pneumatic evacuation of impurities in the channel, the self-aspirating rotor system, the particular design of the rotor transport channel, the adoption of separators with particular profiles that determine a better distribution of fibres in the groove of the rotor, are able to produce yarns of a better quality and more similar to those made on ring spinning frames.

The following figures show a macroscopic view of the structure of the two types of yarn, the first produced on a modern rotor spinning frame (100% cotton Ne 30), the second on a conventional machine (100% cotton Ne 30).

It can be seen that the first yarn presents better evenness and less hairiness. As a consequence, the improved parallelisation of the fibres and more regular final structure will give the yarn better elongation resistance, and therefore generally offer more sophisticated performances.
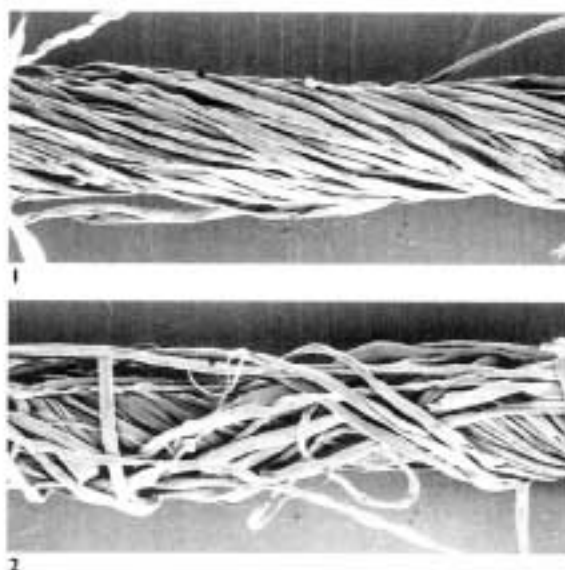
Fig. 56 Open-end yarn structures

Furthermore, the waxing system is able to guarantee distribution of the wax over the yarn in a regular manner according to the quantity desired.
The machine is automated by carriages for automatic piecing of the thread and package doffing of a number variable between 1-2-4 per machine.
A machine normally has two completely independent sides, with automatic distribution of empty tube yarn piecing carriage, package doffer and rotor cleaning. The machine is generally mounted with modules of 24 units on 2 sides and carries a maximum number of 288 units per machine.

The machine also has a system for quality control, productivity and maintenance. The computerised system automatically controls production, it manages the spinning units and shows output data for each individual unit. Furthermore, the system is capable of self-diagnosis when machine alarms occur and in the eventuality of inefficient individual units.

It is also possible to apply electronic yarn clearing systems to eliminate yarn defects directly on the spinning frame.

Winding

Winding is the creation of large yarn packages that can be easily unwound. This makes using the yarn on subsequent machines both easier and more economical.

In order to form packages of the right weight for subsequent processing stages, the winding machine can be fed by ring-spun yarn bobbins, by packages originating from open-end spinning machines, or by cylindrical/conical packages derived from previous processing stages.

Packages can thus be subdivided according to their shape:

a – cylindrical
b – conical, with tapers ranging from 5° 57° to 9° 15°
c – cones with tapers of up to 4° 20°

The yarn unwound from the package passes through yarn tensioning and control systems, and with the help of a grooved cylinder, is wound evenly around the package; the yarn enters the recess in the cylinder, thus the rotary movement of the cylinder corresponds to the translation of the yarn.
Winding machines currently have independent heads with individually adjustable motors.
A modern winding machine can process yarns ranging from a count of Ne 2 to finer ones, at a winding speed of 400 to 2000 m/min.
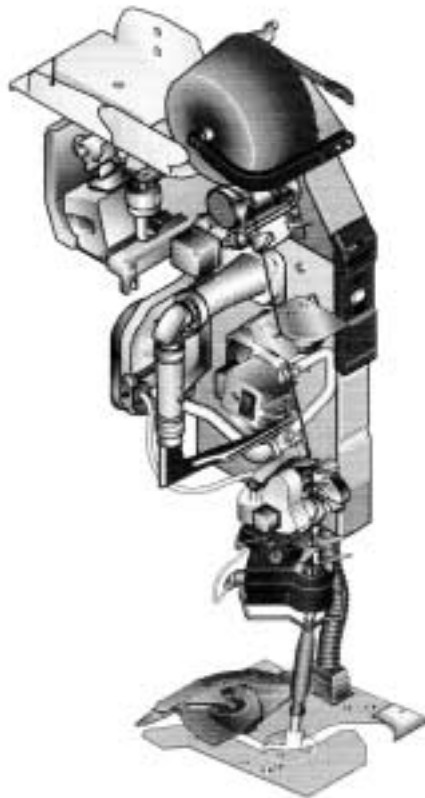
Fig. 57 Winding head

Winding is more than just transferring yarn from one package to another. Further functions of winding are to check the yarn and to eliminate any faults found. This is done by a process called "clearing", i.e., by passing the yarn through an electronic device, known as a yarn clearer, which assesses it according to set parameters (fault section and length). If these set values are exceeded the yarn is cut and spliced – a splice being deemed preferable to a fault. Splicing is done using the air-splicing system or the Twinsplicer system, which, reconstructing the yarn mechanically, also checks the untwisting, tail draft, tail condensation and twisting, thereby improving the result of the operation. A join created in this way is less visible, consistent, stronger and repeatable. There exists an innovative combined water- and air-driven splicing system that is particularly suited to compact cotton yarns.

The machine is equipped with a special device to avoid the winding defect known as ribboning. This problem is caused by irregular package formation following the deposition of too many coils in certain points. Basically, the package-holding arm is made to effect an oscillating movement both in the vertical (A) and in the horizontal (B) planes (see Figure 58). These two movements can be combined in various ways so as to respond to all processing requirements.

Friction

Counterweighing
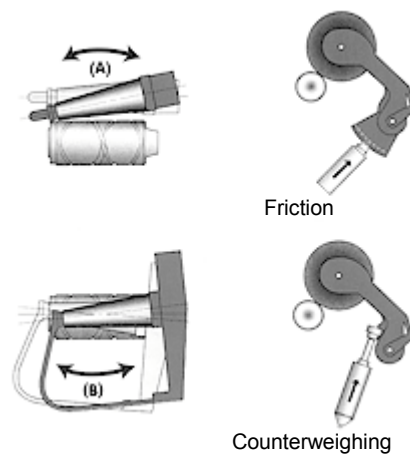
Fig. 58 Anti-ribboning device

The tension of the yarn is constantly monitored by an electronic sensor located prior to the cylinder. Thanks to the headstock computer, this sensor interacts with the yarn-tensioning device to modify, as necessary, the tension exerted on the yarn. This keeps the package density constant.

A modern winding machine carries out the following operations automatically;
• package doffing
• bobbin loading
• cone feeding
• linkage to spinning frames with bobbin picking up

For the last of these, the machine can be equipped with a system that allows it to detect two different lots of bobbins and to keep them separate by the application of lot identification tags, which are inserted into the flange and detected upon winding head entry.

Retraction winding machine for bulky yarn production

This machine is equipped to carry out, in continuous mode, the shrinking of acrylic yarns and HB, also containing elastane, and the production of bulky yarns (blended and pre-dyed).

It has a maximum winding speed of 1000 m. per minute and a shrinking field of 0-30 %.

The operating principle, illustrated in Figure 59, is the following: the yarn is pneumatically inserted and, by means of a rotating distributor nozzle, wound in parallel coils around 4 aprons, which effect a slow translation movement. The yarn winding areas and part of the aprons are suspended in a forced air circulation chamber heated by electric resistances. This chamber (oven), whose temperature can reach 165° C, is where yarn retraction occurs; the yarn, supported only by the two upper aprons is perfectly free and able to shrink in ideal conditions. Exiting the shrinking chamber, the shrunken yarn passes through a cooling zone, after which it is unwound and then wound on to a new package. A overfeeder roller reduces the tension of the yarn as it leaves the oven.
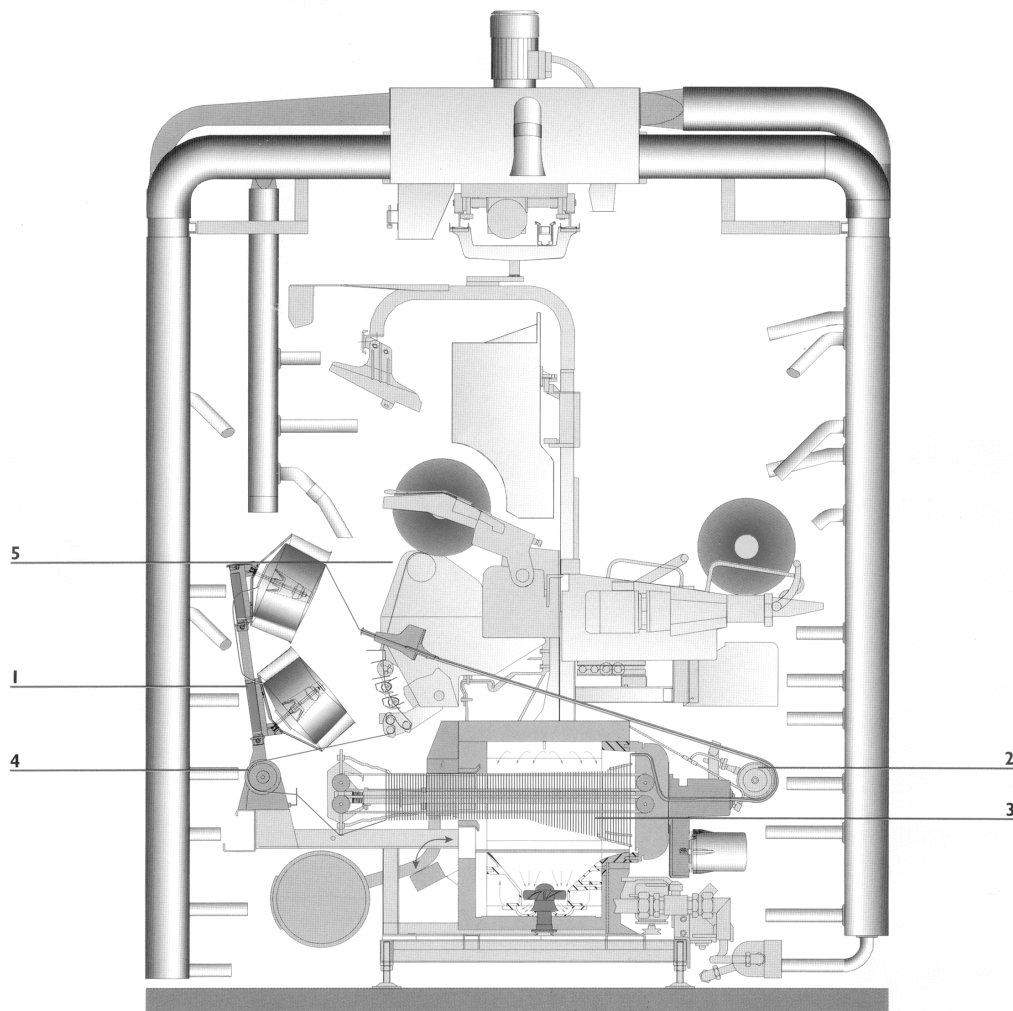
Fig. 59 Shrinking stage: 1- feeding creel; 2 – entry overfeeder pulley;
3 – yarn distributing unit; 4 – takeup overfeeding roller; 5 – winding head

Waxing

Waxing serves to lubricate the yarn, reducing to a minimum its coefficient of friction with the parts with which it comes into contact.

This operation is normally carried out on yarns destined to be processed on knitwear machines, on which smooth running of yarns is essential.

Waxing is carried out on the winding machine, which is equipped with a postive-drive adjustable waxing system that guarantees constant waxing of the yarn; there is also control device that stops the machine should the wax run out.
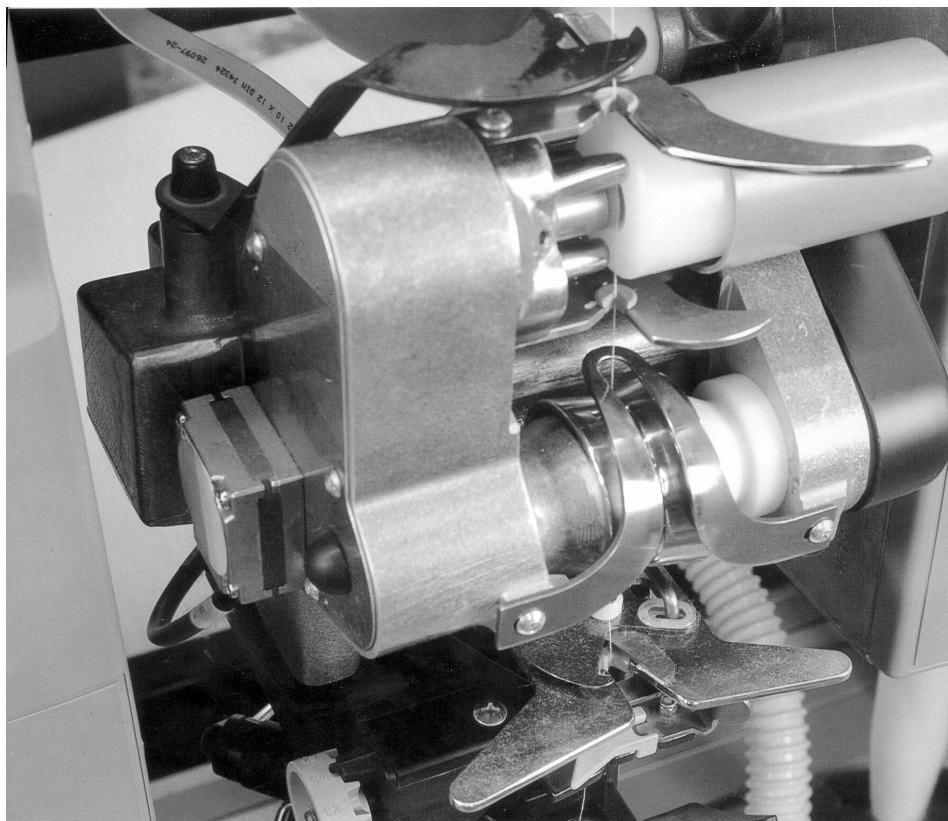
Fig. 60 Waxing device

Singeing

Singeing is an operation carried out in order to eliminate yarn hairiness. The singeing system consists of a package-to-package winder and a gas burner.

The yarn is passed through the flame, which singes the protruding fibres that cause the hairiness. It runs at a rate of 400 to 1000 m/min.

The machine must, in order to obtain even singeing, maintain a constant yarn speed and an even flame.

The singeing system, in addition to normal machine control devices, also has a fly fibre evacuation system and a flame temperature control system.

Since this operation reduces the weight of the yarn, even by as much as 5-6 %, the yarn count will also be modified, and this must be borne in mind when designing the yarn.

Doubling

The purpose of this operation is to unite two or more ends on a package prior to twisting. The doubling machine, like the winding machine, is fed by packages of yarn, generally pre-cleared, which are positioned in its lower section. Unlike the winding machine, the doubling machine must have yarn tensioning devices that can guarantee even tension of all the yarn ends, as this is essential for successful twisting.

The packages produced can be cylindrical or conical, and the winding speed can exceed 1000 m/min.

Fig. 61 Doubling machine

Twisting

The purpose of this operation is to unite, by twisting, two or more doubled yarn ends, in order to obtain a stronger yarn. It is a two-stage process: first doubling and then twisting. Some modern machines carry out these two operations contemporaneously.
In the past, twisting was carried out using ring twisting machines, which are similar to ring spinning frames, except that they are fed by packages of doubled yarn and via a feeding cylinder that consists of a metal shaft with pressure cylinders to keep winding speeds constant.
Nowadays, two-for-one twisters are used, thus called because the yarn undergoes two twists for each turn of the spindle.
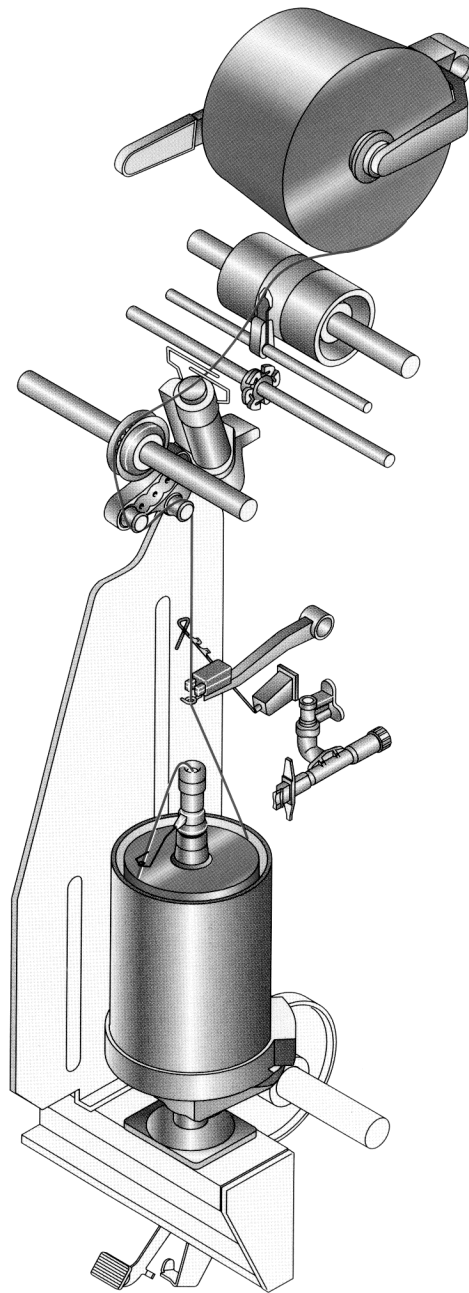
Fig. 62 Two-for-one twister

The operating principle is illustrated in Figure 63, which shows how the yarn undergoes a first twist between its entry into and exit from the spindle (A-B) and a second twist between point B and the thread guide C. This is possible because the doubled yarn package does not move; instead, it is the yarn that revolves around the package.

1st twist	2nd twist	Full twist
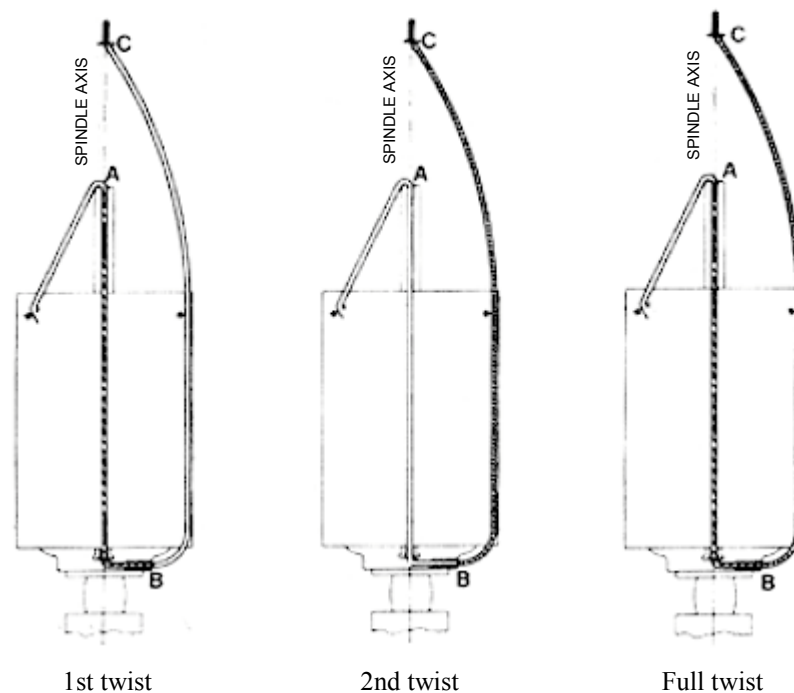
Fig. 63 The principle of two-for-one twisting

The twisted yarn is then wound, forming one package per spindle located in the upper part of the machine.

The advantages offered by this machine, in comparison with the old ring spinning machines, are the following: two twists are effected for each turn of the spindle and this means higher output rates, direct winding of large packages, fewer knots, and the possibility of carrying out 2-ply assembly directly on the machine.

The machine produces, directly, packages with the following tapers 0°- 3°30'- 4°20' - 5°57'. It is possible to have different spindle gauges: 200-240-300 mm, and the number of spindles, which depends on the gauges, can range from 16 to 360.

The machine is equipped with gear boxes, to vary the number of twists, the twisting direction (S/Z) and the yarn crossing angle.

The two-for-one twisting machine currently offers high operational flexibility, working both with controlled and free balloons, extracting the balloon limiter.

This makes it possible to process delicate fibres that could otherwise be damaged by excess friction. Following the carrying out of doubling on special machines, and providing certain measures are taken, it is also possible to process woollen, cotton, viscose and silk yarns that incorporate the elastane thread that is increasingly used in the manufacturing of textile goods.

An optional electronic system can be employed to monitor correct functioning of the machine. This system detects missing yarns, the presence of extra yarns, and, in accordance with planned tolerances, the formation of tangles. Modern two-for-one twisting machines incorporate pneumatic threading systems and an automatic tying carriage, a package lifting system, and slowing of the machine in the event of yarn breaks or the package running out (following breaks, this slowing action is delayed to allow the twisted yarn to finish winding and thus to avoid damaging the surface of the package), a travelling blow/suction cleaner.

If required, waxing can also be carried out, and in some machines, in order to reduce the effect of friction on the yarns, oil is applied through a device located on the spindle head and comprising a tank and a bush that, by capillary action, allows the oil to rise, reaching the yarn contact zone. This operation is carried out before the first twisting stage and using an adjustment nut the quantity of oil can be regulated, bringing different parts of the yarn surface into contact with the distribution bush.

As already mentioned, one kind of two-for-one twisting machine can effect doubling and twisting contemporaneously.

As shown in Figure 64 below, which illustrates this machine, there are two packages on the spindle from which, following separate paths, the two threads are unwound. These are subsequently twisted together.
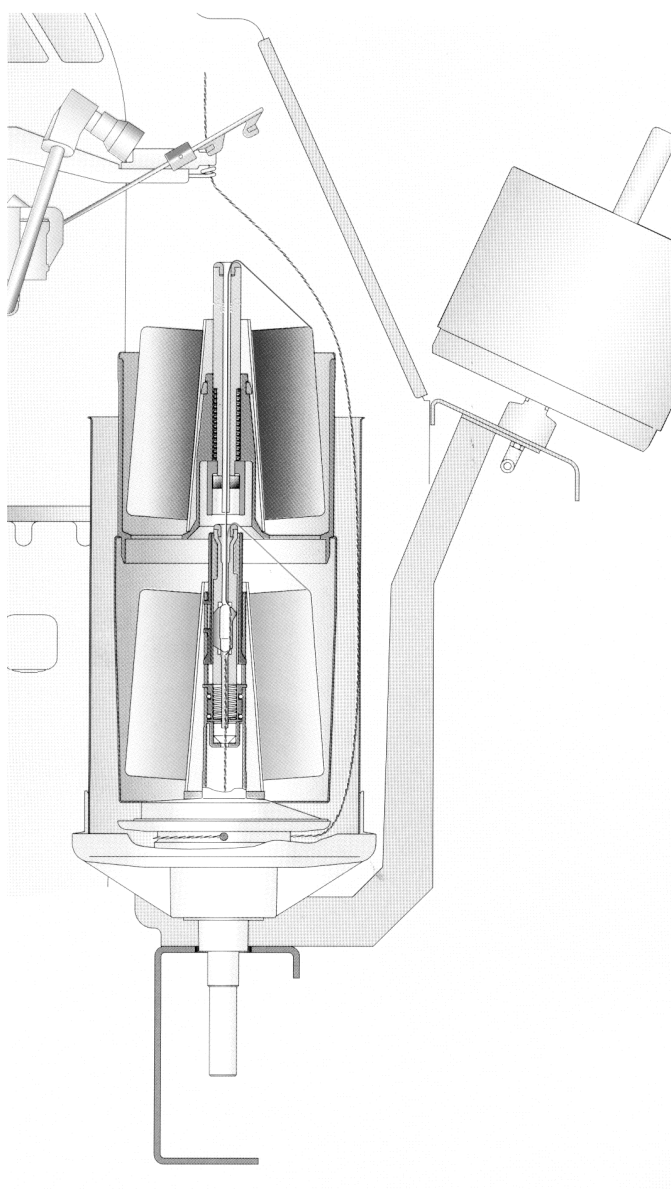
Fig. 64 One-step doubling and twisting

Reeling

Reeling is a skein preparation operation (generally the preparation of skeins prior to dyeing). The reeling machine is fed by yarn packages and winds the yarn onto a reel, thereby forming the skein. Winding can be carried out either modifying the yarn crossing angle or by adjusting the skein width up 400 mm. The diameter of the reel is normally 54" and it has a speed of 400 rpm. Skeins can sometimes reach 5 kg in weight.

Fig. 65 Detail of a reeling machine

Winding-off

There is one particular type of winding machine that is called a winding-off machine. It is fed by skeins that have just come from the dyeing process and it produces packages.

The winding-off head is basically the same as that of a normal winding machine, while a special system is required to unwind the yarn from the skeins, positioned on the reels, making sure that, when tangles cause yarn tension, the yarn does not break.

This system is a tensioning device through which the yarn passes; if it is too taut, the process speed is reduced to facilitate winding-off, then normal speed is restored. In the event of considerable tension, the device stops the winding-off head and the machine operator undoes the tangle.

The traditional unwinding machine has a non-controlled reel feeding system and can therefore work at speeds of up to only 300 m/min.; the latest machine models, on the other hand, use controlled reel systems with independent electronically controlled motors and built-in brakes that allow the head to be stopped quickly, preventing the yarn from breaking. These machines work at rates of around 600 m/min.

Automation of Transportation and Packing Operations

Introduction

By way of completing the spinning processes described in the previous pages, and in order to reflect the textile industry's constant efforts to remain competitive and to go on offering the market high quality yarns at competitive prices, consideration must also be given to the need to automate the end-of-cycle operations.

In the face of the various working conditions presented by today's spinning sector, and given the ease-of-management demanded of automations of this kind, the latter tend to eliminate all the intermediate finished yarn handling stages, thereby relieving personnel of the more repetitive and laborious tasks and at the same time guaranteeing:
• higher plant productivity
• accurate package handling
• high-quality packaging

In particular, in situations in which production volumes are high enough to justify considerable investments, opening up the way for fully automatic systems, it is also necessary to guarantee:
• no style mixing
• high performance from production machinery
• orderly material flows
• reliable handling
• flexible processing cycles

The automation processes relating to machine operation tasks within the mill are not motivated only by the need to keep labour costs down; they also reflect a more complex strategy that can be broken down into the following objectives:

1. better use of staff and reduction of their margins of discretion, so as to optimise distribution of tasks;
2. close adherence to operating procedures, resulting in opportunities to verify processing at any time and in any stage;
3. possibility of increasing or reducing the production capacity of a system or of machines, to suit the workforce and changing market needs;
4. a systematic approach to planned controls and easy classification of products to be handled;
5. foolproof identification of articles handled and recording of all packages dispatched.

Below we give two examples of how these principles can be applied: first in the package unloading, transportation, palletisation and packing zone and second in an automated cell for the packing and handling of packages.

Package unloading, transportation and packing

The most recent yarn package handling and packing systems allow applications specifically developed both for open-end spinning and for winding.

In the first case, systems – of varying degrees of sophistication – have been developed for the "intelligent" management of open-end spinning machines.

These systems are based on the concept of monitoring the progress of production as a whole, so as to be able to manage doffing occurring contemporaneously on different machines and to optimise sequences without penalising single performances.

Regardless of how many rotors each of the machines in the production line has, automatic unloading of this kind of spinning machine involves the delivery, in the direction of the packing areas, of *whole "trains" of packages.*

In the second case, while still bearing in mind the need for real-time monitoring of the progress of production, the surveillance systems in operation, regardless how many heads each of the machines present in the production line has, allow the management of *single packages* or *sections of trains.*

In both situations, the groups of packages being delivered, not necessarily being multiples of the final packing module, may need to be sorted by article (yarn count) and stored temporarily, prior to packing (Figure 66).
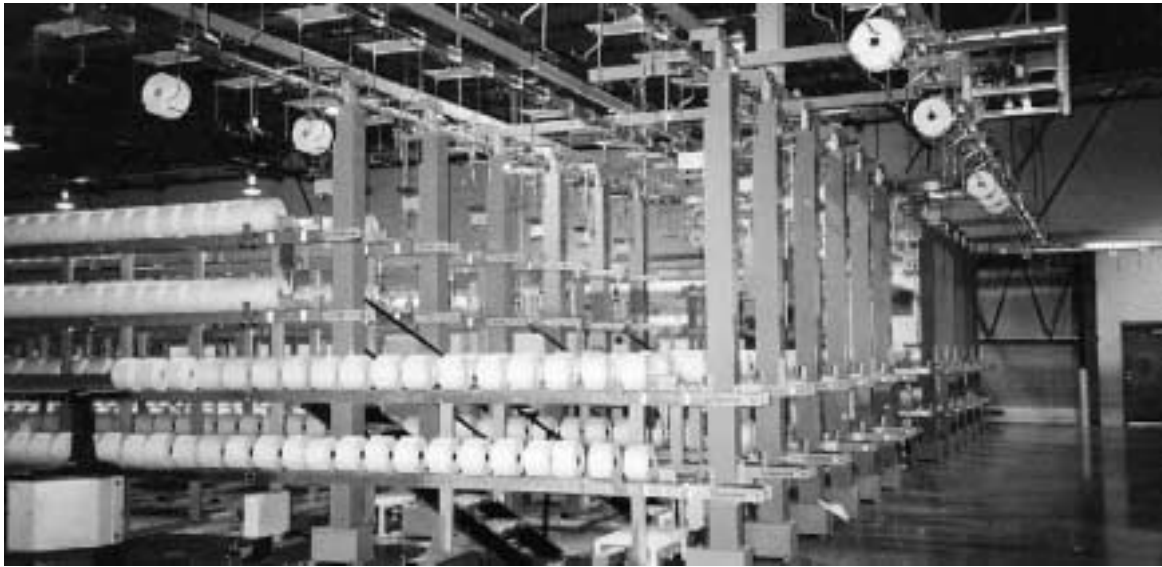
Fig. 66 Package pre-storing conveyors

Once the packages have reached the predetermined number, lifters (installed in front of each spinning machine) pluck them – two at a time in the case of open-end spinning machines and singly in the case of winding machines – from the collection conveyors inside the machine and transfer them, oriented as necessary, to the weighing units of an aerial chain conveyor (or alternatively to a suspended collection belt), which runs in front of the unloading points, and conveys them to the packing area.

Correct identification of trains and single packages in transit is fundamental in order to guarantee correct sorting during the final handling stages. This is done by the writing and subsequent reading of magnetic tags on each weighing unit (or, alternatively, by tracking of the trains themselves, a system in which the packages pass in front of a series of photocells that detect and count them).

If the final packing module is a pallet and if it is not possible to install, for each article produced, a sufficient number of pre-storing conveyors to hold the total number of packages needed to complete it, then the packing area will have a number of pallet points – as many points as there are (different) articles being produced in the spinning mill – where the packages are progressively deposited.

If the final packing module is a *box*, then the packing area will have a number of collection conveyors – as many conveyors as there are layer separators – for the temporary storage of the number of packages needed to form a group of boxes.

In certain situations, it is still possible to compensate for the number of packages actually leaving the spinning machine and to make up directly, with the number of packages needed (a multiple of the final packing module to be made up), the pallet or series of boxes required. This is done, thanks to in-line vertical rotary stores, either by storing excess packages or by adding to the existing packages.

The packing units (palletisers or boxing machines) are PC-controlled machines that can handle packages singly or in groups according to the production capacity required of whole system. These machines, entirely automatically, make up the pallets (through the placing of layer upon layer) or fill the boxes with layers of packages.

In palletisation cycles, the pallets that are being made up are conveyed inside the machine by service shuttle or, alternatively, it is sometimes the palletiser itself that moves to the operating area; in the case of boxing cycles, on the other hand, the boxes move independently, on service rollers into the boxing station.

Palletisers are Cartesian robots driven by brushless electric motors. They are equipped with pneumatic single or multiple spindles that pick up the packages, already centred and oriented as necessary, directly from the tube and deliver them, according to the required geometry, in the layer that is being made up (Figure 67).
These robots also insert separators, and handle empty and full pallets.

Fig. 67 Package palletiser

Bagging and boxing machines, on the other hand, pack single packages ready to be dispatched in boxes; a sheet of polyethylene wrapping is first conveyed to a wrapping unit, where it is employed to form a tube. It is then sealed in several points to form a bag..

For the subsequent boxing stage, it is possible, through the combined feeding of two motorised conveyors, to assemble a layer of packages arranged ready for boxing

Robotised cell for automatic package handling

This technology is based on the use of anthropomorphic robots equipped with special tools and designed specifically for handling packages. The robot is part of a fully integrated system that incorporates a series of machines and special devices.

The main advantage offered by this solution derives from the robot's multi-purposeness and operational flexibility. Indeed, the robot replaces a series of dedicated machines used in traditional systems, thereby reducing drastically the costs per unit transported.

Technologically, this solution stands out for its high running speed, complete positioning accuracy and maximum reliability.

Autopacking systems – complete systems for draw-twisted yarn packages – exemplify perfectly this new technological trend.

These systems handle packages plucked from transportation carriages. The packages, once identified through special ID disks that a special machine applies to the tube collar, pass through quality control stations, before being automatically bagged and packed in cardboard boxes, which are then sealed and labelled.

The system comprises three main areas:
• Transportation carriage line
• Package transportation disk line
• Empty/full box line

The packages, in the various production areas, are loaded manually onto single-side carriages with 72 slightly angled pegs. These carriages are moved manually to the carriage line entry point. Once they have been fed into the line, the carriages advance automatically until they reach the package picking up point.

Here, there is a hydraulically-operated overturning platform, equipped with carriage anchoring devices. When the carriage is in position, the platform rotates through 85 degrees, positioning the packages so that they are perfectly horizontal and can be gripped from above by grippers located on the head of the robot.

The robot is a six-axis machine with its own control system.

When the packages are in picking position, the head grips 4 packages contemporaneously and then ascends, sliding the packages off their respective pegs.

The robot then carries out rapidly a pre-programmed cycle, depositing the 4 packages on as many transportation disks (on the disk line).

Fig. 68 – View of the handling and packaging robot

The cycle is repeated until the carriage is completely empty.
At this point, the platform returns to its rest position; the empty carriage is released and the carriage line starts to move again, pulling the carriage towards the exit from the line.
Should there be another, full carriage already present, this is immediately placed on the platform and the robot starts the unloading cycle again.
The disk line is a group of motorised rollers arranged in a closed circuit. The disks, carrying the packages, are transported around the circuit, passing through the various operating stations.

In the first of these, each package is given a product ID disk. This is applied, by pressure, to the tube collar of the package by means of a special, pneumatically-driven automatic machine. The machine has an 8-chamber rotating drum, and each chamber can contain a different type of disk.
Once the disks have been applied, the packages proceed to the visual inspection stations, where an operator enters the relevant data into a terminal linked up with the management system.

