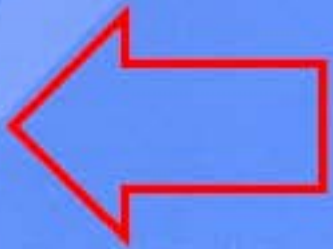


by Carmine Mezza, Paola Zonda



# KNITTING

REFERENCE BOOKS OF TEXTILE TECHNOLOGIES





Ente Morale dell'Associazione Costruttori Italiani di Macchinario per l'Industria Tessile  
*Moral body of the Italian Association of Textile Machinery Producers*

Via Tevere 1, 20123 Milano (Italia)  
Tel. +39 024693611, fax +39 0248008342  
e-mail: [info@acimit.it](mailto:info@acimit.it), <http://www.acimit.it>

**KNITTING**  
REFERENCE BOOKS OF TEXTILE TECHNOLOGIES

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English translation: Studio Trevisan – Vigevano (PV)

## Foreword

I am pleased to present the second in a series of four textile machinery technology handbooks that the ACIMIT Foundation is producing for use in Italy's institutes of textile technology.

This particular book looks at machinery, accessories, auxiliary equipment and technologies relating to knitwear, a segment in which Italy boasts companies of international prominence and advanced "know-how".

This knitwear handbook follows the one on weaving, published in October 2000. A thousand copies of the weaving handbook have already been distributed and it has been translated into English for distribution overseas.

The third handbook in the series, on textile finishing, is due to be published in Italian by the end of 2001, while the one on spinning will be ready in spring 2002.

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

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 producing handbooks that respond, as far as possible, to students' learning needs, the ACIMIT Foundation decided, in agreement with the heads, 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 heads 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 technicians, etc.) who sends us suggestions and corrections that might enable us to improve this publication and increase the value of the whole enterprise.

*October 2001*

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

## Acknowledgements

The ACIMIT Foundation wishes to thank the heads and teachers of the following schools without whose willing and energetic collaboration this book could not have been produced:

- ITIS Buzzi – Prato
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- ITIS Leonardo da Vinci – Carpi (Modena)
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- ITIS Leonardo da Vinci – Naples
- ITIS Marzotto – Valdagno (Vicenza)
- ITIS Paleocapa – Bergamo
- ITIS Sella – Biella
- ITIS Varese – Varese

\* \* \*

The knitwear handbook was written by the following teachers:

- Prof. Carmine Mazza

A graduate in Mechanical Engineering from Naples Polytechnic, Carmine Mazza is now a teacher of clothing textile technology and production organisation at the technical college I.T.I.S. Facchinetti, Busto Arsizio.

- Prof. Paola Zonda

An expert in textiles, Paola Zonda graduated in Biology from the University of Modena; she is textiles coordinator of the technical college (I.T.I.S.) of Carpi and a lecturer in textile design at the University of Bologna.

The ACIMIT Foundation wishes to thank both for the time and enthusiasm invested in the project.

\* \* \*

Pictures 3, 4, 5, 107, 108, 115 and 116 are taken from Prof. Francesco Viola's book, *Tecnologia delle macchine circolari per calze*, Gesto Editore.

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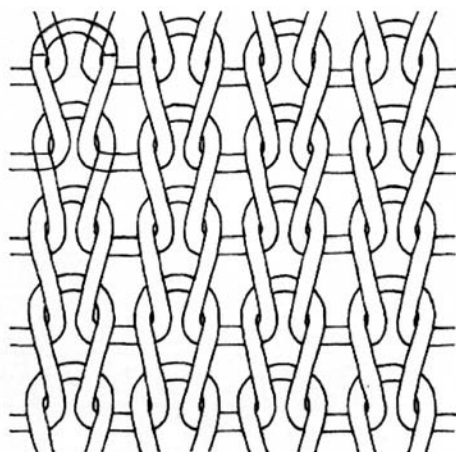


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## Basic Technology

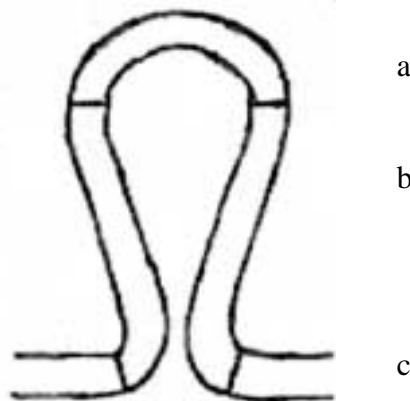
### General Remarks

A discussion about knitting technology must be dealt both as an analysis of the technical cycles of knitting as regards the machines used and the mechanisms involved in the process, and as an analysis of the technology of knitted fabrics in terms of their structures and their physical and mechanical properties.



*Picture 1 - Knit fabric*

In its simplest form, a knit fabric (picture 1) is made by the longitudinal and vertical repetition of the same element, the loop, which is the basic element of the fabric.

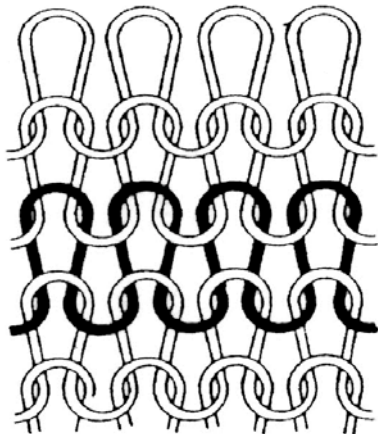


*Picture 2 - The loop*

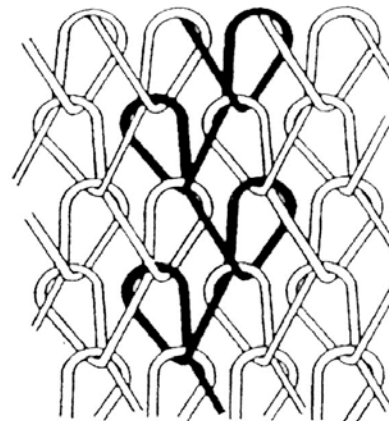
The loop (picture 2) is a length of yarn that is forced to assume a curvilinear shape. It can be divided into three main sections:

- a: loop top
- b: loop side and bottom
- c: half interloop

The interloop is the yarn that links two consecutive loops together. The horizontal or vertical repetition of loops forms the typical structures of knit fabrics, which can be divided into WEFT KNIT FABRIC and WARP KNIT FABRIC, respectively.



*Picture 3 - Weft knit fabric*



*Picture 4 - Warp knit fabric*

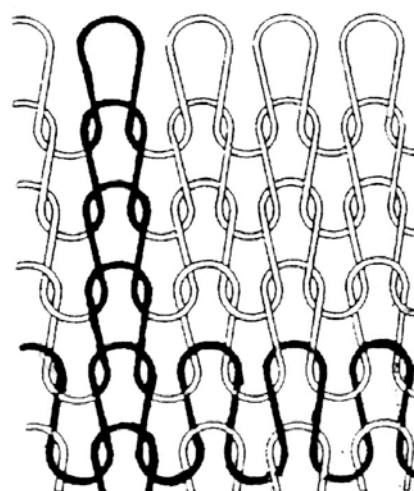
In weft knits (picture 3) the interloop links two consecutive loops placed horizontally; when one loop breaks, the entire fabric can be undone simply by pulling the free end of the yarn.

In warp knits (picture 4) the yarn is knitted vertically or diagonally and loops are formed accordingly; to knit the fabric, it is necessary to use many threads simultaneously, allowing the loops formed by the different threads to bind together.

In this case, the knit fabric is run-proof. Therefore, the warp knit fabrics are also called “non-run“ or “ladder-proof “.

From a physical point of view, a fabric can be described as a flexible structure, made up by the vertical and horizontal repetition of two elements: the course and the wale.

The word “course” defines a row of horizontal loops, belonging or not to the same yarn; “wale” means a row of loops laid vertically one upon the other (picture 5).



*Picture 5 - Course and wale of a weft knit fabric*

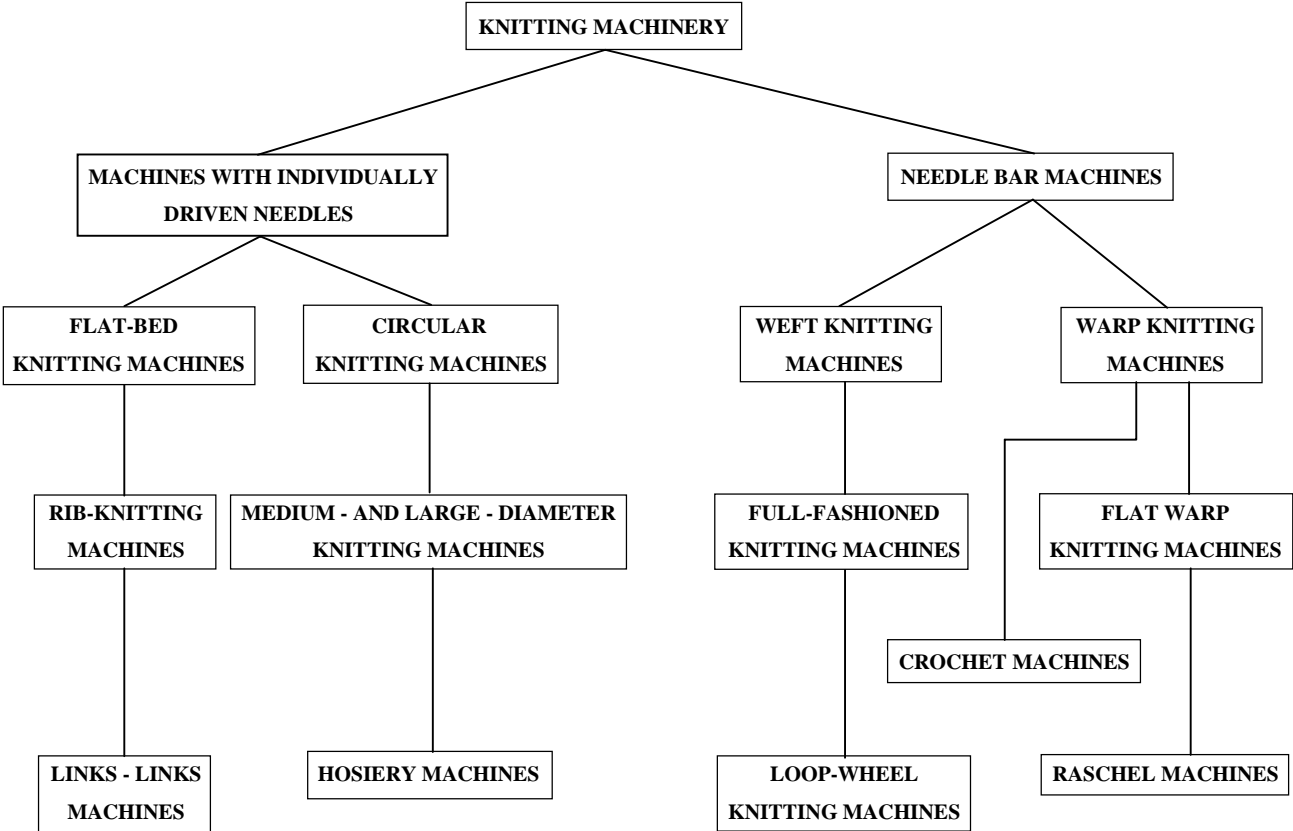
# Classification of Knitting Machines

The machines used for the manufacturing of knit fabrics can be divided into machines with individually driven needles and needle bar machines.

The former type of machine incorporates needles which are moved individually by cams acting on the needle butt; they are used for producing weft knits and are subdivided into circular knitting machines and flat-bed knitting machines.

The needles used can be latch needles or compound needles.

The needle bar machines incorporate needles which move simultaneously, since they are all fixed to the same bar; we distinguish full-fashioned knitting machines and circular loop-wheel machines for the production of weft knit fabrics, which only use spring-beard needles, and warp knitting machines which use spring-beard needles, latch needles and compound needles.



## The Three Main Types of Needle

The needle is the basic element of loop formation.

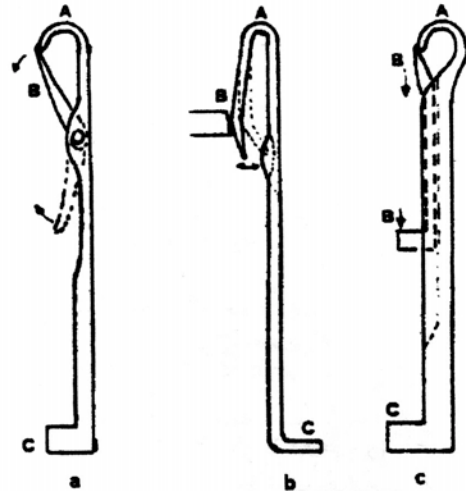
There are three most commonly used types of needle (picture 6): the latch needle (a), the spring-beard needle (b) and the compound needle (c).

We can divide a needle into three main parts:

A. the hook, which takes and retains the thread to be looped;

B. the hook opening and closing device, that allows the hook to alternatively take a new thread and release the previous one;

C. a system allowing the needle to move and form the loop.



Picture 6 - The three main types of needle

During the loop formation the hook must be closed in order to transfer the previous stitch already formed on the new thread; this operation takes place in different ways according to the type of needle used.

With the latch needle, the latch is hinged at a certain distance from the hook and can revolve:

- the anticlockwise rotation, produced by the pressure of the loop, which is originally inside the hook, opens the hook to allow a new thread to be fed;
- the clockwise rotation, produced by the pressure of the loop on the stem, allows the hook to be closed and subsequently knocked over on the new thread.

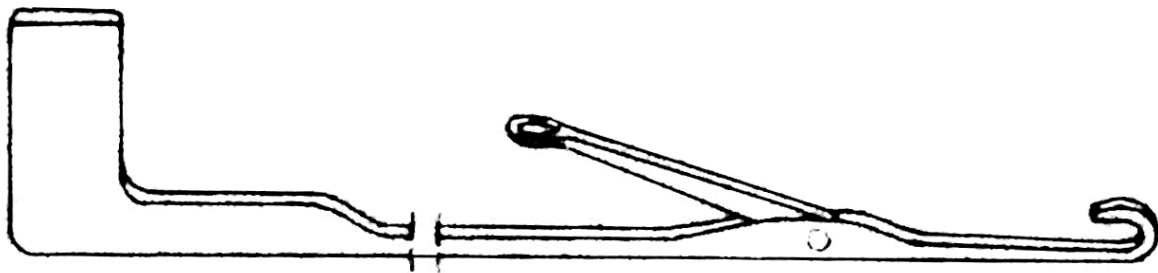
In spring-beard needles, the hook is closed by an external device, the presser, which, at a specific time during the stitch formation, comes in contact with it and makes it bend and close.

When the presser is pulled away, the hook springs back and opens the needle automatically.

The compound needle includes (inside the internal groove of the stem) a sliding closing element, which opens and closes the hook through its upward and downward motion.

The use of the latch needle for knitting machinery has become increasingly widespread over the last few years; the main advantage of this needle is that it has a reduced stroke, which means a higher speed and increased production capacity without stressing the thread during the transfer steps. In addition, it offers a wider sampling potential and a better quality of the fabric manufactured. The main drawbacks include higher costs and a more complicated operating technology.

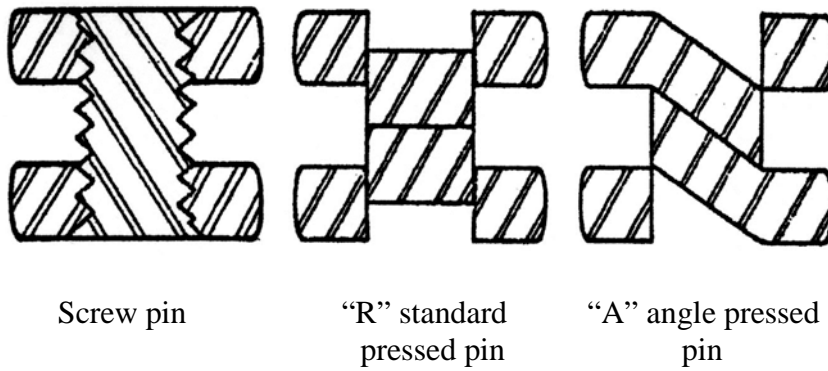
## The Latch Needle



*Picture 7- The latch needle*

The elements which characterise this type of needle (picture 7) are the following:

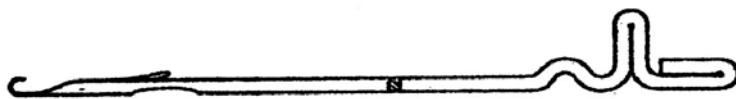
- the stem: the stem is the main part of the needle and its thickness is proportional to the machine gauge; the stem is arranged between the rods and the pockets of the needle bed, which acts as a guide; the stem can be bent to allow the needle to keep the position set by the selection mechanism.
- the butt: the butt is the stem section in contact with the cams or the selection mechanism; cams and selection mechanism generate the upward and downward strokes of the needle: the height of the butt can vary according to the different operating possibilities. A latch needle can have one or more butts, arranged at different levels.
- the hook: the hook is the upper end segment of the stem. It picks up the yarn fed by the thread guide to form the stitch. Height, diameter, length, thickness, shape and position are the main parameters of a hook.
- the latch holder: the latch holder is the part of needle carrying the latch pin.  
The latch can be assembled in three different ways (picture 8):
  1. it can be screwed (this manufacturing technology is rather complex);
  2. it can be “R” standard pressed (when it has a straight hole);
  3. it can be “A” angle pressed (when it has a slant hole).
- The latch: it is shrunk on the pin and it can freely rotate in both directions; its length determines the stroke the needle must cover to form the stitch.  
At the latch end there is a recess (the “spoon”), which allows the thickness resulting from the mating of the latch and the hook to be reduced.  
The yarn must fit under the open latch but the surface on which the loop must slide must not be too thick; for this reason, a special pocket, or “throat”, is machined on the needle stem.



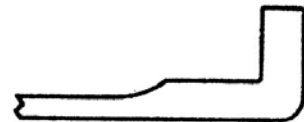
Picture 8

From a manufacturing point of view we can have two different types of needle:

- wire needle
- die-cut needle



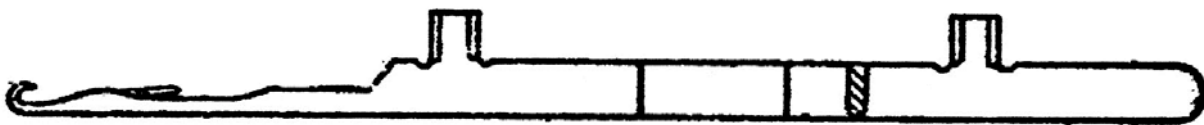
Picture 9 – Wire needle



Picture 10 – Pressed butt

Die-cut needles (picture 9) are made from a steel wire shaped through various machining steps to create a flat profile and form a hook, the section accommodating the latch, and an end butt with tail; sometimes the butt is not obtained with a bending process but by a pressing one (picture 10).

Die-cut needles (picture 11) are made from a steel plate of the desired thickness, which is die cut so as to create the shape of a butt with or without a tail; the hook and latch fitting are created with a special process.



Picture 11 - Die-cut needle

The manufacturing process with the wire needle is the simplest and most cost-effective one, while the die-cutting process gives better technical results and imparts greater stiffness to certain sections of the needle.

A critical feature of all needles is the gauge; it is directly connected to the strength of the needle which must bear the stress and strain generated during the various technical cycles of the knitting process.

The gauge of the needle is directly proportional to the gauge of the machine; the needle must be neither too thick (if so there would not be enough space between a needle and the next one for looping the yarn) nor too fine since in this case the needle, besides being too weak, could compromise the resistance of the binding pattern which would result poorly balanced.

The table in Picture 12 shows the gauge of needles according to their thickness. The values are indicative, as the real value of the needle gauge is only given by the manufacturer's specifications.

GAUGE OF THE NEEDLE	THICKNESS IN MILLIMETRES		THICKNESS IN INCHES	
	from	to	from	to
2 ½	2.286	to more than	0.0900	to more than
4	1.778	- 2.283	0.0700	- 0.0899
8	1.625	- 1.750	0.0640	- 0.0699
10	1.447	- 1.600	0.0570	- 0.0639
12	1.168	- 1.420	0.0460	- 0.0569
18	0.939	- 1.170	0.0370	- 0.0459
24	0.838	- 0.910	0.0330	- 0.0369
30	0.762	- 0.840	0.0300	- 0.0329
36	0.685	- 0.740	0.0270	- 0.0299
42	0.635	- 0.660	0.0250	- 0.0269
48	0.584	- 0.610	0.0230	- 0.0249
50	0.533	- 0.560	0.0210	- 0.0229
54	0.482	- 0.500	0.0190	- 0.0209
60	0.431	- 0.450	0.0170	- 0.0189
70	0.343	- 0.400	0.0136	- 0.0169
75	0.337	- 0.340	0.0125	- 0.0135
80	0.266	- 0.300	0.0105	- 0.0124
85	0.245	- 0.250	0.0100	- 0.0104

*Picture 12 - Table indicating the gauge of the needles with reference to their thickness*



## Needle Specifications

The typical “European” specifications for a needle includes a word, a number (usually a four-digit number) and a final combination of letters and numbers.

For example: Vota 78.60 G.02

The capital letter at the beginning of the word ( “V”), identifies the origin of the needle (obtained from a wire, pressed or die-cut), the type, the number of butts and the type of tail.

The other capital letters have a very precise meaning, except for the vowels “e” and “a” which are added to make the word pronounceable, and indicate the shape and the height of the butt, the eventual existence of a groove and its size, the length of the tail and some other features of the needle.

The next group of numbers identifies the needle according to the length and the gauge.

The first part (78 in the example) indicates the whole length rounded off to the mm (in our case that makes 78 mm); the second part indicates the gauge of the needle in hundredths of millimetres (in our case the gauge of the needle is equal to 0.60 mm).

The final group of letters and numbers has to be read as follows.

The first capital letter indicates the needle manufacturer

(For example Z for Torrington, E for Exeltor, G for Groz-Beckert).

The next number is used to distinguish a specific needle among all the needles produced by the same manufacturer.

The next letter refers to some particular features of the needle: for some needles an “A” indicates that the latch has been fixed with an angular pressed pin while an “R” means that the latch has been fixed with a straight pressed pin.

For other needles, the latch fixing method is indicated by a “0” before the last number.

A “0” indicates that the latch has been fixed with a standard pressed pin; no “0” means that the latch has been fixed with a screw pin.

## The Stitch Formation Cycles with the Three Types of Needles

### Stitch Formation with a Latch Needle (picture 13).

At the beginning of the process, the needle is positioned on the knock-over plane with the loop thread inside the hook, closed by the latch.