In the next station, the packages are passed through a special bagging machine, which slips a protective HDPE (high-density polyethylene) bag over each one.
Once this operation is complete, the packages are ready to be packed. The disk line forwards them to the packing station. Here, the robot transfers the packages from the transportation disks into cardboard boxes supplied by the box line. These boxes are made up, upstream of the box line, by a special box assembler.
The other packing materials (moulded plastic bottom and top plates) are fed by two separate lines to the positions ready for plucking by the robot, which inserts them into the packing boxes in the correct order.
The filled boxes are transported by the box line to a labelling station, and subsequently to a station in which they are automatically closed and sealed.

WOOLLEN SPINNING

Woollen spinning cycle

The classic product is based a well established technology, reflected in the following spinning cycle:

Stage 1   PREPARATION   opening, blending and cleaning the material

Stage 2   CARDING   processing of the blend and production of the roving fineness

Stage 3   SPINNING   transformation of the roving into yarn

In spinning, the classic drawing, twisting and winding operations can be carried out both by continuous ring spinning machines and by discontinuous selfacting machines.
It is also possible to use spinning-twisting machines to produce fancy yarns in a single operation.

Preparation

Introduction

Crucial in order to obtain a homogeneous, strong and even yarn is optimal blending of its component fibres. If this applies when processing lots of a single material, then efficient blending becomes even more important in the woollen spinning cycle, in which the fibres' adherence to the fundamental parameters determining spinnability can vary considerably. Blends generally present the following characteristics:
  • a very high number of components (even in excess of 10), present in highly variable proportions (sometimes even very small percentages, below 5%)
  • fibres presenting highly dissimilar characteristics, particularly as regards their length (there are situations in which 25 mm waste are blended with synthetic fibres over 80 mm in length)
  • widely varying colours, sometimes not constant from the start to the end of a single lot
  • presence of foreign matters and impurities, sometimes originating from packing, or, more often, attributable to the origin of the material, (for example in the case of regenerated fibres, waste, processing waste)
  • the need to use high-performance additives, to promote fibre cohesion and to facilitate their sliding over one another, as well as their processability on machines.

A blending and preparation system may or may not be based on the number of components in the blend, and it is this which determines the type of spinning process to be carried out on the raw stock.

Preparation system based on the number of components (instant)

A series of bale pluckers – their number corresponds to the number of components to be blended – that are also equipped with weighing devices work parallel with one another, unloading the required proportion of each of the various types of fibre on to a transverse vertical apron (Figure 69).
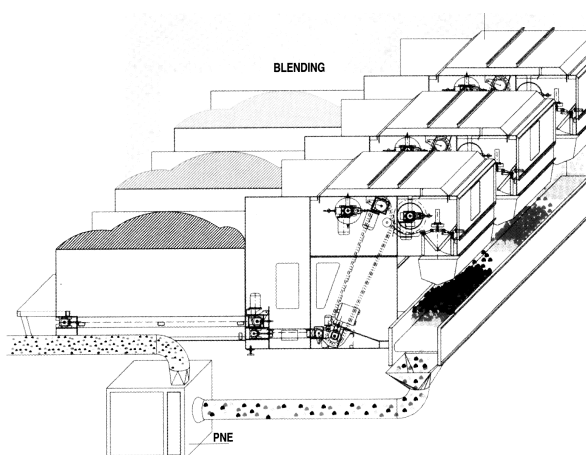

Fig. 69 Bale pluckers working parallel with one another

The fibres are collected, through a contemporaneous stratification process, which guarantees the production of blends that immediately present the composition required of the end product.
In the subsequent stages, the material is opened, oiled and, if requested, stored.
Clearly, a process of this kind, simple and inexpensive, is preferable for the production of lots that do not vary much, given that there is a limit to the number of components that can be handled by the system, which is not required to perform thorough blending. Instant preparation is often preferred by producers of nonwovens, precisely because it is best suited to materials that are relatively standardised, as regards both colour and composition.

Preparation system based on the number of components (global)

In this case, preparation involves a series of sequential operations, some of which can be repeated, perhaps several times, according to the characteristics of the materials and the level of quality required. As a result it is a more sophisticated and complex process than the previous one, but also more versatile.
The classic cycle is as follows:

1. bale plucking
2. dedusting
3. fibre opening
4. oiling
5. stratification and blending
6. plucking with blending apron
7. storage and supplying the carding room

The stages that tend to be repeated are, above all, opening, oiling and blending, although once oiling has been carried out, the dedusting stage is excluded from the cycle as it would not be efficient on oil-impregnated material.
A complex preparation line of this kind is suitable for the processing even of small and highly variable lots and is thus described in more detail below.

Bale plucking

The bale plucker is the first machine in the cycle, as it carries out a preliminary plucking and partial blending of the fibres. The bales, which are compressed when they reach the spinning mill, are first removed from their protective wrapping and then placed on the conveyor that feeds the bale plucker, which separates the fibres, returning them to their open-tuft state and thereby ensuring even feeding of all the subsequent machines. Furthermore, depending on the operating width (this generally ranges from 2 m to 5 m), the machine can be loaded with parallel rows of bales; alternation of the various components will result in a preliminary blending, which will be improved and rendered even more thorough in the subsequent stages.
The working of this machine (see earlier Figure 69) is based on a principle of opening, obtained through a vertical apron made up of wooden steel-spiked staves.
The table hooks the fibres and, blending them, raises them upwards to a point where a cylinder knocks off any excess material. An unloading cylinder, located behind the blending apron, frees the fibres from the spikes of the apron, and sends them to the hopper.

Dedusting

From the bale plucker the fibres are pneumatically conveyed to the blowroom, which opens the tufts and removes all types of dust and impurities.

The material is fed, via an entry hopper, into the blowroom, in which there operates a cylindrical drum with a diameter of around 600 mm. (the drum can sometimes be cone-shaped). Its surface is covered with blunt steel spikes (Figure 70).

These spikes are arranged helically to favour, together with the suction effect, the progress of the material. The rotation of the cylinder has two effects: the material is opened thanks to the action of the spikes on the fibrous mass (this opening is often increased by also lining with spikes the inside of the carter with which the moving fibres inevitably come into contact) and dedusting thanks to the cylinder repeatedly and violently striking against an underlying grid.
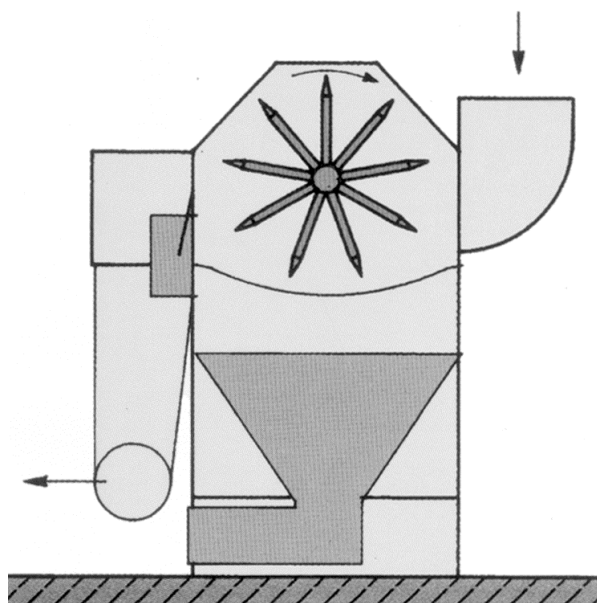
Fig. 70 Blowroom

The whole machine is subject to suction and the dust is collected in special filters; the material, on the other hand, undergoing contemporaneously, the rotary action of the cylinder and suction along the operating width, effects a helical movement around the drum and exits from the side opposite to that on which it entered. It is then transferred by the delivery hopper into the transportation conduit.

Opening

This stage is usually carried out by an opening willow in the case of shorter fibres and by a willow in the case of longer ones.

In the opening willow the fibres, evenly and constantly fed to the conveyor, are drawn inside the machine by two licker-in cylinders, which have grooved surfaces to help them to retain the material. From this cylinder nip area the fibrous mass is violently taken up by a drum that rotates rapidly in a clockwise direction. This drum is covered with wooden staves that have sharp steel spikes (Figure 71).
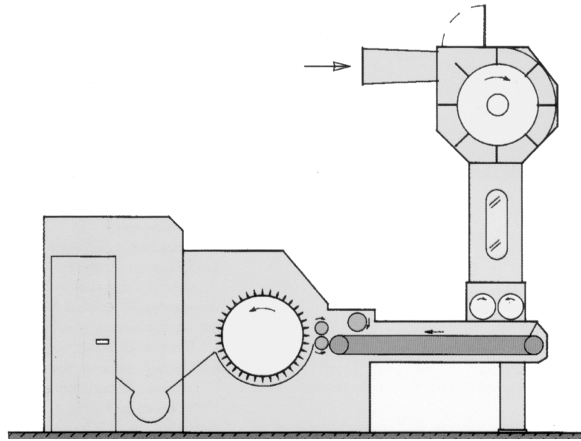
Fig. 71 Opening willow

The action of the drum spikes and the large difference between the peripheral speed of the surface of the drum and that of the feeder cylinders result in opening of the material.

In the opening willow, the material passes from the feeding conveyor to the feeding cylinders (Figure 72). The surface of the machine's main drum, like the worker cylinders and card strippers, is covered in rigid, curved spikes, which exert a strong opening and blending action. The material is detached from the drums spikes by an unloading cylinder.
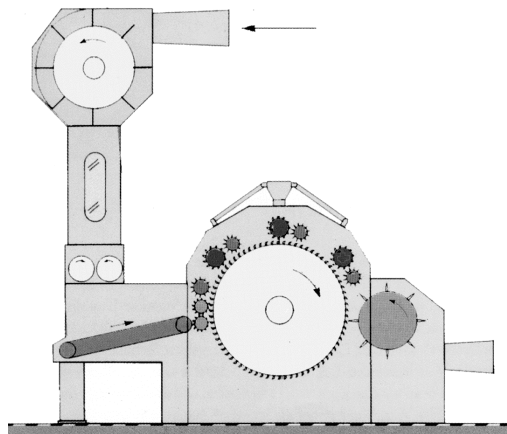
Fig. 72 Carding willow

Oiling

Oiling of the fibre blend is fundamentally important, because it increases the coefficient of friction between the fibres (which is particularly low in the case of short fibres). This favours the cohesion of the card web and of the rovings; it also help to reduce the coefficient of friction between the material and the machine's metallic clothings. The oiling emulsion is generally made up of oiling agent, emulsifier, softener, anti-static agent, condensing agent, additives and water. Naturally, the proportions in which these products are present in the emulsion varies considerably according to the type of material to be processed and its requirements. The emulsion usually accounts for at least 5-6% of the total weight of the blend, while its upper limit is impossible to establish, as it depends too much on the type of fibre being processed.

The emulsion is prepared in a steel tank. From here, it is pumped to the oiling chamber, which distributes it continuously onto the fibres (Figure 73).
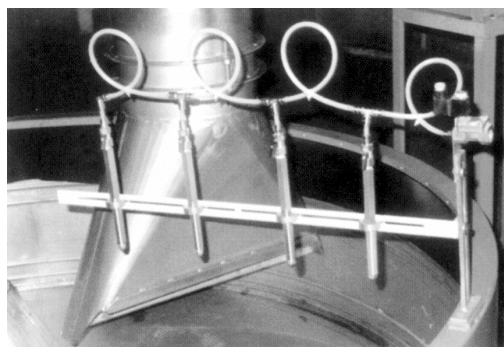
Fig. 73 Oiling in a rotating tank

The fibrous material is deposited on a circular plate which rotates slowly, so that all the fibres are passed under the spraying device, made up of a series of nozzles.

Safety systems cut off the supply of emulsion in the absence of fibres, while the speed of rotation can be adjusted according to the amount of fibre being processed.

A central cone prevents the impregnated fibres from becoming mixed up with still-to-be-treated ones while a control sensor, an oscillating rod whose end registers the volume of material present, regulates the quantity of fibre undergoing oiling, stopping the machine if too much material is present. A fan picks up pneumatically the impregnated fibres, to be conveyed to the next stage.

Blending

After oiling the fibre is sent to the blending rooms, where, traditionally, the material is laid down horizontally and carefully broken down into many thin layers, in such a way as to optimise blending with the subsequent vertical plucking. Mobile conveyor belts are often used in place of traditional pneumatic transportation of the fibres. Indeed, for the blending of heterogeneous fibres, the box filling system with blowing of the material has an undesired separating effect that is attributable to the different dynamic behaviour of the fibres, in turn determined by their volume. More modern systems effect mechanical stratification, without the application of air, thereby making it possible to apply the emulsion during the loading of the box, while the fibres are being deposited in layers (Figure 74).

Fig. 74 Stratification in the cell without air

Plucking with blending apron

Once it has been laid horizontally in layers, the material has to be plucked in the direction perpendicular to that in which it was laid down. This allows optimal blending.

This plucking operation is carried out using a fixed or a mobile blending apron.

The blending apron is a conveyor belt that has spikes on its surface, and is angled not completely vertically, but in such a way as to form, thanks to its inclination, an angle slightly greater than 90° with the horizontal fibre. Given its size, the conveyor practically intersects the section of the chamber, thus the fibres become attached to the spikes of the upwards-moving apron; then, once they have reached the top, they are detached by a doffing cylinder and collected in the unloading device.

Telescopic tubes connect the blending apron, which runs on tracks throughout the inside of the box, to the pneumatic transportation system, which feeds the material to subsequent processes (Figure 75).

Other tracks, outside the chambers and perpendicular to the previous ones, allow the blending apron to be moved, as necessary, between adjacent chambers.

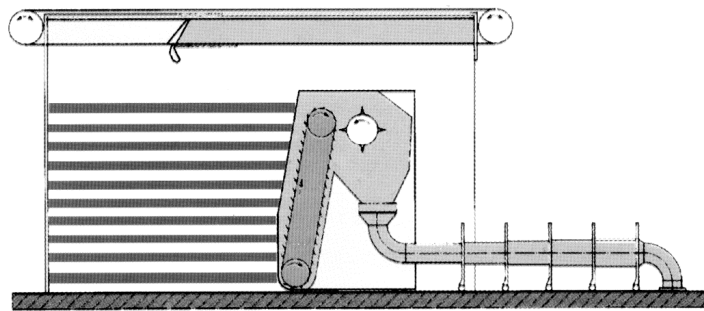

Fig. 75 Cell with channel filling and mobile blending apron emptying

In the fixed blending apron picking system (Figure 76), the cells have a moving base that transports the fibre to the blending apron, located on the room entry side, while on the other side, a retaining wall advances to prevent material from slipping backwards.
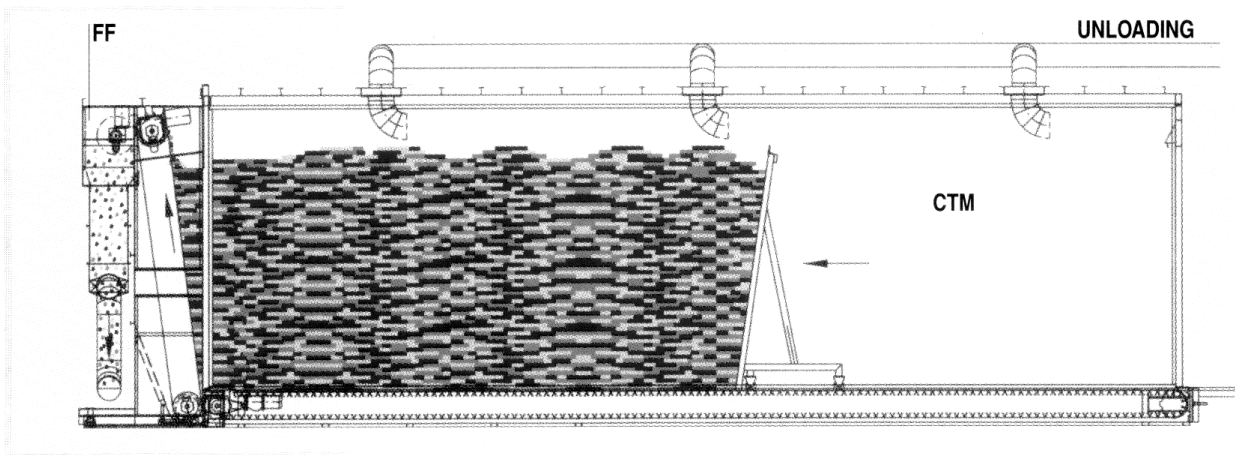

Fig. 76 Cell emptying with a fixed blending apron system

Storage and carding room supplying

Leaving the blending chambers, the fibre can once again be put through the opening machines, or if it needs further homogenisation (this applies particularly if one of the components is present in only a very small proportion), submitted to a second or even third blending and relative picking. Finally, the material is transferred to storage cells, ready to be fed, from special hoppers, to the carding room equipment loader .
The storage cells (Figure 77) are equipped with a fixed blending apron whose plucking system is driven by special photocells that control the level of material present inside the hopper.
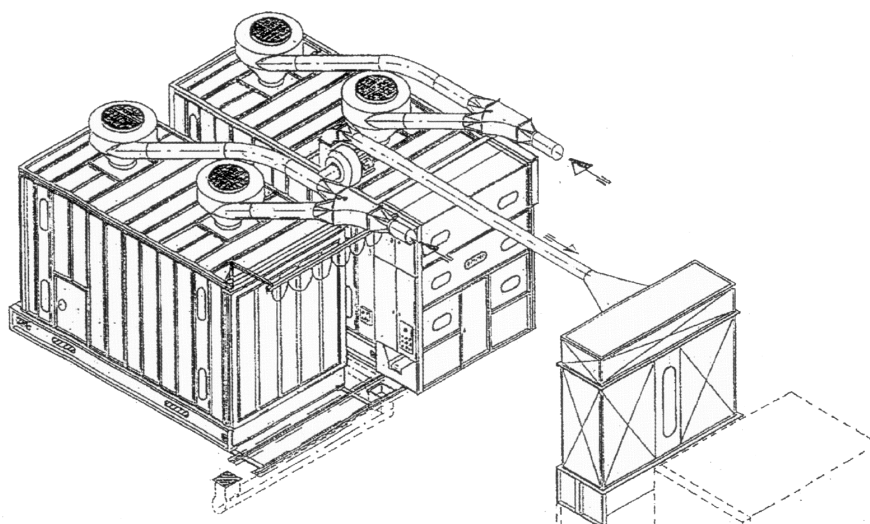
Fig. 77 Storage cells

The volumetric hoppers, in turn, ensuring (through a control system based on photocells and timers) constant discharging of fibres into the loaders, guarantee the carding room equipment autonomous operation.

Automation and safety

In an automatic preparation cycle, the only intervention on the part of the operator is to supply the bale plucker with bales, while the prepared material, delivered by the storage boxes, is fed directly to the hoppers that supply the carding room equipment loaders, thereby creating a direct link with the carding room.
The machines are connected up by a pneumatic transportation system that renders processing productive and safe.
Automation has led to an improvement in blend quality, without depriving the system of any of its flexibility, allowing the repetition of cycles on the different machines, and their exclusion, and thus guaranteeing optimal processing of the most varied and the most homogeneous materials.
There have also been considerable improvements in terms of the healthiness of the working environment, with marked reductions in dust concentrations, and in the area of accident prevention.
Figure 78 illustrates a preparation system.
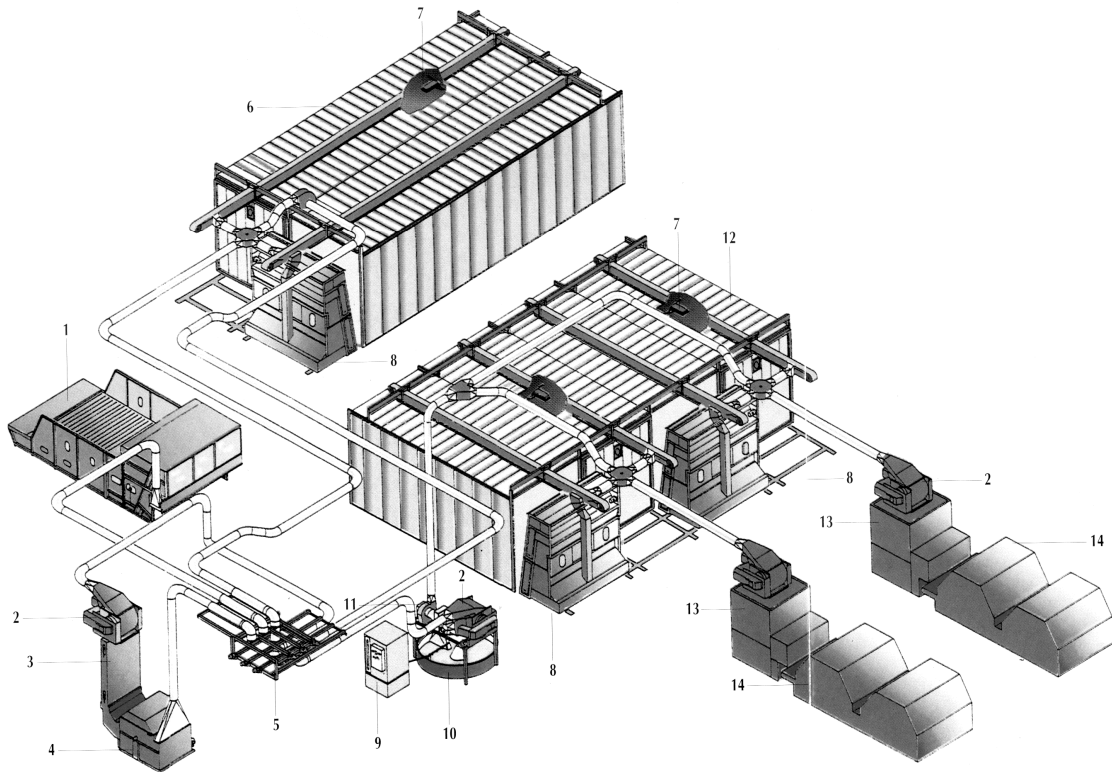
Fig. 78 Complete preparation cycle

1 Bale plucker
2 Condenser
3 Vibrating wall
4 Fibre opening
5 Exchanger
6 Blending chamber
7 Deposition device

8 Mobile blending apron
9 Oiling pump
10 Oiling tank
11 Fan
12 Storage chamber
13 Card loader
14 Card

Carding

Carding functions

Carding fulfils a series of precise objectives, serving:
- to open the blend fibres fully and definitively
- to arrange (as far as their length allows) the fibres parallel with one another
- to remove impurities
- to blend the raw material further
- to reduce the blend to a web of fibres and to divide it up into rovings of the required count, suitable for feeding to the spinning machines.

Carding plays a crucial role in all spinning cycles, and its role is never more central than in the woollen spinning cycle, in which it incorporates different functions, all essential in order to obtain the level of quality required of the product.

Basically, passing the material over the card undoes tangles of fibres and therefore makes it possible to remove all kinds of impurity. This is achieved thanks to the action of the spikes covering the surfaces of cylinders that rotate around parallel axes.

The equipment also fulfils another function, which is both delicate and fundamental: it has to guarantee the accuracy and evenness of the web count and subsequently of the roving count. Indeed, the definitive spinning machines that operate within the woollen spinning cycle can impart only a very low draft, which means that there is practically no possibility, at this stage, of intervening to correct the yarn count.

The carding room equipment thus performs the same operations already carried out in the preparation stage, this time more thoroughly, supplying the divider with rovings of the right count.

Operation of the card

The card used in woollen spinning is traditionally the sort with cylinders (covered with clothings that are angled to varying degrees), which rotate at different speeds, effecting the three cardinal actions: carding, stripping and raising. Appropriately combined, these three actions allow opening of the tufts, continuous detachment of the fibres from the card clothing, which would otherwise soon become clogged up, and delivery of the material from the machine at the end of a processing cycle.

The type of the clothing and the direction and peripheral speed of the cylinder characterise unambiguously the operating principles of the machine.

Modern cards are fed by automatic loaders that, connected up with storage boxes containing the ready prepared fibre blend, deposit the required quantity of material onto an endless belt or a conveyor (Figure 79). Once they reach the feeding conveyor (1) the fibres, which have been checked and compressed by a cylinder or by a sheet, are fed into the card by feeding cylinders (2), which have a low peripheral speed, corresponding to that of the conveyor. The feeders rotate in opposite directions to one another and are covered in needles, inclined in the direction opposite to that of rotation.

These cylinders, which have to be strong and inflexible in order to feed the fibres to the beater cylinder (4) as evenly as possible, are accordingly very small. Indeed, if the cylinders are small, then so is the area of contact (approximately triangular in section) between them and the beater cylinder, the area in which the material escapes control.
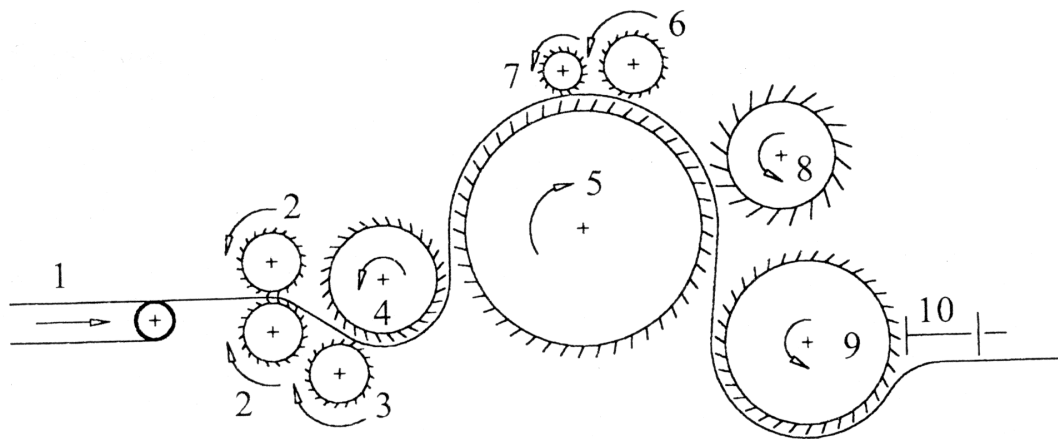
Fig. 79 Diagram of a card

The beater is the first cylinder to open the fibres and arrange them parallel to one another. Rotating in an anti-clockwise direction and equipped with clothing that is also inclined in an anti-clockwise direction, the beater cylinder, reaching a peripheral velocity that is considerably greater than that of the licker-in cylinders, subjects the fibres to a violent action, stripping the upper feeding cylinder and effecting a carding action with the lower one. This carding action serves to condense the fibres on the feeding cylinder, and it is therefore necessary to position a stripper (3) below it, in order to return the material to the beater cylinder.

The beater cylinder is stripped by the large drum, on the surface of which are located the various pairs of worker and stripper cylinders. The carding action is performed when the clothing of the drum (5), which is travelling at high speed, brings the fibres into contact with the clothing of the working cylinders (6), which rotate more slowly, and retain some of the fibres.

The fibres caught on the surface of the worker cylinders are detached thanks to the action of the stripper cylinders (7), which rotate more quickly and thus remove the material from the clothings, feeding it back into the processing cycle. The fibres are finally returned to the drum, which, thanks to the fact that it has a higher peripheral speed than the stripper cylinders, now strips them.

There is also a carding zone between the drum and the comber roller (9): the function of the comber roller is to retain and condense the fibres, before unloading them from the machine.

Delivery of the card web is helped by the raising action of the fly cylinder (8), which, having straight, long and flexible needles, draws the fibres to the surface of the drum, where the combing roller can easily detach them.

The effectiveness of this raising action, on the part of the fly cylinder, is significantly increased thanks to a pneumatic effect created by the fast rotation of this cylinder with its long, flexible needles, due to which the fibres are sucked from the base to the tips of the clothing needles.

The web of fibres picked up by the combing roller is detached by the doffer comb (10), which is equipped with a rapidly oscillating blade.

84

Clothings

There are two types of clothing for cards: the sawtoothlike wire and the flexible clothing. Flexible clothings (Figure 80) have needles embedded in a base strip, made up of layers of felt or flexible material.
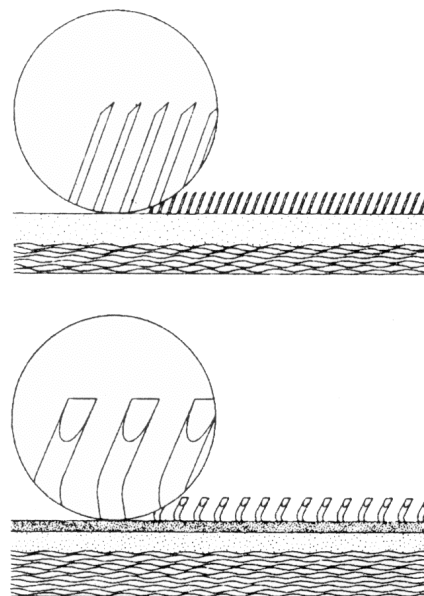
Fig. 80 Flexible clothings
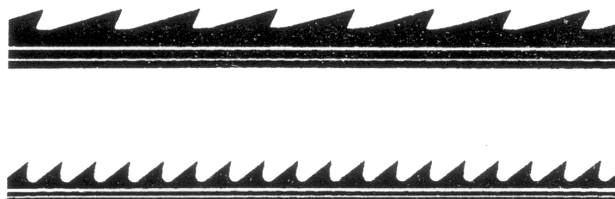
Fig. 81 Sawtooth wires

Wires (Figure 81) are made up of a steel thread with sharp-edged teeth. This makes them quite wear-resistant.

When it comes to choosing between wires and flexible clothings, it must first be remarked that there are, in general, clear advantages to be derived from using former. These advantages are, first of all, increased production levels, because wires are rarely saturated and the material is less recycled, and a less frequent need to carry out cleaning and re-sharpening, which consequently leads to a reduction in idle times. Furthermore, the life of wires is many times greater than that of flexible clothings, which means that they also cut costs considerably; finally, precisely because of the short time the fibres themselves remain on the card, wires also cause fewer fibre breaks, thus the semi-processed product has a longer average fibre length.

However, there can be major obstacles to the use of wires on cylinders other than those of the pre-carding unit, where sawtooth wires are essential in order to effect the first and the most intensive opening operation. One, when materials are particularly heterogeneous, is the presence of foreign bodies in the blends: in this situation, wires are more liable to break, and to sustain serious damage, than flexible clothings, because while the latter spring back quite easily, wires can often become irreparably dented, making it necessary to replace many metres.

Another contraindication for the use of wires can be the presence of very greasy blends.

Excess grease, that has not been absorbed by the fibres, is deposited on clothings. If these are flexible clothings, it becomes mixed with the layer of fibres that are deposited at the base of the clothing needles. Thus, it is periodically removed during cleaning. Wires, on the other hand, which become just as contaminated with grease, gather far fewer fibres and this makes them more difficult to clean. Finally, with wires, the material is not recycled to the same extent, and the carding and blending effect is less pronounced.

The flexible needles currently used are all curved knee-type needles. This is because, as they flex (Figure 82), the simultaneous rotation of the knee and foot allows the distance between the clothings to be kept constant, guaranteeing even processing and accurate counts.
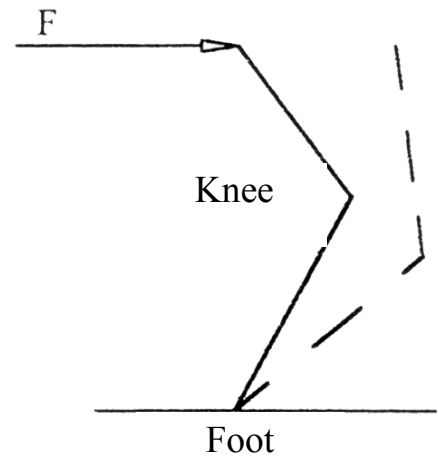
Fig. 82 Curved needle.

Loader

The equipment is fed by a loader, which has to deliver a precise amount of fibre blend in a given unit of time to guarantee accurate and continuous production of the required count. This necessity is the result of the continuity of production, which does not allow, while the machine is running, intervention to control or possibly correct the material count. The loader (Figure 83) takes material from the volumetric hopper, which is supplied by the storage boxes, and puts it into the pre-carding unit of the first machine.
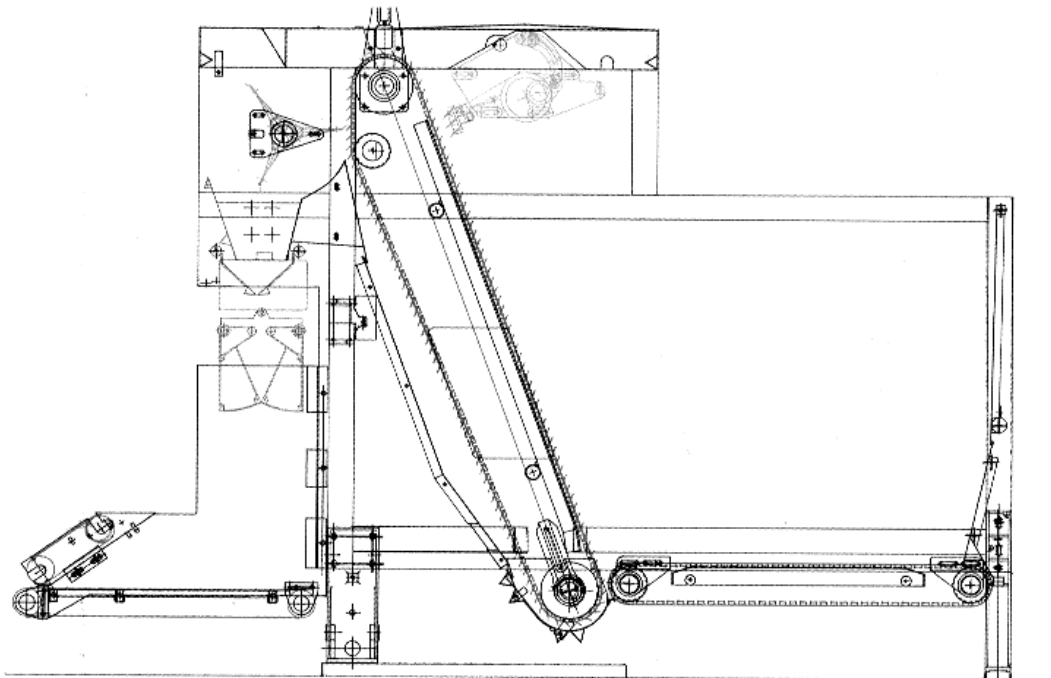
Fig. 83 Diagram of the loader

The most widespread type of loader is the weighing loader, which guarantees weighing constancy over time. The fibre blend is conveyed upwards from the lower part of the feeding chamber by an apron covered with spikes (blending apron). The fibres that have become attached reach the top of the roller and fall into the hopper, while any left over are knocked off into the feeding chamber by a lattice. The fibres are made to fall onto the conveyor at regular intervals through the opening in the hopper, which has two filling speeds: a rather high initial filling speed, to keep production up, and a slower speed, for precision completion of loading; once the required weight has been reached, a diaphragm prevents fibres already falling from landing on the conveyor.

In the most recent models, this high-precision weighing loader is mounted on the loading cells and the weighing operation is computerised. The computer:

- sets and checks the weight of the material fed to the weighing unit, intervening automatically to make adjustments
- controls the unloading of the material onto the feeding conveyor, in synchronisation with the speed of the equipment
- automatically regulates weighing cycles
- automatically triggers, according to the quantity of material being fed, the second running speed of the blending apron.


The carding room equipment

Carding room equipment can traditionally be broken down into three machines (or sometimes just two, when the raw material requires less intensive treatment) and a number of drums that is determined by the type of processing being carried out.

The carding action is repeated a number of times on each of the machines, thus, by the time they are delivered as a web, the fibres have undergone a considerable number of processing stages, which have left them clean and reasonably parallel with one another, even though they are undoubtedly shorter. A compromise has to be reached between the need to open the tufts and the need not to impoverish or excessively shorten the fibres and it is this compromise that, for each raw material, determines the most opportune number of machines and drums to be used in processing.

In the woollen spinning cycle, the basic equipment, of which a number of variants exist, is made up of three machines: the first is called the breaker card, the second the cross card and the third the divider card. An automatic conveyor links the various machines, guaranteeing continuity of production and making carding a single process, albeit one characterised by repeated, increasingly thorough operations.

By means of an underground belt, the automatic conveyor (Figure 84) plucks the web as it leaves one carding unit and feeds it to the next: during this operation, the inclination of the fibres can change by up to 90° in relation to the feeding direction.

Fig. 84 Automatic web conveyor
with underground belt

The breaker card

The breaker card, fed, via the conveyor, by the loader, is made up of two drums connected by a conveyor cylinder.

The first drum, equipped with a feeder group and a series of working-stripping cylinder pairs, makes up the pre-carding unit, and is entirely wired. It opens further the material originating from the preparation stage, eliminating impurities and the largest neps, and thereby also protecting the flexible clothings on the subsequent processing cylinders against excessive wear and damage.

The peripheral speed of this first drum is around 300 m/min, that is around half that of the subsequent drums, because initially the fibres need to be processed more gently in order to avoid breakages or the uncontrolled formation of tangles.

Thanks to the action of a conveyor cylinder, the material passes from the pre-carding unit to the second drum, which is clothed with needles, and to the pairs of worker-stripper cylinders, the fly cylinder and the comber roller. The comber roller is unloaded by the doffer comb and the web is fed to the crossing card on a conveyor belt.

The intermediate card and epurator

The purpose of the conveyor that transports the material from the breaker card to the intermediate card is precisely to feed the web to the second machine, by means of condensation on an endless tape doubled with other tapes, in such a way that the fibres are overlapped forming a criss-cross effect with the feeding direction. This method of feeding the intermediate cross card creates a more intense carding effect and better blending of the material, particularly important when processing blends with a heterogeneous composition and many colours: indeed, in this way, any stripes of colour that are present are distributed across the whole width of the machine and the fault is better compensated for. This card is entirely equipped with flexible clothings and can be made up of one or two drums, according to processing requirements.

When it is delivered by the intermediate card the web passes through the epurator (Figure 85), which is made up of two hardened, ground and polished steel rollers, subjected to pressure by two pneumatic pressure devices, acting on the pins of the upper roller. This passage through the epurator results in the elimination (through the pressing effect of the rollers) of further impurities, increasing the web cleaning action crucial for optimal processing.

Fig. 85 Pneumatic epurator

Finisher card

This card, again entirely provided with needles clothings, is generally made up of a drum preceded by a fly cylinder with a pair of worker-stripper cylinders, and it serves to obtain a sliver that is as highly processed as possible.

The purpose of the divider (Figure 86) is to split the sliver produced by the condenser into a certain number of rovings – this number varies according to the working width and count required – and (by means of the rubbing sleeves) and to give these a rounded form, a prelude to the cylindrical appearance of the yarn; finally it serves to wind them onto beams that will subsequently feed the spinning machines.
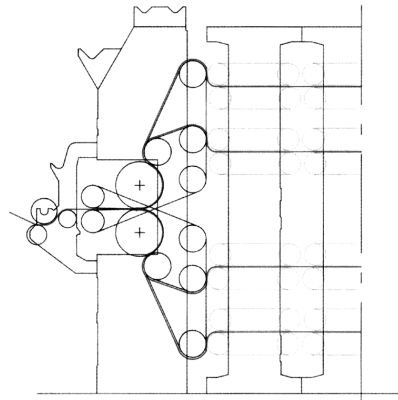

Fig. 86 Divider

Division of the sliver is obtained thanks to a series of leather aprons which, crossing over one another, effect a proper cutting action. Conceptually, this operation is the equivalent of drawing, and indeed the result is the same as that of a drawing of the web, numerically equivalent to the total number of divisions applied:

$$S \text{ divider} = N° \text{ of rovings}$$

In the woollen spinning process, the roving delivered by the divider, proceeds directly to the spinning machine, without the possibility of undergoing any further adjustment. This is unlike the considerable scope for adjustment presented by the worsted wool cycle, in which the length of the fibre allows repeated doubling operations and drawing on the drawframe. This is the reason why woollen yarn is characterised by rather high structural unevenness. This unevenness is the result of the upstream characteristics of the fibres and manifests itself in the roving stage, without there being any scope for corrective intervention in the subsequent passage to the spinning machine.

Composition of the carding room equipment

Due to the number of operations carried out and their crucial importance, the carding room equipment is a complex and imposing installation. Its role, basically, is to produce extremely regular rovings at the highest speeds compatible with the process.

The criterion which determines how many cards are used is above all the type of material being processed, in other words, the fineness of the fibre and the openness of the blend: characteristics that in turn determine the fibre count that can be achieved.

Indeed the equipment, like the whole spinning process generally, is quite rigidly specialised for the production of fine, medium and coarse counts, whose spinnability is influenced by the density of the clothings and by their number, by the number of carding points (the more of these there are the finer the count), by the number of rovings produced by the divider, and by the speed of the various cylinders. The number of machines and drums used depends on the extent of carding and blending that is necessary.

The automatic two-card system is suitable for processing coarse counts or high-quality yarns for knitted or woven goods, while the three-card system is mainly employed to process new or regenerated materials.
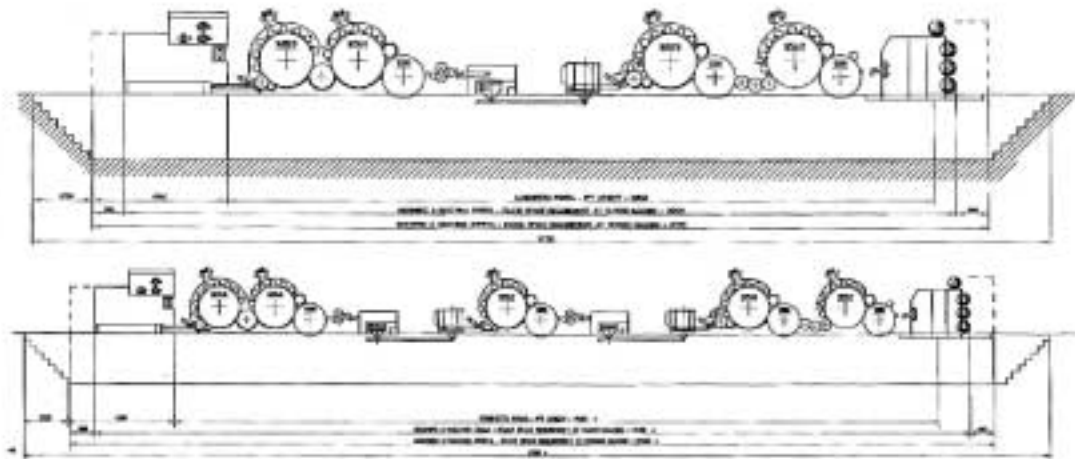
Fig. 87 Two- and three-card installations

Workplace safety and technical features

Considerable progress has been made in the area of workplace safety (owing to its structure, the card is, unfortunately, a highly dangerous machine): as a result, the carding units and the sides are now protected and fitted with safety devices. The widespread installation of automatic cleaning devices has made an important contribution to efforts to increase safety in the workplace, eliminating the need for manual intervention in this generally rather risky operation.

Technical characteristics of carding room equipment:

- working width: from 2,000 mm to 3,500 mm
- diameter of drums: from 1,500 mm to 1,650 mm
- diameter of comber rollers:1,280 mm
- number of working cylinders: up to 6 per drum
- number of cards: two or three
- number of quills: 8/12/16/20, depending on the working width and count
- number of rovings: max. 360
- production rate: max. 70 m/min, depending on the count and type of fibre
- range of yarn counts: up to 48 Nm

Settings and production

The main equipment settings concern the draft and production.

Adjustment of draft is important in order to obtain the required roving count, given that the draft imparted by the spinning machine in the woollen cycle has quite narrow limits. The mechanical draft can be calculated as follows

$$S = Vp / Va$$

in which Vp represents the speed of the comber roller and Va that of the feeders of the last machine.

Production, on the other hand, can be adjusted by increasing or reducing the speed of the comber roller in relation to that of the large drum, in other words by adjusting the condensation of the fibres for the formation of the web. The speed of the comber roller is thus limited by the evenness of the web, which must be uniform and not present thin places or tears

The divider output is expressed as:

$$P = Vp \times T \text{ web}$$

in which

$$T \text{ web} = N° \text{ rovings /roving Nm}$$

Automatic quill doffing

A recent development is automatic doffing of the quills on the divider, while the machine is running. This allows complete doffing of full quills, without reducing the speed of the equipment (Figure 88).

The cycles occurs as follows:
- automatic loading of empty quills
- gathering of rovings at the two ends of each quill
- automatic doffing of full quills
- shifting of empty quills into working position – collection of full quills on a special rack
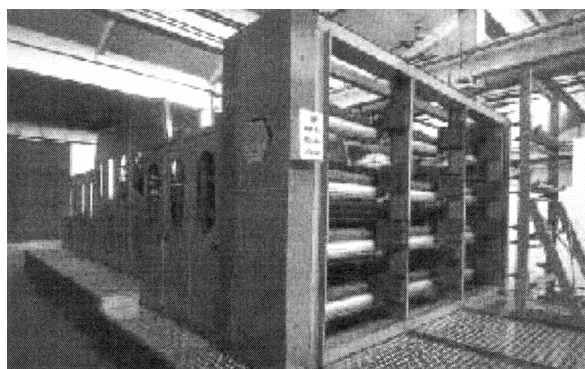

Fig. 88 Automatic doffing on the divider

As well as improving carding room productivity, the automatic doffing device makes it possible to feed the spinning machine with quills whose length corresponds exactly to that of the rovings, thus reducing roving waste.

Ring Spinning

Working principle

The beam with the rovings rests on the feeding cylinder, which, being grooved, makes it rotate through friction. The draft range is made up of a set of feeding cylinders and a set of drawing cylinders whose anti-static rubber-covered cylinders exert adjustable pressure. The yarn runs through the nip point of the two drawing cylinders with a to-and-fro motion to prevent sleeve surface wear.

The draft range, which is located on an inclined surface to allow the twists to ascend as far as the nip point of the two feeding cylinders, is followed by the yarn guide, which serves to keep the yarn perfectly aligned with the spindle axis, facilitating its winding onto the spinfinger (Figure 89). The spinfinger is essentially an extension, of varying shapes and sizes, of the end of the spindle.

The aim, in any case, is totally or partially to eliminate the spinning balloon, thereby reducing the yarn tension, and improving its strength, elasticity, evenness and obviously production rate (given the optimal exploitation of the traveller speed that derives from this).
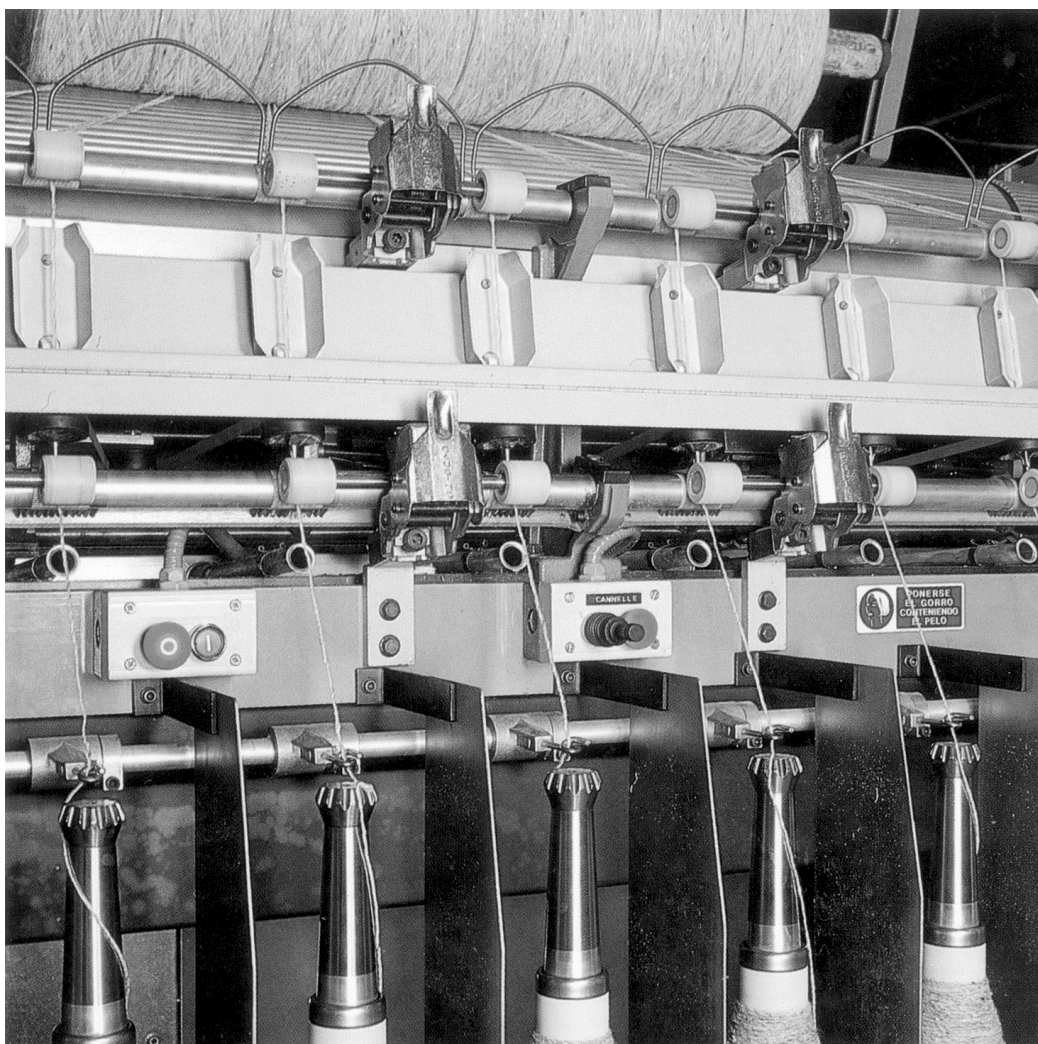

Fig. 89 Draft range and spinfinger

The yarn receives twists as it is pulled by a traveller that revolves on a ring around the spindle. Indeed, before being wound onto the spool, which revolves as one with the spindle, the yarn hooks up the traveller, which, being pulled, shares the spindle's rotary motion.

To effect winding, the traveller, which runs on a steel ring concentric with the spindle, is thus made to revolve around the spindle, effecting slightly fewer rotations per minute than the spindle itself, thus imparting one twist to the yarn per revolution of the same in the given unit of time. The twists per metre imparted can thus be expressed as

$$T/m = n_c / V$$

in which n_c indicates traveller revolutions and V the speed with which the yarn is wound onto the spool, which is also the same as the delivery speed from the drafting range.

The winding of the yarn, and the contemporaneous twisting of the same, delays the traveller in relation to the spindle, therefore the coils of yarn wound onto the bobbin correspond to the traveller delay.

The following relationship is thus established

$$n_f = n_c + n_a$$

in which n_f represents the spindle revolutions and n_a the coils.

Short fibre drafting

In this case, the rovings are not very cohesive or strong, therefore drafting must necessarily be very reduced (usually carried out at rates of between 20% and 50%) and supported by special fibre control devices. The shorter length of the raw material does not generally allow the fibres to be nipped by the pair of feeding cylinders or by the delivery cylinder, therefore resulting in a high percentage of floating fibres. Indeed, very short fibres do not fit the ideal pattern of behaviour within the draft range (whereby a fibre, nipped by its end by the pair of feeding cylinders, moves forward within the draft range controlled by contiguous fibres until it reaches the nip point of the pair of delivery cylinders, where it undergoes an acceleration), because floating fibres tend to change speed in an uncontrolled and premature manner, drawn by friction by those that the cylinders have already trapped. This is the cause of defective drafting, to which remedies can be sought in two ways:

1. through the adoption of drawing rates that are very low in relation to the length of the fibres
2. by carrying out, using appropriate devices, effective fibre control.

The so-called false twist draft is made up of a rotating organ, through which the roving runs, inserted in the draft range, close to the delivery cylinders. In a static situation, the roving would, in this way, receive false twists, that is to say in the opposite direction downstream and upstream of the rotating element. During motion, however, the situation that emerges is quite different, in that twisting is distributed and remains only in the stretch between the feeding cylinders and the point of rotation, while in the part that follows, as far as the drafting cylinders, twisting disappears, leaving the roving weaker and thus subject to breaks: this is why the rotating element is positioned as close as possible to the drafting cylinders.

Drafting and twisting is a perfectly valid procedure for fibres of a certain length, while for shorter ones it needs to be integrated with the drafting-laminating unit, which allows good control of the fibres, preventing them from floating. The control devices must guarantee the running of longer fibres as well, thereby effecting drafting in ranges of adequate width.

One valid solution is that of a pressure roller with high circumference, on which the fibres can assume a stable arrangement.

When wanting to apply a high draft ratio, thereby obtaining good adjustment of the roving, a draft range with a false-twisting device can be used, completed by a second range with a laminating unit: integration of these two systems makes it possible to increase the draft, and to achieve a stable value and stable results (Figure 90)
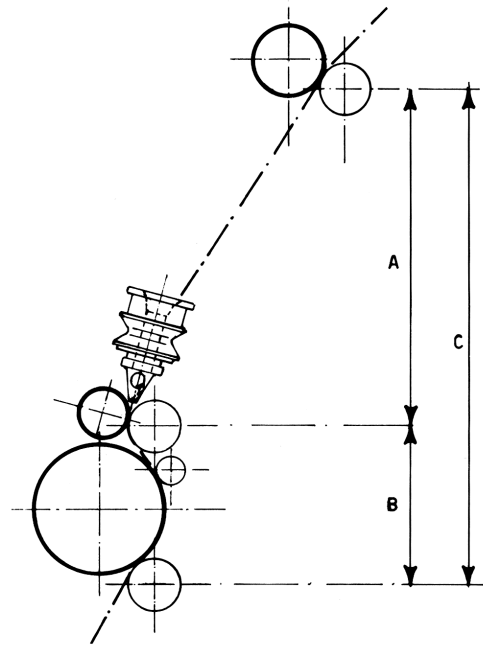
Fig. 90 Draft range with false twist followed by a range incorporating a laminating unit

In reference to the figure, the total draft to which the roving is submitted is calculated as follows

$$S_{total} = S_C = S_A \times S_B$$

Spinfinger

The spinfinger serves to retain the yarn, which is wound around it forming coils, thereby countering the centrifugal force that is the main cause of balloon formation.

This problem, typical of ring spinning machines since it derives from their very working principle, is very evident in the case of woollen and semi-worsted ring spinning frames, due to the coarseness of the yarn and the large size of the spool and ring. It is known that the factors negatively affecting yarn tension are essentially related to the size of the balloon, to the square of the rotation speed and to the various sources of friction: yarn-air, traveller-air, traveller-ring.

The coils wound around the spinfinger form a sort of reserve that supplies material when yarn tension is higher (winding of the kernel and on the smaller diameters of the frustrum) and gathers it in again when the tension drops. This allows it to cope with periodic changes in winding tension, eliminating the balloon totally (this is the solution adopted in the case of coarse yarns) or partially (the solution preferred for medium-fine and fine yarns).

The main difference between the two types is the path followed by the yarn, which, having formed a few coils around the spinfinger, runs around the tube to reach the spool formation level (this is in the case of total elimination of the balloon), while in the case of partial balloon elimination it is detached from the tube, forming a smaller balloon.

Clearly, therefore, to avoid the risk of fibres getting caught and breaking, the tube has to be well finished. The adoption of the spinfinger has allowed an increase in the tube length, with consequent benefits in terms of productivity.

Furthermore, the spinfinger allows the twists to be more evenly distributed, reaching as far as the delivery cylinders at the end of the draft range: sometimes, friction with the thread guide causes local elimination of twists and thus a considerable weakening of the yarn and increased risk of yarn breaks.

It is worth noting that modern, electronically-controlled machines use continuous spindle-speed variation during the formation of the bobbin (kernel, build-up and end), as well as during the coil deposition and winding/binding, in order to keep the yarn tension constant.

Ring

The rings are positioned on the ring rail, which has a channel that is connected with the central automatic-dosing lubrication system. The rings usually have a diameter of 75-95 mm in the case of fine yarns, 110-140 mm in that of coarse yarns and up to a maximum of 300 mm for very coarse yarns. Naturally, the spindle rotations are inversely proportional to the diameter of the ring, in accordance with the following:

$$V_c = \pi \times \Phi_a \times n_c$$

Where
V_c = peripheral speed of the traveller
Φ_a = ring diameter
n_c = number of traveller revolutions

The speed of the traveller is theoretically restricted to around 40 m/s (but this can be much lower if problems connected with the working principle are exacerbated by problems relating to the strength of the yarn, which is highly variable and depends on the type of fibres). Thus all wool spinning machines are characterised by a speed that is, on average, lower than that of worsted wool spinning machines. In particular, the table below refers not only to the classic set of rings with diameters ranging from 75 mm to 140 mm, but also to those reserved for particularly coarse yarns, with diameters of up to 300 mm.

GAUGE	Φ RING	H TUBE	COUNT	SPINDLE	
(mm)	(mm)	(mm)	Nm	(rpm^{-1})	
106	75 – 80	350 – 400	8 – 30	10.000	FINE YARNS
120	90 – 95	400 – 450	6 – 16	8.500	
145	110	450 – 500	4 – 12	7.000	COARSE YARNS
165	127	500 – 600	2 – 8	6.000	
180	140	600	1 – 5	5.500	
240	200	700 – 800	0,5 – 4	3.800	EXTRA COARSE YARNS
300	300	700 - 800	0,5 - 3	3.000	

Spinning machine automation

Efforts to automate the spinning machine concern both bobbin and quill change.
Following the automatic descent of the ring rail, the cycle occurs in the following stages:
- yarn breakage, removal and raising of the bobbins above the spinfinger
– unloading of full bobbins on to the conveyor belt
– automatic reloading of empty tubes onto the spindles
– cutting of the rovings being processed and unloading of empty quills onto relevant conveyor
– deposition of full quills (via a suspended chain device) onto the feeding drum
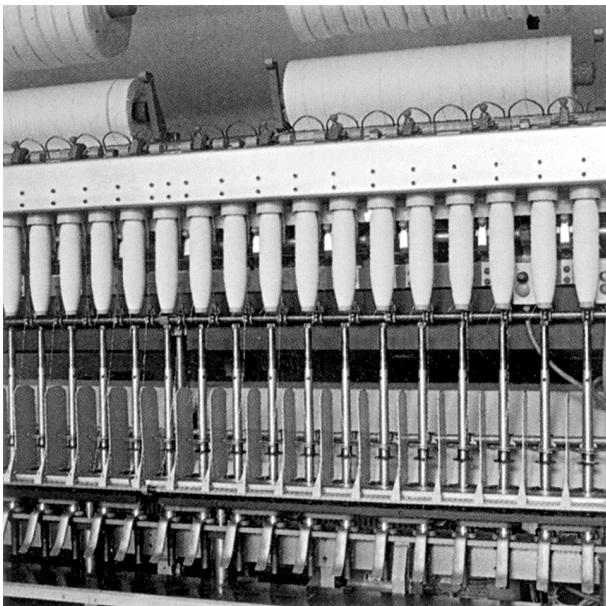– automatic splicing of the rovings.
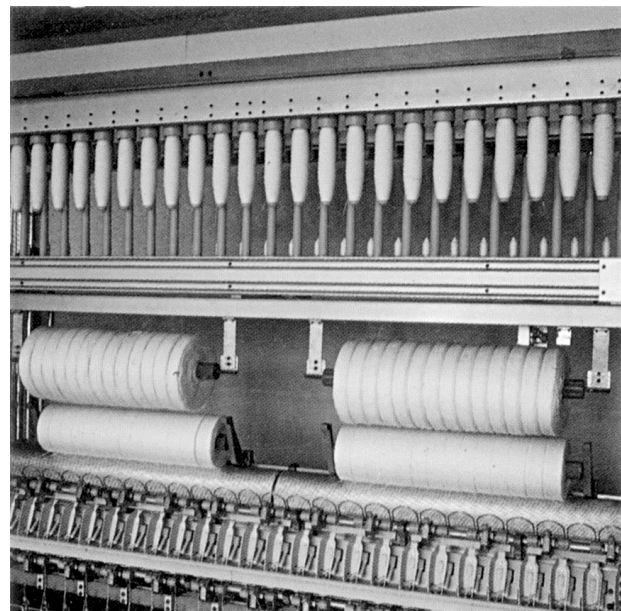

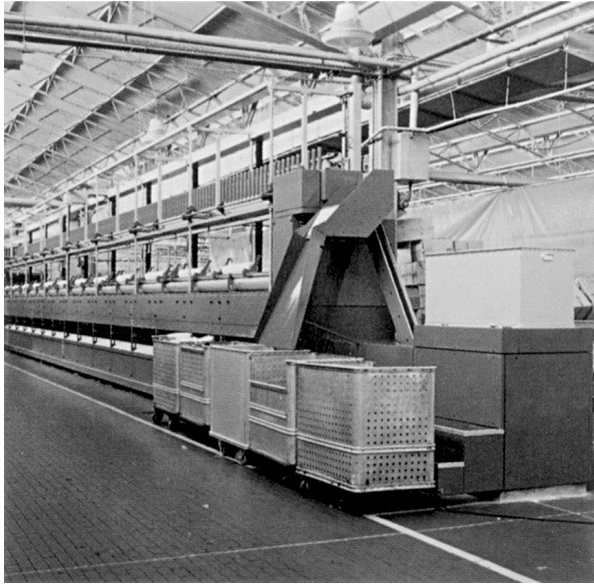*Fig. 91 Start of bobbin unloading stage*

Fig. 92 Raised, removed bobbins

Fig. 93 Bobbin unloading and tube reloading
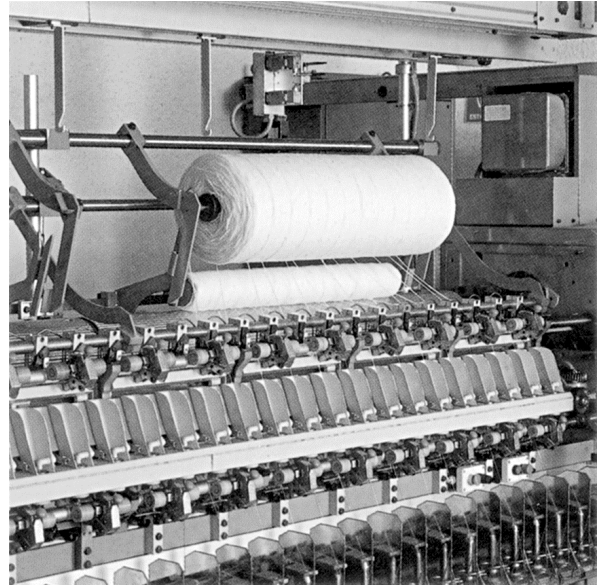
Fig. 94 Quill change and roving splicing

Selfacting Spinning Machine

Working principle

The selfacting machine is a discontinuous-type spinning machine that, operating cyclically, forms a given length of yarn and then winds it onto a cop.

These two stages, which take place separately, are characterised by the reciprocal movement of the two parts that make up the selfacting machine: a moving carriage, which, in each working cycle, effects a forwards and return motion, and is where the feeding quills are located, and another fixed carriage that accommodates the spindles (Figure 95)

Fig. 95 View of an automated selfacting spinning machine

In each working cycle, a length of yarn (the so-called run-out) is produced, which corresponds to the distance travelled by the moving carriage.

The working cycle of the selfacting machine can be broken down into three stages:

1) the forward motion of the roving-carrying carriage with drawing and twisting of the fed roving
2) carriage stopping and ultimate twisting, compensation for shortening and preparation for winding
3) carriage return and winding of the yarn onto the cop

98

1st Stage

During feeding, the beams onto which the rovings are wound are made to rotate by the grooved cylinders on which they rest, in such a way as to unwind the material, which then passes through a pair of cylinders to create a nip point and to be fed to the spinning machine.

In this stage the spindles start to turn slowly, while the feeding table on the rails, starts to distance itself from the spindles, moving at a speed greater than that of the roving unwinding. This results in progressive drafting, while the spindles increase their speed of rotation, imparting pre-twists. The spindles are positioned slightly lower than the feeding frame and show an approximately 15 degree inclination towards it, thus the coils of yarn that become twisted around the end of the spindle tend to slip off it, becoming transformed into twisted coils on the yarn. Each twist is thus produced by a spindle rotation and constitutes a failed winding (Figure 96)
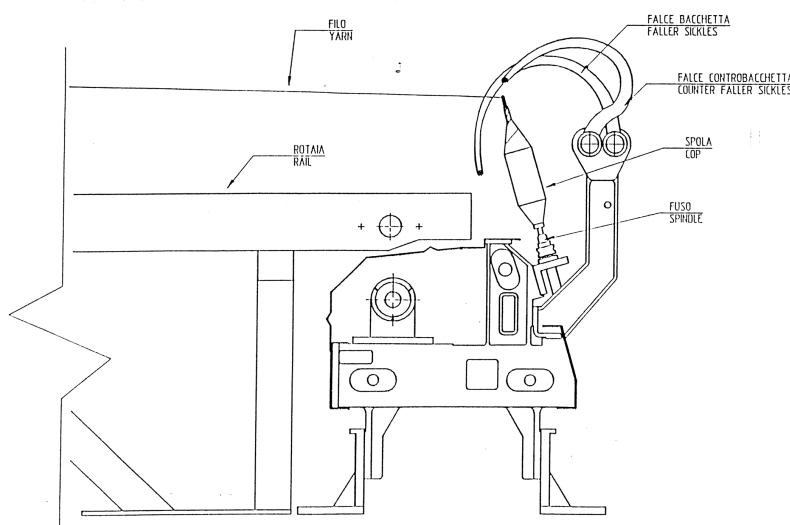

Fig. 96 Twisting stage

The pre-twists, thus called because they are formed during drafting and represent only part of the total, definitive twists, are fundamentally important because they bind the fibres together, making the roving strong enough to withstand drafting without breaking and increasing its evenness. The tension to which drafting subjects to the roving increases in proportion to the number of pre-twists imparted, while parallel with this the elongation at break is reduced: the twists per metre needed in order to obtain the highest elongation at break value at the highest possible draft ratio can thus be evaluated experimentally. Naturally, the draft ratio (usually between 20% and 50%) is also influenced by extremely variable factors, such as the type of material being processed, the characteristics of the fibres, and the amount of emulsion present on them.

Pre-twists are also very useful in compensating for possible roving irregularities. In fact, the fibres, due to their short length and marked heterogeneity will very rarely be well aligned and parallel with one another, as a result the roving will usually have an uneven shape, characterised by thicker and thinner places. Consequently, the pre-twist plays a positive role as the twisting action is stronger where the roving is thinner, giving to these points a higher resistance to drafting, unlike the thicker places – less twisted and therefore weaker – which will thus be homogenised with the rest of the roving. Behaving in this way, the fibres promote "intelligent" drafting distribution, varying the intensity more or less according to need.

Analysing this phenomenon in greater depth, it can be hypothesised that the pre-twists serve to slow down the movement of the fibres, extending the initial straightening and alignment stage, and are probably helped in this by the vibrations induced in the roving by the rotation of the spindles and the consequent escaping of the coils off the spindle tips. Spindle rotation increases progressively as the feeding table becomes more distant, according to a curve adjustable according to the requirements of the yarn: at the end of this motion, the roving is drawn, pretwisted and even.

2nd Stage

At the end of the drafting stage, the feeding frame remains still and the spindles rotate at maximum speed, imparting the twists that, added to the pre-twists already conferred, reach the definitive value to be given to the yarn. The twists are, in the same way as the pre-twists, distributed along the length of roving thus far processed although now the process is considerably speeded up to reduce as far as possible the duration of this stage, which is non-productive.

The twists lead to a shortening of the yarn, which can be compensated for in two ways: by returning the feeding carriage, or by overfeeding the roving.

At the end of twisting, a few coils of yarn remain wound around the end of the spindle, preventing the subsequent winding of the yarn onto the cop. These can be unwound by making the spindles rotate briefly in the opposite direction. The release of these coils reduces the tautness of the length of yarn produced, and this tautness thus has to be restored. This is where faller sickle comes in, to guide the winding, and the counter faller sickle, to maintain adequate tension during winding.

3rd Stage

The faller and counter faller sickles are two devices that can be likened to thin metal rods that form part of the spindle carriage and run across the entire front of the same: when the carriage starts its return, the faller sickle lowers rapidly as far as the maximum cop diameter, effecting the binding coils needed to render the cop compact; they then ascend returning as far as the minimum diameter, to effect the winding coils, which are overall about 4 or 5 times longer than the previous ones (Figure 97).
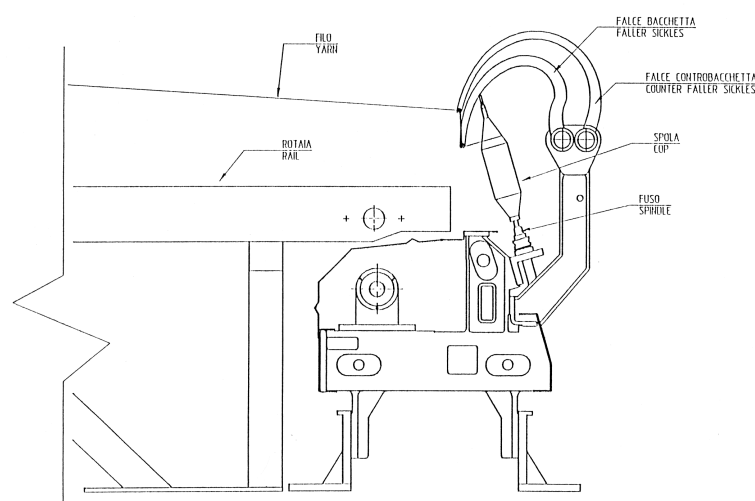

Fig. 97 Cop winding stage

While the faller and counter faller sickles control, respectively, the yarn distribution motion and its tension throughout winding, it is also necessary to vary the speed of rotation of the spindles in accordance with the laws regulating the formation of the cop's conical layers. Once the carriage has returned and the winding is finished, the faller sickles have fulfilled their function and return to their starting position, allowing coils of yarn once more to wind around the end of the spindle, at the start of a new working cycle.

Winding is the machine's productive stage, during which the yarn is wound onto the cop thanks to the rotation of the spindles and the contemporaneous return of the carriage.

On the other hand, it is also a very delicate stage that must ensure the formation of a compact and adequate-size cop, that will guarantee optimal unwinding during subsequent processes (winding, warping...)