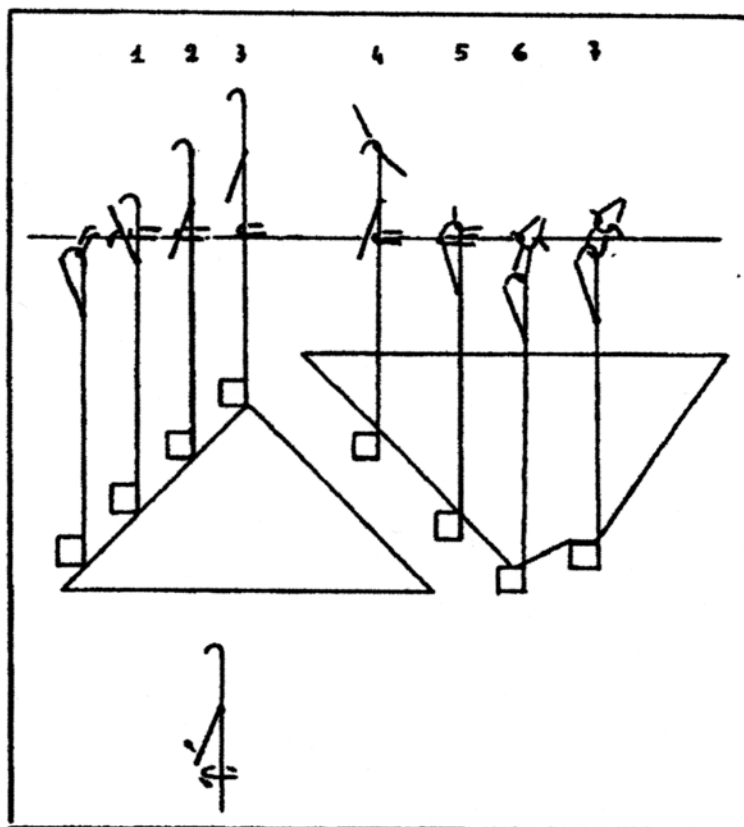
The upstroke motion of the needle makes the thread slip downward touching the latch; this makes the latch rotate anticlockwise and open the hook.

Once the needle has reached its maximum height on the looping plane, the latch opens wide and the stitch moves along the stem.

The needle now begins to move downward. On reaching the tuck-stitching plane, it catches a new loop thread.

In the further downstroke of the needle the stitch already formed touches the latch, making it rotate clockwise. As the needle continues its downward motion, this stitch begins closing the latch on the hook.

The needle reaches the end of its stroke (i.e. its lower point) and the previous stitch, after having closed the hook completely, is knocked over on the new loop forming a new stitch.



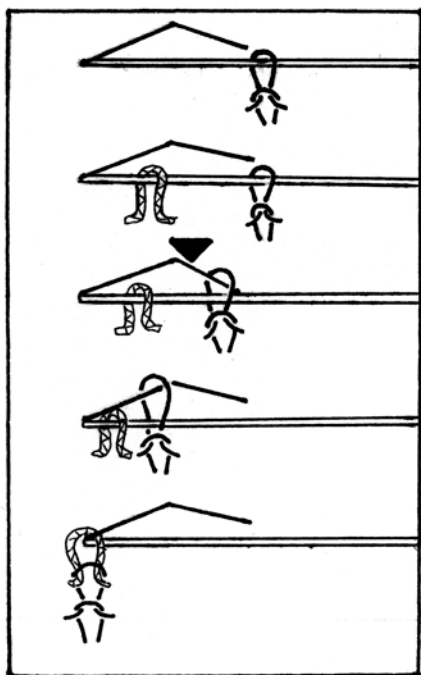
Picture 13 - Stitch formation with a latch needle

## Stitch Formation with a Spring Beard Needle (picture 14).

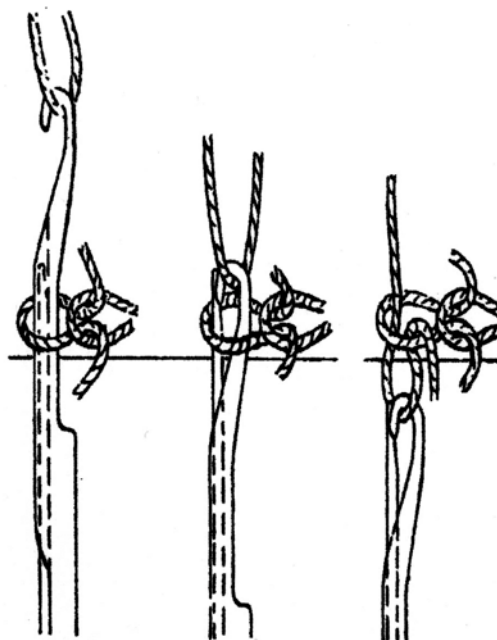
The needle moves upward and the loop thread, originally inside the spring beard, moves along the stem.

Once the needle has been fed, the thread is introduced inside the spring beard, by means of an external device; at this point, the presser closes the spring beard.

While the needle is in the non-knitting position, the stitch can move on the hook. Then, when the needle begins to move downward, it slides on the hook and knocks over on the new yarn fed at the end of the stroke.



Picture 14 - Stitch formation with spring beard needles



Picture 15 - Stitch formation with compound needles

## Stitch Formation with a Compound Needle (picture 15).

The hook is opened by the upward motion of the needle and by the insertion of the slide in the groove on the stem; the stitch moves on the stem, going below the tip of the slide.

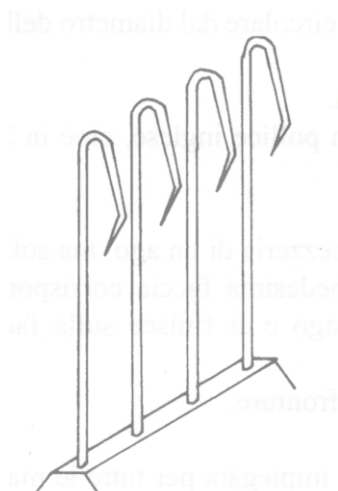
The needle, now completely open, is fed with new thread and then starts to move downward.

The slide moves with a certain delay in relation to the needle and this makes the hook close and the previous stitch to be knocked over on the new thread.

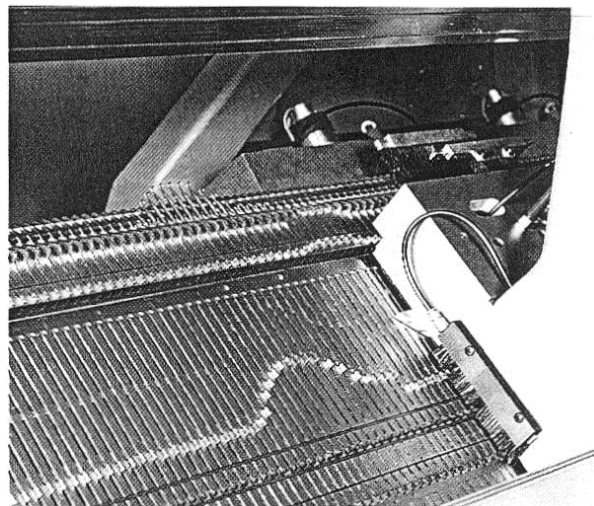
## The Needle-bed

The needle-bed of a knitting machine is made up by the needles. As we said before, the needles can be all fixed on the same needle bar (picture 16) or can be driven individually in a grooved plate, according to the type of knitting machine.

All knitting machines can be equipped with one or two needle-beds, according to the model.

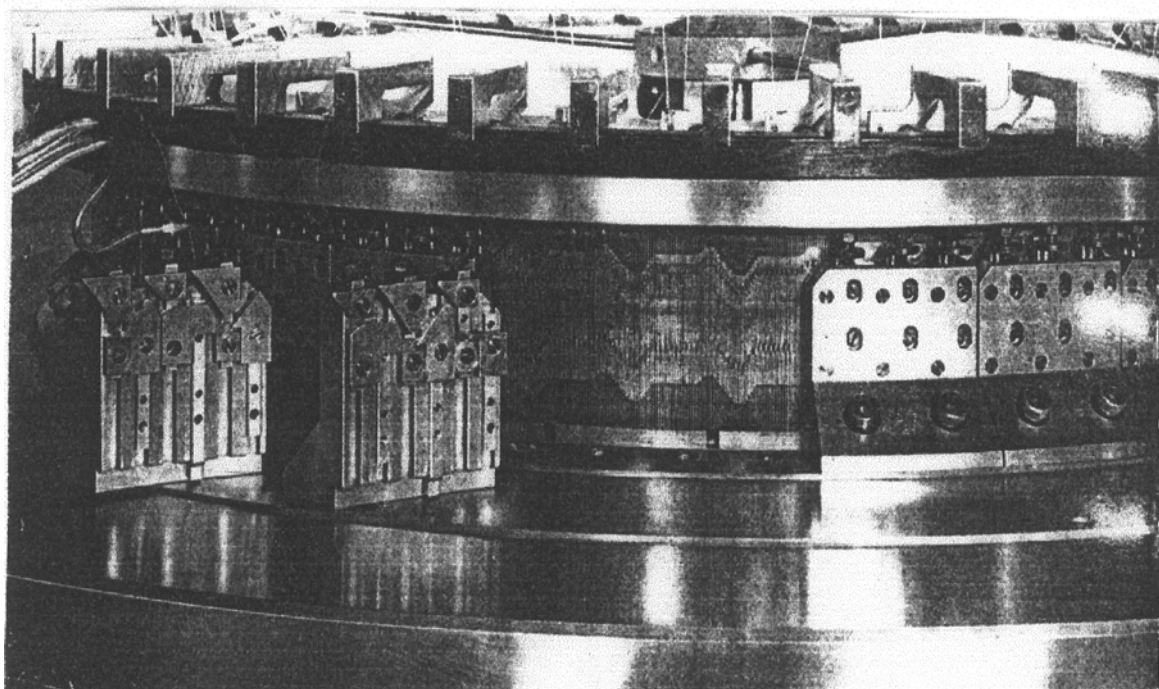


*Picture 16 - A needle bar with spring beard needles*



*Picture 17 - The needle-bed of a flat knitting machine*

The needle-bed of a knitting machine can be flat (picture 17) or circular (picture 18). It is made up of a steel body provided with grooves where the needles with hook and butt turned upward slide. The milled grooves guide the needles during the knitting process.



*Picture 18 - The needle-bed of a circular knitting machine*

The needle-bed is characterised by two elements:

- the operating width
- the gauge

The operating width is the maximum working area and varies according to the type of machine (picture 9): for example in a flat-bed machine the operating width is the distance between the first and the last needle while in circular knitting machines the operating width is the needle-bed diameter.

The gauge is the population of needles on a certain length of bed.

The English Gauge is the number of needles included in an English inch, that is to say how many are included in 2.54 needle-bed centimetres.

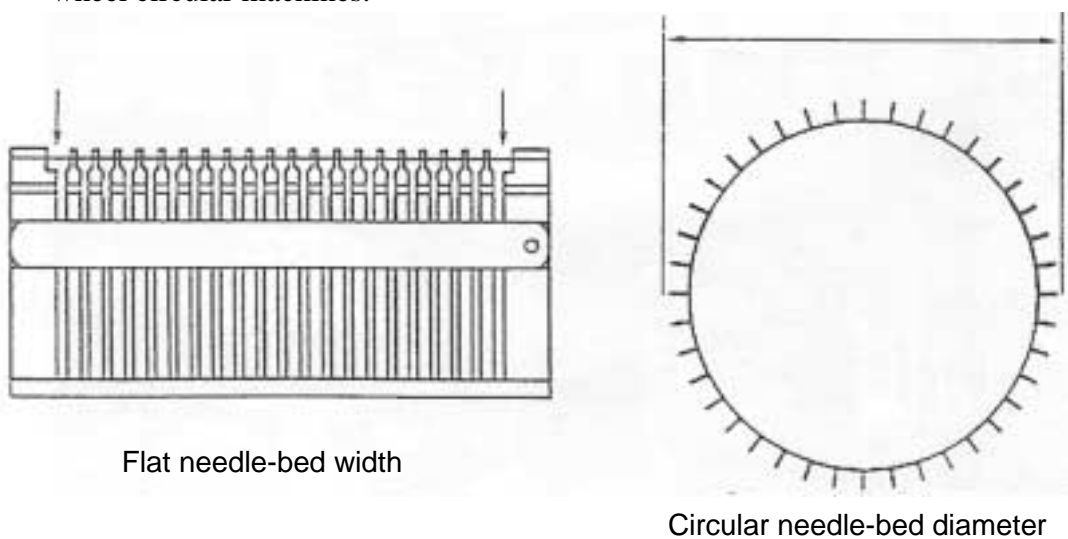
From a conceptual point of view, the English inch is measured from the centerline of a needle but usually it is the distance corresponding to 1 inch, measured from one side of the needle to the same side of another needle within 1 inch. For example: if we start from the right side of the first needle we will have to reach the right side of the last needle.

The gauge refers always and only to one of the two needle-beds.

The English gauge is indicated with a capital E and is used for all the weft knitting machines and warp knitting frames.

There are also other types of gauges used for other machines and specifically:

- the English Raschel Gauge for Raschel looms is indicated with the capital letters “ER” and refers to the number of needles included in 2 inches, that is to say in 5.08 centimetres;
- the GG Gauge is indicated with the capital letters GG and refers to the number of needles included in 1.5 inches, that is to say in 3.81 centimetres. This gauge is used for flat-bed full-fashioned machines and for English circular machines.
- French Gauge is indicated with the Gros symbol and refers to the number of needles included in 1.5 French inches, that is to say in 4.16 centimetres. It is used for loop-wheel circular machines.



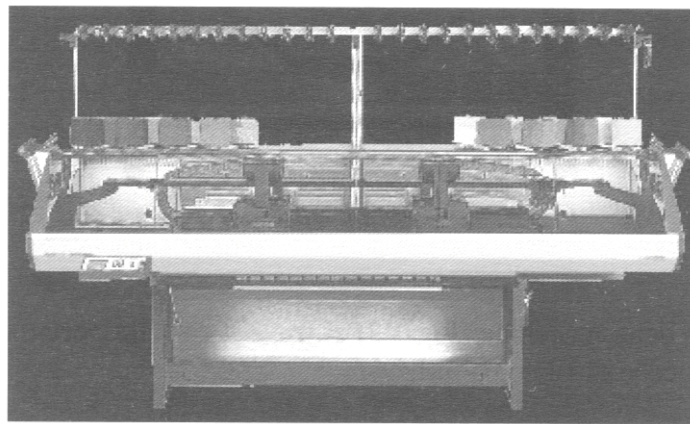
*Picture 19 - Operating width*

## Flat Knitting Machines

The flat knitting machine is a two-bed machine (picture 20).

The most important mechanical features of a flat knitting machine are:

- the supporting frame
- the yarn feeding system
- two needle-beds made up of flat grooved plates
- a carriage provided with cam-locks for needle control
- a transmission system
- a fabric take-down motion
- a central programming unit
- a needle-bed racking system



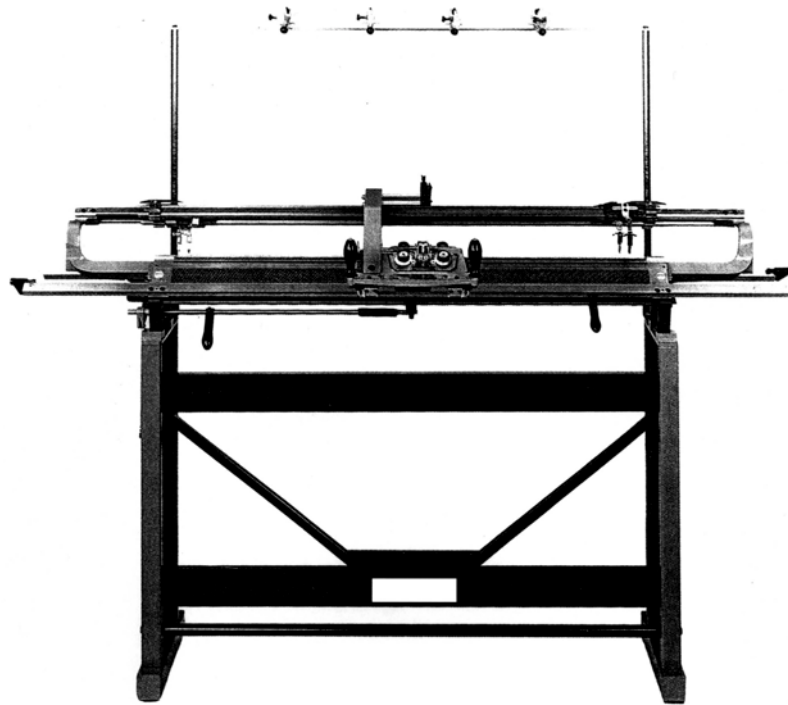
*Picture 20 - Flat knitting machine*

The two flat beds can be:

1. Inclined by  $90^{\circ}$ - $100^{\circ}$  with respect to one another, with a staggered arrangement of the grooves accommodating latch needles or compound needles.  
The two flat beds are the “front needle-bed” (indicating the needle-bed closer to the operator) and the “rear needle-bed” (indicating the farther).
2. Both are arranged on a horizontal plane (at  $180^{\circ}$ ) with the grooves, which are positioned opposite to each other. Double hook needles slide inside the grooves; these needles are moved by special sliders, which can transfer the stitches to the front bed - or to the rear bed for links-links or purl knitting processes - according to the type of patterns.

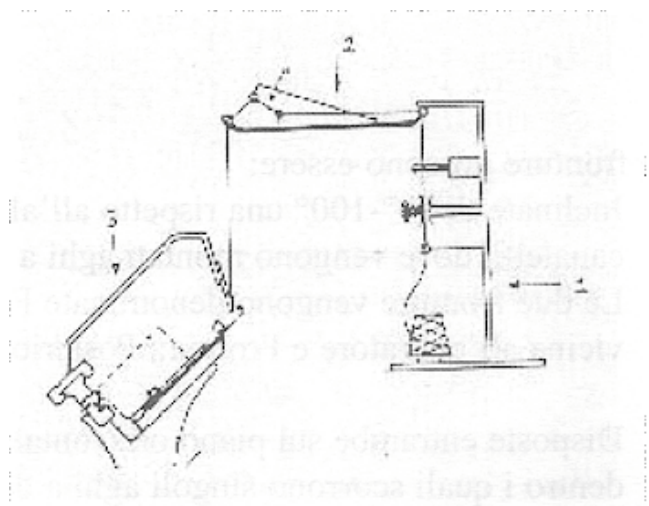
## The Manual Flat Knitting Machine

The manual flat knitting machine is made up by a frame carrying the base; this structure supports all the needle beds and motions necessary for the knitting process (picture 21).



*Picture 21- Manual flat knitting machine*

In the rear side of the machine (picture 22) there is a spool rack for storing the yarn spools.



*Picture 22 - Feeding system*

1. Spool rack
2. Thread tensioner
3. Thread guide

The yarn unwound from the spool is picked up by the feeding system: a tensioner, which adjusts the feeding tension and a thread guide, driven by the machine carriage, which provides the needle with yarn at the proper time.

The tensioner is made up by a spring-load flexible arm, that lowers when the yarn tension increases, to feed a bigger quantity of yarn, and lifts up when the tension decreases.

## The Needle-bed (picture 23)



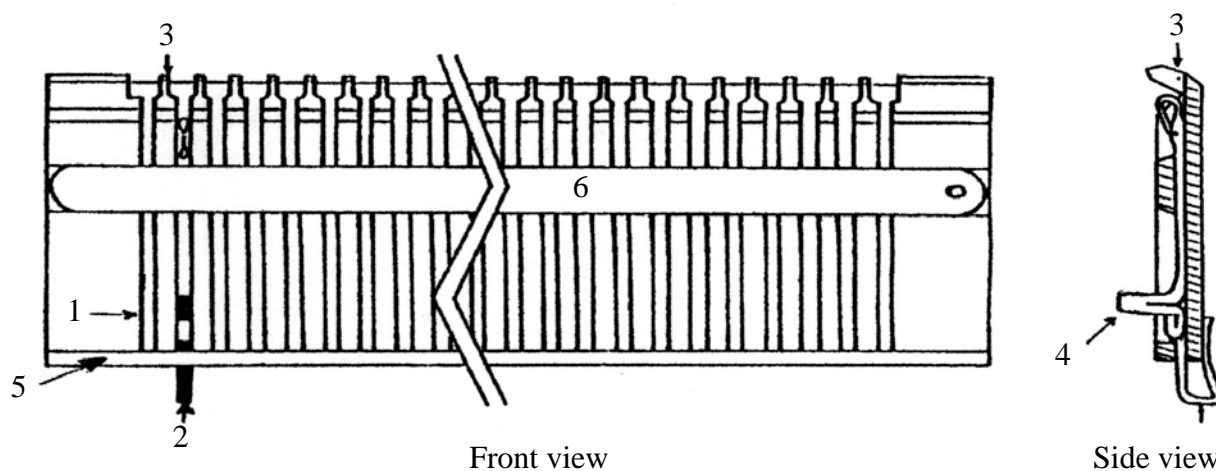
Picture 23 - Needle-bed and carriage of a manual flat knitting machine

Picture 24 shows the needle-bed and the motions of a manual flat knitting machine.

The needles (4) accommodated inside the grooves (1) of the needle-bed can be either in a knitting or in a non-knitting position and are moved by special springs (2).

Placed between the grooves in the upper part of the needle-bed, the knock-over jacks (3) act as supports for the yarn fed during the stitch formation.

A spring securing bar (5) and a needle securing bar (6) are also attached to the needle-bed to keep needles and springs in a correct sliding position.



Picture 24 - The needle-bed



## The Carriage

The carriage (picture 25) is made up of two metal plates linked by a stiff bridge (P); the plates work individually and simultaneously on the front and the rear needle-beds.

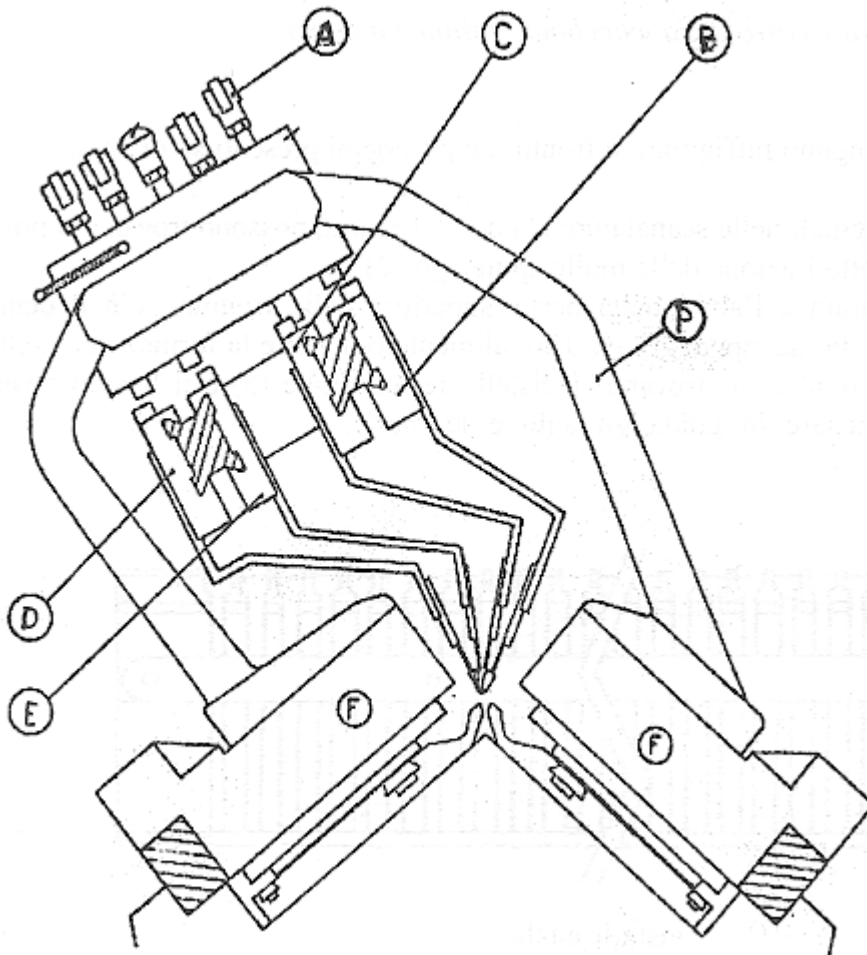
The carriage carries out a double function and can be used:

1. to select the needles and make them raise or lower to form the stitch;
2. to select and drive the thread guides which feed the needles.