Automation

In the electronically-controlled selfacting machine, the driving and control of feeding, drafting, twisting and bobbin formation is managed by a microprocessor that permits optimal regulation of the spinning parameters, in relation to the characteristics of the raw material, as well as the formation of a controlled-tension cop.

The spinning machine can be equipped with a quill and cop change automation system.

The cycle is made up of the following stages:

- doffing of the cops followed by their transportation and deposition in containers situated alongside the machine. The cop-doffing unit descends from its rest position above the machine and proceeds to slide the cops off the spindles, simply snapping the yarn, carrying out binding and underwinding.
- placement, on the spindles, of empty tubes picked from a container alongside the machine, w here they are oriented appropriately and positioned on a rack.
- quill change with unloading of the empty beams at the side of the machine. This stage is preceded by the pre-arrangement of the quills, with manual positioning of the new rovings in gripping devices (these are all part of the operator's routine tasks and do not, therefore, negatively affect performance). The empty quills are moved away from the feeding table and replaced by the full ones, prepared earlier.
- splicing of the roving by superimposition of the old over the new roving.
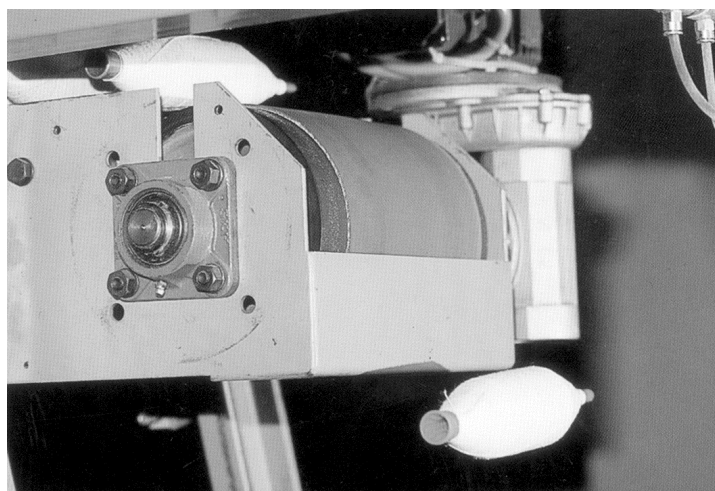

Fig. 98 Full cop doffing

Fig. 99 Container of loose tubes

Fig. 100 Tubes orderly positioned on the rack

Technical features

- number of spindles: max. 900
- max. spindle speed: 11,000 rpm
- max. mechanical speed of the feeding frame: up to 8 cycles/min (depending on the stroke)
- spindle gauge: 62-65 mm
- spindle height: 320 mm
- stroke: from 3 m to 6 m

Fancy Yarns

General remarks

A fancy yarn is characterised by special effects (knots, slubs…) that alter its section, rendering it irregular, in accordance with a pre-established pattern, and sometimes incorporating colour effects.

These products are widely used in the hand knitting and knitting sectors, which exploit to the full the fanciness of these yarns, but they are also used to a considerable extent in weaving too, particularly in women's clothing.

Fanciness in a yarn can be obtained using different processes, creating infinite scope for effects, often combined, which can be added to other designs that are now regarded as "classics".

The woollen spinning cycle, due to the way it is structured and even more due to the characteristics of the raw materials used, allows special fancy effects to be obtained within the spinning cycle

Spun fancy yarns

In the preparation stage, it is possible to create two types of fancy yarn: yarns with loose hairs and knop yarns.

In the first case, the effect is obtained by adding loose hairs to the blend, giving the yarn a fuzzy appearance and a silky hand. The presence of loose hairs generally necessitates three passages through the blending chambers, the second one involving an extended pause, long enough to allow the blend to "rest".

Loose hairs are generally fibres of animal origin (sheep, camel, reindeer), although sometimes synthetic fibres can be used (Trital, three-lobe fibres). These however give the yarn a more "brindled" appearance.

In the second case, the fancy yarn is obtained by adding pills of felted wool to the blend. Again, the blend must pass through the blending chambers three times, in order to ensure even distribution of the pills in the blend. To prevent opening of the pills during carding, the initial slashing should be particularly thick as it will be gradually eliminated along the carding line.

The presence of the pills gives rise to a diffuse and uneven swelling of the yarn section along its entire length. This is a result of the imperfect carding and the colour, too, will have a melange appearance.

In **carding** it is possible to obtain knop, malfilé and slub yarns.

The first, obtained through the insertion (using a special distributor) of pills on the second card web, will have a different appearance from the type described earlier. In this case, carding is carried out according to the normal slashing parameters, therefore the section of the yarn is larger only in the proximity of the pill, whose colour stands out and therefore does not give rise to a melange effect.

A malfilé yarn is characterised by its unevenly distributed thick and thin places. This yarn can be obtained using a blend of long fibres (L > 40 mm), which account for 60-70% of the total and short, noil-type fibres, accounting for the remaining 30-40%. This undergoes imperfect carding, with thick slashing for resisting the action of worker and stripper cylinders and comber rollers.

To obtain a slub yarn, carding is carried out as normal and the effect is inserted at the stage of the condenser card, prior to the divider.

A special, computerised device, programmed according to the size and frequency of the slubs, intervenes pneumatically on the fly cylinder, increasing both its descent on the drum and, therefore, its extraction of fibres from the clothings.

On the **spinning machine**, meanwhile, it is possible to produce doubled yarns, obtained by feeding two or more rovings into the machine's draft range: the resulting yarn is bulky with few twists.

Another interesting opportunity is offered by the friction spinning machine, which, normally employed to produce yarns for technical uses (automotive industry, protective clothing, filters…) and for the furnishing sector (covers, carpets), can also be employed to produce fancy yarns.

Friction spinning machine

The friction spinning machine (Figure 101) operates on the basis of a principle of mechanical/aerodynamic spinning.

Being an open-end spinning machine, it effects direct transformation of sliver into yarn and delivers, at high speed, very large packages.
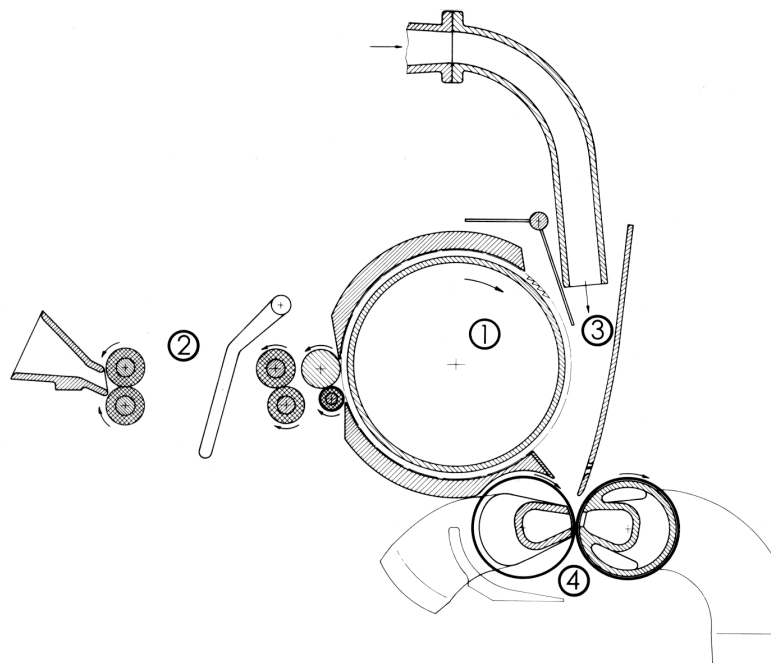

Fig. 101 Friction spinning machine

A rotating carding cylinder (1) breaks up the sliver applying a high draft between the entry (2) and the clothed surface of the cylinder itself. Thanks to a strong pneumatic suction effect (3), which increases the draft, the fibres are detached from the cylinder and transferred along the nip generatrix of the pair of spinning cylinders (4).

These are perforated and exert a suction effect on the fibres, which become twisted due to the friction effect and the torque imparted by the two cylinders, which have the same direction of rotation. The yarn is formed from the inside outwards by superimposition of the individual fibres, which, ultimately, become twisted round one another and strongly bound together. The yarn leaves the nip area of the two cylinders, parallel with their axis of rotation, and is then wound onto cylindrical packages at a rate of around 250-300 m/min.

The friction spinning method, while creating cohesion of the material only with a rather high number of fibres in the cross section (yarn count ranging from 3 to 10 Nm), is not as influenced by the characteristics of the fibre as all the other types of spinning. It allows the processing of natural or man-made fibres with counts ranging from 3 to 15 dtex and lengths of 5-100 mm: compared with traditional spinning machines, these machines clearly benefit from using heterogeneous, even regenerated, materials.

Furthermore, the possibility of using different types of filament as the core means that the yarn is quite strong. In order to obtain particular fancy effects, the spinning machine can be fed with slivers of different colours and materials. Within the maximum admissible loading limits (30 ktex), it is possible to feed various slivers (for example 5 6-ktex slivers), whose fibres will be arranged coaxially, creating a layered effect. Yarns can thus be constructed with the shortest and weakest fibres in the middle and the longer and the more valuable fibres at the outside or with whatever colour effect you like.

An experiment is currently being carried out to verify the possibility of using slivers originating both from cotton cards and from sets of carding cylinders with sliver delivery without the divider and from the worsted wool cycle.

Twisted fancy yarns

The classic fancy yarn is a twisted yarn made up of at least three yarns; of these, one serves as a support and is called the **core**; this is twisted with a second, usually overfed, yarn to create the desired design, this is called the **effect**. A second twisting stage serves to confer stability, uniting the semi-processed product resulting from the first operation with a third yarn, called the **binder yarn**. These three functions, core, effect and binding, can also be fulfilled by a greater number of yarns than this. A twisted fancy yarn can indeed be made up of a high number of yarns and there can be a roving in place of the effect yarn.

The twisting of fancy yarns is normally carried out using the following two types of machine:
1. ring twisting frame
2. hollow spindle twisting machine

The twisting of fancy yarns can involve two subsequent operations (this is the traditional procedure, currently less used), or a continuous two-stage process: in this latter case, a combined machine has to be used, equipped with a hollow spindle and ring system. Clearly this is the more productive solution, but the choice is generally dictated by the type of fancy yarn that is to be produced.

Ring twisting frame

In the first operation, the core and effect yarn are fed by separate cylinders, in order to allow overfeeding of the latter, while the twisting that binds them together is imparted, in accordance with the ring spinning principle, by the traveller.

In the second operation the binder yarn twists around the semi-processed yarn with a lower twist and in the opposite direction to the previous stage. This results in a partial loosening of the effect, resulting in a soft yarn.

Hollow spindle twisting machine

In this machine the hollow spindle with the binder yarn is positioned between two pairs of cylinders, while a hook, below the spindle and rotating in the same direction, twists the core and effect yarn (Figure 102).
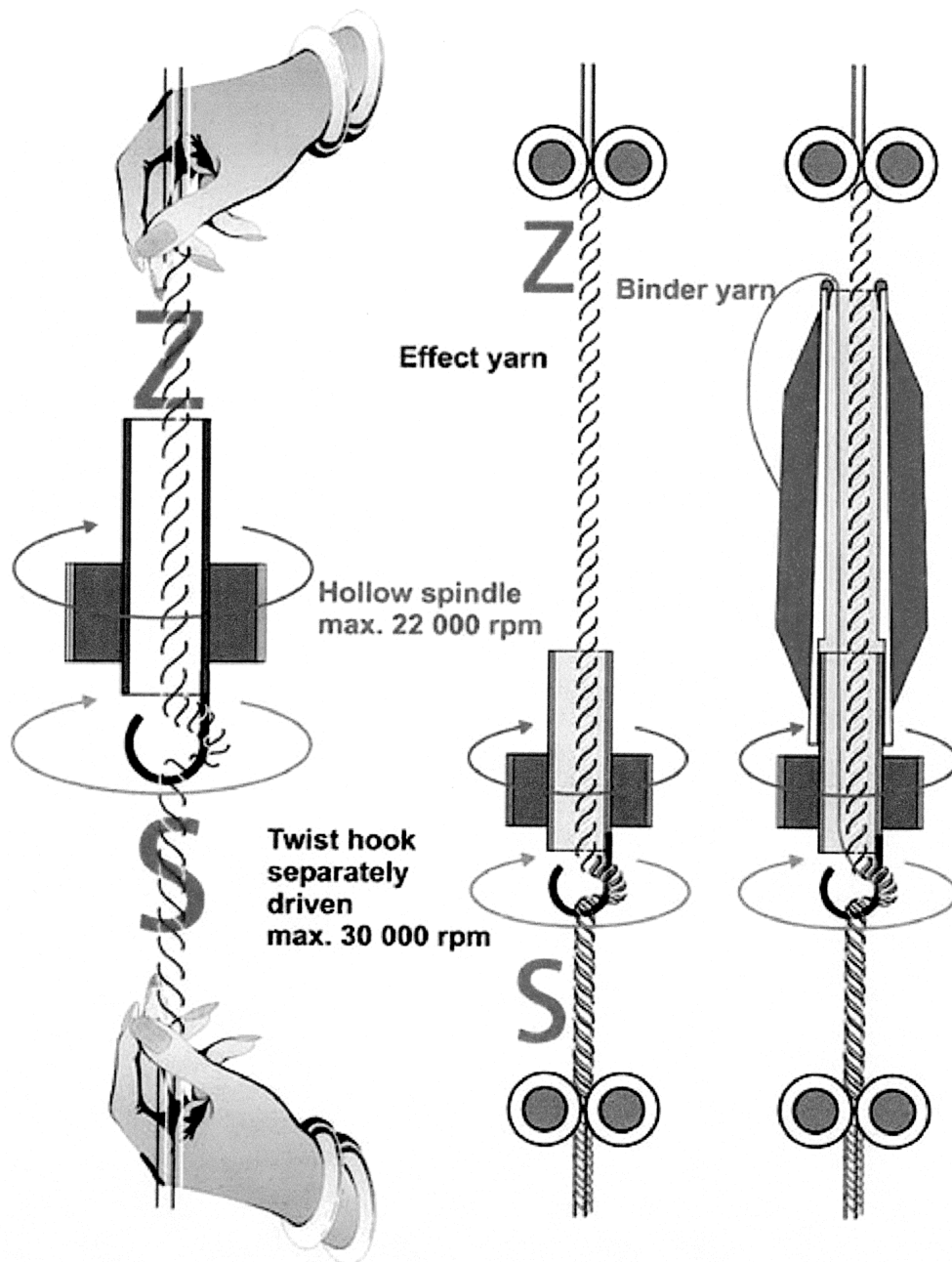

Fig. 102 Principle of the hollow spindle twisting machine

Given the intermediate position of the spindle – it is located between the pair of feeding cylinders and the pair of delivery cylinders – the twists imparted during this first stage are in the opposite direction between the first and second length of the two yarns.

The binder yarn runs inside the hollow spindle, parallel with the semi-processed core-effect yarn, as far as the twist hook, which makes it twist round the other two yarns, stabilising the product.

If the twist hook is driven as one with the spindle, and thus accomplishes the same number of rotations, the twists imparted to the core and effect yarn will number the same as the final binding twists. To prevent an excessively high number of twists making it necessary to stabilise the yarn with a steaming process, a separate hook twist drive has been developed that can rotate at a higher speed than the hollow spindle. The yarn is wound onto a package.

Spinning–twisting machine

The twisting of a fancy yarn can also be accomplished using a machine that combines the two processes, ring and hollow spindle.

In this case the first operation is carried out by the hollow spindle, preceded by the core and effect yarn feeding group. Below the hollow spindle, which holds the binding yarn, is located the ring spindle, which winds the yarn directly and the twists are loosened as an effect of the relative speed between the first and the second stages. Indeed, the ring spindle cannot rotate as fast as the hollow spindle and while this results in a softer yarn, the rate of production will inevitably be lower, given that the bobbin will also have to undergo a subsequent winding stage. When the machine is fed with yarns rather than rovings, it becomes an out-and-out twisting machine (Figure 103).
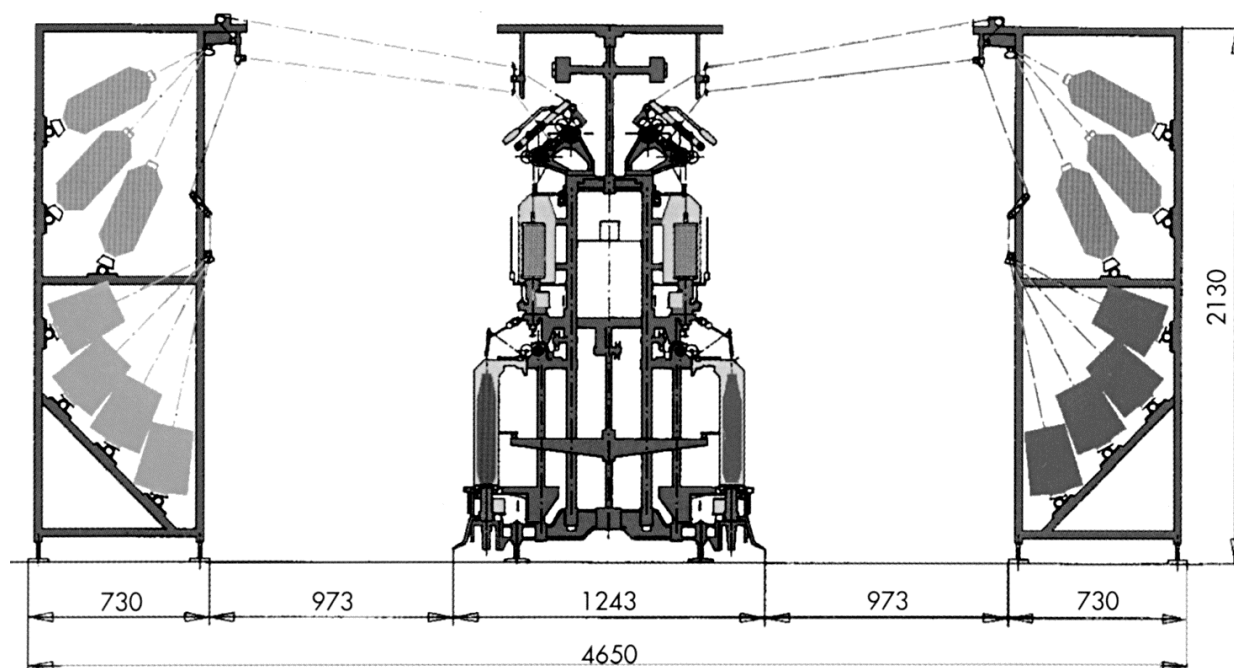

Fig. 103 Twisting machine

When the effect is obtained by a roving, the machine must also effect drafting; this is why it is called a spinning-twisting machine (Figure 104)
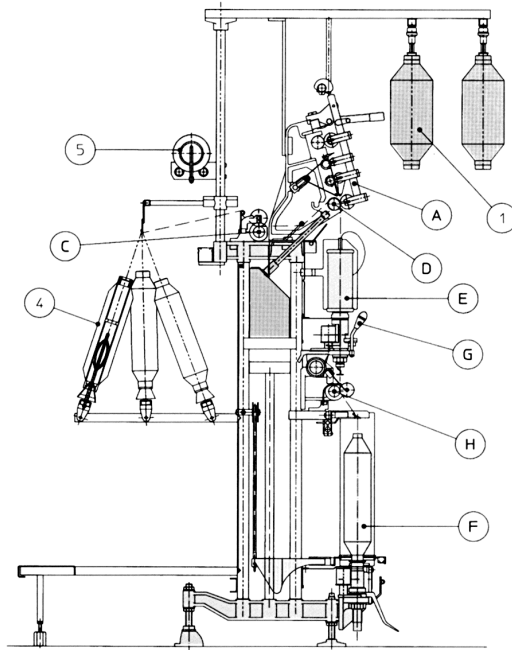
Fig. 104 Spinning-twisting machine with drafting line

The fed material is the roving (1) on spools, which is drawn by the laminating unit (A). The core yarns (4) are fed by the cylinders (C) and reach the exit from the drafting-laminating unit, where they are united with the effect yarn at point (D). Cylinder (5) is used for elastane, for the possible production of stretch fancy yarns. The binder yarn, positioned in the hollow spindle (E), stabilises the effect yarn, and the yarn, via the control cylinder (H), is then collected on the lower spindle (F), where the ring system evens out the twists. Using the handle (G), the operator can stop the spindle to repair breaks or replace the binder yarn package.

Fancy yarns can also be created by feeding more effect yarns, made up both of sliver in cans and of rovings on spools. In this case, the machine has two drafting lines (Figure 105), independently controlled, that make it possible to achieve a vast range of colour effects and constructions.
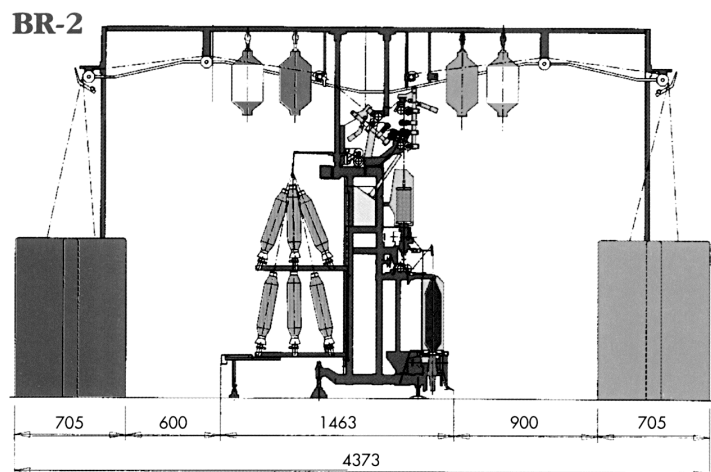

Fig. 105 Spinning-twisting machine with two drafting lines

Technical features of spinning-twisting machines

counts produced: 2-24 Nm
roving count: 0.5-5 ktex
ring diameter: 90 mm or 115 mm (depending on the count)
max. speed (hollow spindle): 12,000 rpm
max. speed (ring spindle): 8,000 rpm
effect: continuous or discontinuous

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,
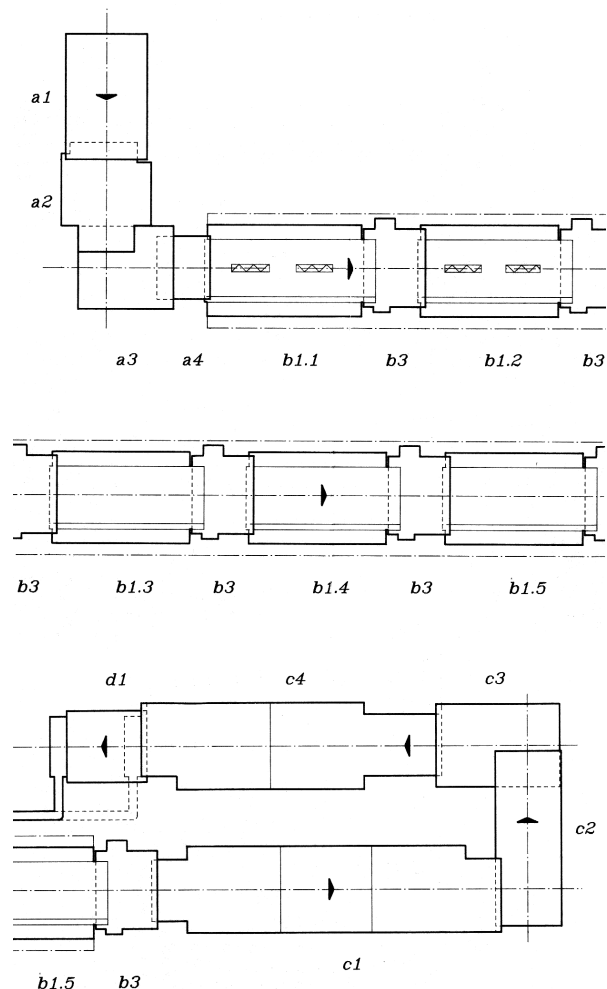

Fig. 106 – A complete scouring line

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- 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.

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.
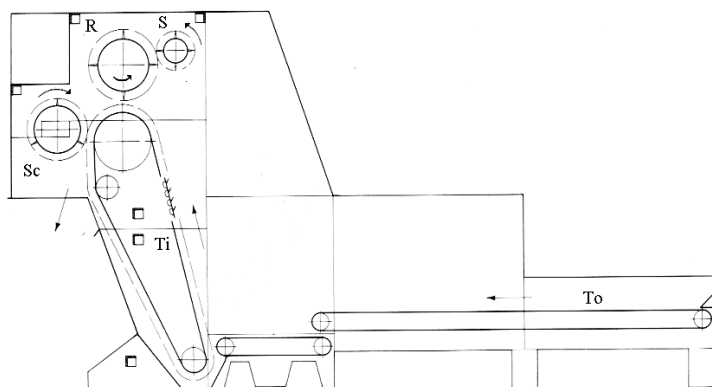
Fig. 107 – Bale opener

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
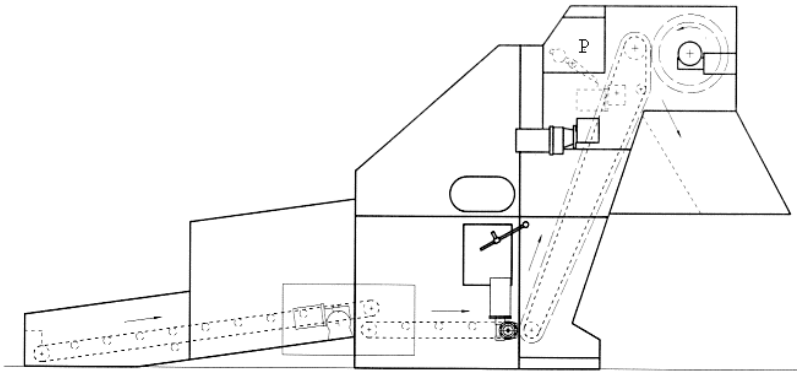
without touching the spikes of the slant apron, thus making the dimension of lumps as uniform as possible.

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).
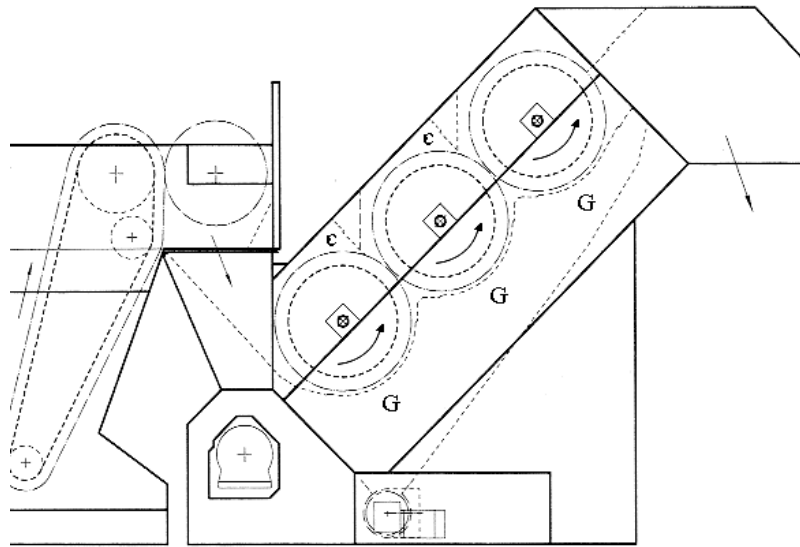
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Fig. 109 - Slant multiple opener-beater

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.
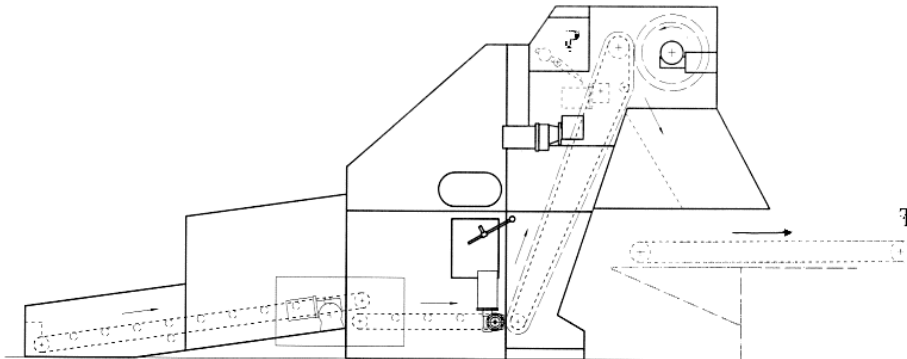

Fig. 110 - Automatic feeder with weighing conveyor

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 $4 \div 5$ successive scouring vats (b1.1 $\div$ 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 $6 \div 8$ litres of water per kg of greasy wool with yields exceeding 70%, to $12 \div 15$ 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);
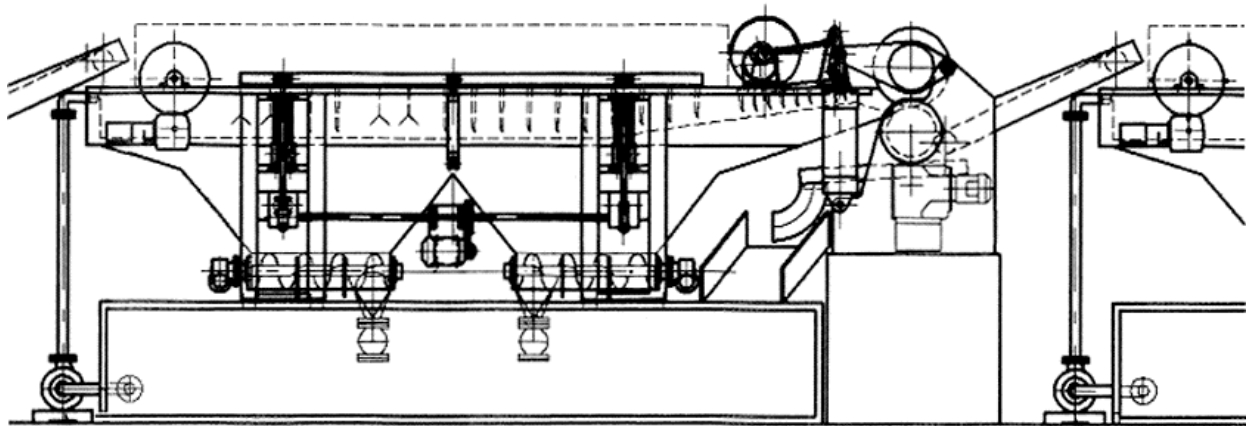

Fig. 114 - Longitudinal section of the second scouring vat in the scouring range
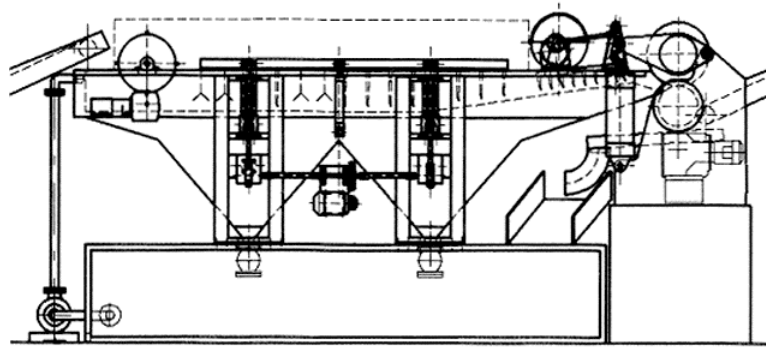
Fig. 115 - Longitudinal section of the third scouring vat in the scouring range

- 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).
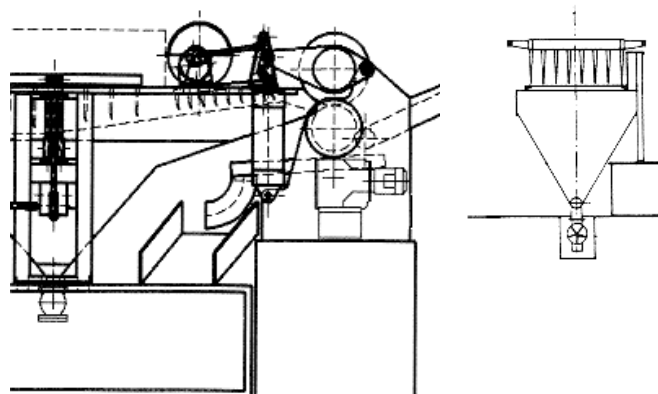

Fig. 116 – Partial side view and front view of the settling trough of a scouring vat.

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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.