The plates include cam locks (F) bearing the drive and control systems of the needles, i.e. the cams.

When the carriage moves right- or leftwards, the thread guides (B),(C),(D),(E) are locked individually by the corresponding pistons (A) on the upper part of the bridge, that are manually driven.

Brushes are also mounted on the carriage to ensure a smooth needle latch opening and grant a correct feeding of the yarn.



Picture 25 - The carriage

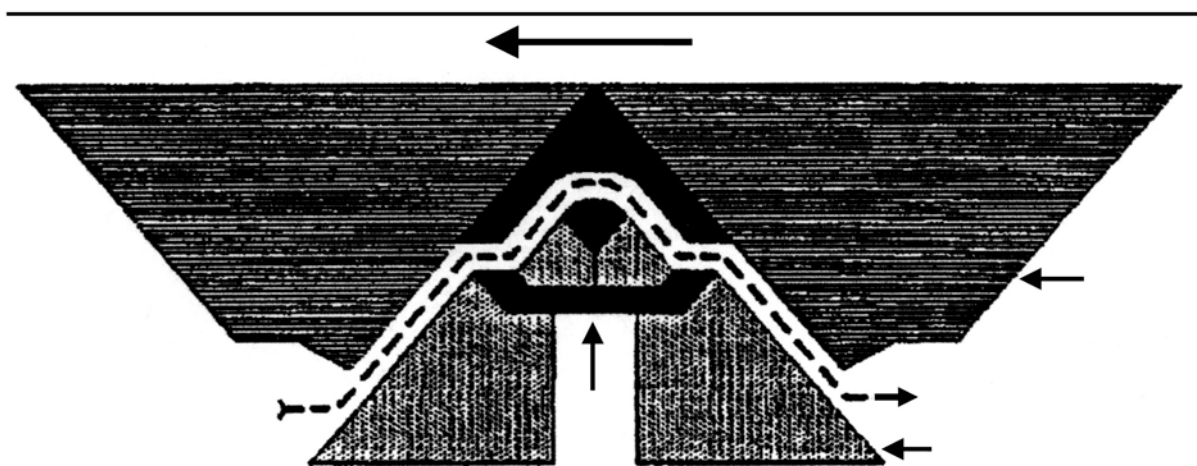
## The Cam-locks

The cam-locks (picture 26) are a cam system which gives the necessary working information to the individual needles; they include a fixed part, working as support, and movable cams, which can be divided into raising cams and lowering or knock-over cams (2).

The raising cam includes:

- A tucking cam (1).
- A looping cam (3).

The fixed or movable cams form a symmetrical channel where the needle butt slides; the needle moves downward and upward in the groove to form the stitch.



*Picture 26 – Cam-lock of a flat knitting machine*

The different parts of the cams are chamfered; their profiles are curvilinear to make the needle move smoothly.

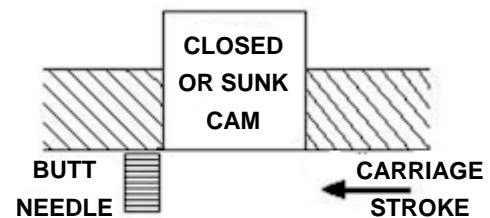
The angle of inclination of the cams ranges between 40° and 50°; these values grant an optimum running of the needle and avoid high pressures between metal parts during the motion and excessive tensions on the yarn during the downward stroke of the needle.

The carriage allows three different work ways according to the needle stroke and to the positions of the raising cam:

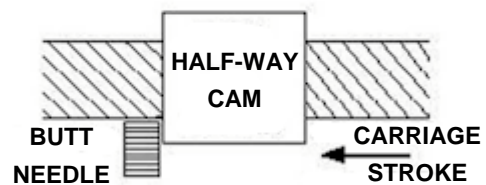
- **KNIT STITCH:** when the needle carries out a complete stroke, reaching the maximum height on the looping plane
- **TUCK STITCH:** when the needle reaches the tucking plane and receives a new yarn while still holding its former loop, thus forming two loops in the one needle hook
- **MISS (or FLOAT) STITCH:** when the needle is not knitting and remains out of the knock-over plane.

The raising cam, both tucking or looping, can be :

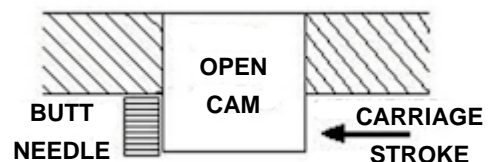
A. Closed or sunk cam



B. Half-way cam



C. Open cam



## High-butt Needles and Low-butt Needles

The latch needle can have two different butt heights which make it a high-butt needle or a low-butt needle (picture 27).



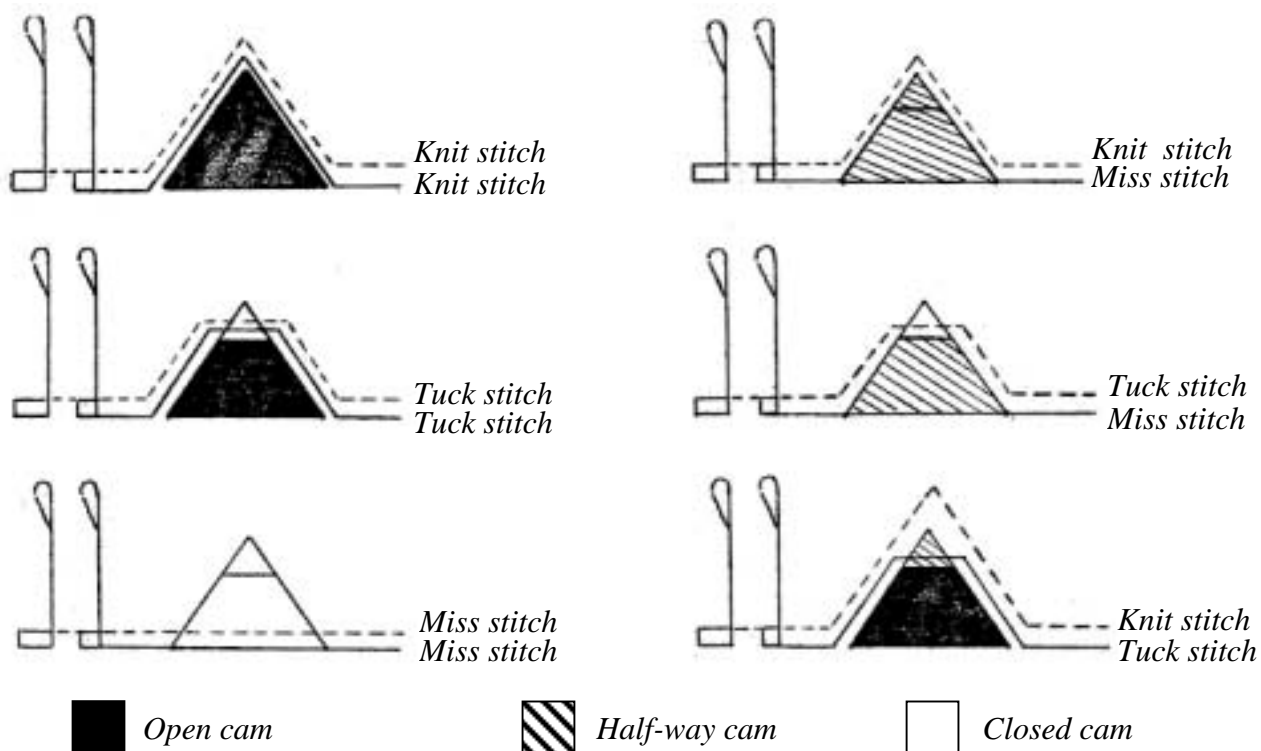
*High-butt needle*



*Low-butt needle*

*Picture 27*

The assembly of high-butt needles and low-butt needles on the knitting machine allows different selection and different manufacturing work ways, according to the positions of the tucking and looping cams (picture 28).

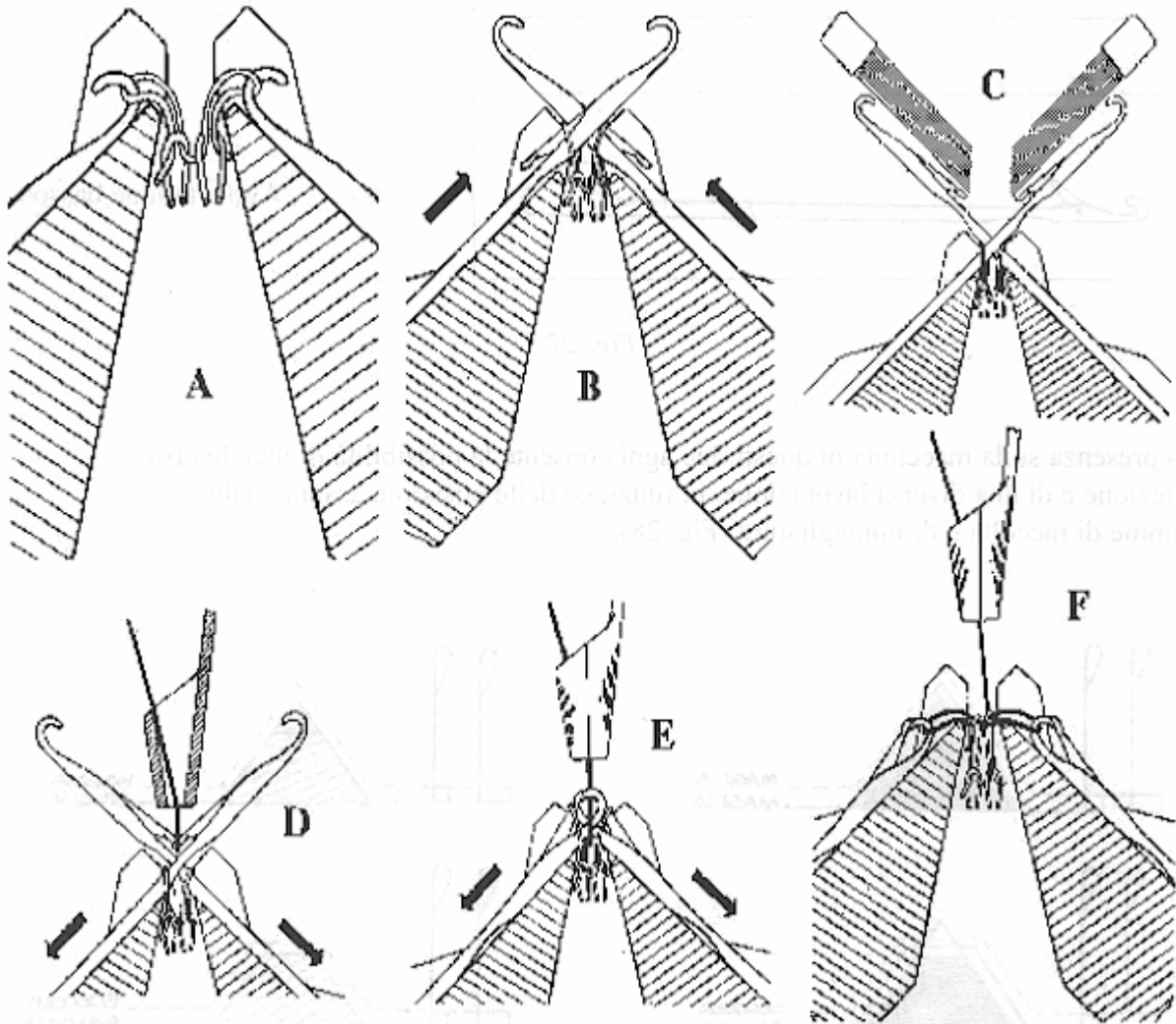


*Picture 28 – The different positions of the raising cam*

## Knit Stitch Formation

The various steps of the stitch formation for the manufacturing of rib knitted cloth are shown in Picture 29.

The following description refers to the work carried out by a single needle, however, the carriage activates the needles of both needle-beds.



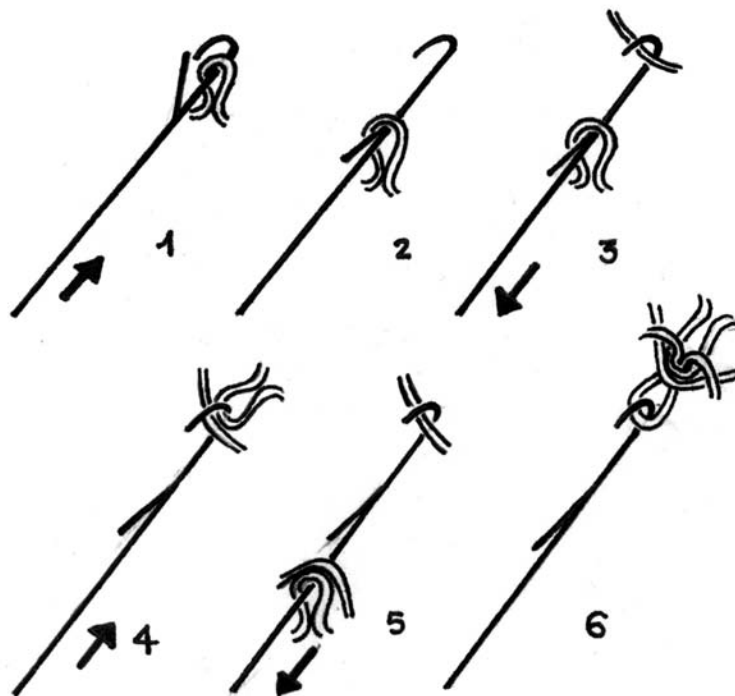
*Picture 29 - The stitch formation*

- A. The needles are in the knock-over position; the loop threads are inside the hook and the latches are closed.
- B. The carriage moves forward and the cam touches the needle butt. The forward motion of the cam with the tucking cam completely out, forces the needle to move upward; the thread inside the hook opens the latch. Once the needle has reached the tucking plane, the latch is completely open and the loop is laid on it.

- C. The forward motion of the carriage makes the needle move upward again, since the looping cam of the cam is completely out. The needle reaches the maximum height on the looping plane and the stitch is transferred from the open latch to the needle stem. This sudden motion can cause a backstroke, that is a reaction of the latch, which could accidentally close with a possible unsuccessful feeding of the new thread and a consequent knock-over failure. This would lead to the formation of a hole or the starting of a run in the fabric. In order to avoid this, the brushes ensure that the latch opens.
- D. Once the maximum height has been reached, the needle is lowered, driven by the lowering cam; after reaching the tucking plane, the thread guide starts working, feeding the thread; the loop rises slightly on the stem and enters the space between the stem and the open latch.
- E. The needle continues its downward stroke; the loop touches the latch and makes it rotate and close.
- F. The needle reaches the bottom, i.e. the knock-over plane; the previous stitch, after closing completely the latch, knocks over on the new thread, forcing it to take up the typical curvilinear shape.

## Tuck Stitch Formation

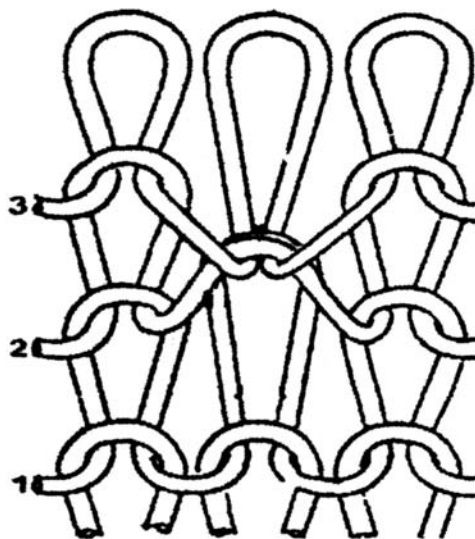
Two consecutive strokes of the carriage are necessary to form the tuck stitch (picture 30).



Picture 30 – Tuck stitch formation

During the first stroke, the tucking cam of the cam is out and the looping cam is not working. Therefore the needle only raises as high as the tucking plane; the loop cannot slip on the stem, and therefore remains inside the hook after having completely opened the latch, in this way allowing the yarn to be fed.

During the second stroke both the tucking cam and the looping cam are activated; the needle rises up to the maximum height allowing the loop and the yarn to travel along the stem. Thereafter, the needle is fed with the thread for the second time; the loop and the first yarn close the latch and knock over on the new yarn. The first yarn does not knock over as a knit stitch but takes a particular position, and fixes on top of the previous knit stitch and at the bottom of the new one, creating a particular effect on the fabric, called tuck stitch (picture 31).



*Picture 31 – Tuck-stitch effect on a single jersey fabric*

### **Miss Stitch Formation**

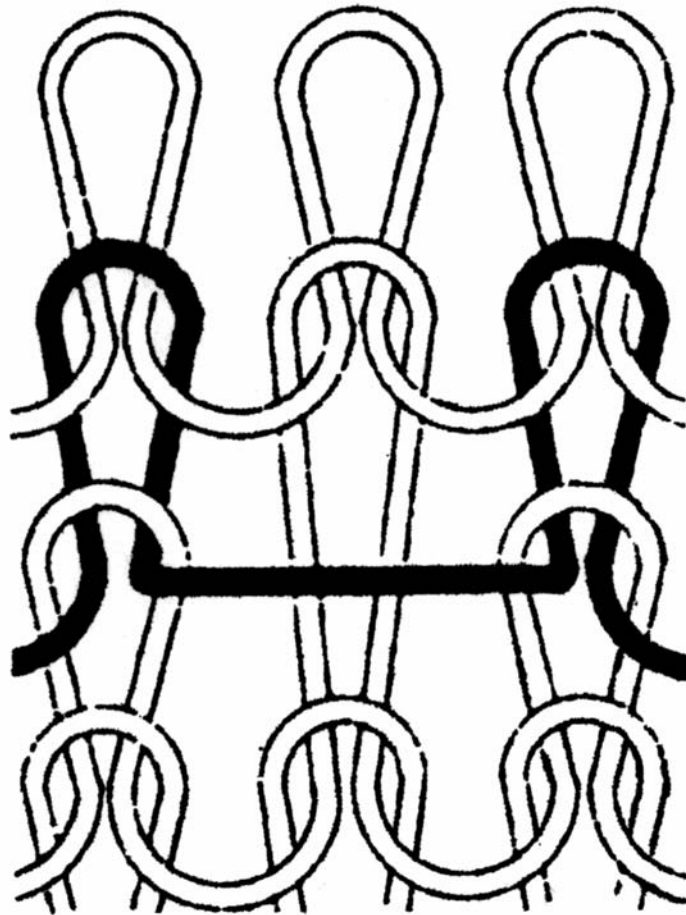
High-butt and low-butt needles are also needed for the formation of the miss stitch (picture 32).



*Picture 32 – Miss stitch formation*

The cam (with a half-way tucking cam and looping cam) meets with the needles: the high-butt needles rise while low-butt needles remain in a non-knitting position. During the downward stroke, the needles which have raised till their maximum height and have transferred the loops on the stem, are fed with a new thread. With the successive downward stroke the latches are closed and the loops is knocked over on the new thread.

The stitches are bound together by longer interloops while the stitch of the non-knitting needle, which can be only knocked over on the next stitch, shows a stretch effect (picture 33).



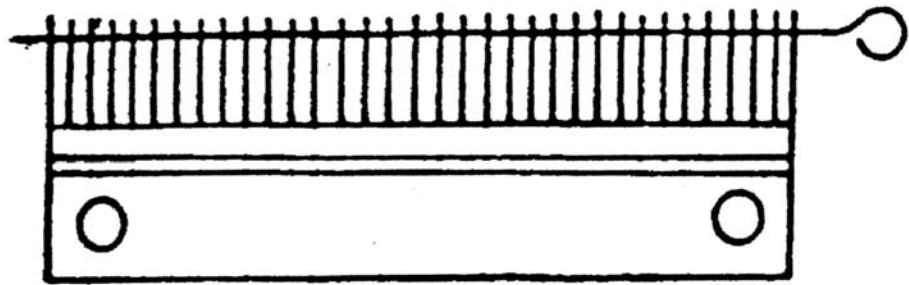
*Picture 33 - Miss-stitch and stretch effect on a single jersey fabric*



## Fabric Take-down

Knitted fabrics require a special system to take them down while they are formed on the knitting machine.

On manual flat knitting machines, after the first stroke of the carriage, a steel reed is fitted into the course (picture 34); the reed is hooked using a steel wire.



*Picture 34 – Fabric take-down reed*



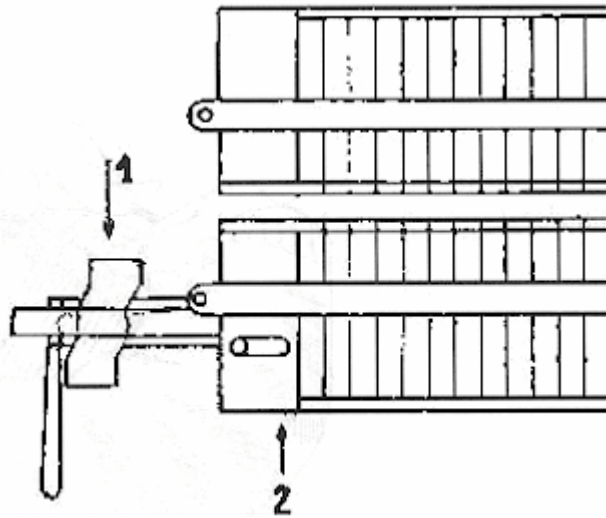
*Picture 35 – Weight holder*

Once the manufacturing cycle comes to an end the steel wire is removed and the reed released.

The machine and the reed must have the same gauge; the holes in the lower part of the reed accommodate the weight-holder hooks (picture 35) to increase the tension on the fabric according to the specific needs.

## Needle-bed Racking

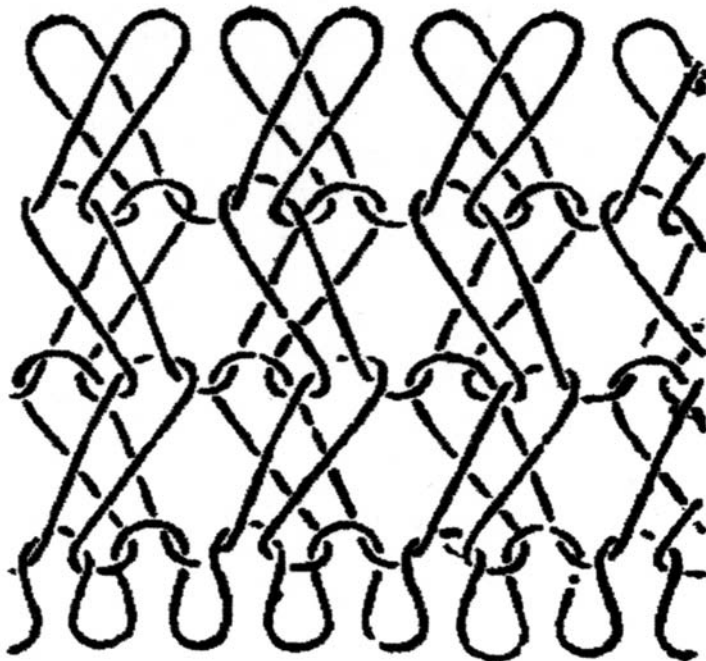
The needle-beds of flat knitting machines are not stationary. All flat knitting machines are provided with a needle-bed racking system which is used for shifting one bed in relation to the other by means of a special cam placed on the machine's side (picture 36).



*Picture 36 - Needle-bed racking*

- 1. Racking cam*
- 2. Needle-bed*

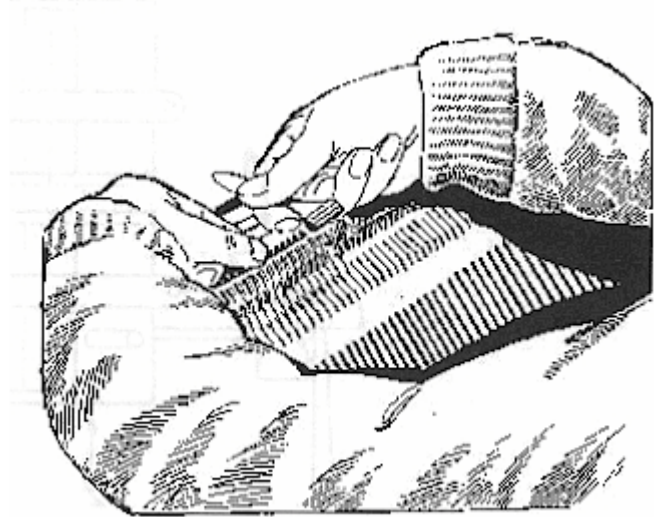
Racking can occur in both directions. The needle-bed can also take different positions: racking over half needle or full needle. The racking motion allows the creation of inclined patterns (right-hand or left-hand) on the knit fabric (picture 37).



*Picture 37 - Effect of bed racking on a rib pattern*

## Stitch Transfer

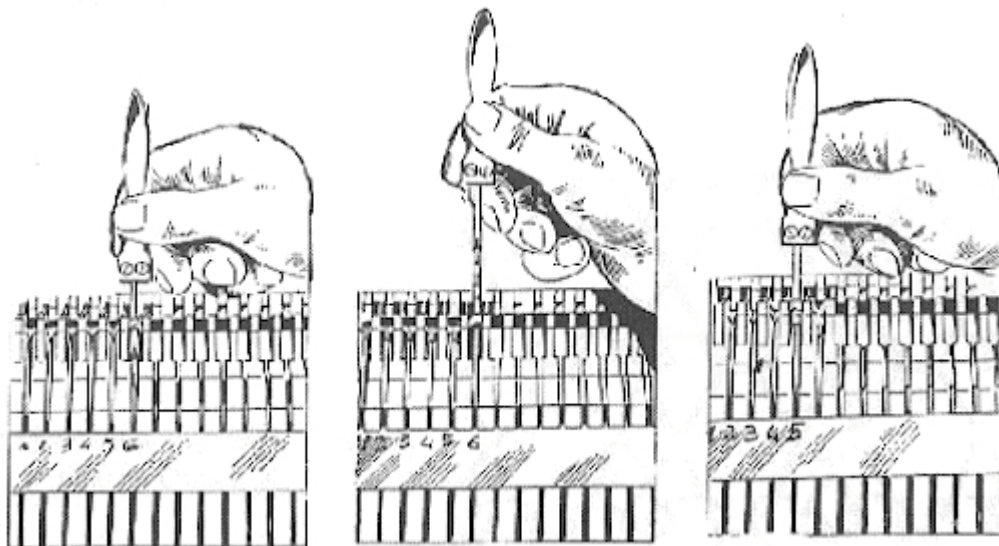
In Picture 36, the transfer of one of the two needle-beds is the half-racking type. The needles are arranged on a front position and cannot work simultaneously; this option is used to transfer the stitches from one bed to another (picture 38).



*Picture 38 - Front stitch transfer*

The stitch transfer can be carried out on contiguous needles of the same bed (picture 39) to obtain special knitting effects.

A special hand tool is used for transferring the stitch manually on another needle.

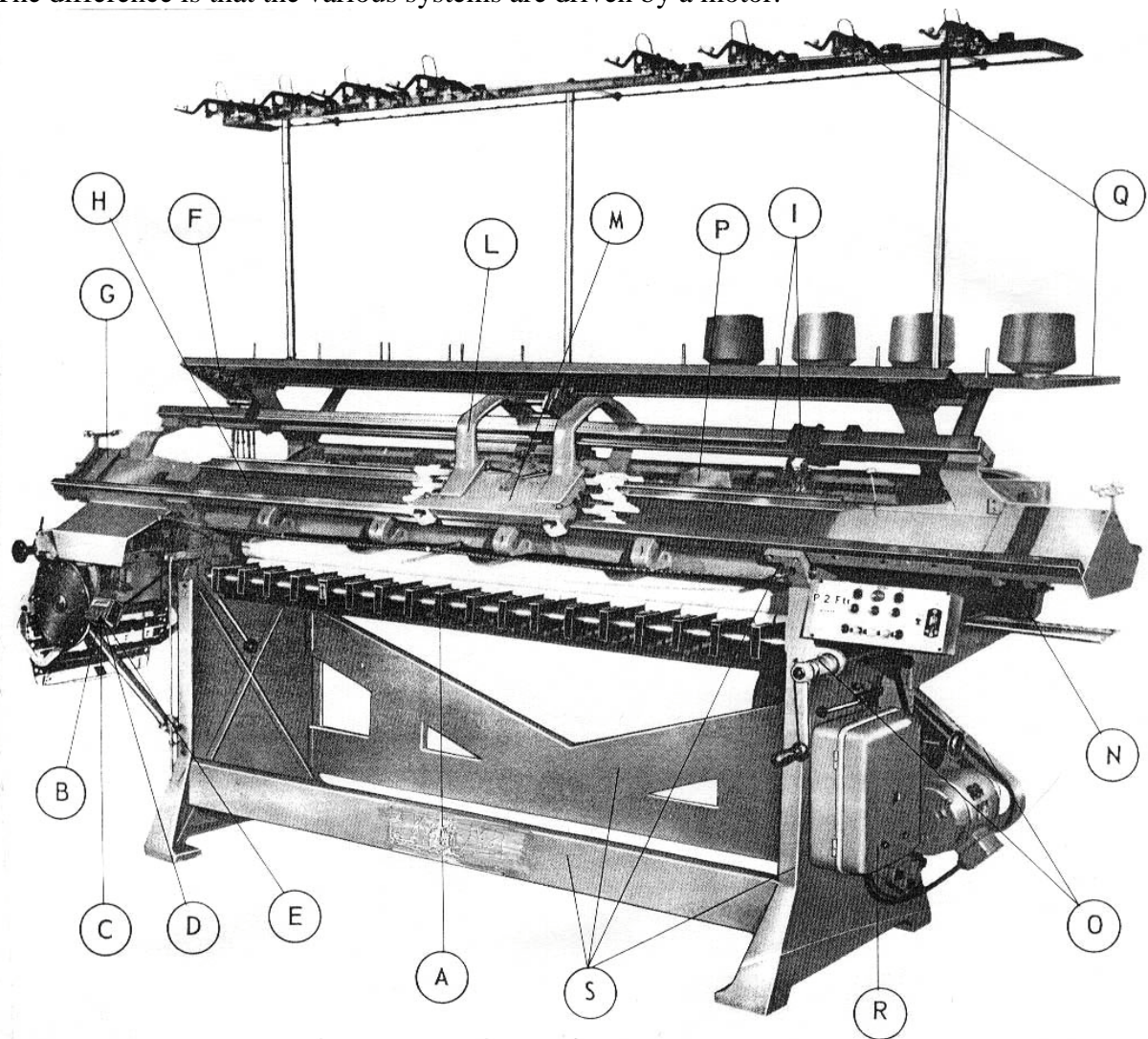


*Picture 39 - Side stitch transfer*

The stitch transfer is a particularly useful in the production of complicated patterns (such as cable, aran and petinet stitches).

## Automatic Flat Knitting Machines

The structure of an automatic flat knitting machine is very similar to a manual knitting machine. The difference is that the various systems are driven by a motor.



Picture 40 – Automatic flat knitting machine

An automatic flat knitting machine incorporates the following systems (picture 40):

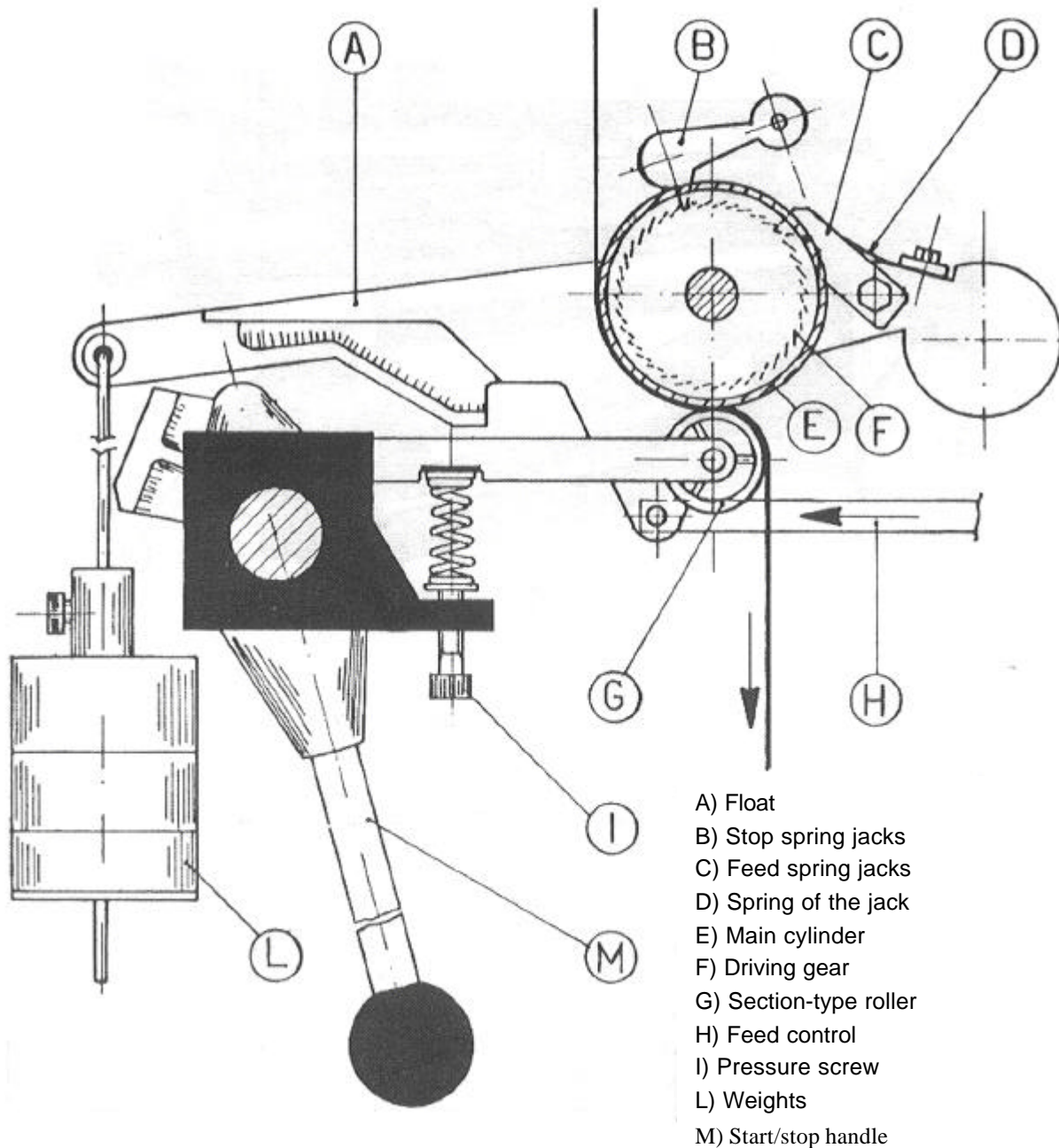
- S: base
- A: fabric take-down motion
- B - E: reading system (to read programs from cards or other punched carriers)
- H: needle-beds
- F - I: thread guide and colour-change system
- L - M: carriage and cam-lock holder
- O - P: drive and transmission system
- R: electric fittings and safety devices
- Q: tensioners
- G: lateral control system

## Fabric Take-down Motion

The fabric take-down motion (picture 41) includes the main cylinder and a series of section-type rollers.

The pressure between the rollers can be adjusted individually by means of a screw to ensure a smooth take-down on the whole fabric width.

The tension can be adjusted to meet specific needs by adding or removing the weights on the weight holder attached to the float.



Picture 41 - Take-down motion

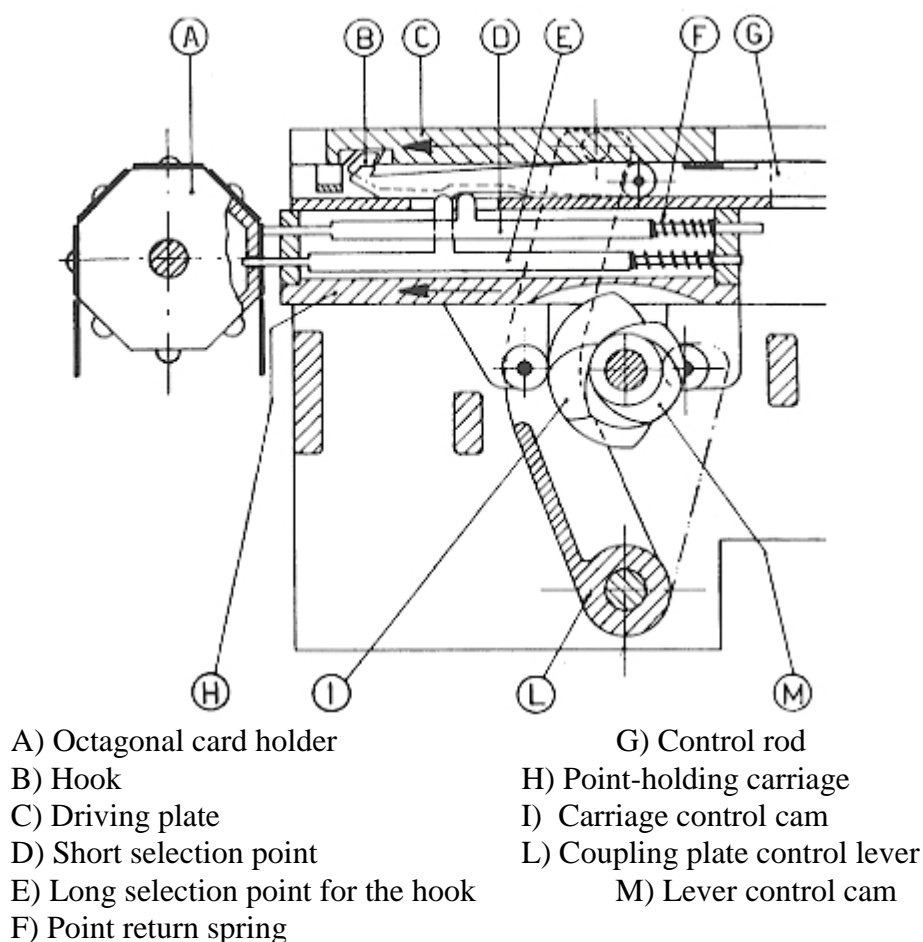
## Program Reading System

For the creation and the repetition of a fabric sample, the functions of each single device contributing to the global functioning of the machine must be accurately controlled (for example: the position of the selection cams, of the raising and knock-over cams, the thread guide selection, the needle-bed racking, the variation of the carriage speed, etc.)

The function control is carried out by means of systems which read the information for each specific manufacturing process.

According to the encoded language used, the information can be stored on different types of supports (cards, bars, magnetic tapes, flexible magnetic disks, CD-ROM, etc. to be prepared in advance) to control the positions of the elements affecting the shape, the structure and the design of the fabric.

The preparation of these elements that carry fundamental information is a crucial task for the knitting operator; the programming is fundamental for the machine and for the manufacturing of the desired fabric.



*Picture 42 – Program reading*

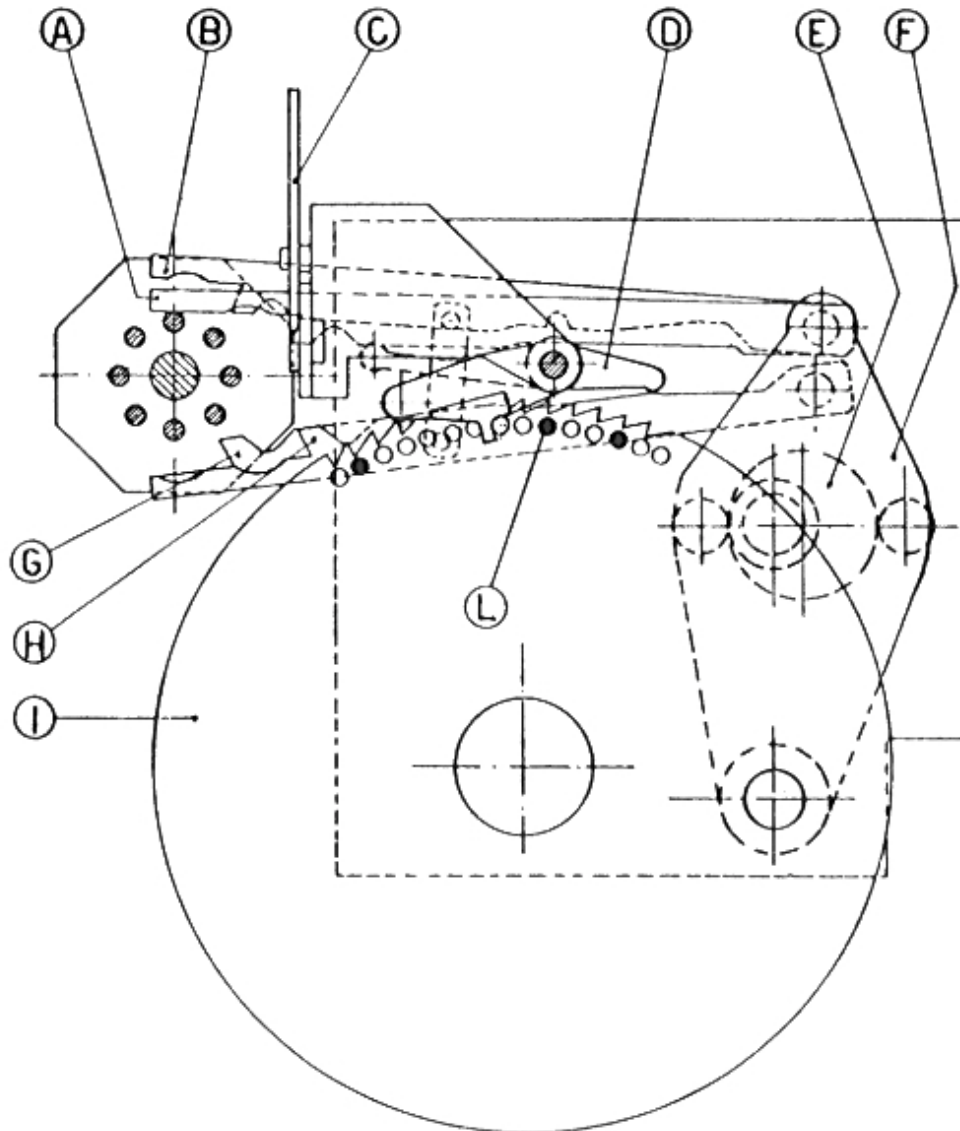
On an automatic flat-bed machine, the program reading system (picture 42) includes several elements which read the programs stored on the punched cards: each hole corresponds to a specific function of the machine.

The cards are flexible and are wound on an octagonal prism.

During the rotation of the prism the points, carried by a carriage, are pushed by special cams and move leftwards touching the external side of the cards.

The holes on the cards provide to select the points which, through the rods, control the various functions.

The machine also includes a disk (picture 43) which controls and reduces the quantity of cards by positioning the command pegs according to the number of times the operator wants to reproduce the work cycle.



- |  |                             |
|--|-----------------------------|
| A) 1 card forward stroke               | F) Bar control lever        |
| B) 2 cards forward stroke              | G) 2 cards backstroke lever |
| C) Card forward stroke control release | H) 1 card backstroke lever  |
| D) Release lever                       | I) Disk                     |
| E) Bar control cam                     | L) Command peg              |

*Picture 43 - Program reading system and disk*

## The Thread Guide

The thread guides move along two bars and are controlled by a keyboard placed on the upper side of the carriage.

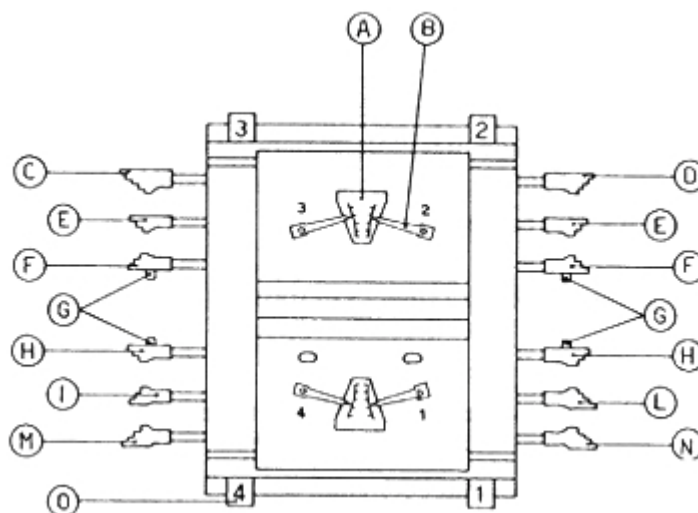
The keyboard is controlled by levers, which receive the commands from the reading system; a thread guide releasing command is also available.