Figure 118 shows the liquor exchange between the scouring vats:

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

- 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,
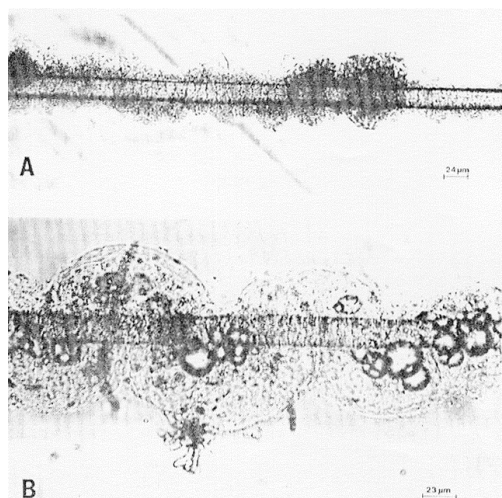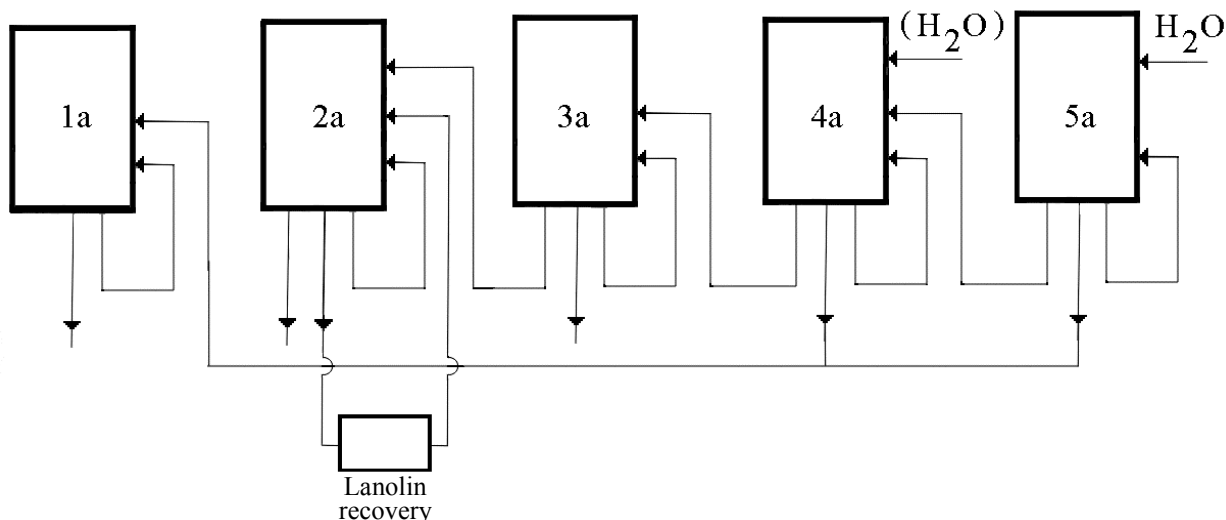

Fig. 118 – Example of liquor circulation between the scouring vats

- 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.
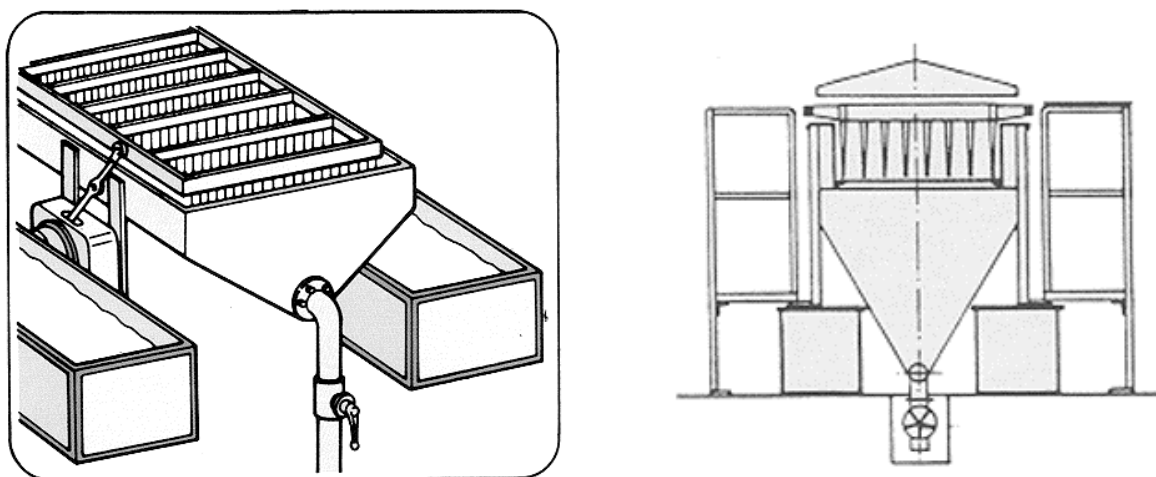

Fig. 119 – Scouring vats with two side settling troughs

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.
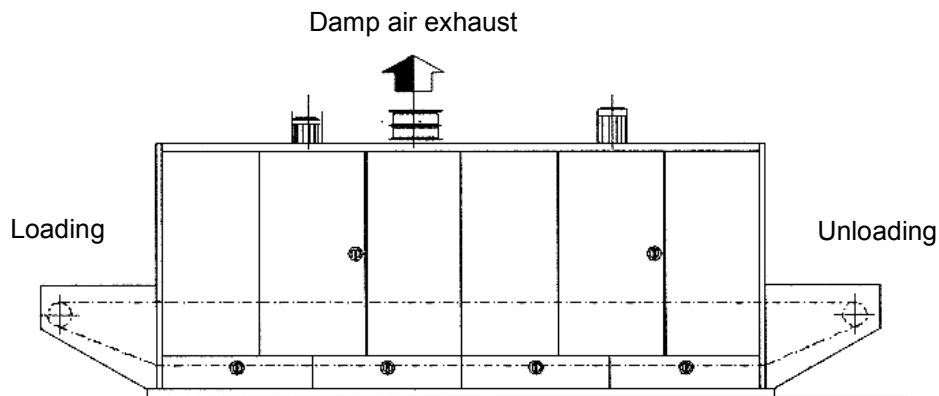

Fig. 120 – Side view of a two-module belt dryer

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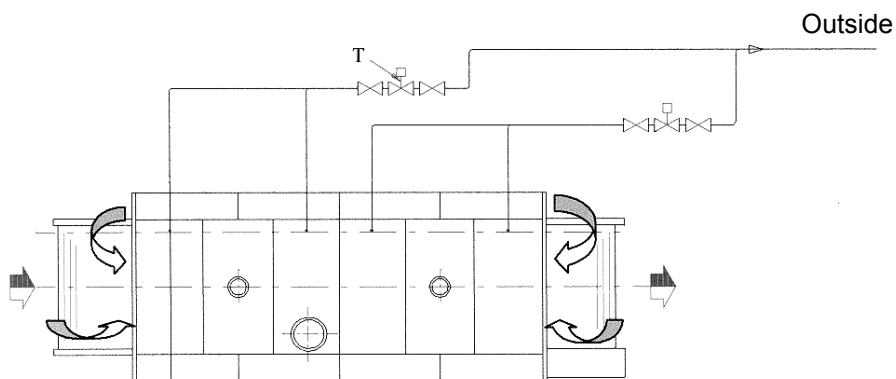

Fig. 121 – Plan of the belt dryer: the arrows indicate the air inlet areas.
"T" stands for temperature controller.

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").
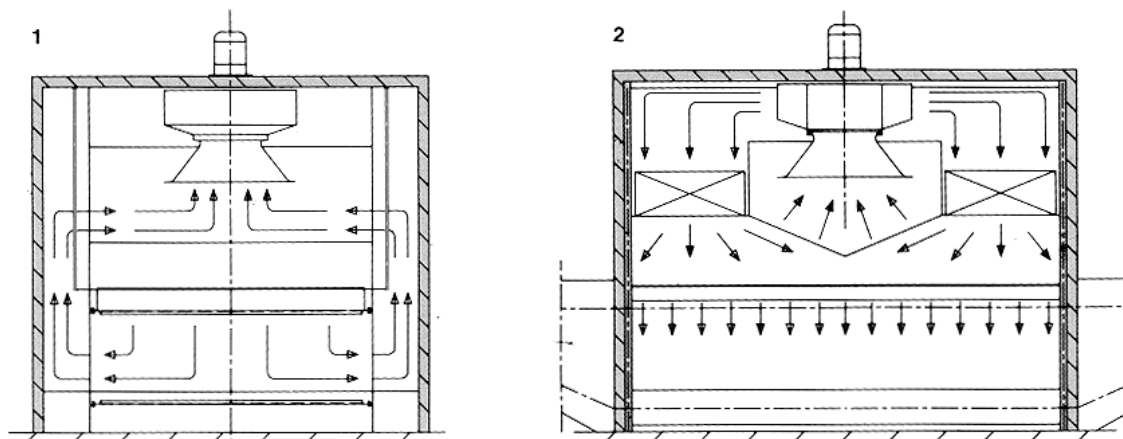

Fig. 122 – Aerothermal chamber: cross section (1), longitudinal section (2)

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.
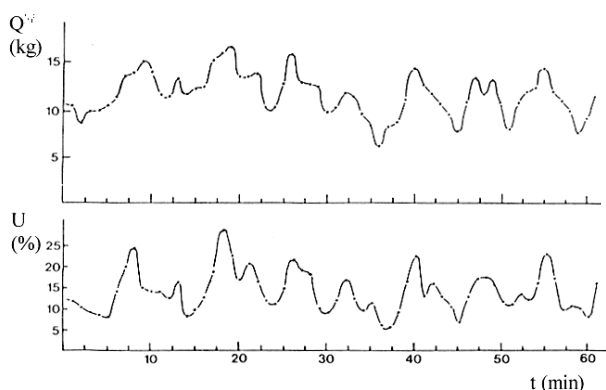

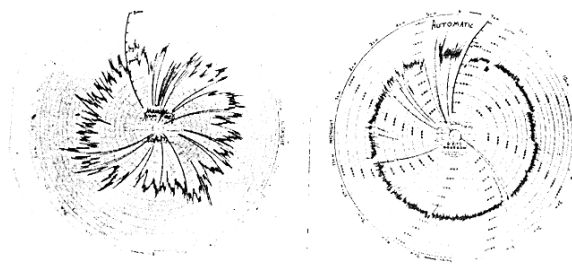
Fig. 123 - Effect of feed variation on residual moisture

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).
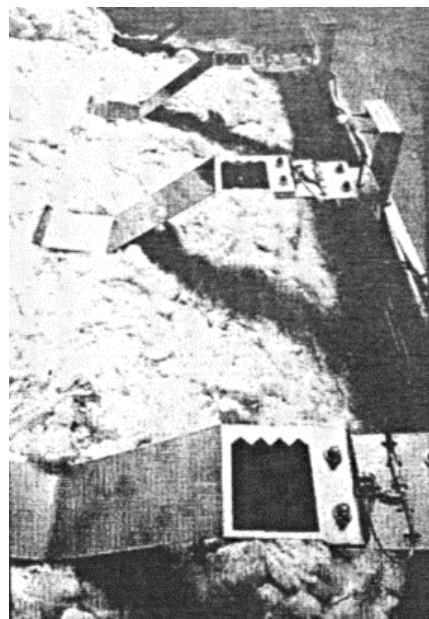

Fig. 125 - Moisture meter

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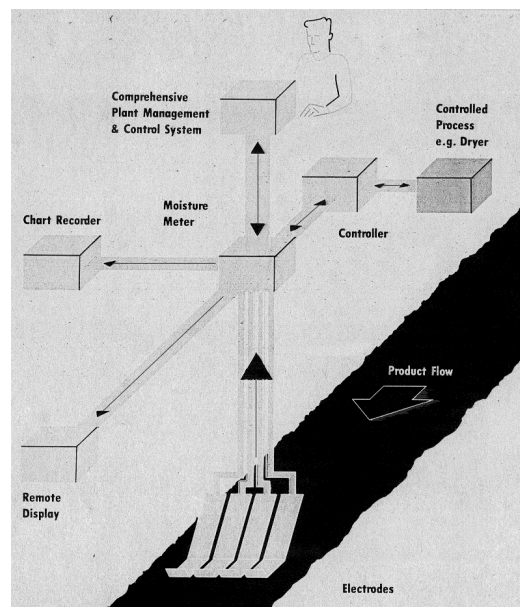and the dwelling time of the wool inside the dryer should be about 90 seconds.

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).
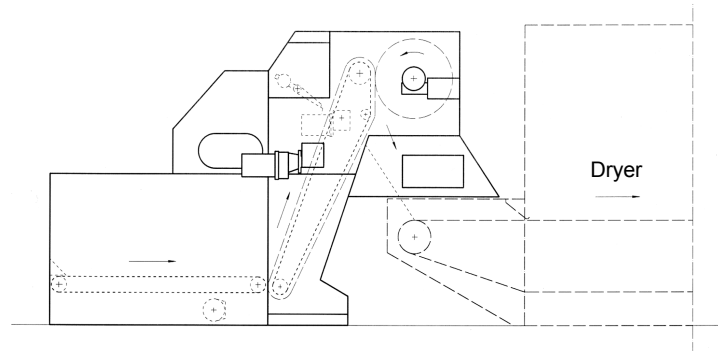

Fig. 127 – Automatic feeder connecting the two dryers

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.
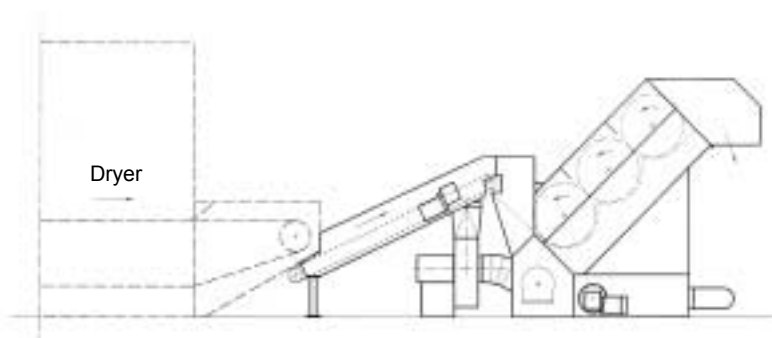

Fig. 128- Multiple slant opener-beater

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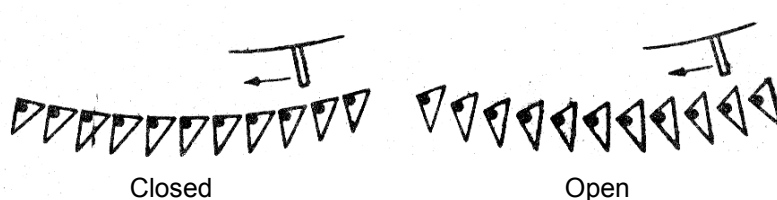
Dirt and waste falling below the grids is taken out by a worm screw and exhausted by means of a fan from the bottom of the grids

Closed   Open

Fig. 129 - Grid

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);
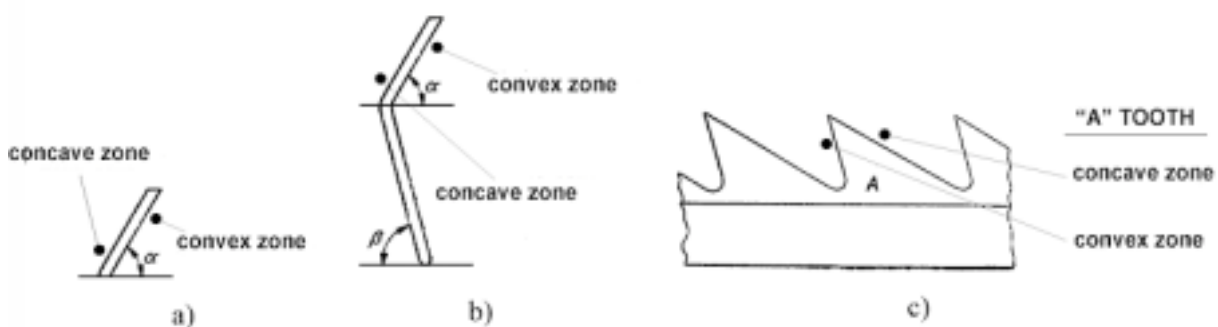

Fig. 130 - Different types of clothing:
a) inclined needle   b) curved needle (flexible)   c) sawtoothlike wiring (rigid)

- 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.
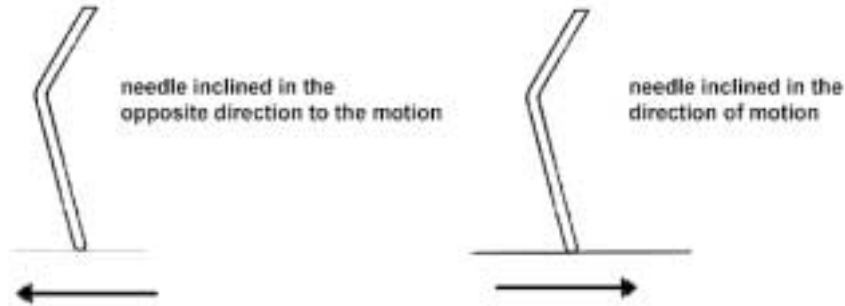

needle inclined in the opposite direction to the motion

needle inclined in the direction of motion

Fig. 132 Interaction between the needles and the fibres
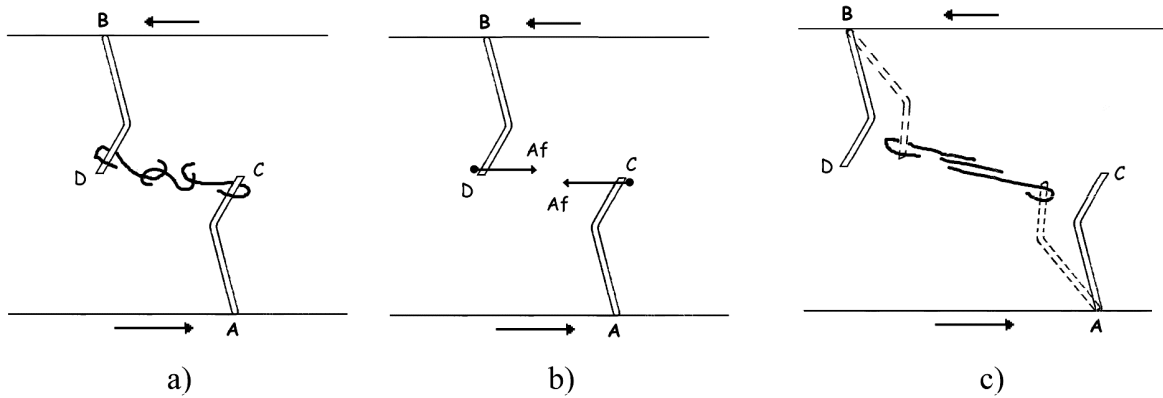

a)   b)   c)

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.
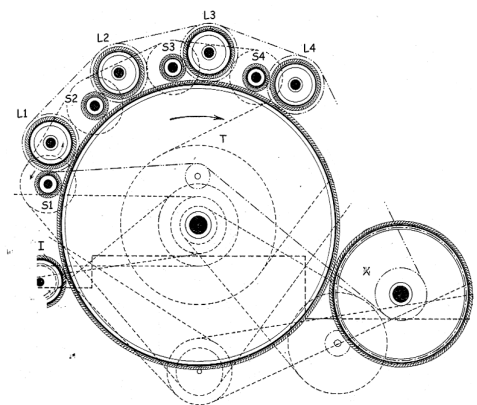

Fig. 133a Carding unit.

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- "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.
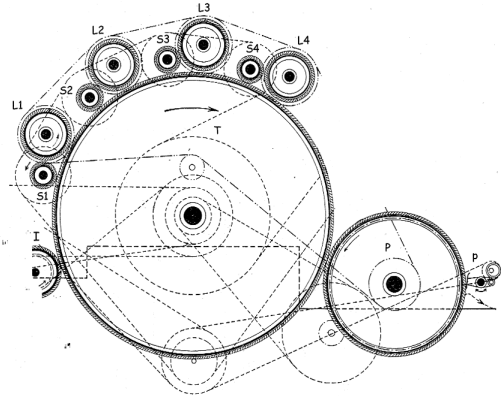

Fig. 133b – Ultimate carding unit

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,
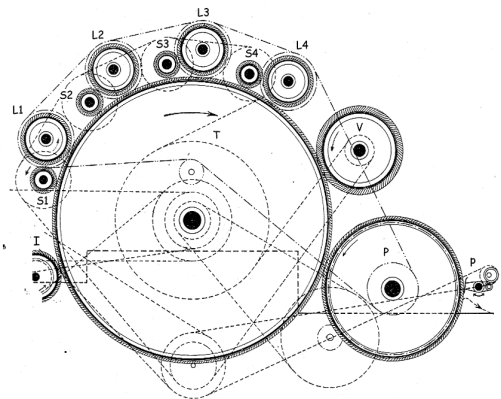

Fig. 133c Ultimate carding unit with fly roller

- 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.
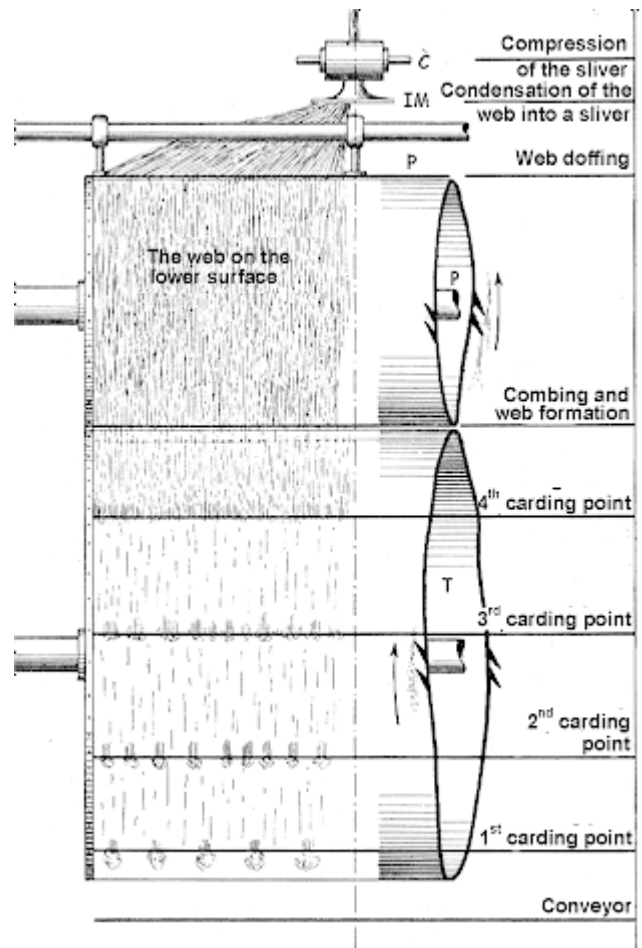

Fig. 134 Operating principle of the ultimate carding unit

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".
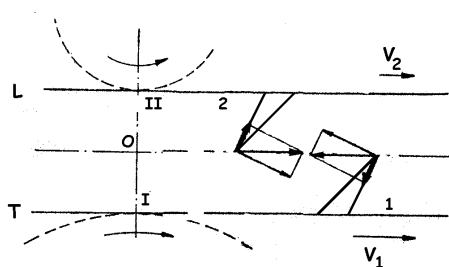
Fig. 135 Carding action

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.

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).
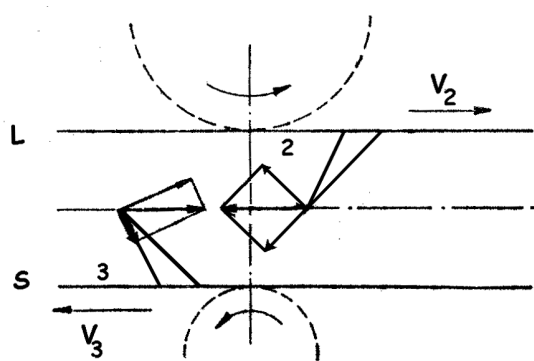

Fig. 136 Fibre transfer

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.

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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

Fig. 137 Fibre transfer

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.

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).

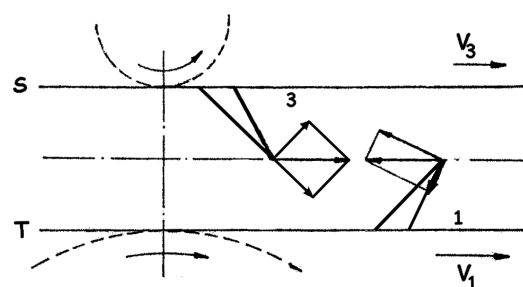The number of worker-stripper sets varies from four to six.

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;

Fig. 138 Carding action

for this reason, the clothing must be periodically cleaned.

The wastes including short tufts and impurities falling under the comber roller and under the drum.
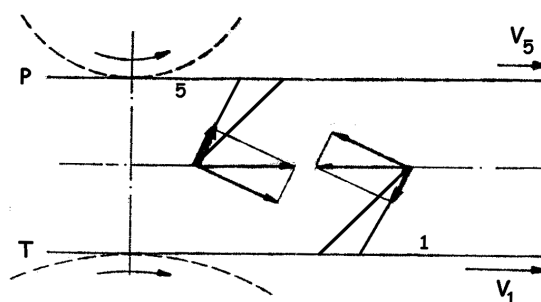
E) Comber plus doffer action

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.
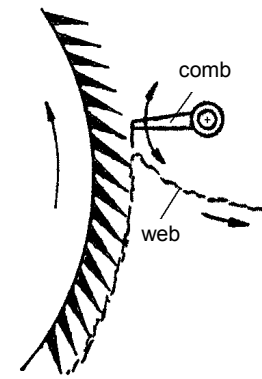

Fig. 139 Doffer comb

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.
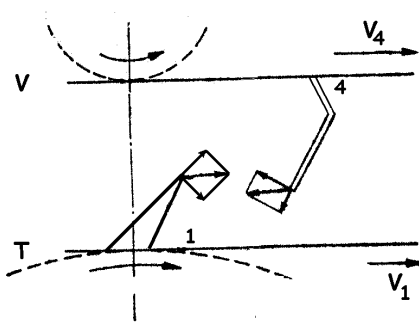

Fig. 140 Fibre raising

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.

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.

Fig. 141 Formation of the fibre web

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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,
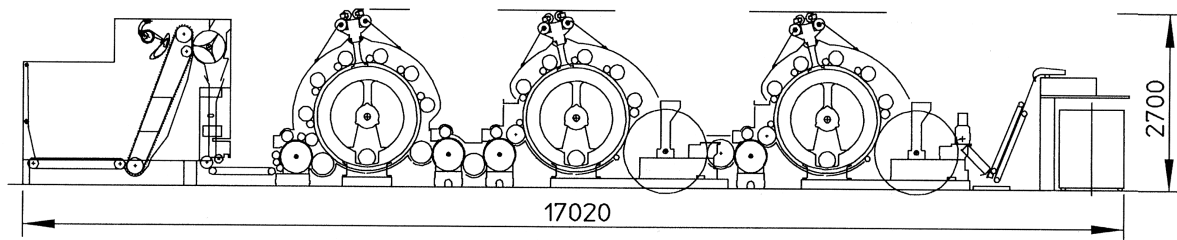• transforms the web into carded sliver.

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.
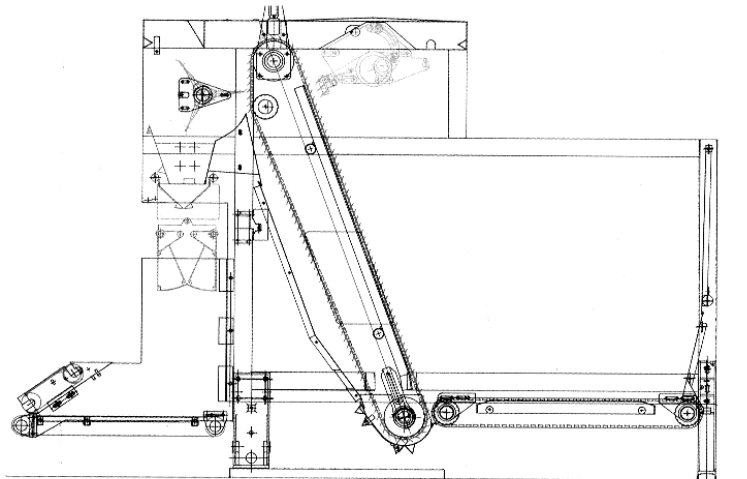

Fig. 143 – Gravimetric feeder

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).

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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).
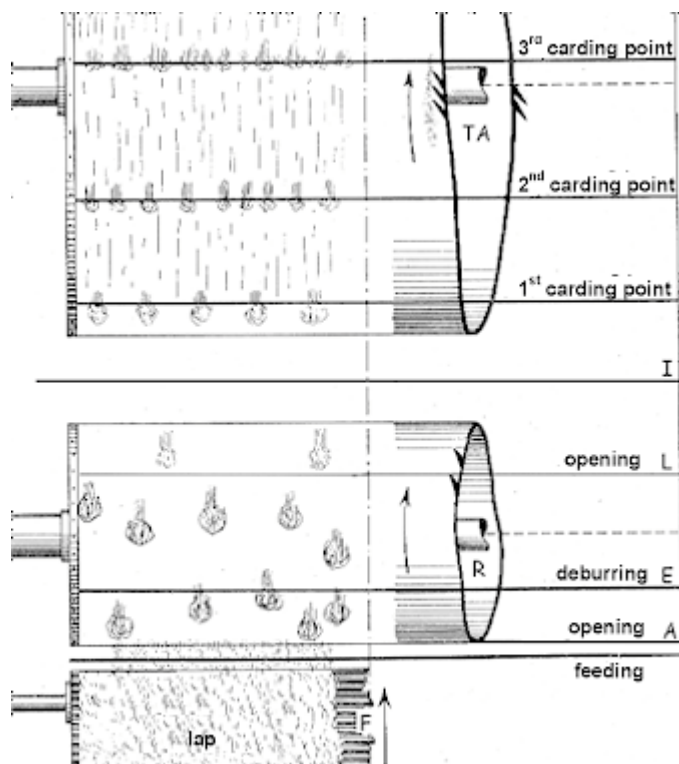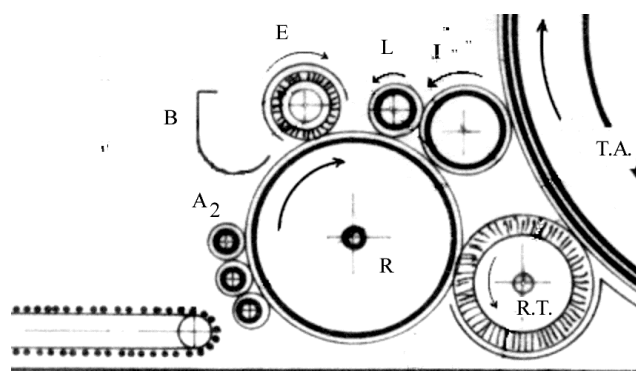

As soon as the tuft is released from needles "A", it is dragged forward by the "R" opener cylinder. The "head" of the tuft is made up by the fibres having an end deeply inserted in the "R" needles while the remaining part ("body" or "tail" of the tuft) includes fibres, more or less entangled, floating 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. 144 – Feeding and opening the web

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.
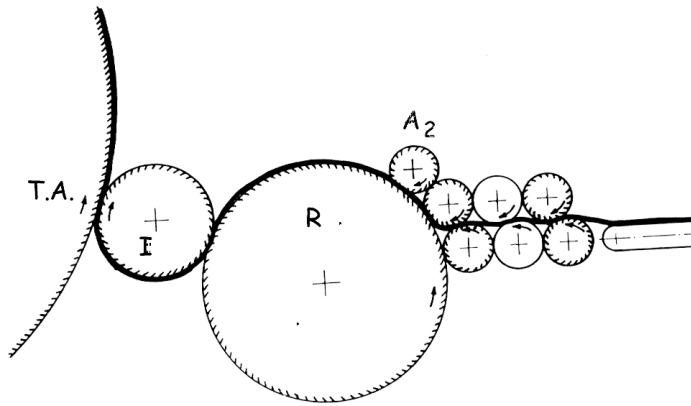

Fig. 146 – Feeding and opening of the web (alternative solution)

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.

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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.
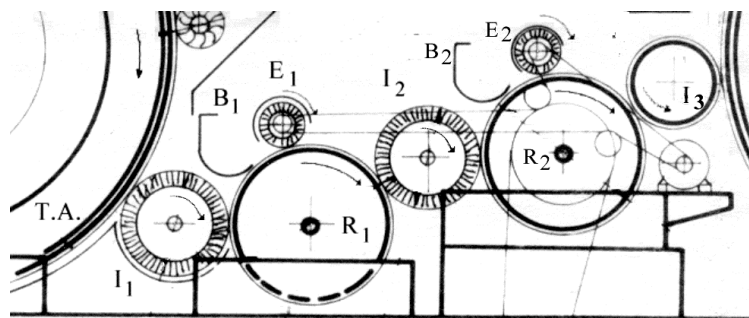

Fig. 147 - Double deburring with Morel clothings

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.
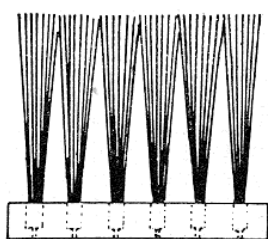

Fig. 148 - Clothing of the cylindrical brush

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.
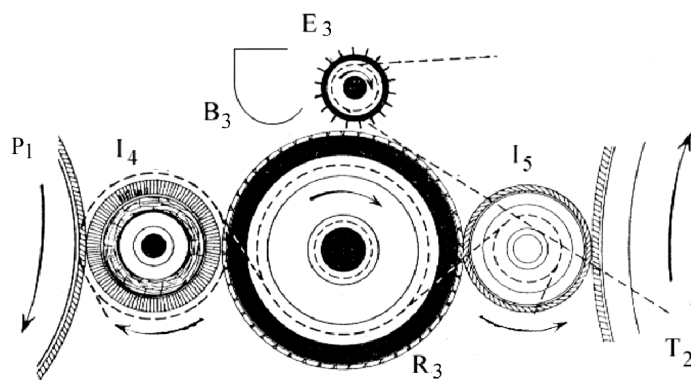

Fig. 149 - Deburring with Morel clothings

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.
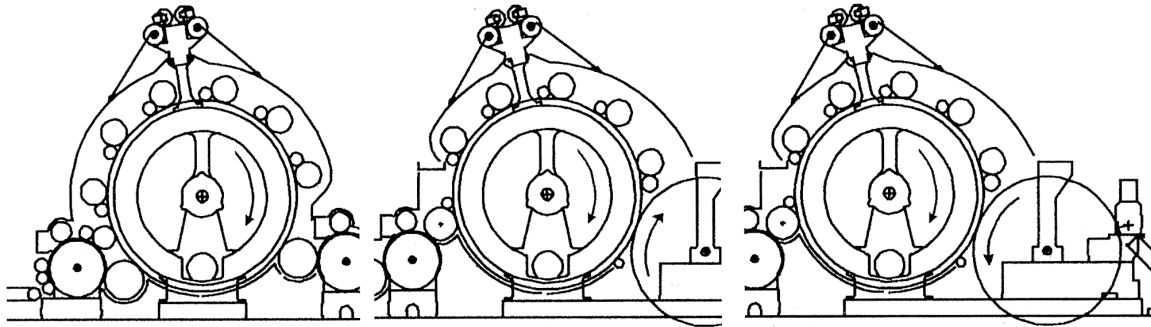

Fig. 150a Pre-carding unit   Fig. 150b First drum   Fig. 150c Second drum

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,

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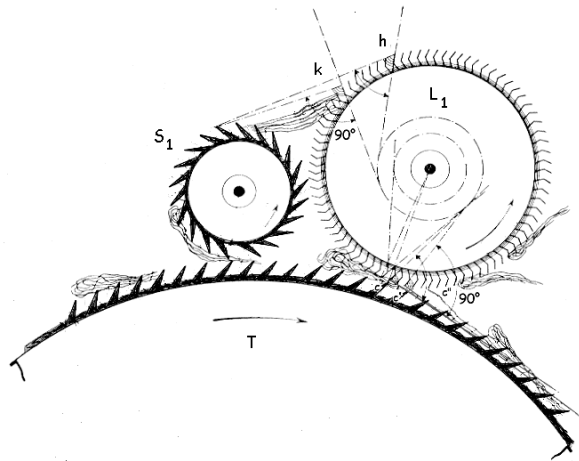
*Fig. 151 The drum-worker –
stripper assembly on the 2ⁿᵈ drum*

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:

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- 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.
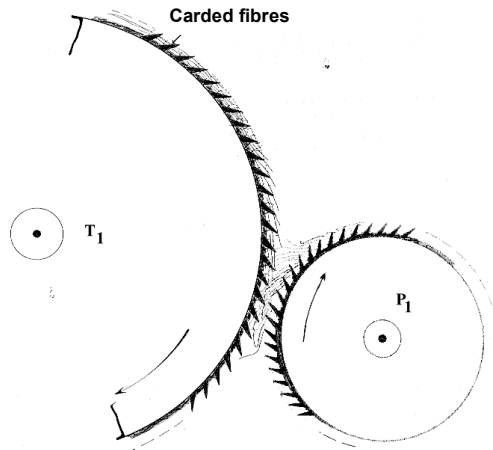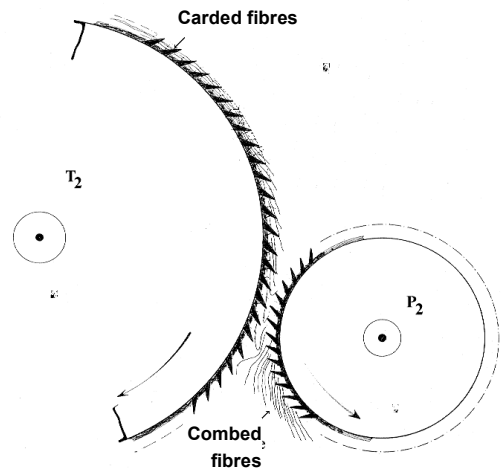
Fig. 152 – 1st drum-comber roller   *Fig. 153 – 2nd drum-comber roller*

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.