At the ends of the thread guide there are special stop blocks, which are positioned by means of the holes on the bars.

## Lateral Control System

At the end of the bars on which the carriage slides, there are two holders with two points that are controlled by special levers. The levers receive the commands from the reading system.

Once the carriage has reached the end of the stroke, the bars (picture 44) hit the points, receive the commands and forward these commands it to the cams.



- A) Graduated plate for reading the position of lowering cams
- B) Pointer that reads the position of the lowering cams
- C) Control head for the raising cam and the rear transfer cam
- D) Control head for the raising cam and the rear receiving cam
- E) Control head for the rear looping cam
- F) Control head for changing the position of rear lowering cams
- G) Reset rod of the lowering cams
- H) Control head for changing the position of front lowering cams
- I) Control head for the front looping cam
- L) Control head for the front looping cam and the low needle transfer selection cam
- M) Control head for the front raising cam and the front receiving cam
- N) Control head for the front raising cam and the front transfer cam
- O) Carriage slide

Picture 44 – Carriage with command levers



## **The Needle-beds**

The two needle-beds accommodate the needles and the jacks.

The needles can be the lateral spring type to transfer the stitches and have high or low butts.

The jacks can be high, medium or neutral; high and medium jacks are used for knitting while the neutral jacks keep the needle in the knitting position.

A bar is attached to the needle-beds which separates the jacks commanding the needles (their butt is above the bar) from the non-knitting jacks (the butt is under the bar).

On the rear needle-bed a racking device can rack one needle at a time, right or leftward according to the commands transmitted by the cards.

The front needle-bed is equipped with a half-pitch racking system for the stitch transfer.

## **Carriage and Cam Plates** (picture 45)

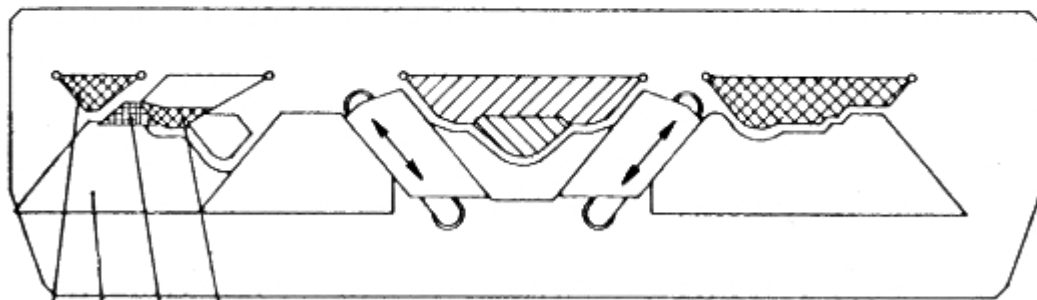
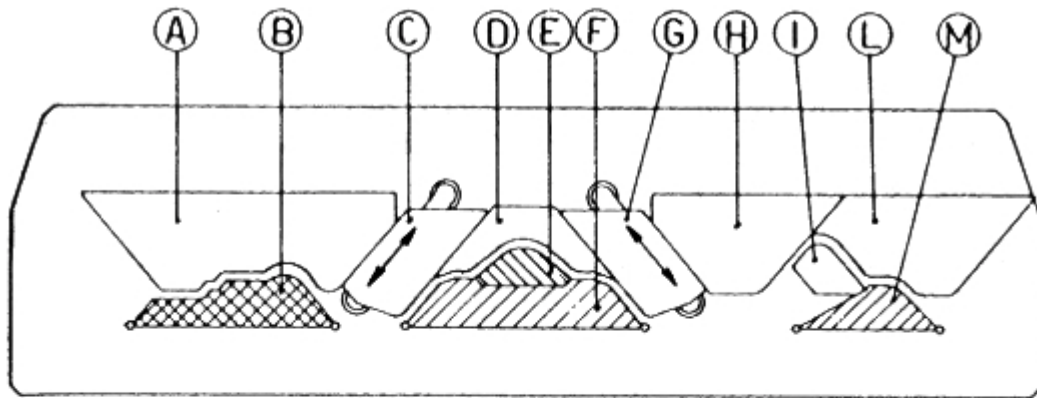
The carriage of an automatic flat-bed machine is more complex than a manual one, since it grants higher working versatility. Furthermore, on automatic machines the transfer of the stitches takes place automatically and is not manually controlled; these machines are also provided with special cams and needles.

The carriage slides on two bars and is driven by the transmission cross joint, from which it can be released for manual control.

When the carriage has reached the end of the stroke, it receives the commands for the cams.


On one end of the carriage, the rods receive the commands from the points. On the opposite end, on the same rods and strictly depending on the command received and the position of the lever, it is possible to read the letters revealing the position of the cams.


REAR PLATE




N O P Q

FRONT PLATE

 Cams that can assume 3 positions: open, half-way, closed

 Cams that can assume 2 positions: open and closed

 Cams that can assume 2 positions: half-way and closed

- |                              |                                |
|------------------------------|--------------------------------|
| A) Fixed upper receiving cam | D) Fixed transfer cam          |
| B) Receiving cam             | L) Fixed upper transfer cam    |
| C) Left lowering cam         | M) Transfer cam                |
| D) Fixed upper central cam   | N) Transfer raising cam        |
| E) Looping cam               | O) Fixed upper transfer cam    |
| F) Raising cam               | P) Lower needles selecting cam |
| G) Right lowering cam        | Q) Transfer cam                |
| H) Fixed lateral cam         |                                |

Picture 45 – Carriage and cam plates

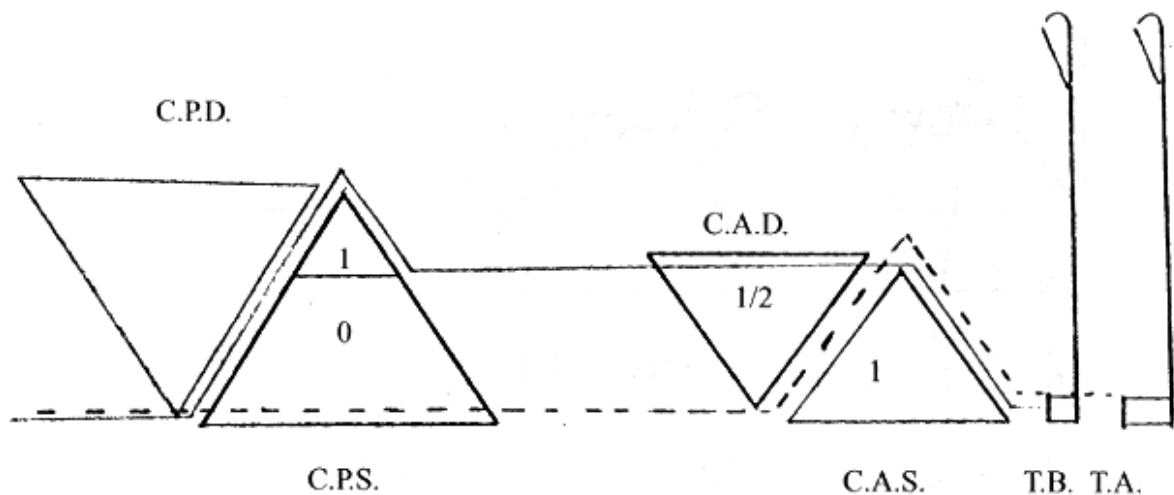
## The Exchange Technique

It is a method for the selection of high-butt and low-butt needles and is mainly used for transferring the stitches from one needle-bed to the other.

By using the needles raising cam on the carriage, it is impossible to lead the low-butt needle to the looping position without the upper one doing the same movement.

The exchange technique allows this possibility.

Near the main group (picture 46) made up of a raising cam and a knock-over cam, there is an auxiliary group of cams, consisting of a mobile raising cam that can assume the knitting position, half-knitting position and non-knitting position, and a fixed lowering cam, which is set half-way.



MAIN GROUP:	C.P.S. =	MAIN RAISING CAM
	C.P.D. =	MAIN LOWERING CAM
AUXILIARY GROUP:	C.A.S. =	AUXILIARY RAISING CAM
	C.A.D. =	AUXILIARY LOWERING CAM

T.A. = HIGH-BUTT NEEDLE  
T.B. = LOW-BUTT NEEDLE

*Picture 46 – Exchange unit*

Before hitting the main raising cam, the needles come into contact with the exchange unit.

By bringing: the auxiliary raising cam in knitting position  
the auxiliary lowering cam in half-knitting position  
the main tucking cam in non-knitting position  
the main looping cam in knitting position,

the high- and low-butt needles hit the auxiliary raising cam and rise till they reach their maximum height.

Afterwards, since the lowering auxiliary cam is in a half-knitting position, the high-butt needle knocks over while the low-butt needle continues its stroke.

When touching the main cam, the high-butt needle is not affected, since the tucking cam is not knitting; the low-butt needle hits the looping cam which is completely open and completes the knitting cycle.

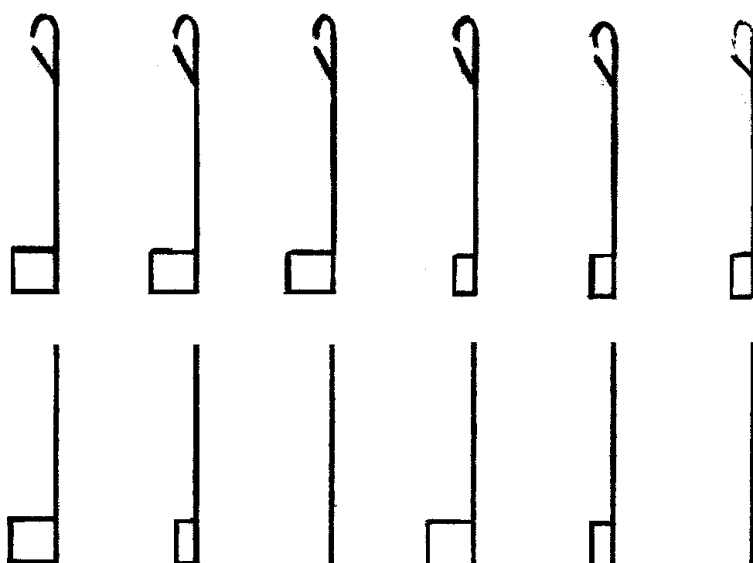
This technique is usually used with sliders for the stitch formation cycle, since the lowering cams can interfere with the selection carried out by the transfer group; there are no problems when using this system for the stitch transferring cycle.

### **Selection with Sliders or Sinkers**

High- and low-butt needles allow limited possibility of operated stitches.

In order to increase the selection opportunities, sliders or sinkers (which can be high-, low- or no-butt) are placed under the needles.

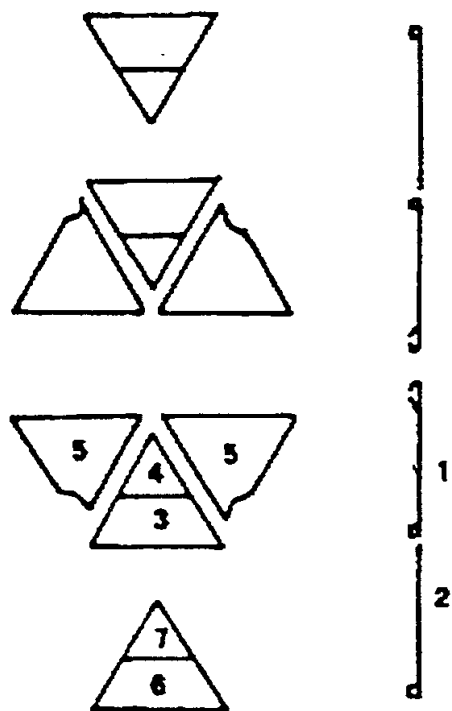
Picture 47 shows further opportunities given by the assembly of sliders or sinkers; a high-, low- or no-butt slider can be mounted under a high-butt needle and the same can be done with a low-butt needle.



*Picture 47  
The picture shows the use of  
needles and sliders*

By correctly arranging the needle and slider cams it is possible to obtain a great number of effects on the fabric, as a result of the combination of different patterns and colours.

The flat knitting machine has two needle-beds; each needle-bed has two cam-locks, one for needle control and the underlying one for slider control, as shown in Picture 48. Instead, for the knock-over, the cams on the upper cam-lock are sufficient.



*Picture 48  
Raising and lowering  
cams for needles and  
sliders*

A further increase in pattern complicacy can require the placing of sinker or slider butts at different levels.

A series of cams can carry out the slider selection, which will bring the corresponding needles into contact with the main cams.

Depending on the position of the main cams, it is possible to select knit stitch, tuck stitch and miss stitch work ways, separately on each needle.

The three technical ways typical on mini-Jacquard machines are also used on full-size Jacquard machines.

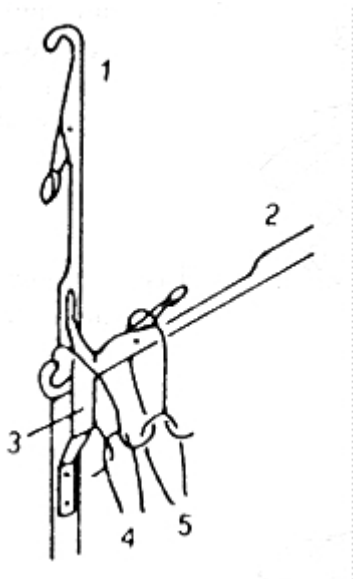
Combined electronic and electromechanical systems now allows a thicker pattern design with colours or operated stitches to be created on Jacquard fabrics.

The selection of sliders can be also carried out according to the drowning principle, by means of levers operating in two different moments to bring the needle on a tucking or a looping position.

The principle of slider selection can also be applied to the transfer of stitches.

## The Stitch Transfer Process

On automatic machines, the transfer of stitches from one bed to the other is carried out by means of special needles: the lateral spring needles or the niche needles



*Picture 49 – Lateral spring transfer needle*

The most common type is the lateral spring needle (picture 49); it is made up of a spring, whose end is fixed on one side of the needle stem.

The upper end is free to allow the passage of the needle hook of the opposite bed.

The carriage includes both the knitting and the transferring cams, divided into transferring cams and receiving cams.

Picture 50 shows the transfer cycle of the stitches carried out by means of lateral spring needles.

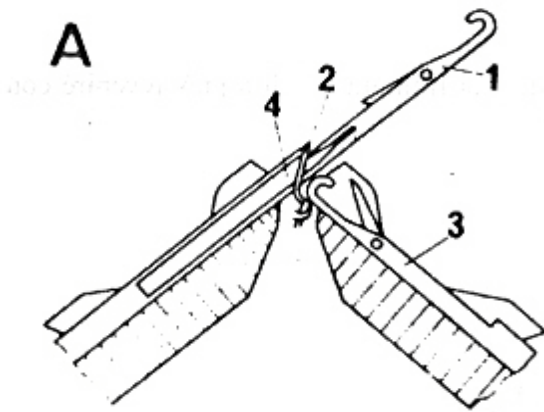
The transfer technique also allows the production of full-fashioned cloths by applying the increasing and narrowing technique.

This provides higher quality in the production of knitted goods.

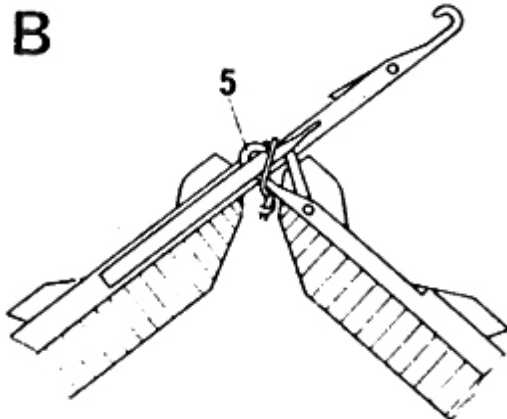
The only inconvenience is represented by longer processing times with higher manufacturing costs.

The last generation of electronic machines can transfer and knit during the same carriage stroke and also offer tensioning and stitch transferring options to adjust the fabric tension according to the work area.

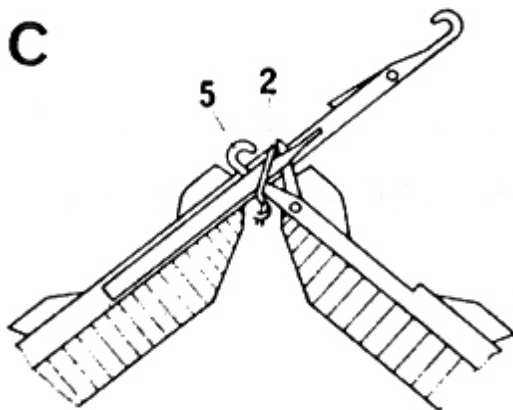
These technical improvements reduce the work time necessary for carrying out the full-fashioning process considerably, guaranteeing better results and improved cost efficiency.



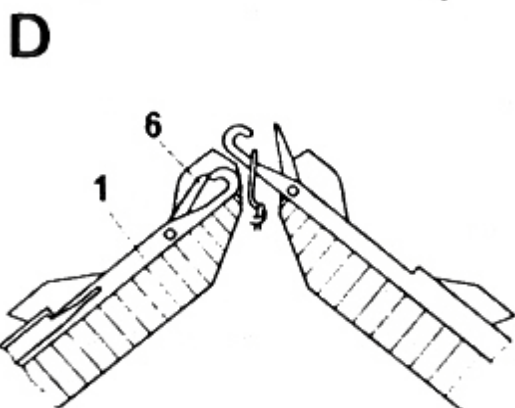
Step A: needle 1, which must transfer stitch 2, raises on the transferring cam, whose special profile takes the transferring cam to a height exceeding the looping plane; in the meantime the stitching plane lowers on the spring; needle 3 on the opposite needle-bed starts raising on the receiving cam.



Step B: hook 5 of the receiving needle enters the spring 4



Step C: the hook of the receiving needle is completely inside the spring; the transferring needle starts lowering; the loop on the spring closes the latch and is left on the receiving needle.

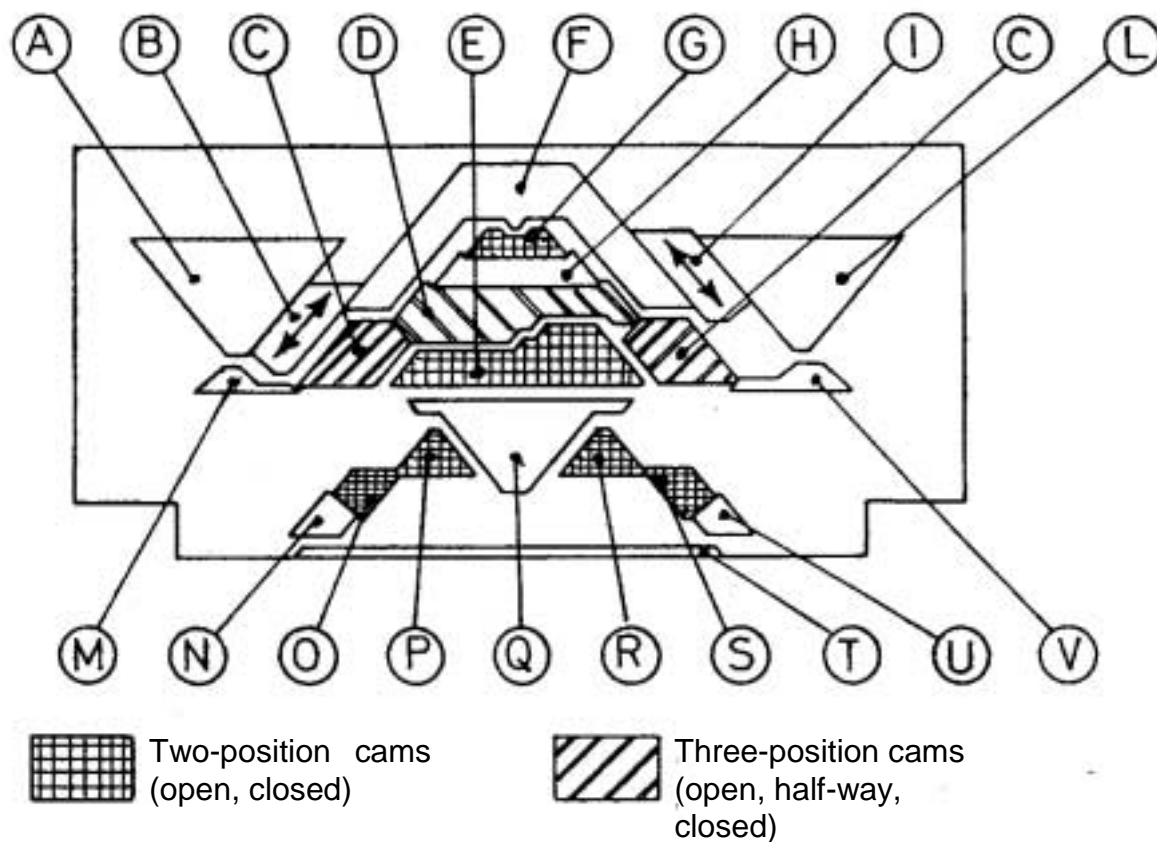


Step D: the transferring needle is empty when it reaches the knock-over plane; the receiving needle knocks over and keeps the received stitch inside the hook.

Picture 50 – Transfer cycle of the stitches with lateral spring needles

## The Integrated Cam-lock

Thanks to the integrated cam-lock it is possible to loop-in or transfer stitches in the same stroke. In Picture 51 you can see the drawing of the carriage plate that carries out this process.



- |                        |                              |
|------------------------|------------------------------|
| A – Fixed lateral cam  | I – Lowering cam             |
| B – Lowering cam       | L – Fixed cam                |
| C – Needle raising cam | M and V – Fixed cam          |
| D – Looping needle cam | N and U – Fixed cam          |
| E – Receiving cam      | O and S – Sinker raising cam |
| F – Fixed upper cam    | P and R – Sinker looping cam |
| G – Transferring cam   | Q – Fixed cam                |
| H – Fixed looping cam  | T – Fixed cam                |

*Picture 51 Integrated cam-lock*



## Electronic Flat-bed Machines

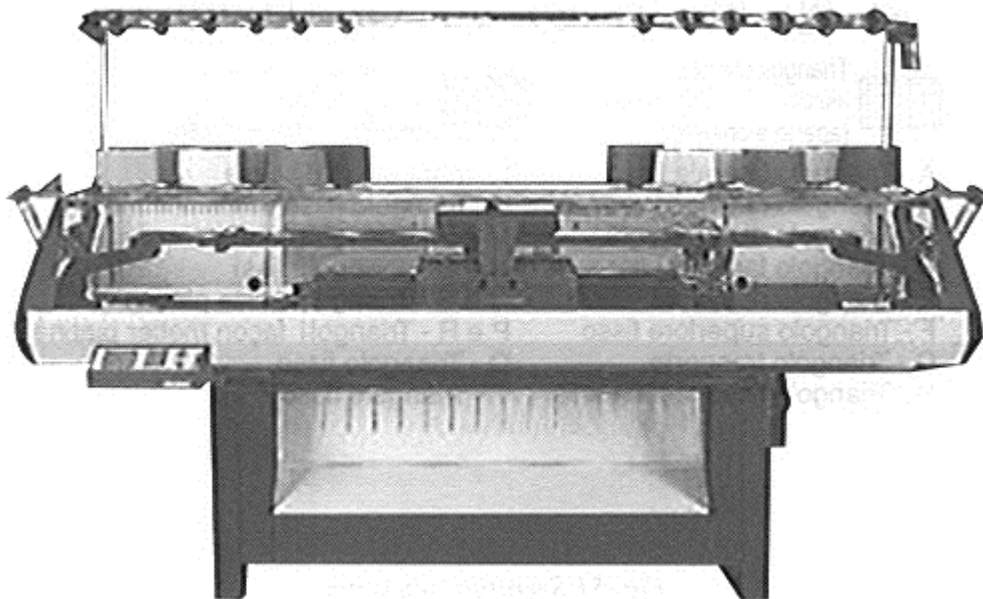
During the last few years, the application of electronics and information technology has brought about significant improvements for the majority of components and systems that make up a flat-bed machine, however the basic concept of the stitch formation has remained virtually unchanged.

Today, there is the tendency to offer computer-controlled electronic systems which, despite their sophisticated structure, allow easier operation, speeding up the programming and control of the different machine functions; for example, thanks to electronic control it is possible to intervene directly on all the machine's components and systems by simply entering commands on the control board.

The knitting, tucking and stitch transferring steps are carried out with the electronic selection of individual needles; all this greatly increases the possibility of knitting Jacquard and other complicated patterns.

Besides the needle selection system, flat-bed machines can also be equipped with a wide range of auxiliary devices, leading to a virtually unlimited combinations. According to the user's specific requirements, the manufacturer can emphasise the machine's output capacity, reliability, space-saving characteristics or cost effectiveness.

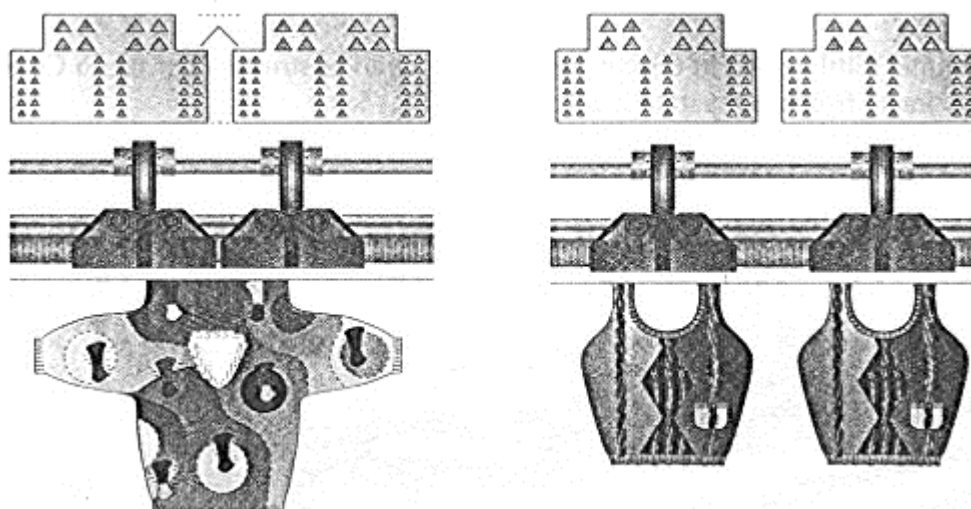
The following section describes the potentialities of modern flat-bed electronic machines.



*Picture 52 – The electronic machine*

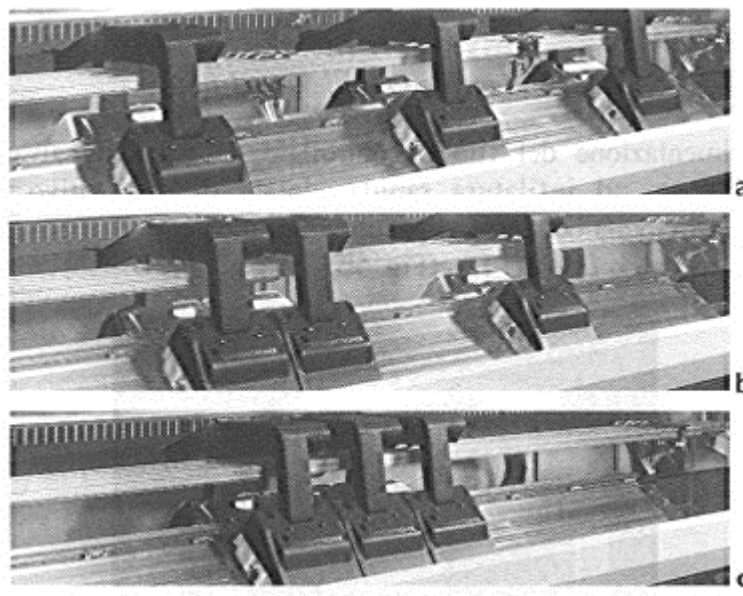
## The Technical Evolution of Flat-bed Machines

- The variable stroke optimises the carriage operation, as the stroke is adjusted automatically to the working range determined by the selection of each single feed system (picture 53).



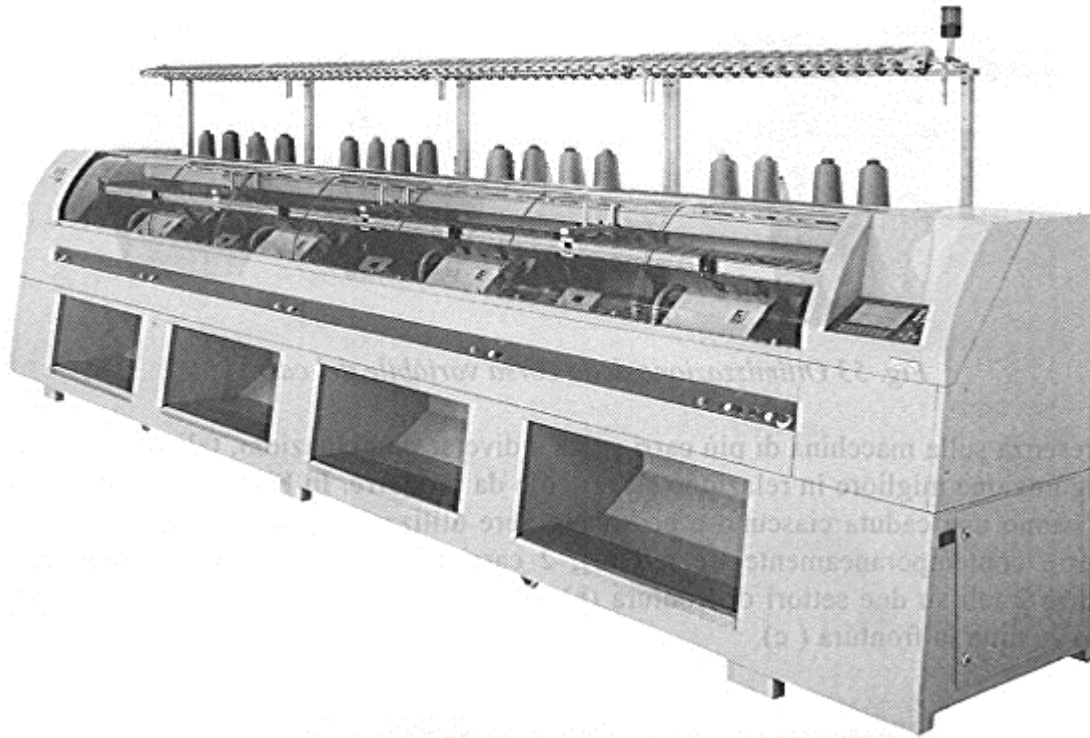
Picture 53 – Optimisation of the variable stroke of the carriage

- The presence of several carriages on the same machine allows different combinations; in fact, the user can choose the best configuration of carriages depending on the pattern to be carried out. In picture 54 for example, each one of the three carriages has its own feed system that can be used either individually, to knit three cloths simultaneously (a); or combining 2 carriages (1 idle) with 1 separate carriage working individually to produce two cloths on two needle-bed sections (b); or combining 3 carriages with 3 feed systems, with the possibility of using the whole width of the needle-bed (c).



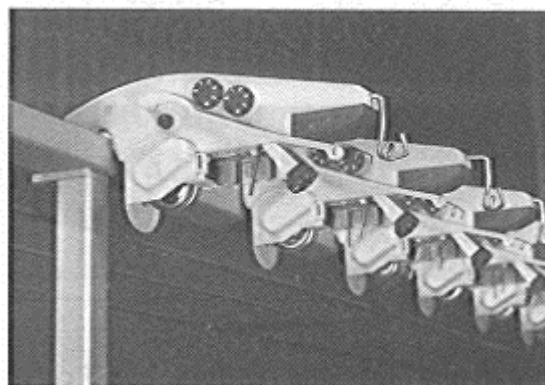
Picture 54 – The modular design of a flat-bed knitting machine featuring 3 carriages with 1 feed-system each

- The “open” carriage (i.e. a carriage without linkage with the two needle-beds) incorporates brand new manufacturing technology which has brought a significant improvement: yarns are fed from above and not laterally. In this way, the thread tension is reduced and thread guides are no longer driven by the carriage but are equipped with individual motors and can be therefore adjusted according to the knitting process underway.
- Multi-section knitting machines are based on the architecture of full-fashioned machines: in fact, each carriage travels on a separate individual bed length (picture 55).



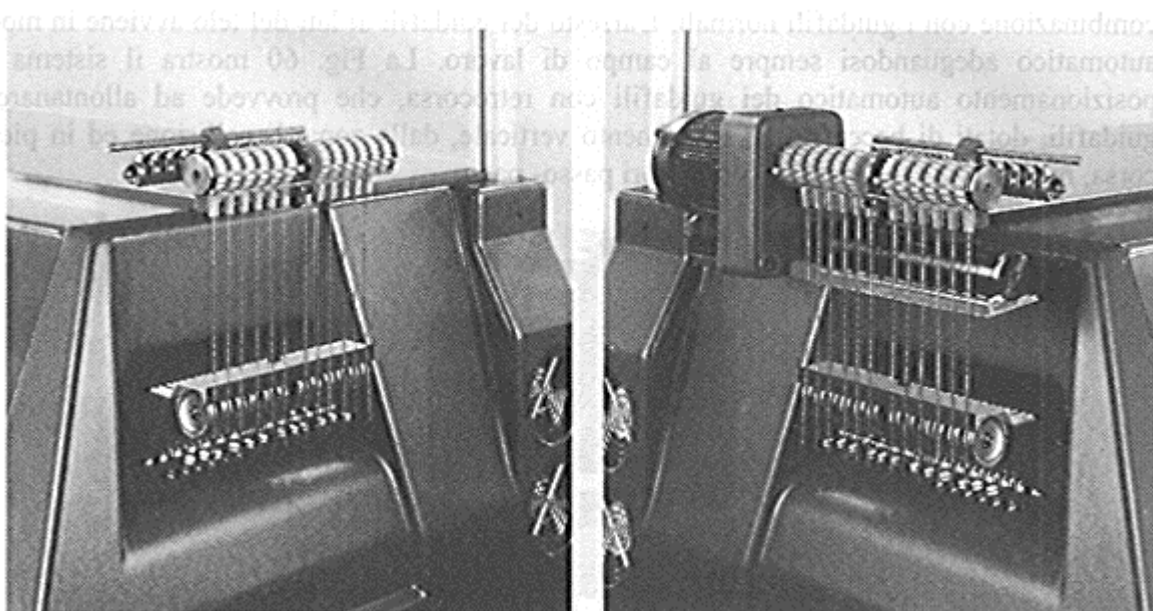
*Picture 55 – A 4-section flat knitting machine*

- The thread feeding system is controlled by quick thread-in knot stop tensioners provided with light signal tower. In addition, an automatic device slows down the carriage speed in the case of small knots and stops the carriage in the case of big knots, breaks or no yarn (picture 56).



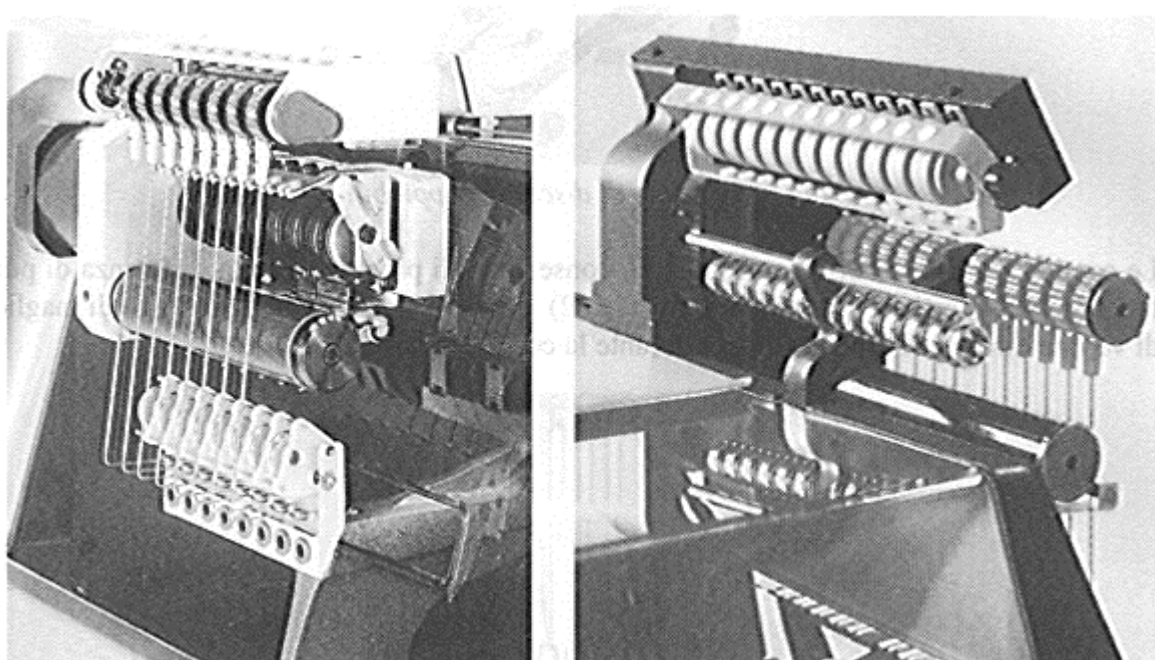
*Picture 56 – Knot stop tensioners*

- The lateral tensioners have small wheels to reduce friction on the yarn (picture 57 and 58).



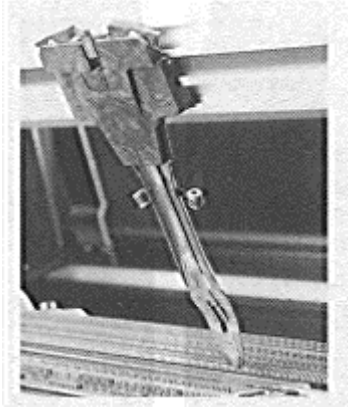
*Picture 57/58 – Lateral tensioners*

- The digital control system monitors the stitch density and considers each stitch as a digital value. Before starting the knitting cycle, the operator sets the desired reference value for the stitch length; the systems monitors the set value and tunes the yarn feeding in order to grant a tolerance ratio not exceeding 1% in size and a uniform stitch density for each cloth (picture 59).



*Picture 59 – Digital control of the stitch density*

- The thread guides slide on special double bars allowing the use of special thread guides for weft insertion or the knitting of intarsia or plating patterns; these special thread guides can be used together with standard thread guides. The thread guides stop automatically on the cloth edge and adjust the stroke according to the knitting range. Picture 60 shows the automatic positioning system of the thread guides with backstroke function. Thanks to this system, the thread guides – equipped with a vertical-insertion yarn hook – can be withdrawn from the contact area during the thread guide stroke, using a stepping-motor device.



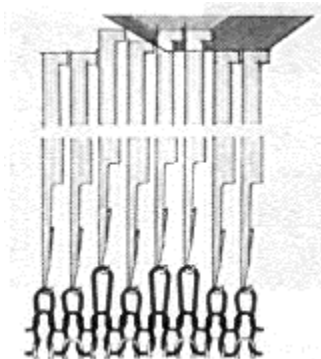
*Picture 60 – Backstroke type thread guide*

- The integrated cam combination system offers a wide range of possibilities to adjust the stitch density; this allows a full exploitation of the options offered by down-type needles (picture 61).



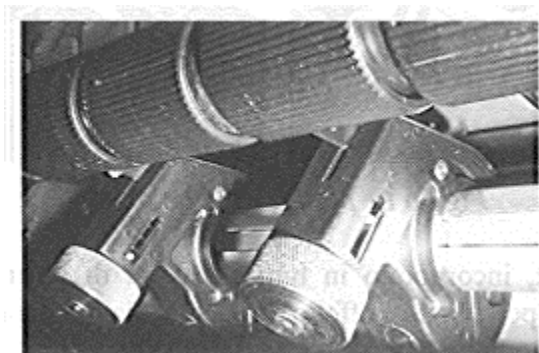
*Picture 61 – Split lowering cams*

- Thanks to special split lowering cams it is possible to programme a difference between long and short stitches (picture 62) for each system and on every single course, as well as to vary the density dynamically during the carriage stroke.



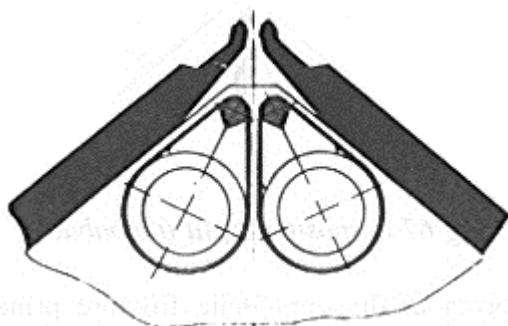
*Picture 62 – Long and short stitches on the same course*

- The racking of the needle bed can be carried out selectively on a certain number of needles equalling at least one needle-bed inch; half-racking is also possible. The needle bed can be racked in a single step, or in two steps to reduce the yarn tension.
- All the functions of the main take-down motion (picture 63) can be programmed; the motion is controlled by automatic devices which adjust the take-down tension on the stitches according to the quantity of knitting needles, so as to avoid density differences on the cloth length when knitting full-fashioned fabrics.



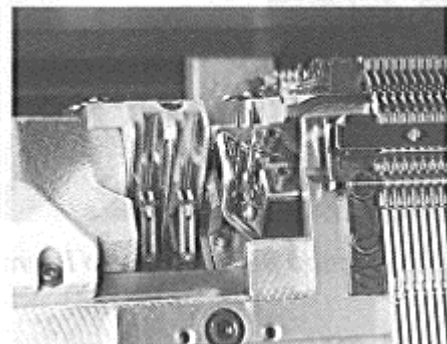
*Picture 63 – Take-down motion with section-type main cylinder and individually adjustable counter-rollers*

- An auxiliary take-down motion, placed very close to the needle-bed, only operates on the needles corresponding to the stitch formation line (picture 64).



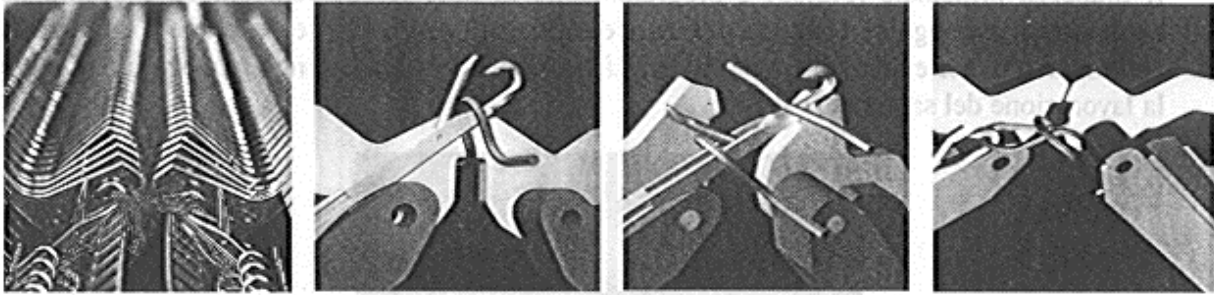
*Fig 64 – Auxiliary take-down motion*

- Thanks to a start-up reed provided with hooks, the knitting process can also be started with empty needles.
- Another important feature guaranteeing the quality of full-fashioned cloths as well as a complete knitting process, is the possibility to retain and/or cut the yarn as desired by means of grippers and cutters, placed on the right and on the left of the needle bed (picture 65).



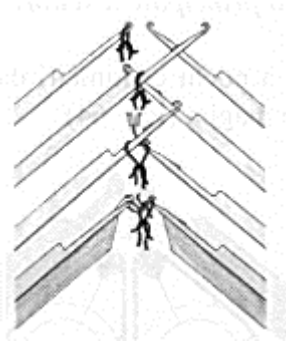
*Picture 65 – Gripper and cutter unit*

- Incorporating movable knock-over sinkers in both needle beds, the press-foot allows a gentle knocking over of the fabric for knitting the most complicated patterns with efficient quality control (picture 66).



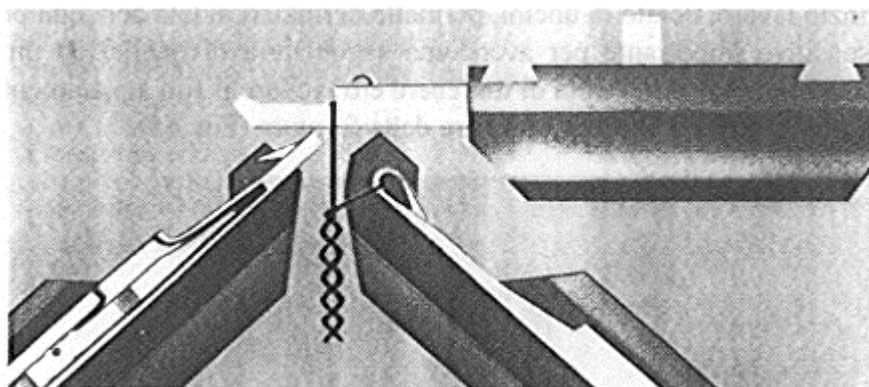
*Picture 66 – Knock-over sinkers*

- By means of the hole-repair motion, the stitch can be split to avoid the so-called “hole effect” during the stitch formation on empty needles, without replacing the cams or the thread guides (picture 67).



*Picture 67 – Hole-repair motion*

- Arranged above the main machine beds, the auxiliary bed incorporates special points which can be selected individually for the lateral transfer of the stitches on the front or on the rear needle bed, transferring and receiving the stitches from one bed to the other (picture 68).