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.

Fig. 155 Turning a fibre upside down

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.
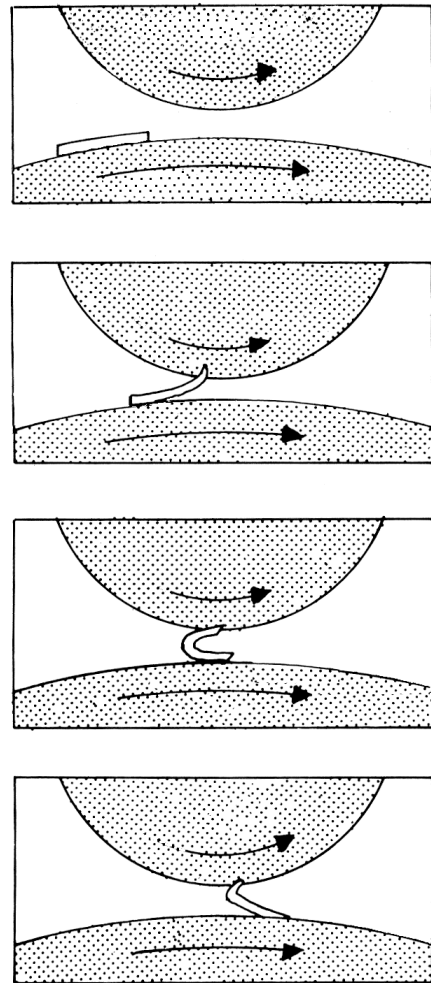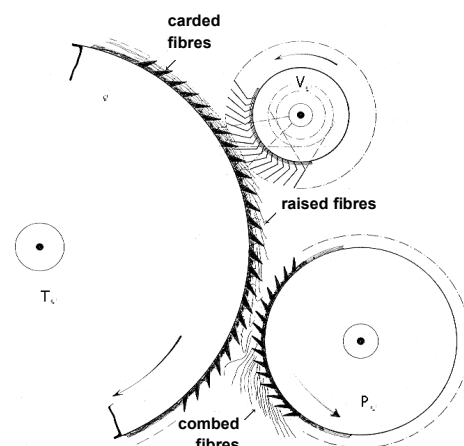

Fig. 156 The effect of the fly roller

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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 $2{,}000 \div 2{,}500$ 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 $100 \div 1000$ kg/h.

Card with double comber

In order to increase the card output by $50 \div 100$ %, 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:

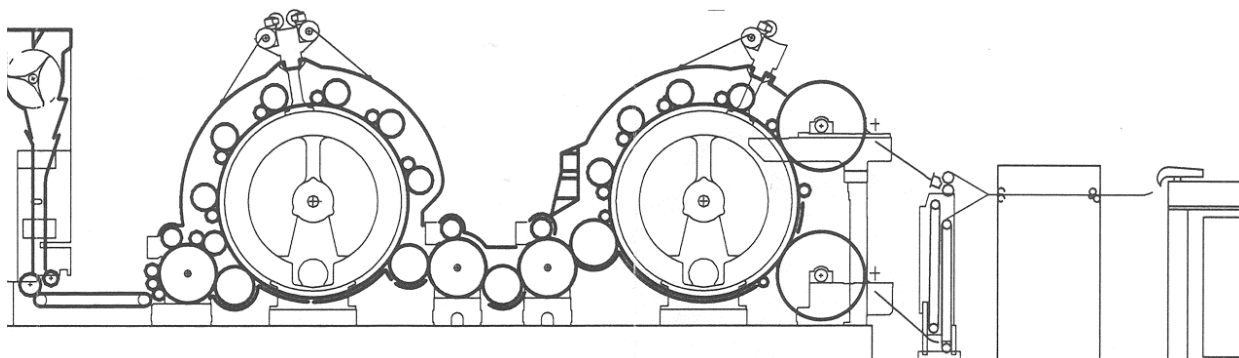| Moisture	65 ÷ 75 %
Temperature	22 ÷ 26 °C

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.
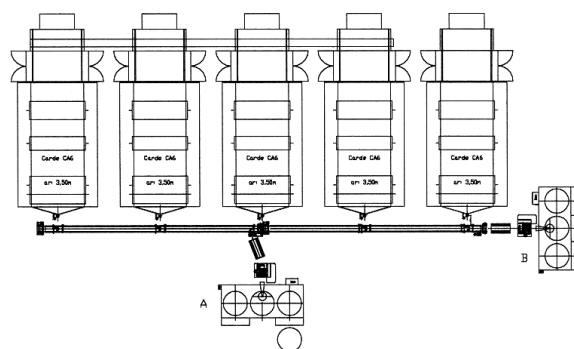

Fig. 159 Double after-card drawing unit

Composition

A lap drawing frame (Figure 160) includes the following components:
1. a conveyor belt with a bending device for each card (Figure 161),
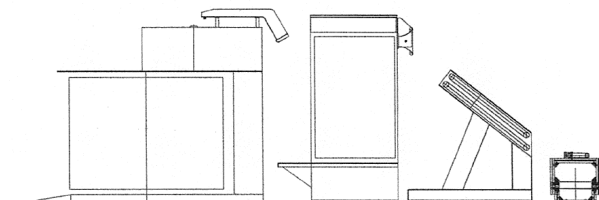2. a double belt inclined conveyor, which brings the card sliver to the height of the drawing head,

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.

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
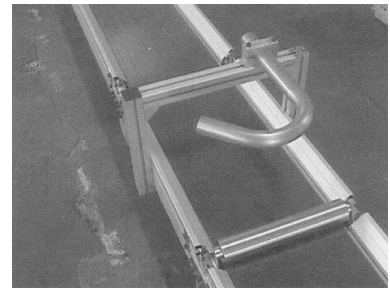

Fig. 161 Sliver guide

Fig. 162 Condenser funnel
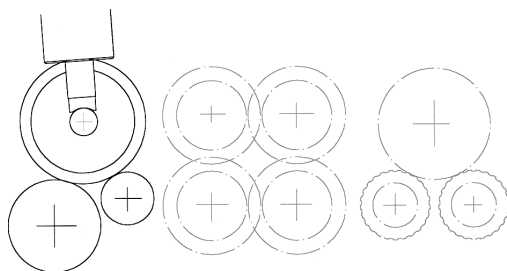
Fig. 163 Drawing aggregate

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

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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.
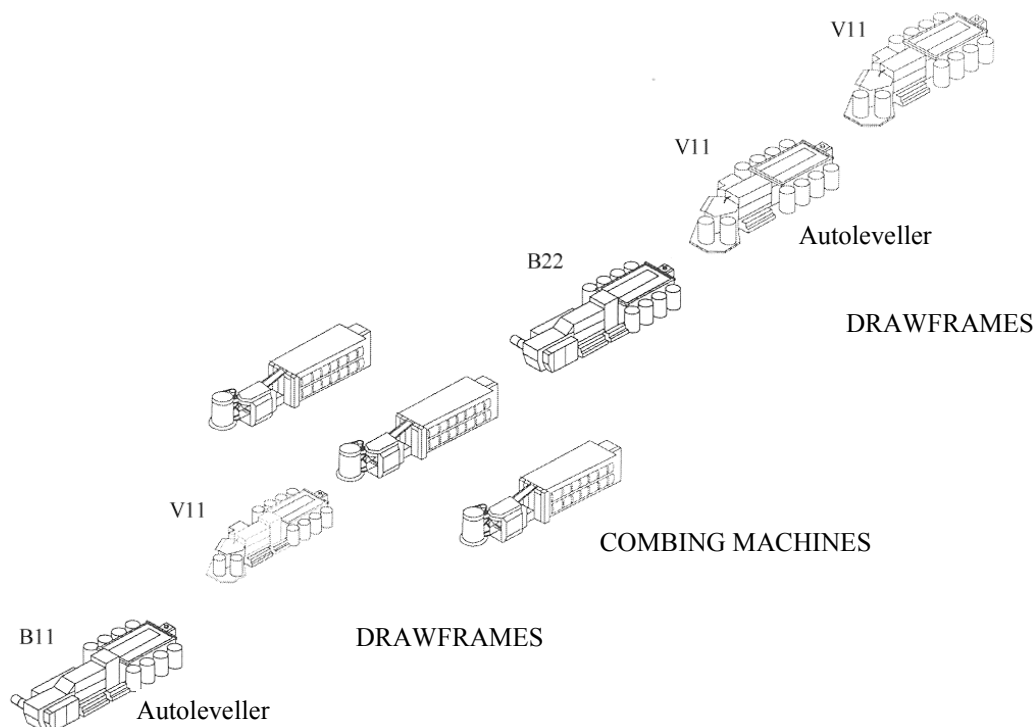

Fig. 165 Combing cycle of 21-micron wool

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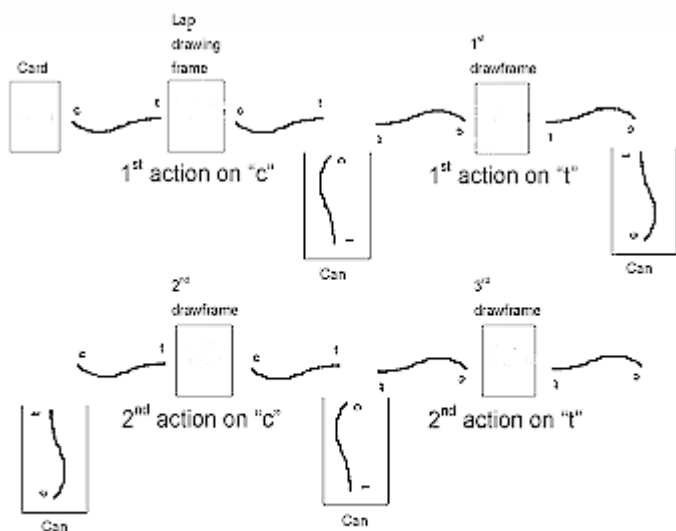
Fig. 166 – Action of the fibres during
the drawing operations

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.
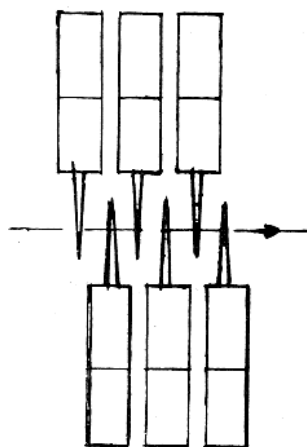
Intersecting drawing frames

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.
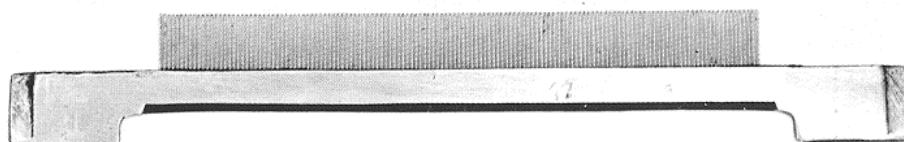

Fig. 168 Comb with end tabs

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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.

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.
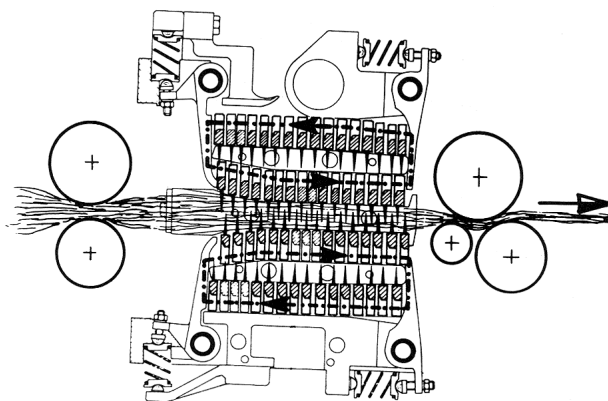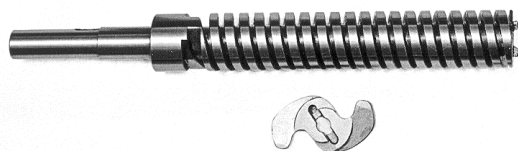

Fig. 169 - Screw-type drafting head

Fig. 170 - Screw and cams

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.

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:

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

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:

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

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.
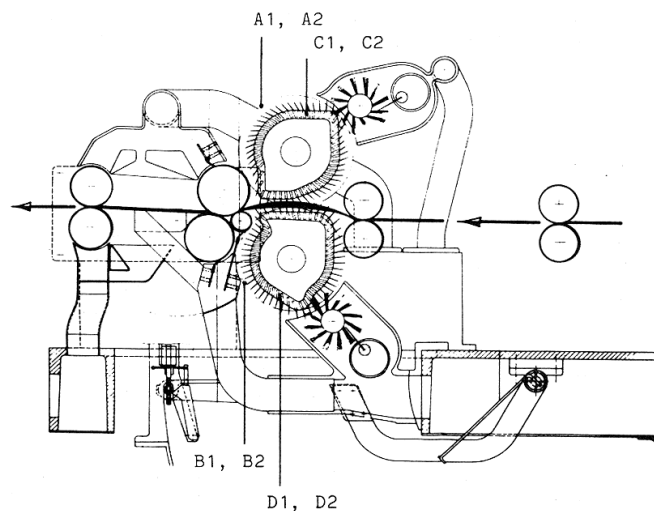

Fig. 171 – Drafting head with rotating flanges (cross section).

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.

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

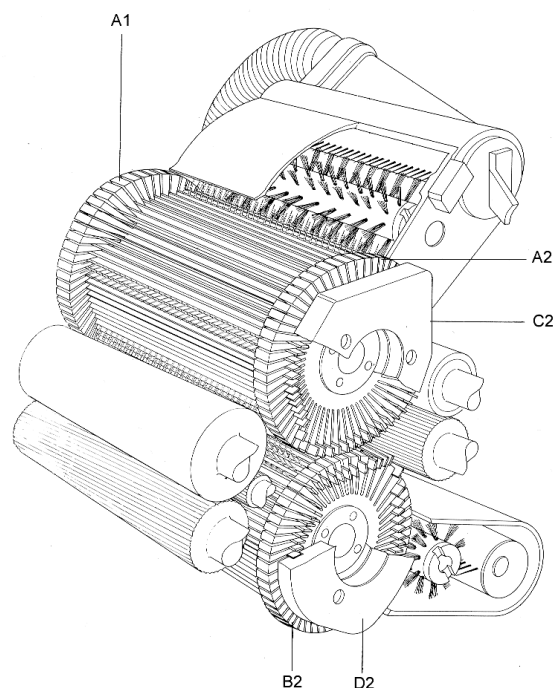*Fig. 172 Rotating flanges drafting head*

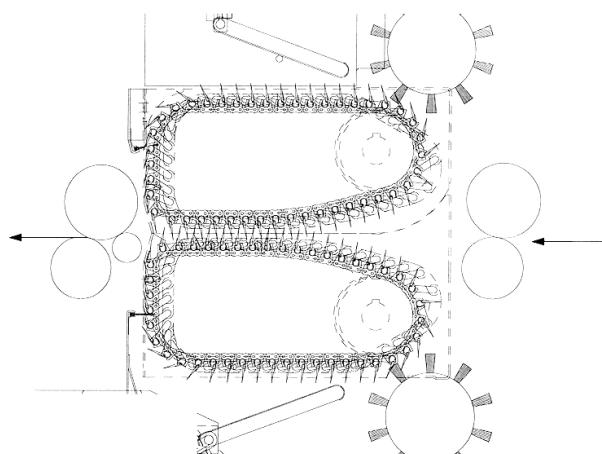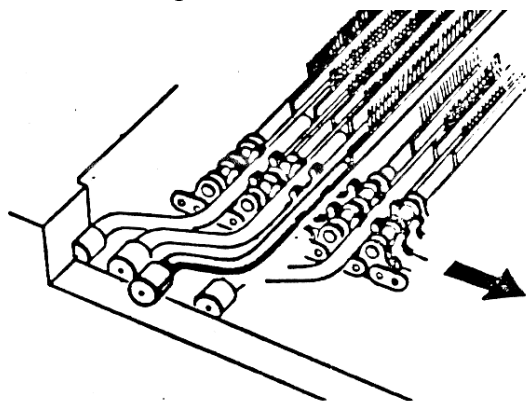*Fig. 173 Chain drafting head*

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. 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.
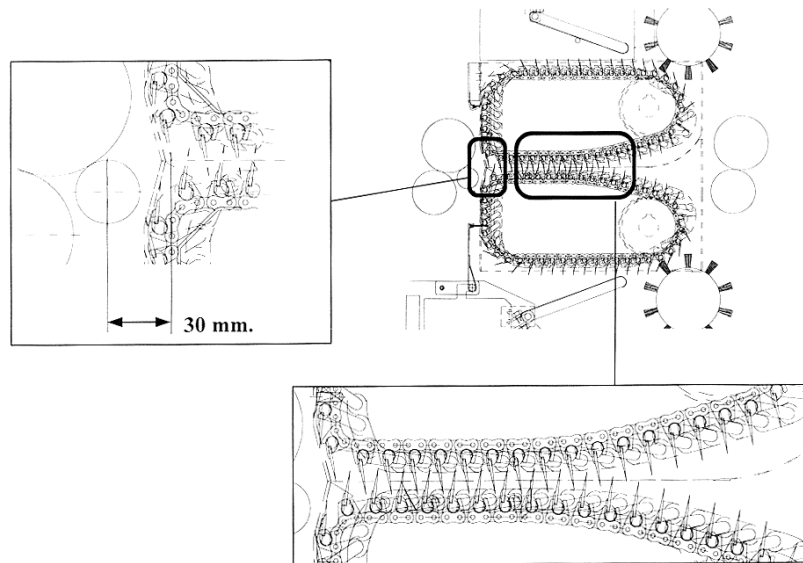
Fig. 175 - Needle inclination

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

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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.
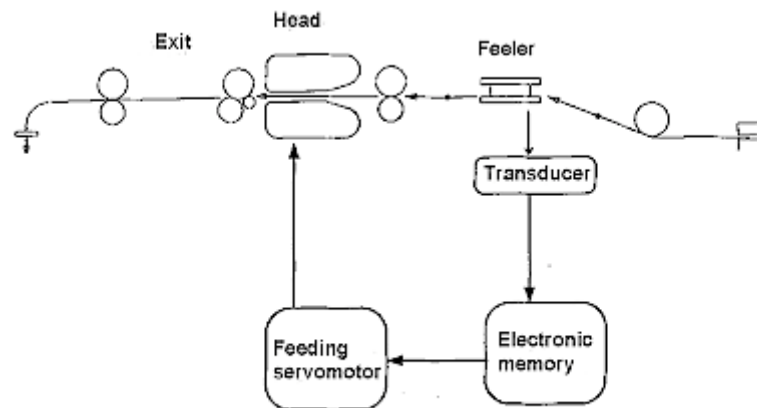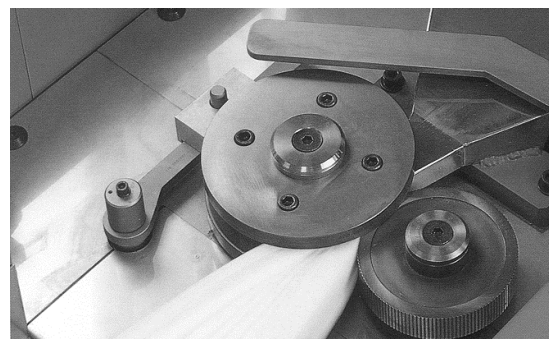
The flow of the sliver leaving the unit is totally controlled to avoid possible false drawing.

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.
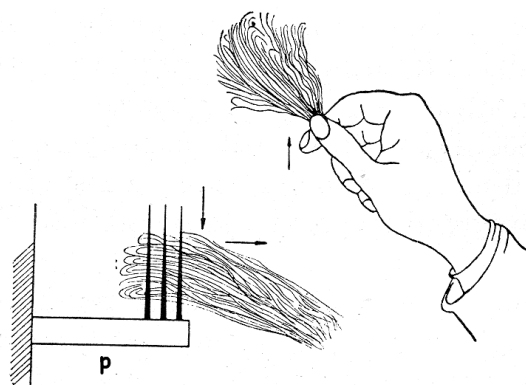

Fig. 178 Introduction of the tuft

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.
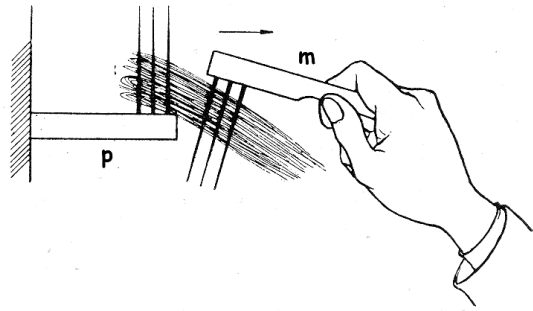

Fig. 179 - Combing of the tuft head

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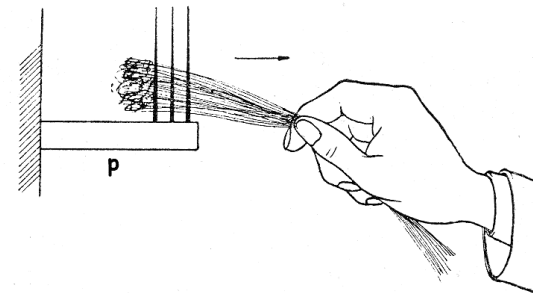
Fig. 180 - Extraction and combing of the tuft tail

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 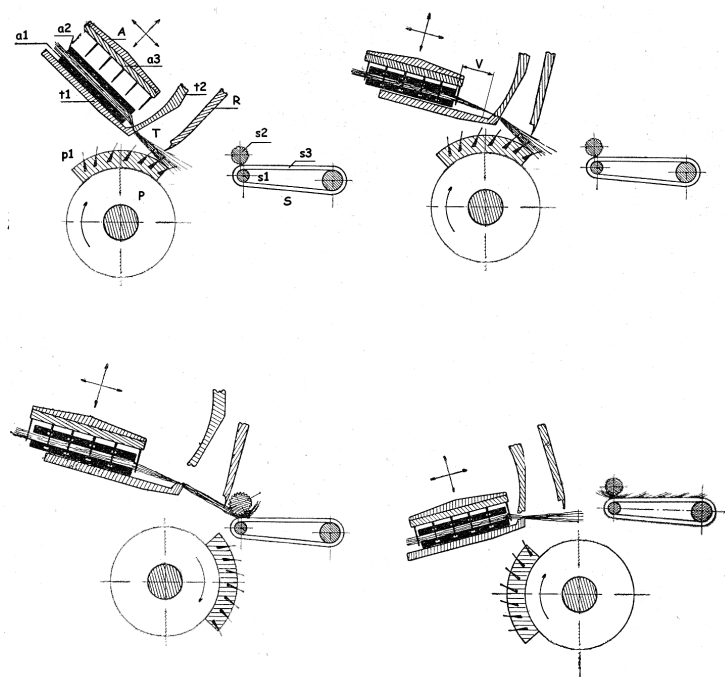on the bottom left side shows the open nipper and the head of the combed tuft held by the other nipper (i.e. the extraction cylinders) leaving the combing machine while the lowered linear comb starts operating on the tail of the tuft.

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:

Combing the tuft head

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.
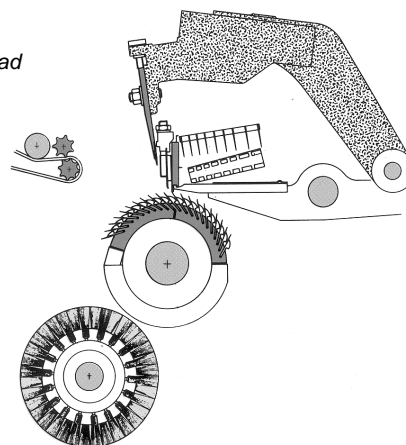
Extracting and combing the tuft tail

Fig. 183 - The two steps of tuft combing

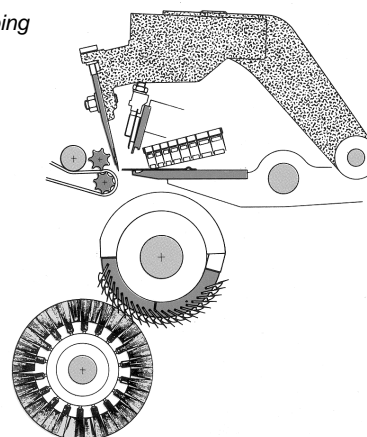While these motions are carried out, the extraction cylinders rotate in opposite direction and draw back a part of the combed tuft, which is made to adhere onto the sleeve thanks to a vacuum action; in this way, the head of the following combed tuft is positioned above the tail of the previous one granting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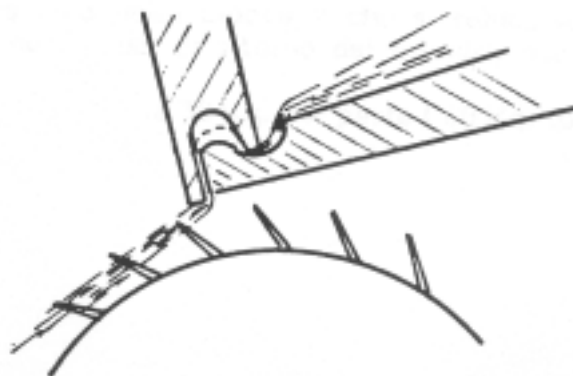

Fig. 184 – The nipper jaws

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.

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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).
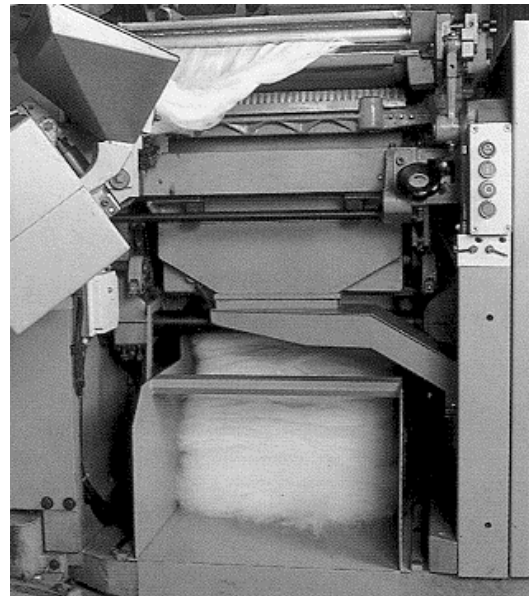
H) Feed and collection systems

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.

Fig. 184 – Noil collection

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

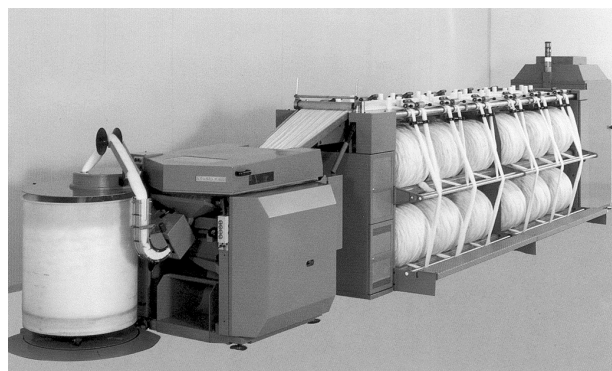| Characteristics			Characteristics		
doublings (cans or reels)	n°	24	gill feeding	mm	4 ÷ 10
loading capacity	g/m	500 ÷ 600	nipper-circular comb distance	mm	0,2 ÷ 2.0
throughput speed	nips/min	200	extraction rollers diameter	mm	28/25
circular comb operating range	mm	440	sleeve size	mm	540x580x3,5
linear 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.
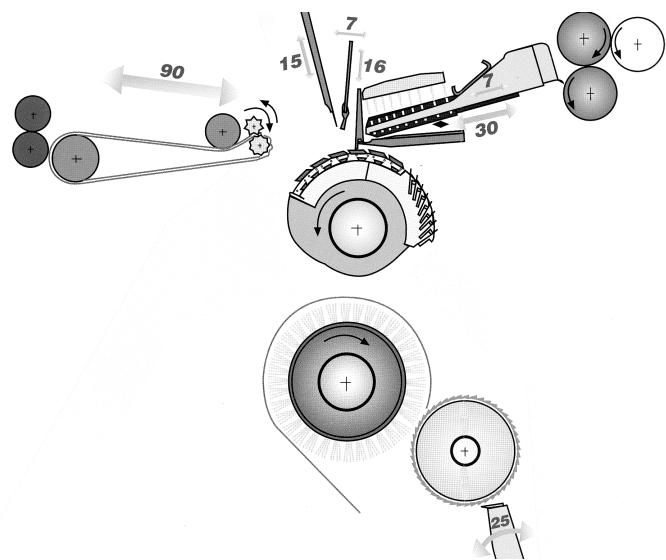
Fig. 186 - Linear combing machine with fixed nipper

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

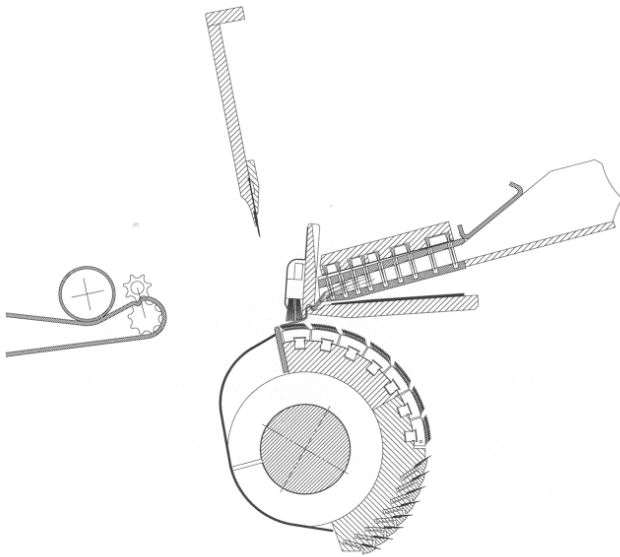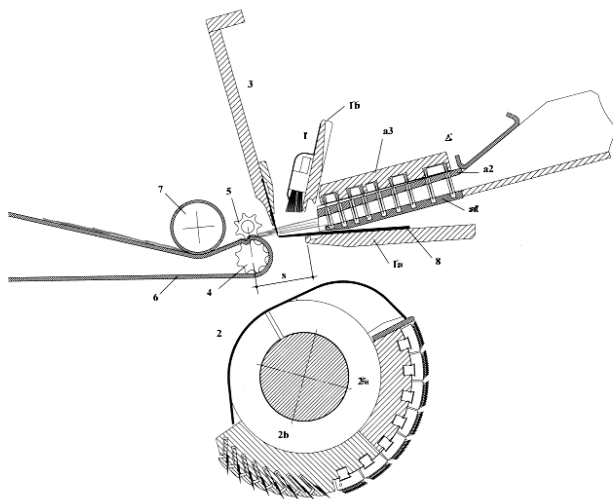The adjacent and overlapped wool slivers forming a compact lap with uniform thickness, are pushed forward by means of a pre-feeding device including 3 rollers, one pressure roller and two feeding rollers, rotating uniformly, which ensure a steady control of the material (Figure 186).

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.

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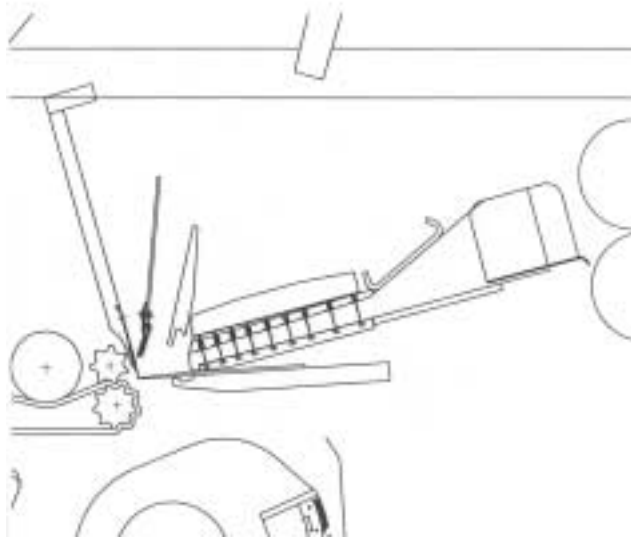 wool combing, pre-open and separate the material while the other denser needle rows ("2b" finishing section) are interchangeable for combing different types of wool and parallelising the fibres. The small bars with needles are arranged on a 264 mm arc.

Fig. 189 -Feed gill

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.
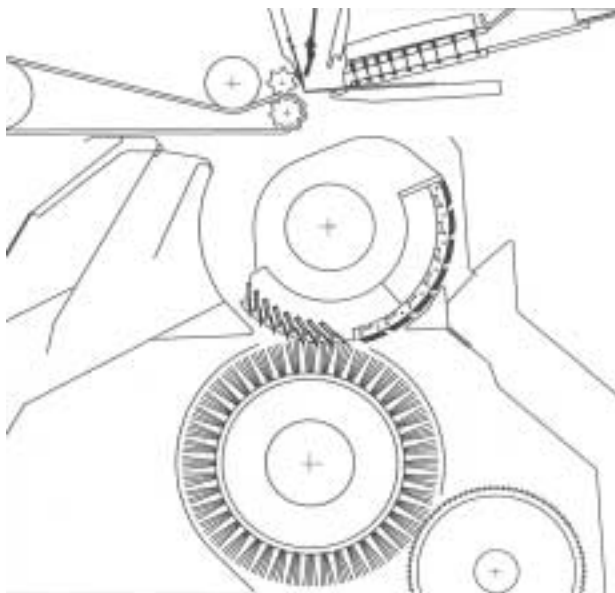
The circular comb carries out one entire revolution per each combing cycle of a tuft (tail and head).

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.

Fig. 190 - Circular comb with brush

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

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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.
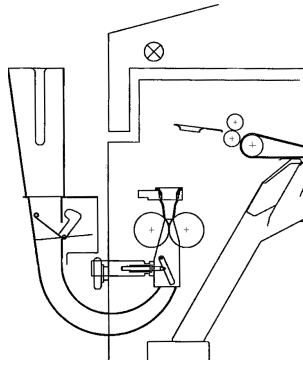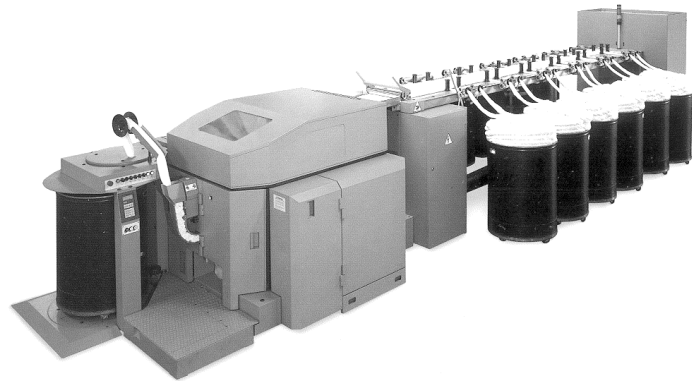
Fig. 191 - Crimping device

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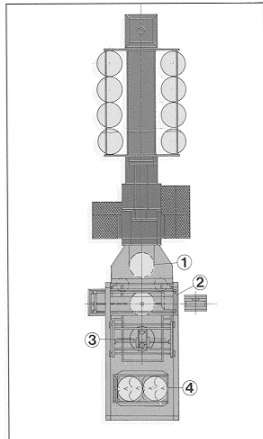
1. Drawframe exit side
2. Rotary platform
3. Bump pressing
4. Bump conveyors.

Fig. 193 - Bump delivery
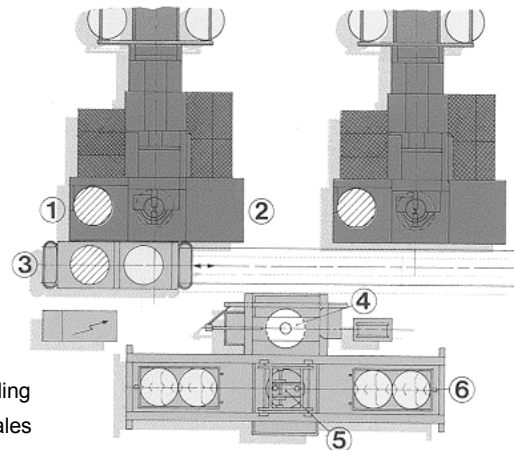
1. Empty can loading
2. Full can unloading
3. Conveyor
4. Bump press
5. Hoist for bump unloading
6. Conveyor for bump bales

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	

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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
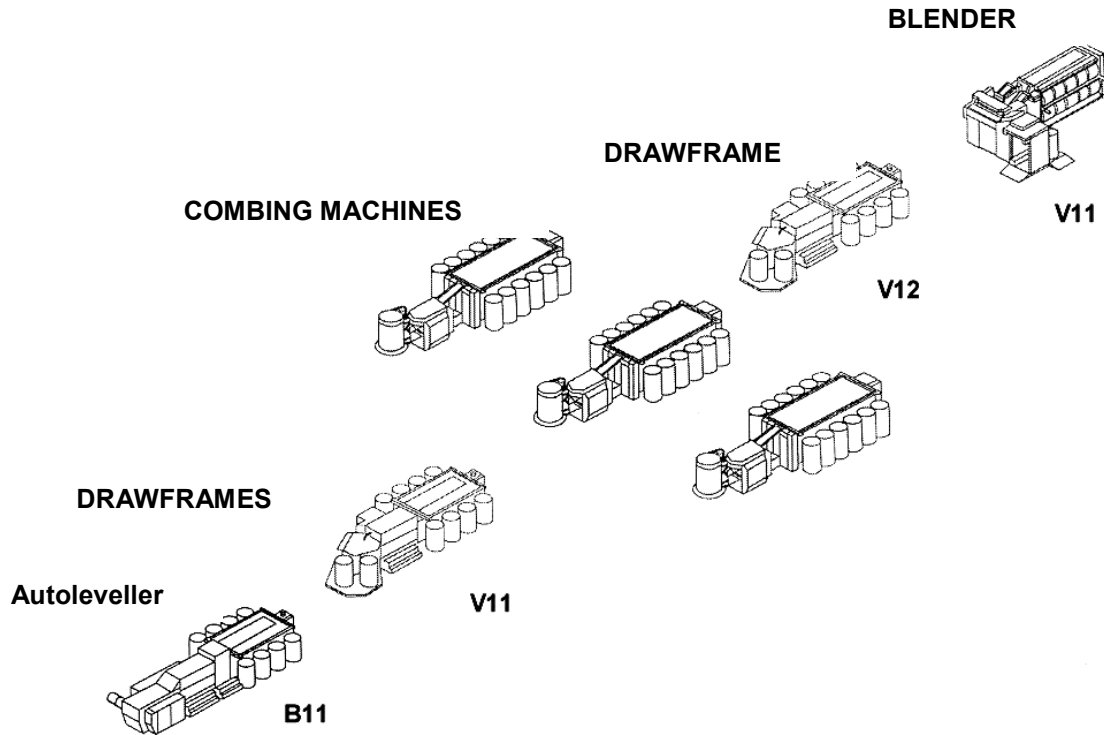2. preparation to recombing
3. recombing
4. post-recombing

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.
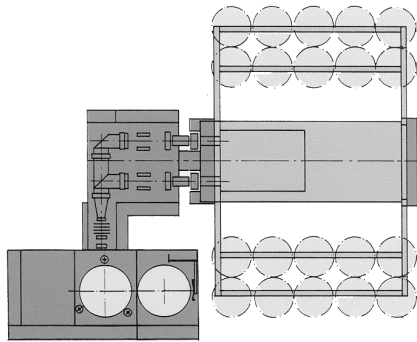
Fig. 196 - Blender

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.
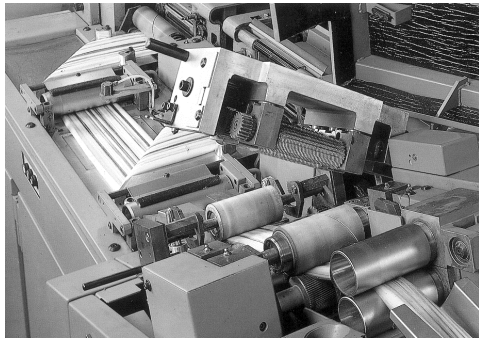

Fig. 197 – Reducing head

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.
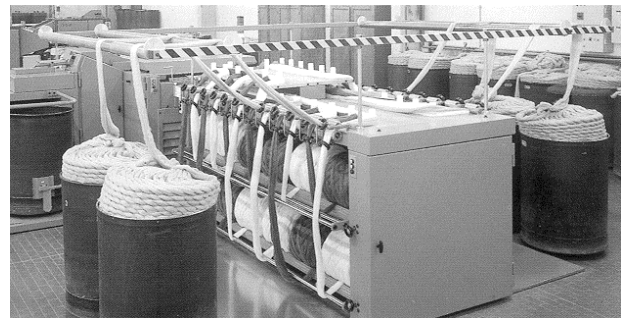

Fig. 198 – Feed rack

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

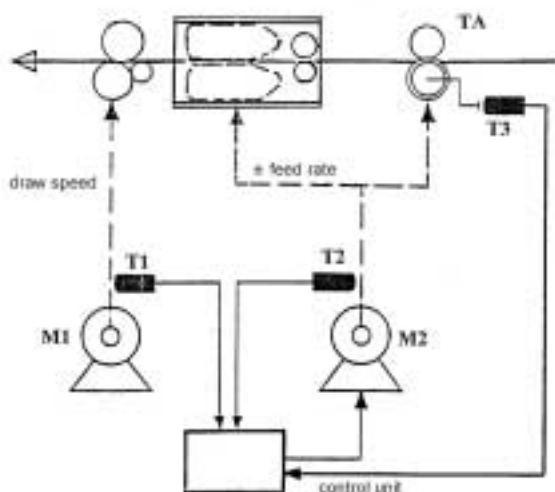| Unit	Te g/m	A	Ce g/m	S	Tu g/m	Vu m/min	N° of Exit Elem.	Pt kg/h	η %	N° of Units	P_p kg/h
Blender	25	24	600	20	30	350	1	630	60	1	378
Reducer	30	6	180	12	15	280	2	504	75	1	378
Combing machine	15	24	360		30	260*	1	48**	94	8	361
Can emptier	30	6	180	6	30	290	1	522	70	1	365
Recomb. Finisher	30	5	150	6	25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

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.

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

Fig. 199 – Electronic autoleveller

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 $\leq$ 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.

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.
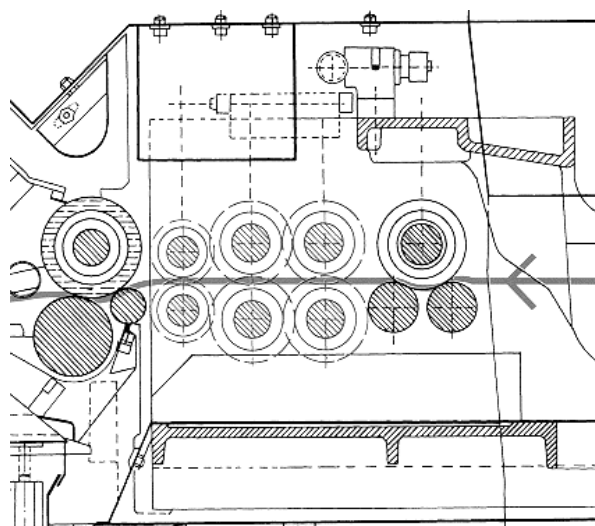

Fig. 200 – Disk-type drawing head

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:
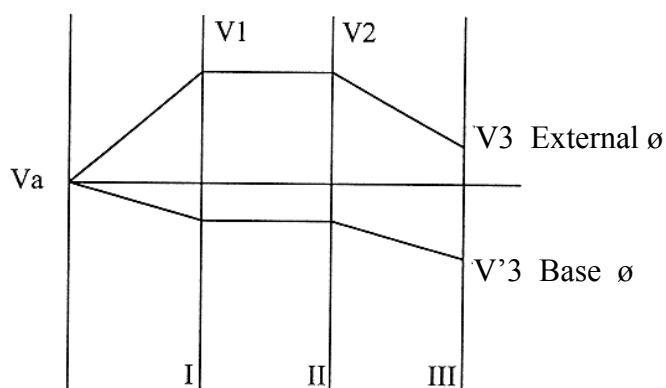
Positions of the draft controllers

$1.05 \div 1.15$ 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:

V1 V2

Va

V3 External ø

V'3 Base ø

Va

I   II   III
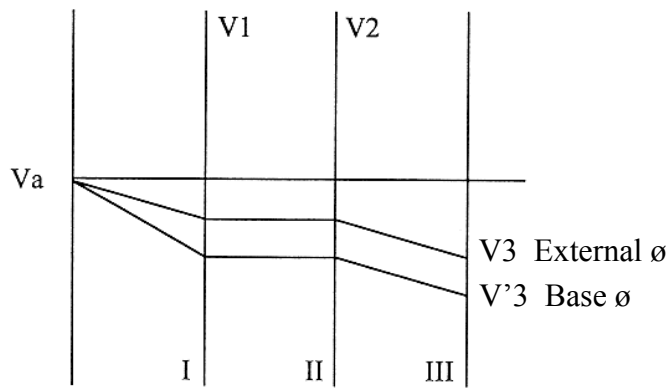
Positions of the draft controllers

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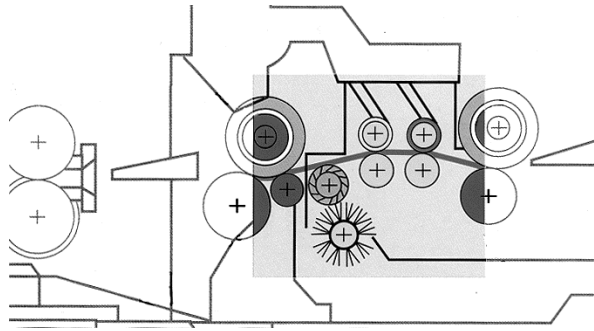
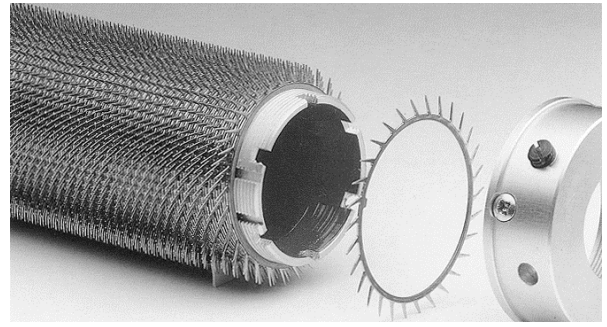*Fig. 201 - Drawing head with Herisson/barrel
cylinder control with elastic nip*

*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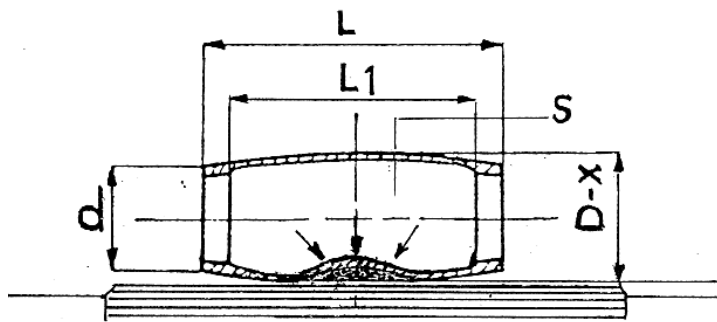 aligned within the elastic zone of the rubber to grant the uniform distribution of the fibres (as explained hereinafter).

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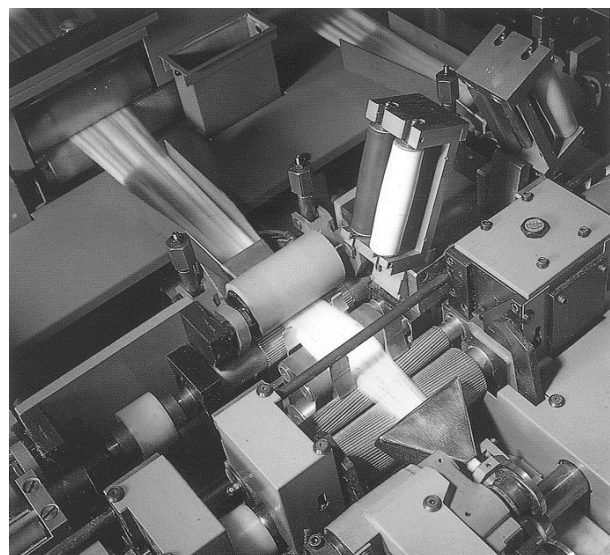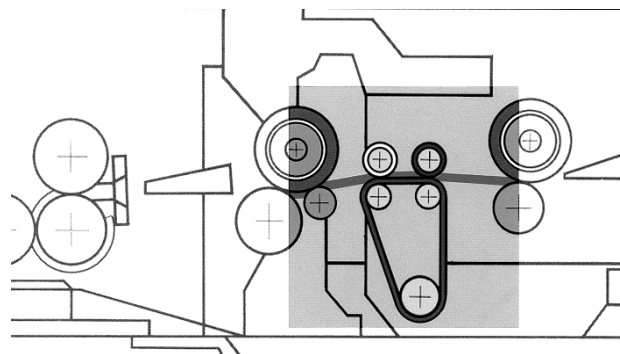
Fig. 204 - Drawing head featuring barrel cylinders with elastic nip

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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.
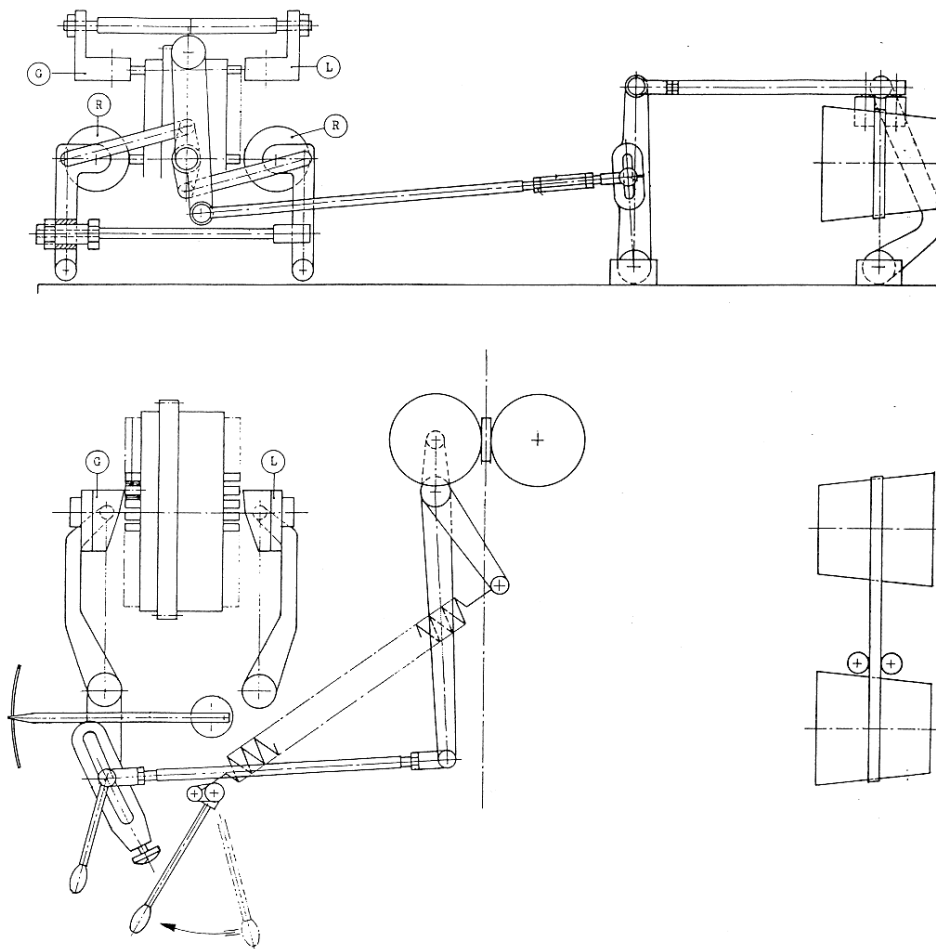
Fig. 205 - Mechanical draft autoleveller

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.

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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.
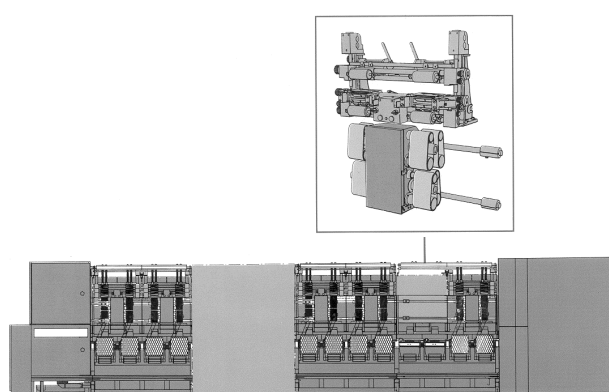
The vertical finisher rubbing frame features a modular structure with 2 drafting units and double rubbing action (Figure 206) working separately and autonomously; the modularity grants the machine non-stop operation also when one or more units are not working. Since a rubbing drafting unit works on 2 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.
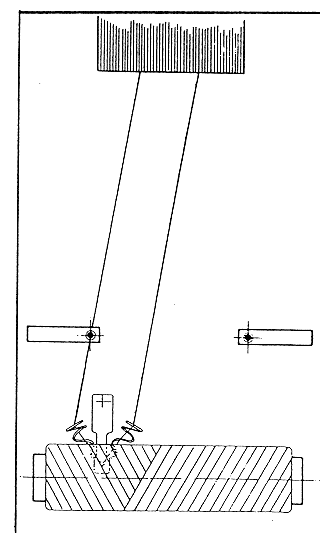

Fig. 207 - Bobbin formation

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.

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

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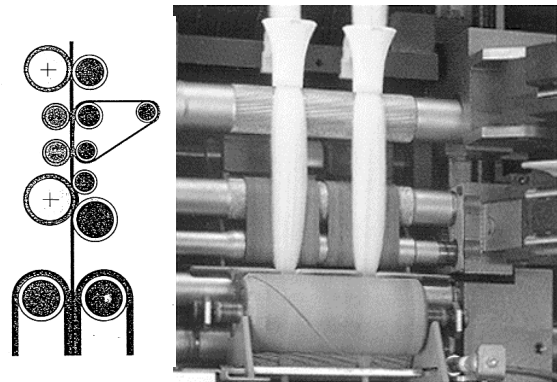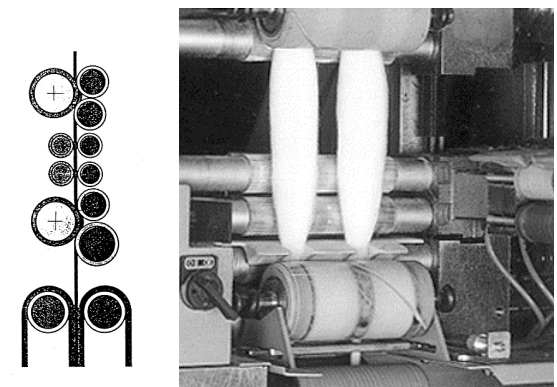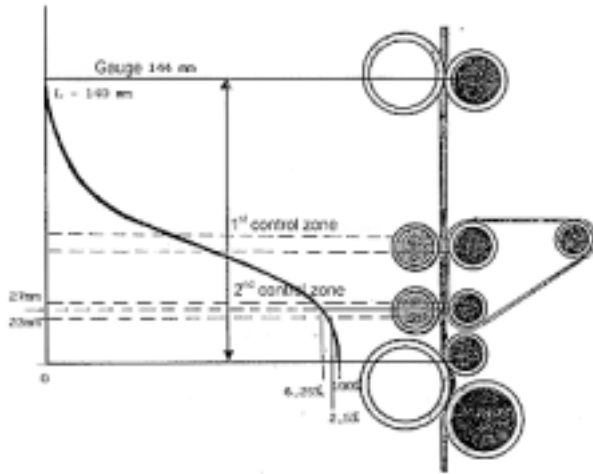
- the rotation of the elastic-control roller with straight rubber cot is effected by the pressure applied on the edges of the bush on the relevant roller; the motion is therefore independent from the material and interferes very little with its cross section,

- 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
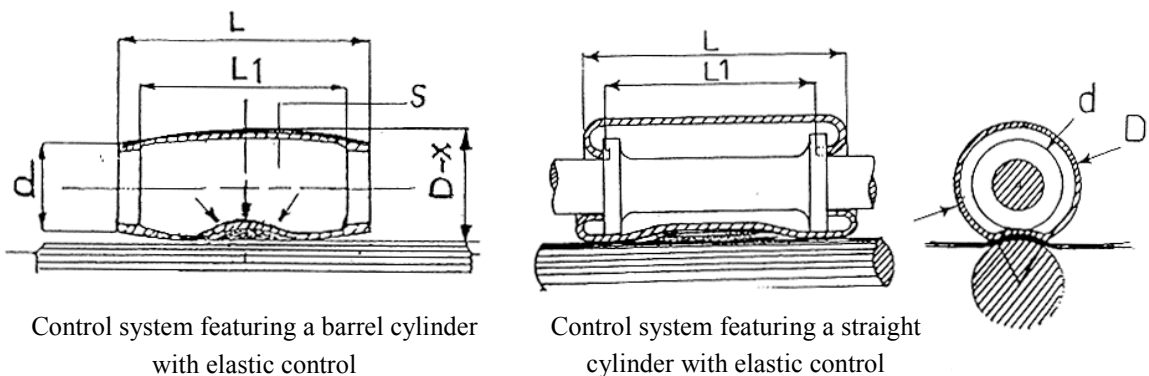
Control system featuring a barrel cylinder with elastic control
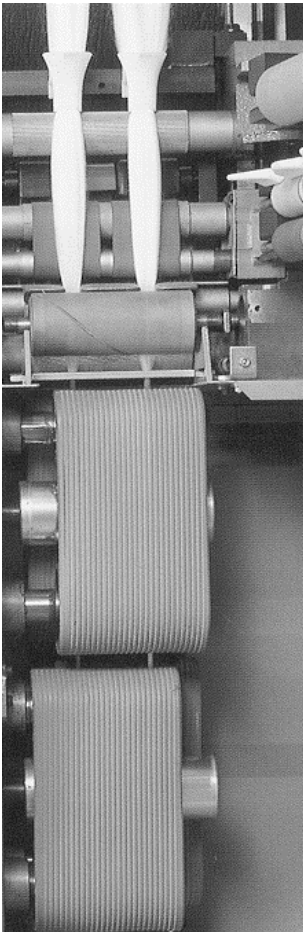
Control system featuring a straight cylinder with elastic control

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).

Sinusoidal diagram of the rubbing process

4 strokes/meter

1 rubbing stroke

sleeve reversal *1m*

Single rubbing range

■ roving
■ rubbing stroke wave

1m

upper rubbing point

4 strokes/meter
double rubbing range

lower rubbing point

t = time taken by the sliver to pass from upper to lower rubbing point
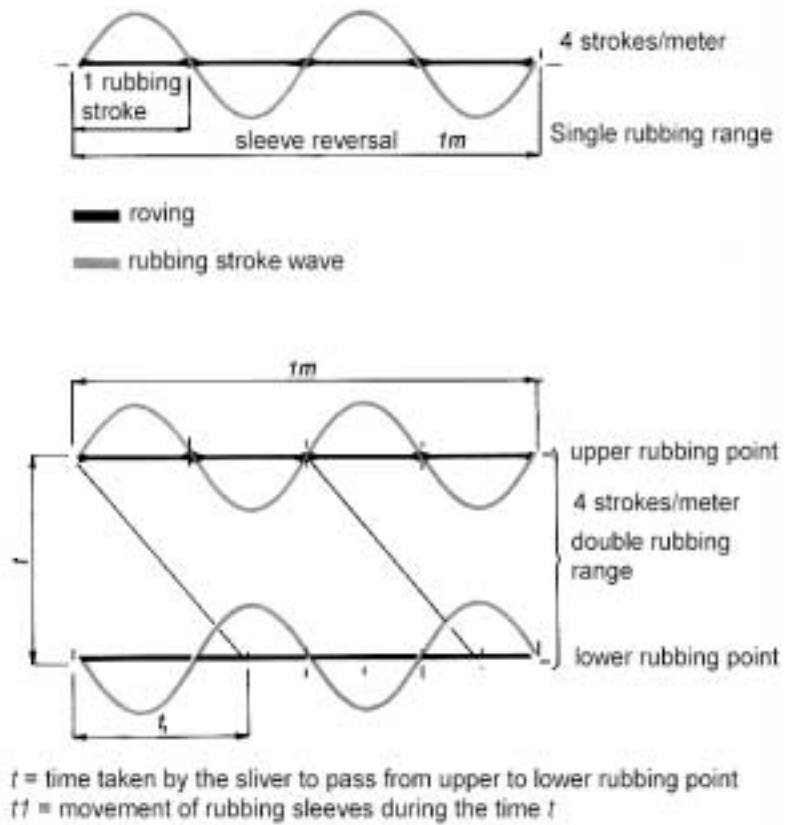*t1* = movement of rubbing sleeves during the time *t*

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):
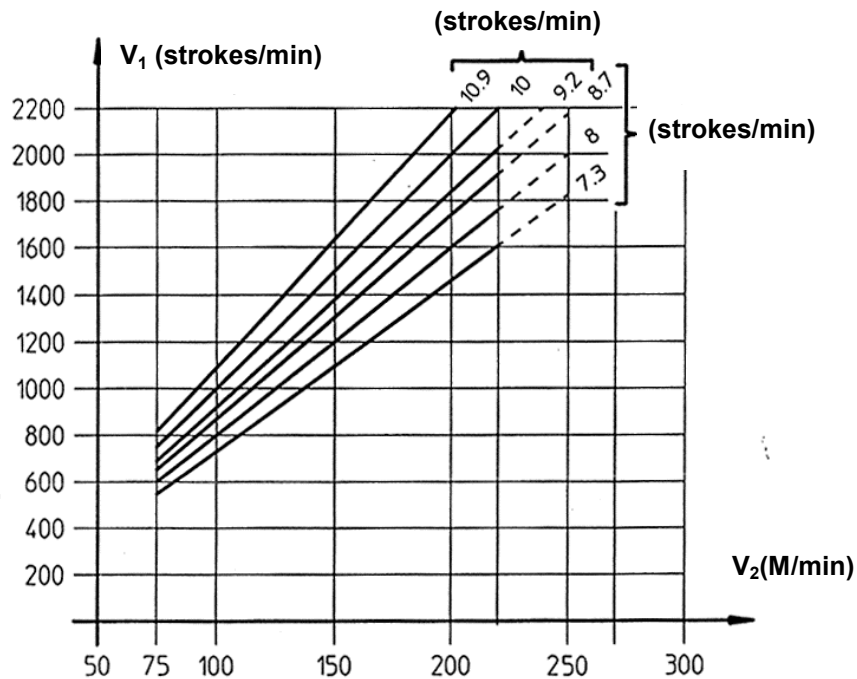

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Table H shows the technical data referring to a finisher rubbing frame equipped with different elastic stroke systems of the fibres during the drawing process.

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.

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.
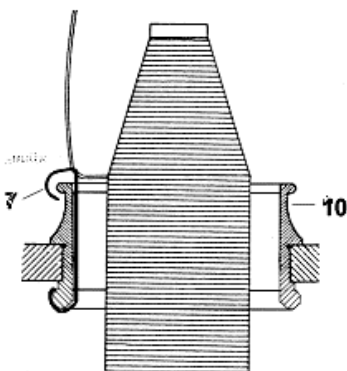

Fig. 213 - Ring spinning diagram
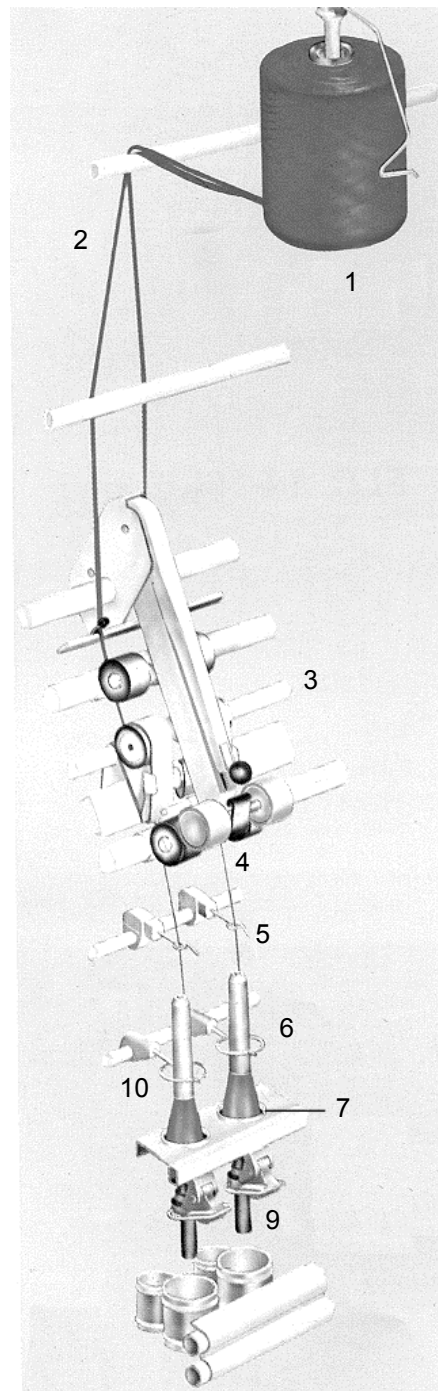

Fig. 214 – Ring and traveller

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.
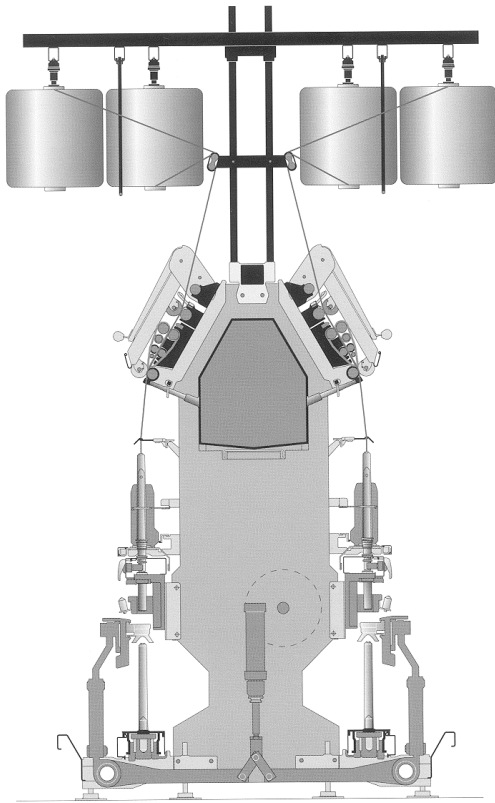
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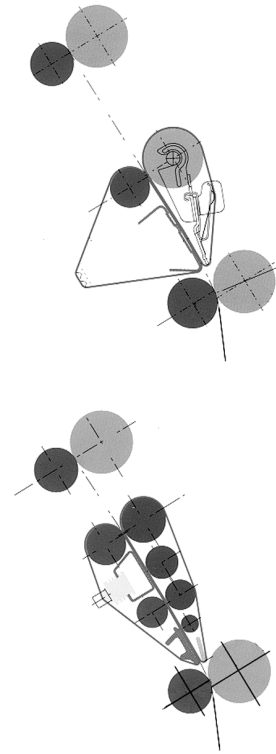*Fig. 215 - Single control ring spinning frame*

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.

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.
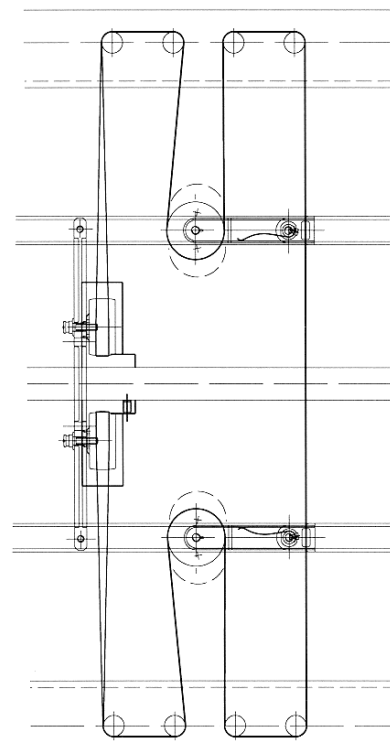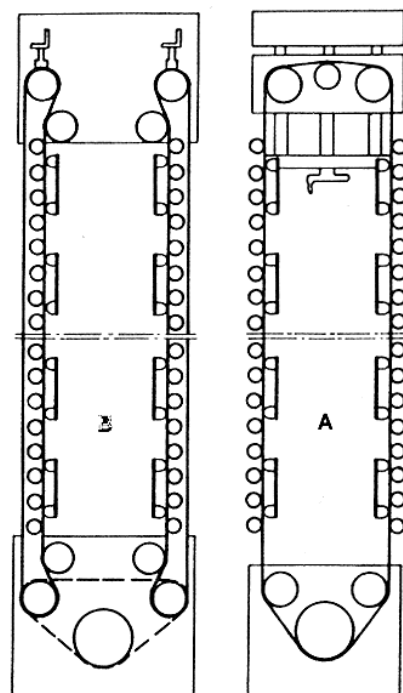

Fig. 217 – Small drive belts

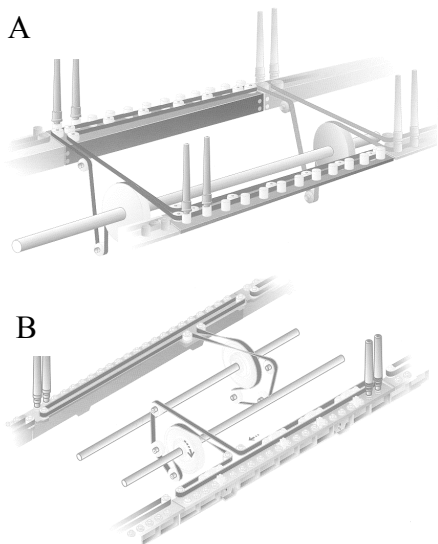*Fig. 218 – Tangential drive belt*

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A

B

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).