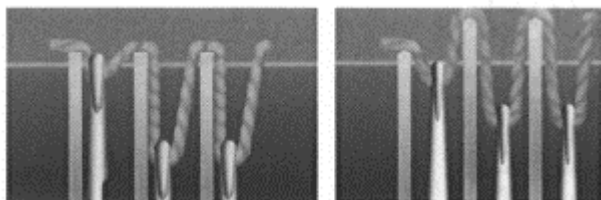


*Picture 68 - The auxiliary bed for the lateral transfer of stitches*

- The new compound needle without lateral spring for the stitch transfer incorporates a sliding split latch (picture 69). While the needle transfers the stitch, the latch raises and splits into two parts; thereafter, it rises further taking with it the stitch to be transferred. In the meantime, the needle in the opposite bed is lifted and inserted in the space created by split latch, below the stitch. The further lowering of the two needles completes the stitch transfer procedure (picture 70).

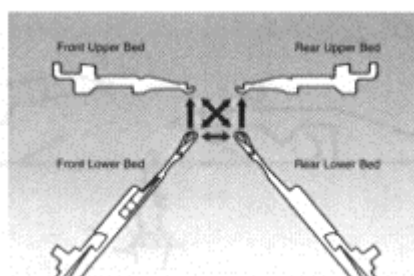


*Picture 69 – A compound needle of a coarse-gauge flat knitting machine*



*Picture 70 – Comparison between  
(a) the formation of an asymmetrical loop using standard lateral spring needles and  
(b) the formation of a perfectly symmetrical loop thanks to split latch needles*

- The innovative solution of the four needle beds consists of the addition of two auxiliary beds above the standard ones (picture 71). An upper auxiliary bed equipped with sinkers acting as individual press-foots is placed above the rear needle bed, while the front bed has an upper auxiliary bed equipped with stitch transfer points, thus allowing the transferral and receiving of stitches to/from all the needle beds. The latter auxiliary bed is divided into two sections, each one equipped with a transfer motion allowing different racking positions, as well as e.g. the asymmetrical decreasing of stitches. Some models are equipped with sinkers moving in opposite direction with respect to the needle direction (countersinkers) to reduce the stroke of the compound needle thanks to a combined motion; this limits the stress on the needles, the yarn and the stitches, which is particularly helpful in critical situations.
- The three-dimensional knitting process allows the creation of multi-layer patterns in a single cycle. For example, on a plain-knit layer, it is possible to add decorative elements such as necks, hoods, pockets, buttonholes, buttons, trimmings, etc. without further sewing work, or manufacture a whole garment by knitting all the parts at the same time or in sequence: body, sleeves or other elements, as a result by-passing the making up stage completely.
- The possibility of employing needles with three different hook sizes (large, medium and small), and changing the distance between the needle beds, allows the application of a wide range of yarn counts, with the result that the different areas of the same cloth look as they were knitted on machines of different gauge.



*Picture 71 – Transfer options with four needle beds*



## Links-links Machines

A links-links machine consists of two needle beds arranged on the same plane (180° with respect to each other); the grooves of each bed are aligned, so that each needle can slide in the grooves of the front or rear bed to knit a plain stitch and a purl stitch on the same wale (Picture 72).

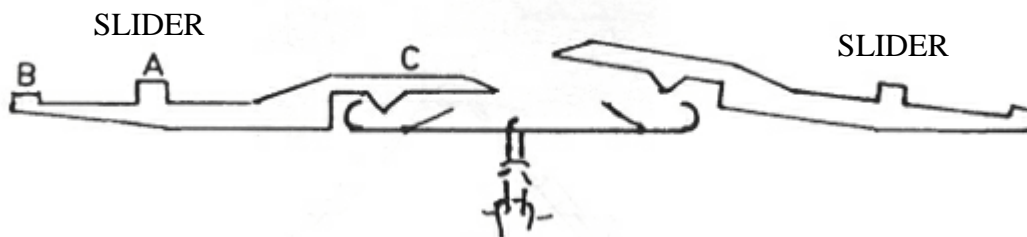


*Picture 72 – Purl stitch pattern*

The needle has two hooks and two latches; it has no butt and is driven by special spring-beard sinkers, called sliders.

Two sliders operate on each needle, and are accommodated in two opposite grooves.

In addition to the spring beard C, which is used to catch the needle, the slider (Picture 73) incorporates two butts: the “A” butt commands the longitudinal movements, while the “B” butt generates an upward oscillation (as a result of a pressure acting on it), allowing the release of the needle.

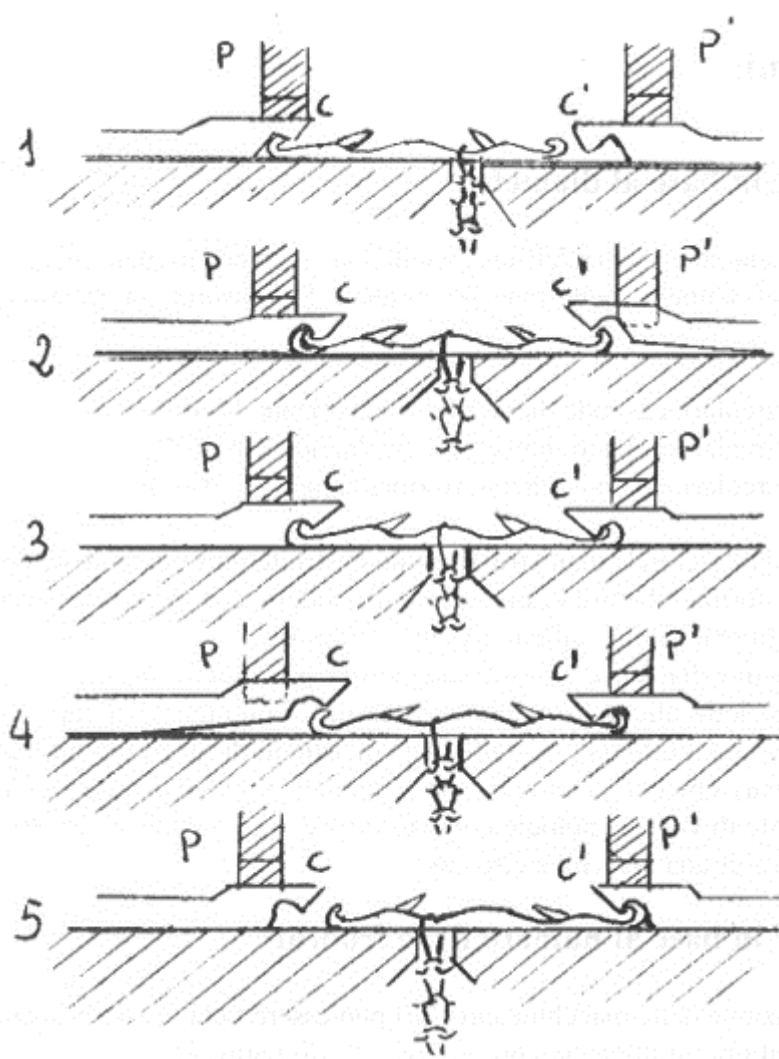


*Picture 73 – Sliders on a links-links machine*

A links-links machine also includes:

- two cam systems driving the two sliders which, for a short time, hold the needle simultaneously;
- two cam systems, which take the sliders back into their respective needle beds; however, only one of them holds the needle, making it knock-over after the yarn has been fed;
- two pressure cam systems with a full and an empty area: when the spring beard of the slider is under the full area, it is pressed against the needle to take hold of it; whereas when the spring beard is under the empty area, the needle is released thanks to the oscillation generated by the pressure acting on the “B” butt of the slider.

Picture 74 shows the various steps of the links-links knitting cycle.



Picture 74 – The links-links knitting process

# **Circular Knitting Machines**

## **Introduction**

All over the world, the majority of knit fabrics are manufactured on circular knitting machines. The high performance level of these machines, the different materials and the range of yarn counts that they are able to process, the wide variety of designs and stitches are some of the reasons which have granted circular machines the market leadership in the knitting sector.

The variety of knit fabrics that can be manufactured with these machines can meet the needs of a very large end user market; from the traditional outerwear and underwear sectors to hosiery, household and car interiors, without forgetting technical textile applications.

## **Classification Criteria**

### **Classification by Diameter**

The most important classification parameter for circular knitting machines is their diameter. According to the machine diameter, we can divide the machines into three main categories:

1. Large-diameter circular knitting machines (from 24 to 40 inches)
2. Medium-diameter circular knitting machines (from 8 to 22 inches)
3. Small-diameter circular knitting machines (from 3 to 6 inches)

Large-diameter machines are mostly designed for manufacturing tubular fabrics while a more restricted number of large-diameter machines are used to manufacture fabrics similar to those manufactured with flat knitting machines.

Medium-diameter machines are designed for the production body-size tubular fabrics, as well as fabrics with welt and separation thread, ideal for the underwear market.

Small-diameter machines are designed for manufacturing hosiery. The architecture of these machines differs from standard circular knitting machines above all from a technical point of view but also for considerable differences in the type of available accessories.

### **Classification by Number of Needle-beds**

Another classification parameter for circular knitting machines is the number of needle-beds, which determines the type of stitch that can be carried out:

1. Single-bed circular knitting machines  
(for jersey and derived stitches: fleece, terry, piquet, floating Jacquard)
2. Double-bed circular knitting machines
  - a. Dial-cylinder knitting machines with 90° needle-beds (for rib knit and similar: cardigan stitches, Milanese rib, bourrelet, Rodier, cable, eyelet and Jacquard stitches, as well as all interlock and intelock-derived stitches, e.g. the pin tuck stitch).
  - b. Double-cylinder knitting machines with 180° needle-bed (for stitches based on the links-links construction)

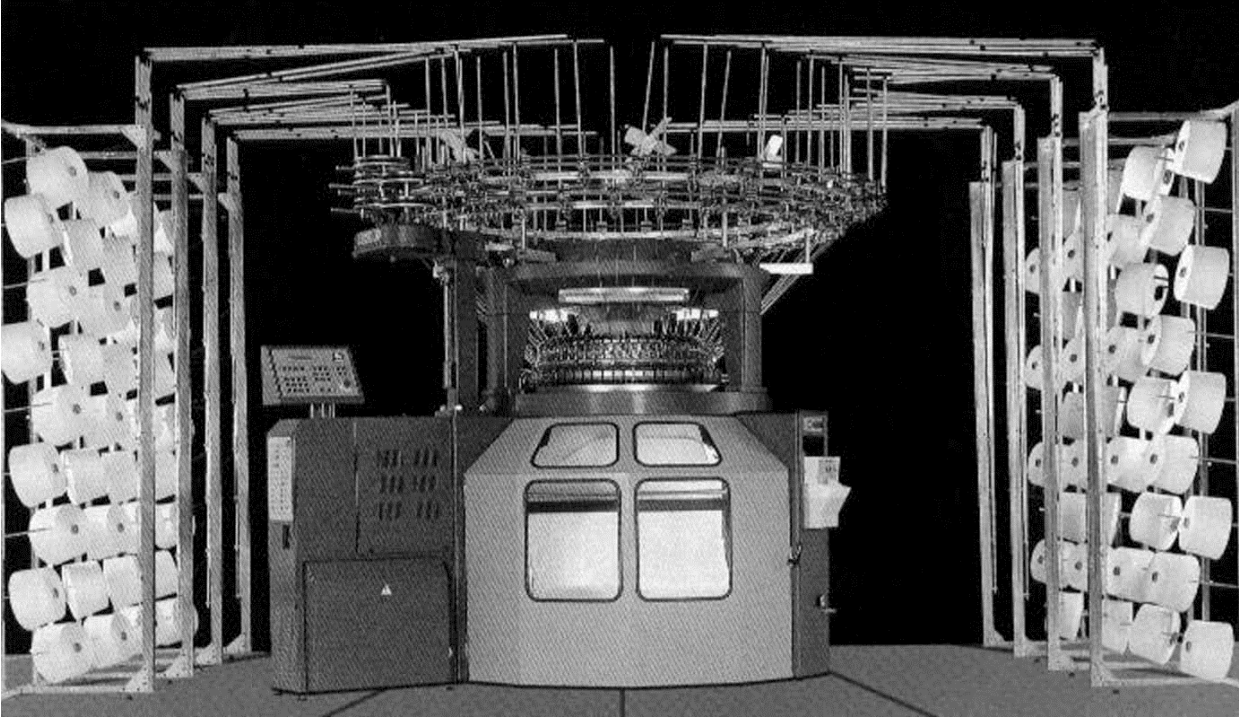
## **Basic Structure of a Large-diameter Circular Knitting Machine**

Circular knitting machines include a number of fundamental elements, based on similar mechanical principles with some small changes according to the different models:

- The machine base. The most recent trend among circular machine manufacturers is to build knitting machines with a solid yet smaller base and an architecture that facilitates access to the machine components for routine operations to be carried out during setting up procedures and production;
- The “core” of the machine, which includes the needle-bed area and all the systems operating during the knitting process. The feed systems are placed along the circumference of the circular needle-bed. Circular knitting machines can be divided into two basic models: in the first one the needle-beds rotate and the cam frame stands still, while in the other one the needle-beds stand still and the cam frame revolves.
- The yarn spools holder. If the system is attached to the upper part of the machine, it is a circular rack; if arranged at the machine side, it is a lateral creel.
- The yarn feeding system, made up by the yarn feeding unit which must ensure a smooth and steady yarn feeding, and a thread guide system which provides the needles with the yarn necessary for the stitch formation.
- The fabric take-down and winding system housed in the lower part of the machine; depending on the machine model, the fabric take-down and winding motion can rotate together with the needle-beds or stand still.
- The drive, usually an inverter drive, i.e. a motor with electronic variation of speed for optimum acceleration and slow-down ramps and optimum throughput speed in all conditions.

Lastly, several machine manufacturers (above all of single-bed machines) tend to build convertible machines, which have the same basic structure and are equipped with special conversion kits which allow the change of stitch formation motions such as cams, cam frames and thread guides to generate different styles.

The cost of these machines is extremely advantageous compared to the investment costs necessary for buying a complete series of machines each one producing a single article.



*Picture 75 – Overall view of a circular knitting machine*

# The Yarn Feeding System

## The Spool Holder

The spools of yarn to be used to manufacture the fabric are arranged on a holder which can be of two different types: the circular rack (fixed on the upper part the machine), or the lateral creel (fixed on the floor beside the machine).

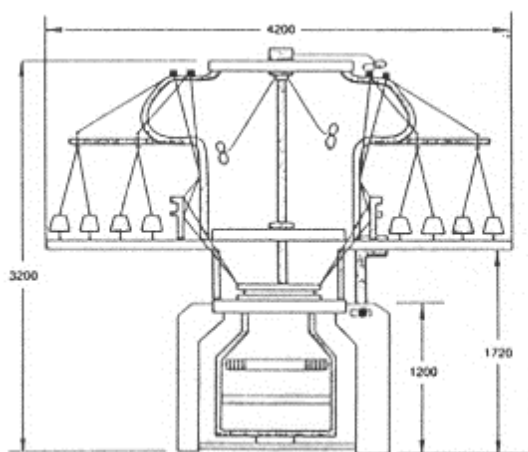
On the spool rack, the number of pegs that hold the spools corresponds to the number of the thread guides on the machine. The yarn is conveyed from the spool through some yarn tensioners provided with sensors which monitor the correct feeding tension. The sensors activate in the case of knots or yarn breaks, and in this case stop the machine automatically with an electric command.

Some machine manufacturers add to their machines a motorised rack lowering system for facilitating the spool loading or machine maintenance operations. The rack is brought back to its original position once the spool loading or maintenance procedures have been concluded.

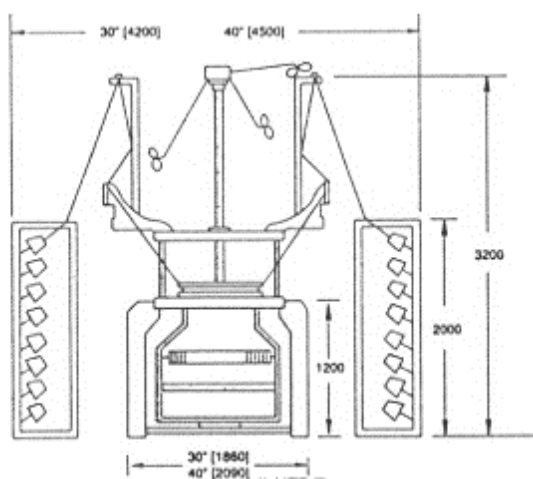
The spool rack is the only system usable on revolving-cam machines, since on these machines also the spool rack must revolve.

The machines with fixed cams can be provided with a spool rack, or in alternative a lateral creel to facilitate spool loading.

The lateral creel is a metal structure positioned on both sides of the machine. The yarn threads are unwound from the spools positioned on the creel pegs. After having passed through special guides and plastic or aluminium tubes, the yarns reach the thread guides on the machine. In this case, too, the yarn path is monitored by sensors which detect possible breaks and knots. The lateral creel is increasingly used as a spool holding system because it facilitates the operator when changing the spools or in the case of yarn breaks, and allows a dramatic reduction of flying dust and particles in the knitting room thanks to the guide tubes connected with an automatic suction system. Although the creel takes up a larger floorspace, it can accommodate a huge number of spools. This allows the possibility of double thread feeding to each feed system, as well as of integrating tail-to-head spool splicers for ensuring the continuous feeding of yarn.



Picture 76 – Spool rack

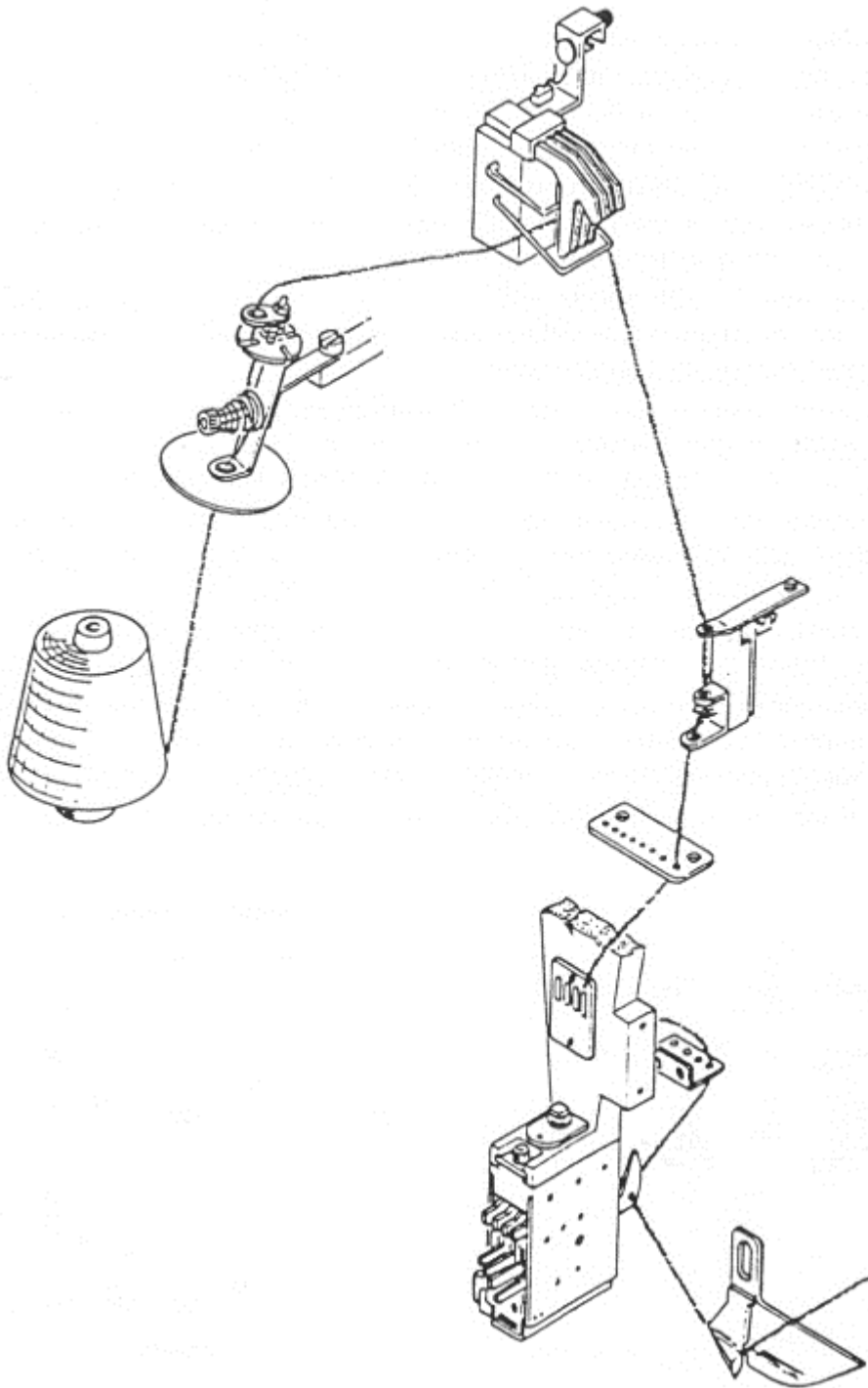


Picture 77 – Lateral creel

## Yarn Feeders

Yarn feeders can be divided into “positive” or “negative” types depending on the possibility of controlling the yarn feeding speed and uniformity.

A yarn feeder is the negative type when the needle takes the yarn directly from the package during the stitch formation step, and the feeding tension of the yarn cannot be controlled.



*Picture 78 – A negative yarn feeding device*

This feeding technique can generate differences in the yarn length used for stitch formation. This is due to the variable tension of the yarn since a new spool has a certain diameter which gradually reduces as more yarn is unwound and fed into the machine. In addition, the spool can be too hard or too soft.

Circular knitting machine manufacturers have eliminated this problem by implementing two distinct solutions:

1. The motorised yarn accumulator levels off the yarn tension since when rotating, it accumulates a certain quantity of yarn on a constant-diameter pulley and then stops. The yarn wound on the accumulator is then conveyed to the thread guide always maintaining the same tension. The machine takes up the yarn, gradually emptying the accumulator, which is then restarted automatically to replenish its yarn reserve.

This solution is particularly indicated when the same type of feeding technique cannot to be applied to all the feed systems due to the structure of the knit stitches. Therefore, yarn accumulators are mainly used on machines for the manufacturing of fabrics of pre-set length, or also of continuous cloths with Jacquard patterns.



*Picture 79 – Yarn feeding accumulator*

2. Positive feed systems control the tensions of the yarn fed by means of a drive wheel or a drive belt system.

The drive wheel systems, which in the past were much more widespread than today, consist of two conical toothed wheels. The thread passes between the two wheels and the quantity of yarn can be adjusted by approaching or withdrawing the wheels. This positive system grants a smooth feeding of the yarn on all the feed systems.

Today, the belt system has by far become the most common positive feeding system. The belt makes the spool rotate, and the number of rotating spools corresponds to the number of feed systems.

By adjusting the belt RPM, the quantity of thread can be increased or reduced. This system grants an accurate control of the yarn tension (picture 80).