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,
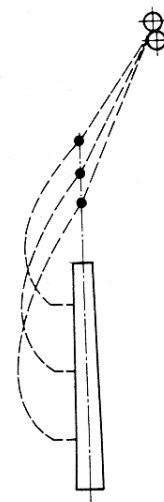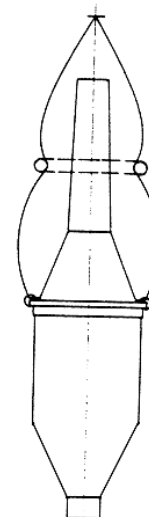• limits the winding of the outgoing material on the draft rollers.

Fig. 220 - Yarn guide
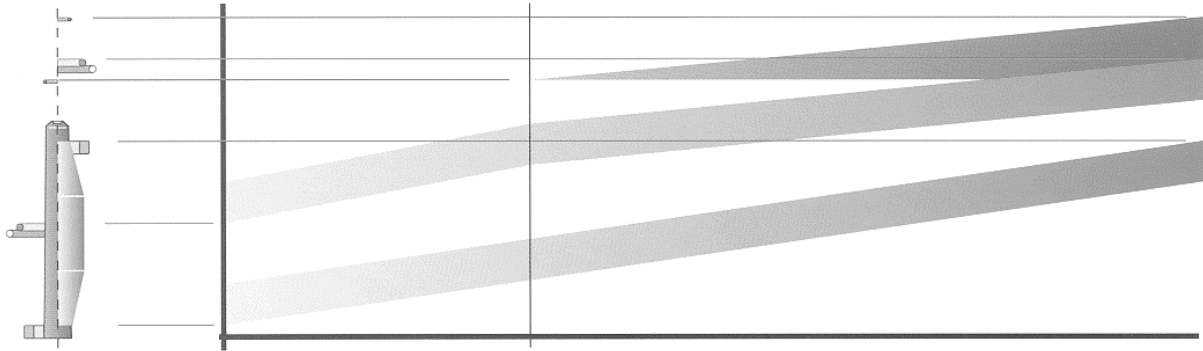
Fig. 221
Antiballoon ring

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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.
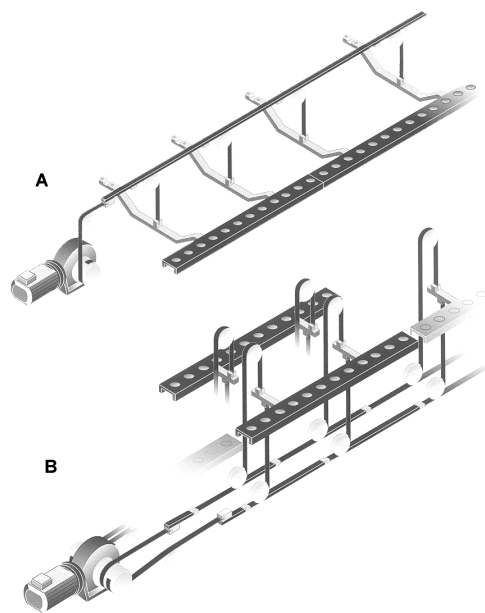
Thanks to the centrifugal force generated, when the traveller rotates the high contact pressure between the ring and the traveller creates huge friction forces that generate heat; the traveller can reach temperatures exceeding 200 ÷ 300 °C since its small mass does not

Fig. 223 - Driving system of the ring rail

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.

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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 $(10 \div 13$ 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.
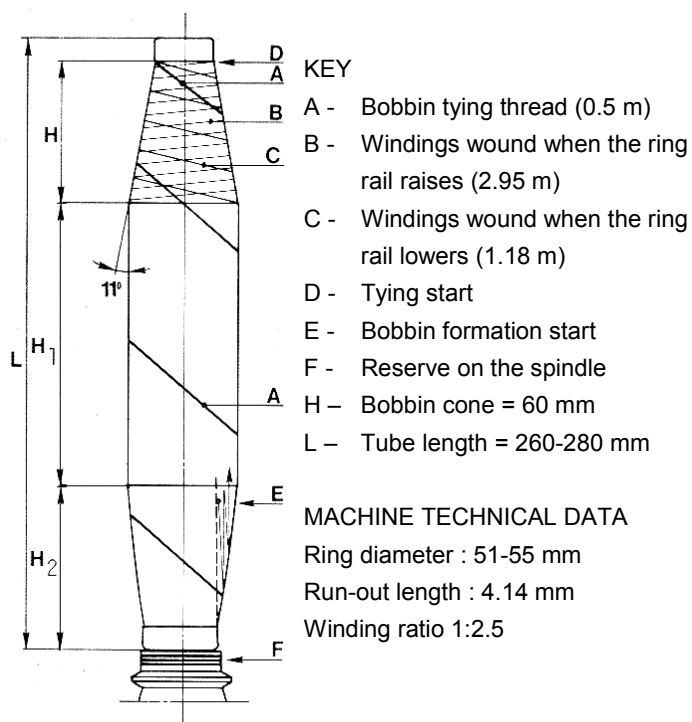

KEY

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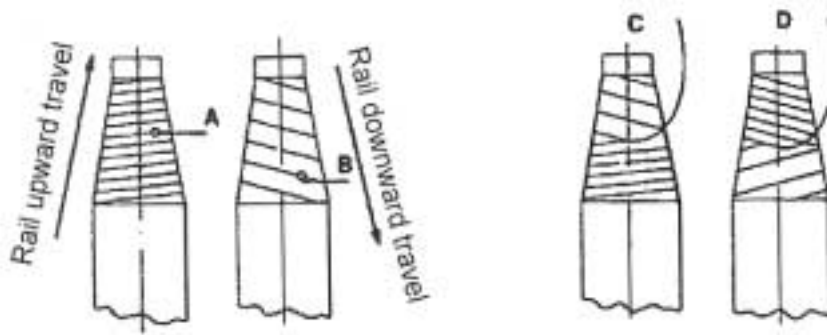
Fig. 225 – Effects of the cross-winding ratio

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).
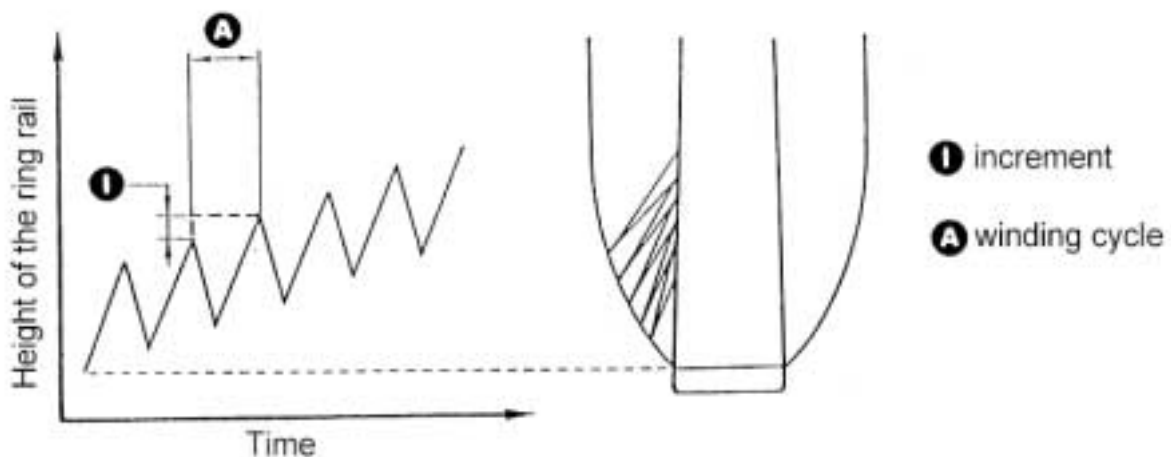

Fig. 226 - Diagram of the ring rail motion

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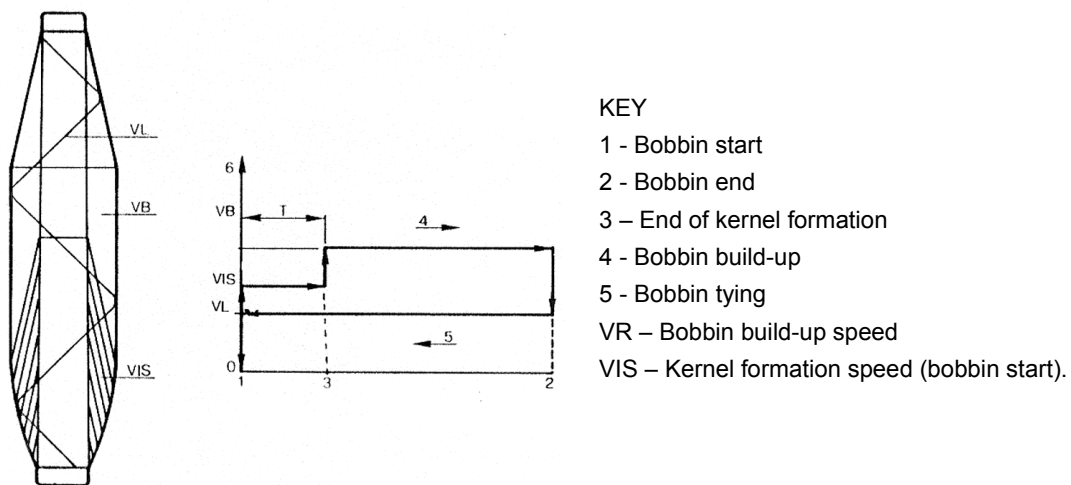
To obtain bobbins of a given diameter it is necessary to consider that the increment is inversely proportional to the yarn count (Nm) and directly proportional to the length of the run-out; in other words, after establishing the diameter of the bobbin, with the same yarn count, when doubling the run-out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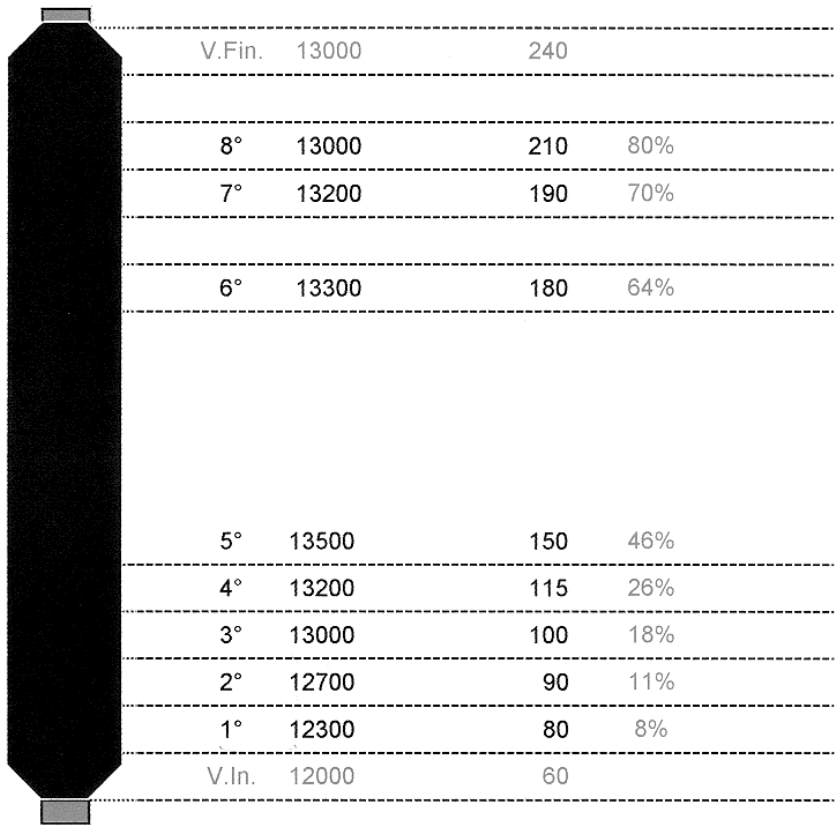
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The spindle speed

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.
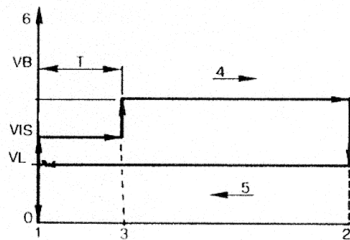To grant a steady tension of the yarn and reduce the number of breakages to a minimum, the spindle speed during the upward travel should be reduced (and increased at during the downward travel).

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
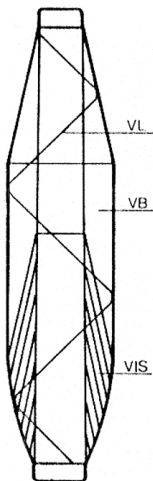
1 – Bobbin start

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).

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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).
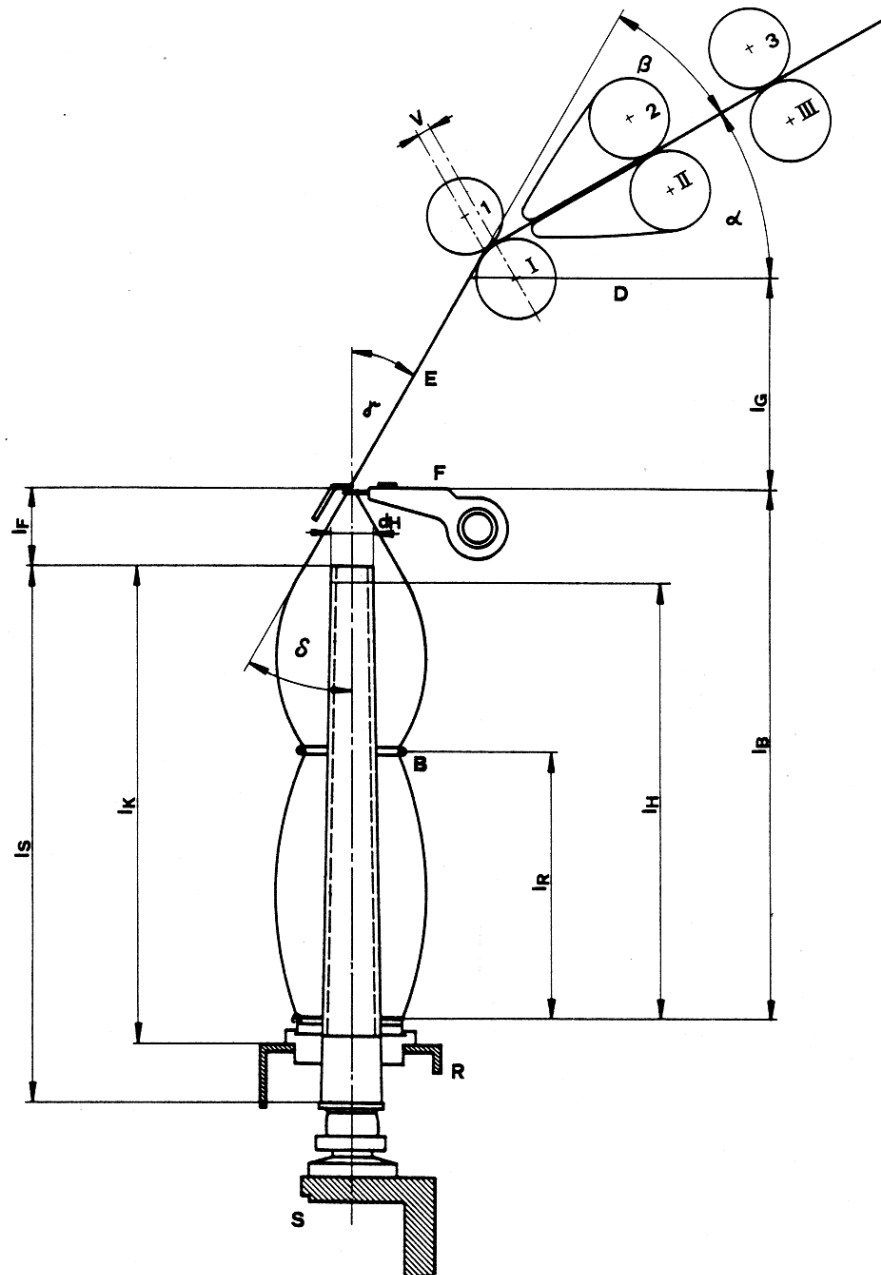

Fig. 227 – Values determining the spinning geometry

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.
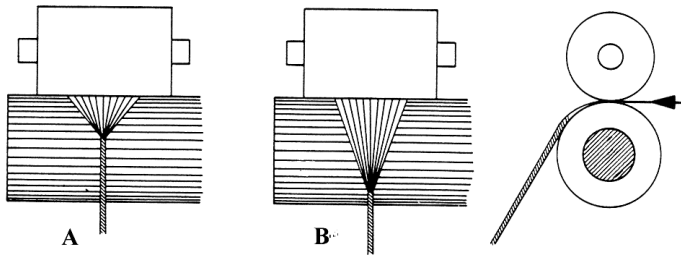

The size of the spinning triangle depends on the spinning geometry and on the position reached by the twists on the yarn; a short spinning triangle (Figure 228A) has a smaller weak zone and will provoke fewer breaks; the fibres at the sides of the triangle are more inclined.
All the fibres move but it 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

Fig. 228 - Spinning triangle

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.
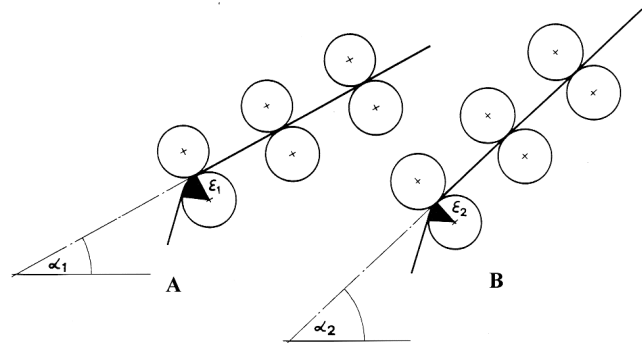

Fig. 229 - Inclination of the drafting unit

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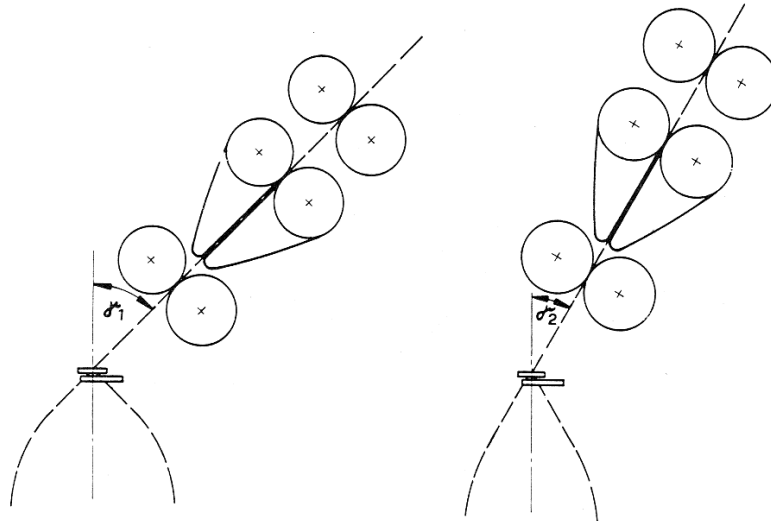
Fig. 230 - Inclination of the yarn with reference to the yarn guide

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.
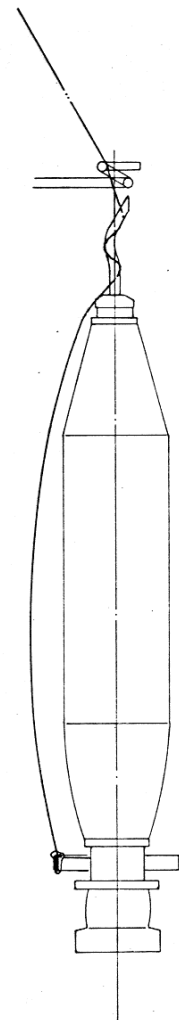

Fig. 231 - Spindle with spinfinger

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).
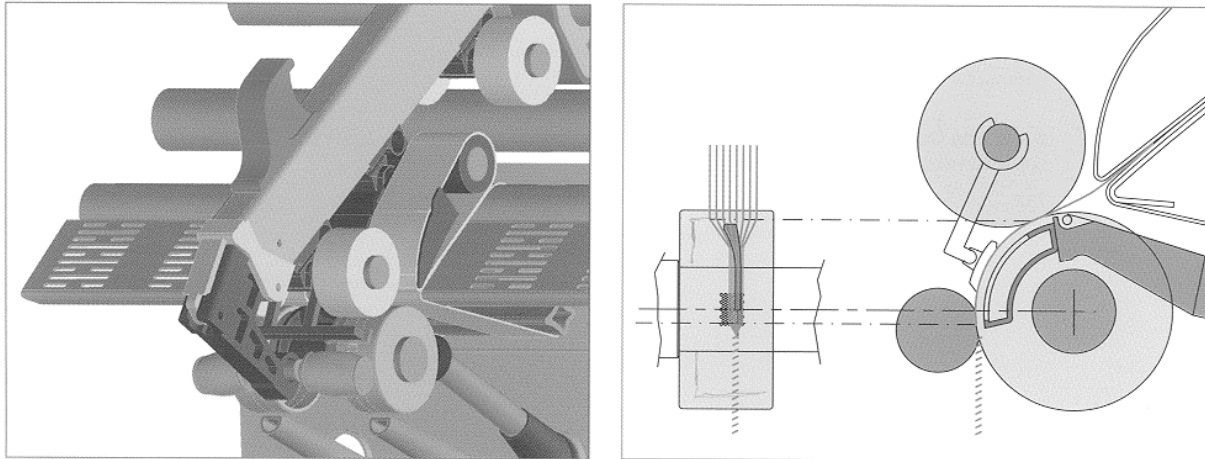

Fig. 232 – Condensation ring spinning frame

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).
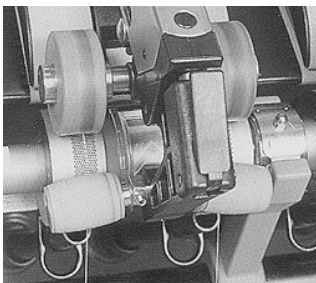

Fig. 233 - Sampre rollers with inclined axes

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).
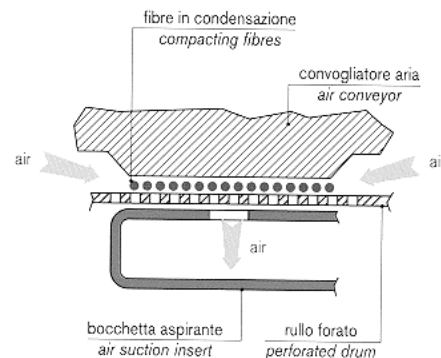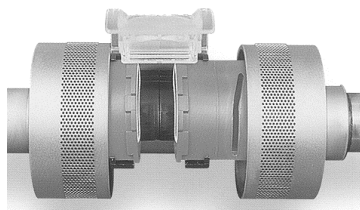

Fig. 234 - Air conveyor

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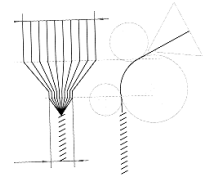Table I shows the main technical features of a ring spinning frame

Fig. 235 – Vacuum insert with slot

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).
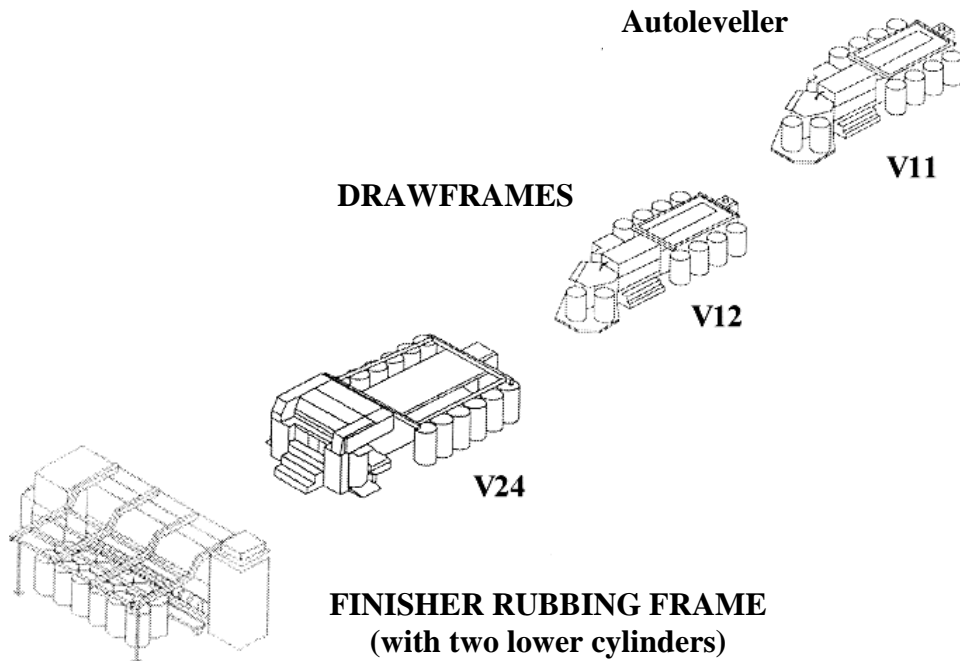
Autoleveller

V11

DRAWFRAMES

V12

V24

FINISHER RUBBING FRAME
(with two lower cylinders)

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

TABLE J

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

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,
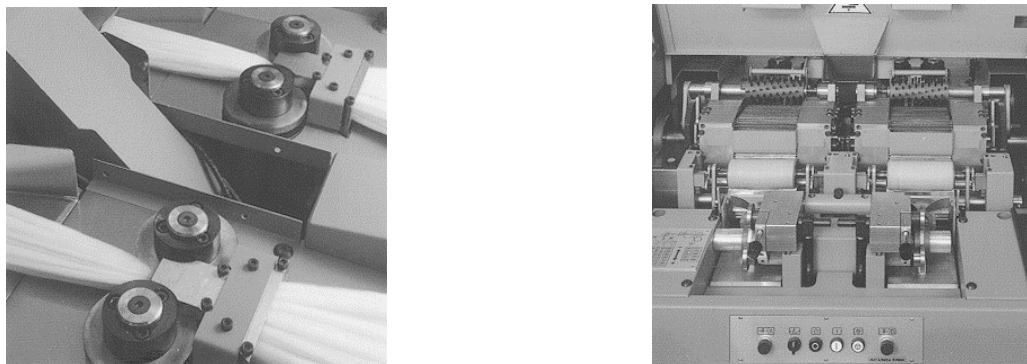• the autolevelling of slivers draft with fewer fibres and therefore more accurately.

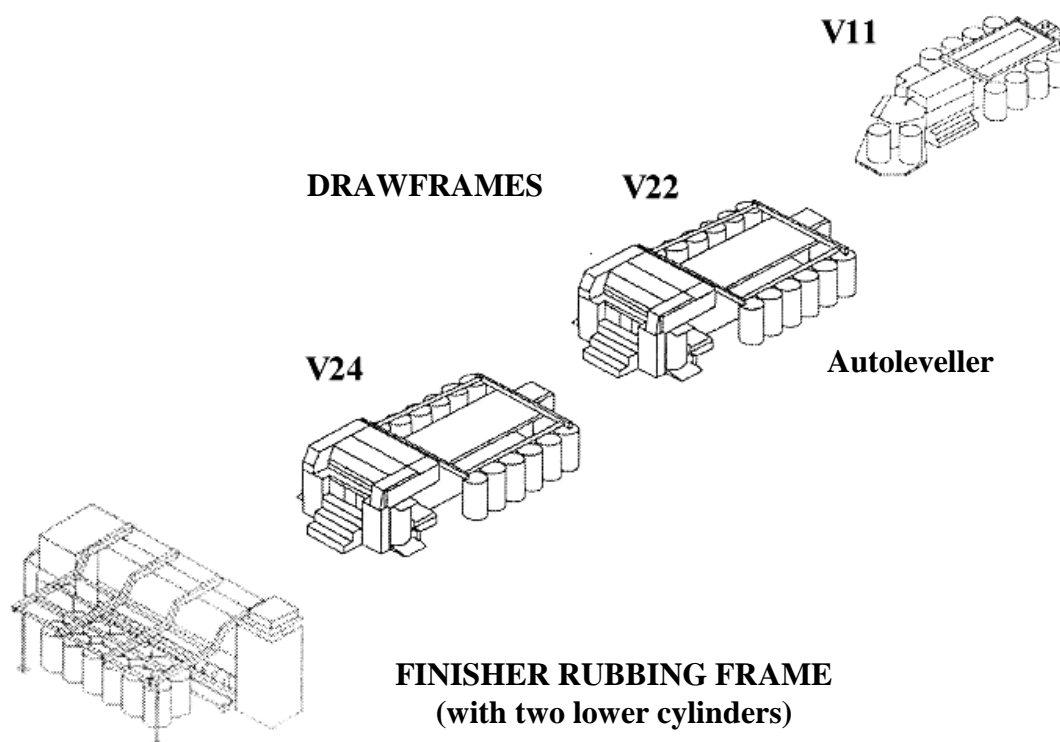*Fig. 238 – Two-head chain drawframe with electronic autoleveller*

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)
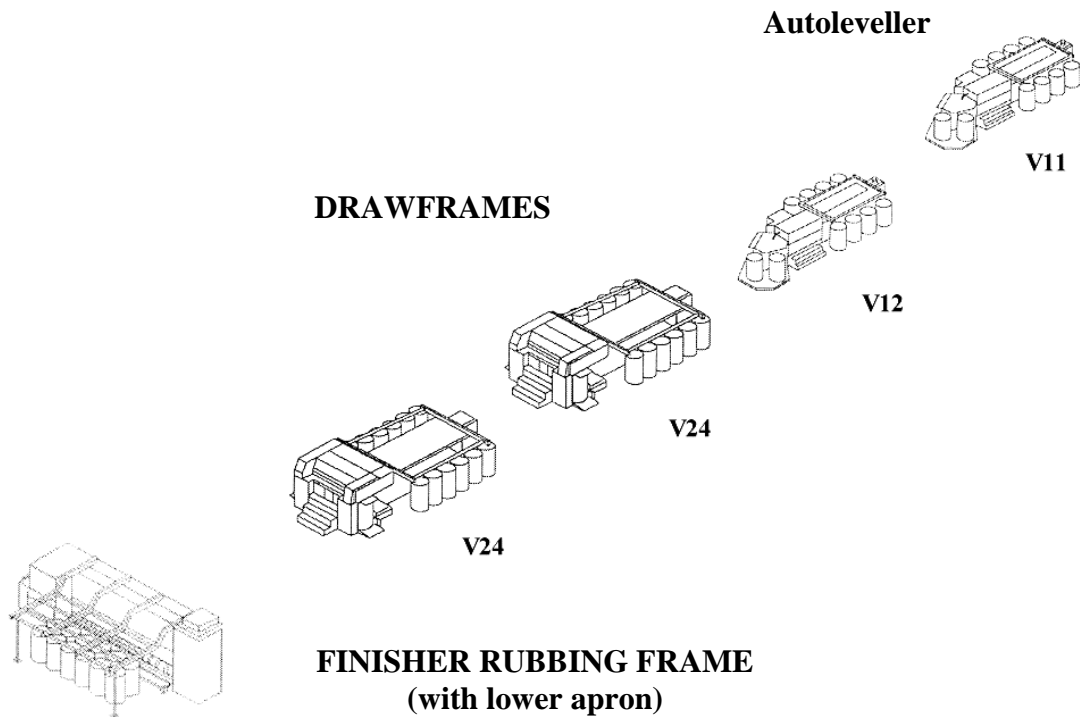Output rate: 315 kg/h Nm 70 wool yarn (Table K)

Autoleveller

V11

DRAWFRAMES

V12

V24

V24

FINISHER RUBBING FRAME
(with lower apron)

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 1 sliver in 1can	25	7	175	7.95	22	1	320	422.4	75	1	316.8
2nd step 2 slivers in 1 can	22	4x2	88x2	8	11	2	320	422.4	75	1	316.8
3rd step 4 slivers in 2 cans	11	4x4	44x4	8	5.5	4	300	396	80	1	316.8
4th step 4 slivers in 2 cans	5.5	6x4	33x4	8.25	4	4	206	197.8	80	2	316.4
Finisher rubbing frame 2 rovings in 1 bobbin	4	1	4	12	0.333	2x24	229	219.6	72	2	316.3
Spinning frame 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)
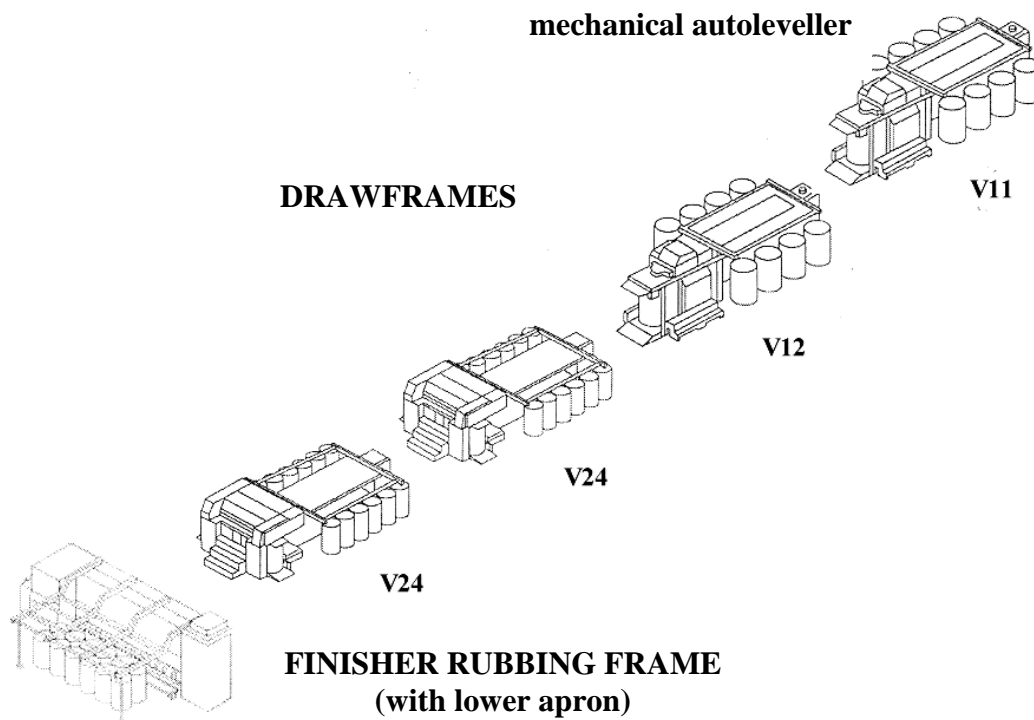
mechanical autoleveller

DRAWFRAMES

V11

V12

V24

V24

FINISHER RUBBING FRAME
(with lower apron)

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

TABLE L

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

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