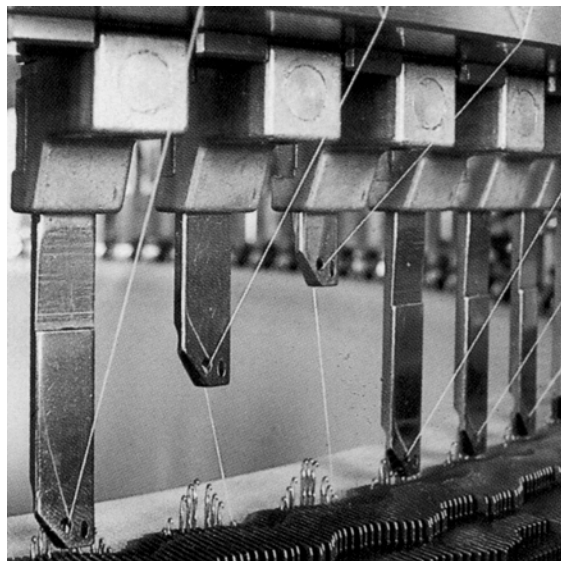


*Picture 80 – Positive belt feeding system*

## **The Thread Guide**

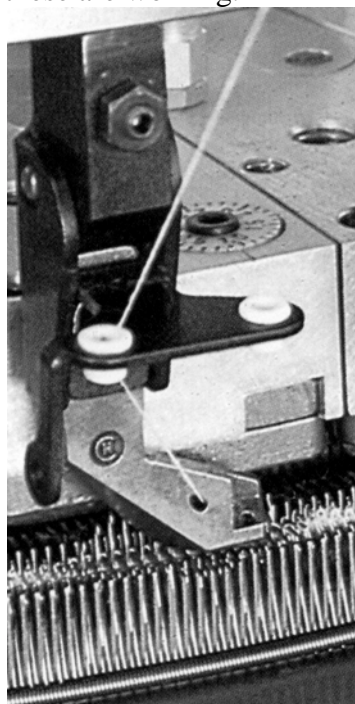
The thread guide is the fundamental element of a yarn feeder.

On circular knitting machines each thread guide corresponds to a feed system. The thread guide is a steel or ceramic plate with a hole for the thread. The thread guide is positioned near the hook of the needle and, besides feeding the yarn, it opens and protects the latches



*Picture 81 – Thread guide for single-bed knitting machine*

The thread guides of double-bed machines feature two holes: one is used for conveying the yarn to the needle on the cylinder while the other hole only serves for feeding the dial needles when these are working.



*Picture 82 – A thread guide of a double-bed knitting machine*

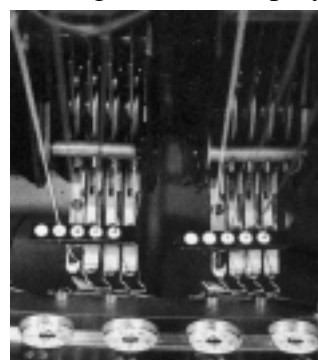
Some machines have more thread guides for the same feed system, e.g. the circular knitting machines for continuous fabrics or continuous striped jersey or those equipped with Jacquard selection systems. The whole set of thread guides mounted on these particular machine models is called stripe pattern motion.

Stripe pattern motions usually includes from four to six threading-in options and a yarn retaining/cutting device. A gripper is positioned between one thread guide and the next to keep the threading-in position while changing the colour on the stripe pattern motion. The machine's head controls the gripper which holds the thread while the scissors cut the thread as soon as it stops.

The yarn remains threaded-in the thread guide, held by the gripper. The thread is released from the gripper and fed to the needles only when the thread guide is activated again. Thanks to a centralised programming system, the different thread guides are only operated when necessary depending on the colour or yarn change.

Special thread guides with double threading-in are used for generating special patterns, for example plating.

Together with the thread guides operating in the stitch formation position, special additional thread guides are employed for feeding the weft yarns.



*Picture 83 – Stripe pattern motion*

## Stitch Formation Motions

Circular knitting machines, both the single or double-bed types according to our initial classification, can incorporate various stitch formation motions depending on the machine's technical features.

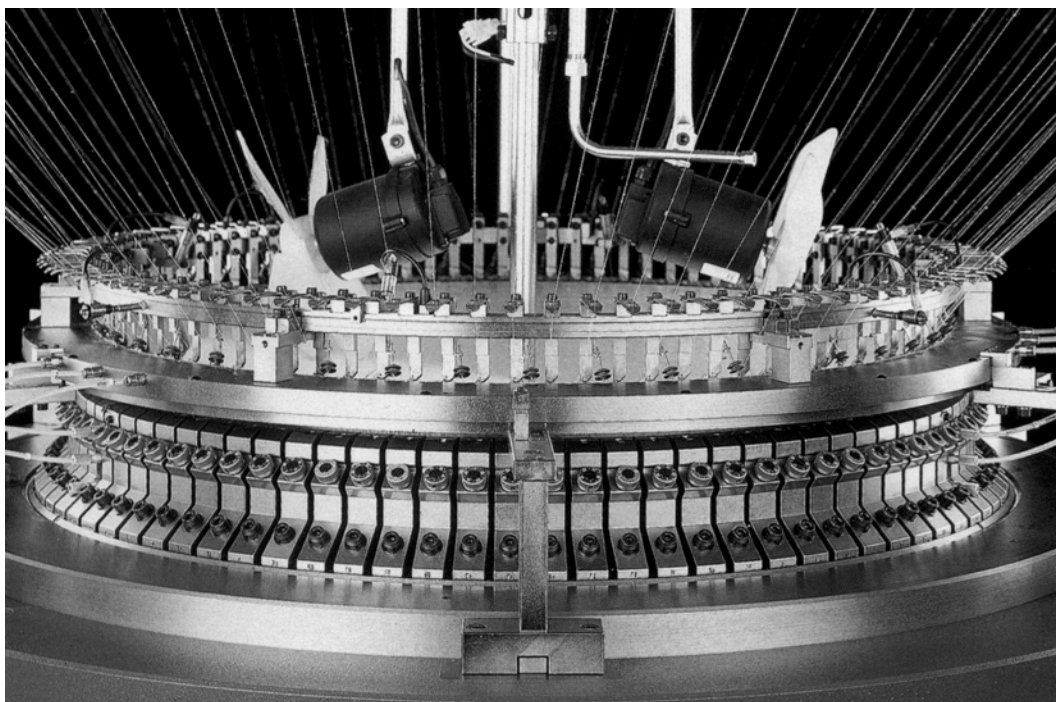
### The Main Components of a Single-bed Machine

Single-bed circular knitting machines are equipped with only one series of needles sliding in the grooves of a circular needle-bed. The needles are usually latch needles but some manufacturers have designed machines equipped with compound needles.

The cams, which drive the movement of the needle forming the stitch, are placed outside the needle-bed; each feed system is provided with its own cam group.

All the cams are fixed to a bearing structure called "cam frame". On single-bed machines, the cam frame is stationary, while the needle-bed revolves.

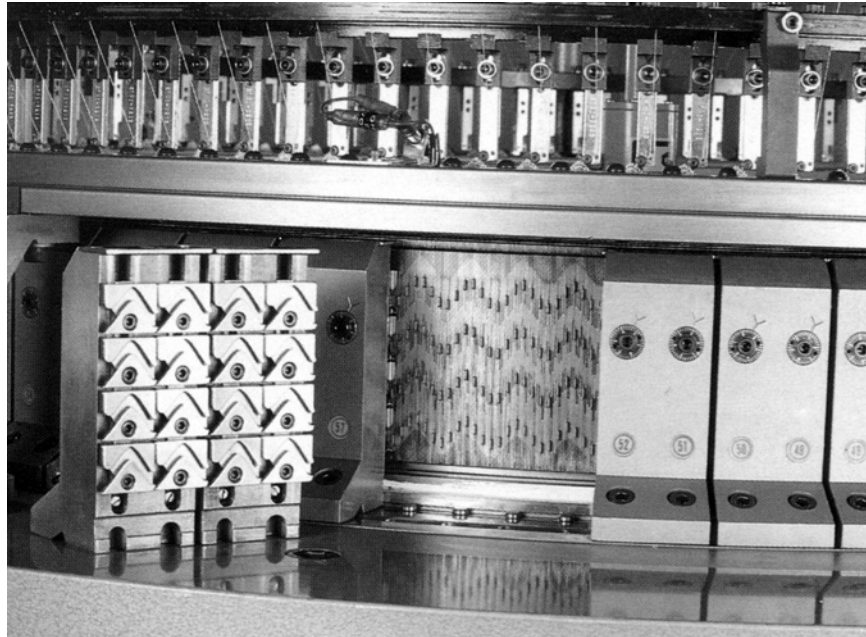
Outside the cams, on each feed system, there are special micrometric screws, which adjust the stroke of the lowering cams and determine accurately the length of the yarn fed.



*Picture 84 –Knitting head of a single-bed circular knitting machine*

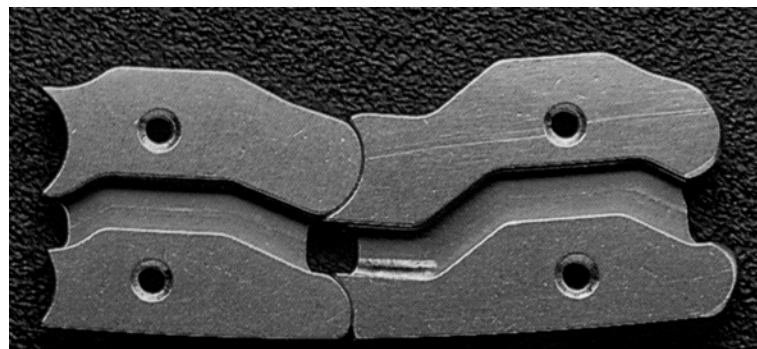
In their simplest structure, the cams are screwed to the cam frame and command a single movement of the needle: for example, when for a certain feed system we only have one group of lowering and rising cams, the selection possibilities will be very restricted. In fact, in this feed system, the needles must knit or remain idle (this is the typical situation of jersey knitting machines). In this case, to modify the pattern it is necessary to change the cam. These technical limits have been overcome by increasing the number of needle butts and the corresponding cam tracks necessary to drive the needle.

Now machine manufacturers are able to offer modern single-bed machines with up to 5 selection tracks.



*Picture 85 – Single-bed machine with 2 open sections exposing the 4 cam tracks.*

Single-bed machines must also incorporate sinkers to carry out the knitting cycle: the sinkers hold the fabric already formed while the needles rise for the next stitch formation cycle. The sinkers also support the fabric when the previous course is knocked-over. Sinkers are driven by special cams whose shape depends on the type of the sinker itself.

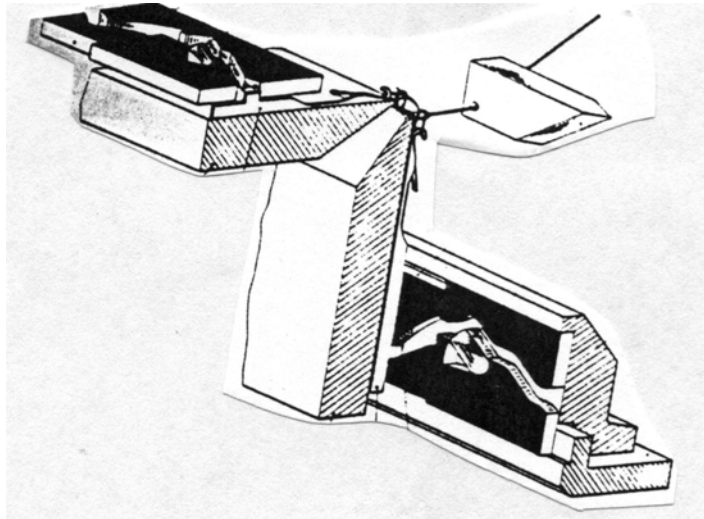


*Picture 86 - Sinker cams of a single-bed fleece knitting machine*

## **The Main Components of a Double-bed Machine**

Double-bed circular knitting machines are equipped with two series of needles: one series of needles fits in the circular needle-bed, called “cylinder”, while the other series is accommodated inside radial grooves positioned at 90° with respect to the cylinder, on a special circular plate called “dial”. Double-bed circular knitting machines usually incorporate latch needles, but some manufacturers also offer machines equipped with compound needles.

The cams that command the various needles are fastened to two cam frames, one around the cylinder and the other above the dial.

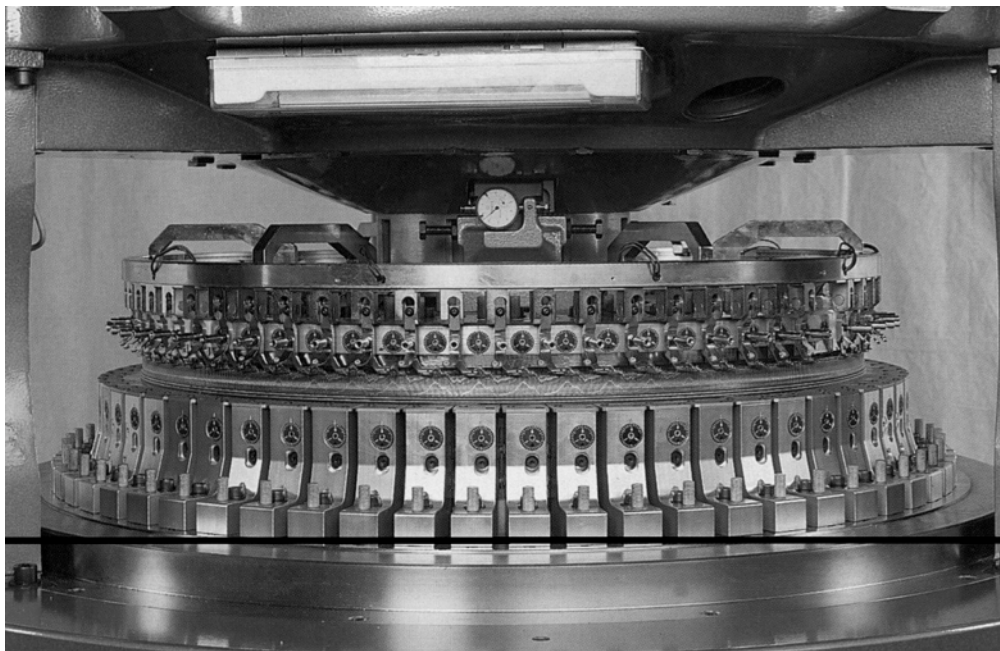


*Picture 87 - Cams e cam frames for dial and cylinder*

Two technical options are available for this type of machine:

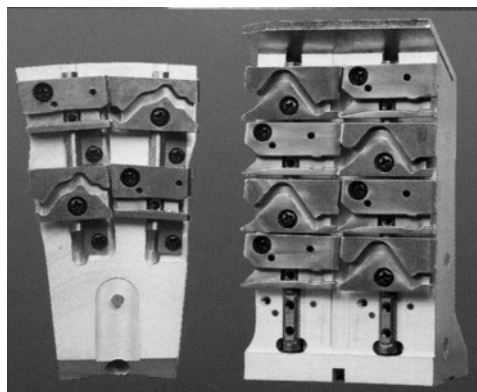
Revolving cam frames and stationary needle-beds (for continuous fabric manufacturing machines)

Stationary cam frames and revolving needle-beds (for cloth manufacturing machines)



*Picture 88 – The knitting head of a double-bed machine*

Also manufacturers of double-bed machines provide a wider range of knitting possibilities by adding extra cam tracks. Today manufacturers offer rib knitting machines, i.e. machines with the needles of the dial staggered with respect to the needles of the cylinder, featuring up to four tracks on the cylinder and two tracks on the dial.



*Picture 89 – Cam tracks for double-bed machines: 2 tracks for the dial and 4 tracks for the cylinder*

Interlock knitting machines make up a very important category of circular double-bed machines. The long and short needles of an interlock knitting machine are placed opposite to one another on dial and cylinder; the needles work alternatively in two consecutive feed systems. Also important are double cylinder machines with double latch needles driven by sliders. On this type of double-bed machines, all the knitting components that operate during the stitch formation cycle are controlled by cams usually sliding inside different tracks.

No sinkers are needed on double needle-bed machines since during the stitch formation cycle, the fabric formed by the rising needles of one needle-bed is held by the needles of the opposite needle-bed.

## **The Technical Evolution**

The rush towards higher productivity has led manufacturers to greatly increase the number of feed systems above all on single-bed jersey knitting machines.

The number of feed systems can be increased either by extending the range of diameters available (manufacturers now offer machines with 60-inch diameter), or by reducing the size of feed systems.

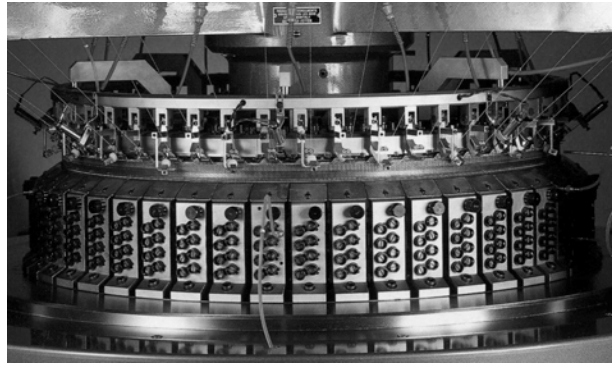
Today, 3 to 4 feed systems per inch for single bed machines and 2 to 2.4 feed systems per inch for rib knitting machines are quite common features. Obviously, the feed systems for knitting more complicated patterns are bigger.

In any case, it is worth mentioning that one of the main problems in the manufacturing of circular knitting machines is the spiral shape of the fabric, and this spiral is emphasised in proportion to the increase in the number of feed systems.

In order to increase the output rates of circular knitting machines, it seems therefore more reasonable to limit the number of feed systems and study new technical solutions for increasing the machine throughput speed.

For this reason, many machine manufacturers have decided to incorporate curvilinear cams sliding inside closed tracks, as a result allowing a constant control of the needle butt during the entire knitting cycle. This method grants higher speeds and safer working conditions.

Furthermore, to reduce cycle times, many manufacturers have provided their machines with special systems ensuring an easier adjustment of cams according to the work to be carried out by the needle. The cams can be adjusted with an external screw without knocking down the machine section (a cam or a group of cams that can be opened at the same time). In this way, it is possible to set the needles easily and quickly on knit-stitch, tuck-stitch or miss-stitch positions.



*Picture 90 – Cam adjusting system with external screw*

## **Selection Systems**

The differentiated selection of needles provides greater possibilities to create patterns with different levels of complexity to meet the needs of a fashion market which requires increasingly sophisticated and innovative garments.

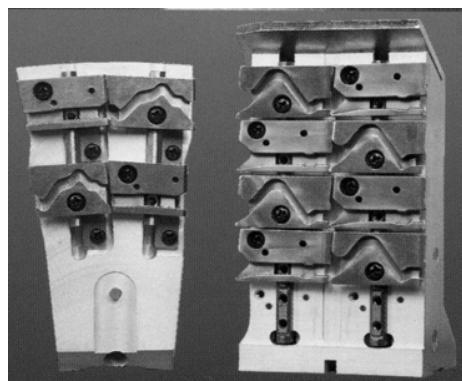
Needle selection can be carried out on circular knitting machines with different degrees of complexity: from the differentiated control of cams acting on high and low butt needles, to needles with multilevel butts (where each butt level matches a cam track), to the selection techniques based on Jacquard motions.

### **Selection by means of Needles with Multilevel Butts**

The most common selection system for the creation of plain (or simple operated) patterns on single and double bed machines, are the needles provided with multilevel butts matching the corresponding cam tracks to carry out the knitting cycle.

The operating principle is quite simple: when the needle reaches a specific knitting level, it generates a knit stitch, a tuck stitch or a miss stitch according to the type of cam sliding in the track corresponding to the specific needle butt level.

Single bed machines can incorporate needles with up to 4 to 5 butt levels for as many cam tracks, while on double bed machines, cylinder needles have 4-level butts and dial needles 2-level butts. The reduced number of tracks on the dial is determined by the fact that the dial has a fixed diameter, therefore the grooves cannot exceed a certain length, with the result that dial needles are relatively shorter.



*Picture 91 – Double bed cam system with 2-level butt needles on the dial and 4-level butt needles on the cylinder*

## Jacquard Selection

Jacquard selection systems allow the knitting of elaborated patterns. On Jacquard selection systems, large clusters of needles can work independently and each single needle in a cluster can work independently from the others (needle-by-needle selection).

The Jacquard systems of circular knitting machines can be divided into two technically different categories:

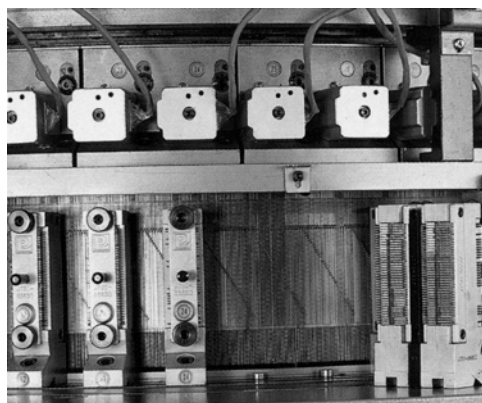
- Mechanical Jacquard selection systems
- Electronic Jacquard selection systems

### Mechanical Jacquard Selection System

In the past, a variety of mechanical Jacquard selection systems were available on the market, but today manufacturers privilege only two types of mechanical Jacquard systems, equipped respectively with

- needle sliders or
- pattern wheels

The slider selection system is the most commonly used system. Under each needle there is a slider with 3 butts: a lower butt for needle raising, an upper butt for loop knocking-over and an intermediate selection butt that can be positioned at different levels. A selection lever acts on the intermediate selection butt. When the lever is idle (i.e. in external position) the slider maintains a vertical position and is pushed upward by the raising cams so that the corresponding needle can assume a working position. When the selection lever is active (i.e. in internal position) the slider is pushed into the guide groove and the corresponding needle assumes a non-knitting position. The selection lever is controlled externally and each manufacturer has developed its own solution to control the selection lever (e.g. fixed turrets with plug-in cartridges for pattern selection, punched cards system, reeds etc.)



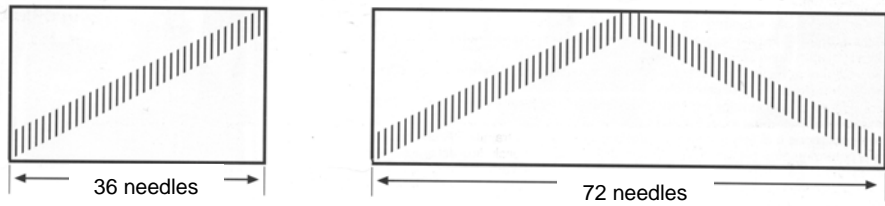
*Picture 92 – Mechanical slider selection*

The most recent models of circular knitting machines incorporate 37 selection levels (mini-jack machines). On double-bed machines, the selection levels are limited to the cylinder. In addition to the pattern selection levels, these machines also feature two extra levels to facilitate the selection change-over procedures.



The selection butts of sliders are usually arranged as follows:

- diagonally
- symmetrically



*Picture 93 – Arrangement of the selection butts of sliders*

With the slider butts arranged diagonally, the pattern design includes in its width a number of wales equal to the number of selectors. In symmetrical arrangement, the width of the pattern design is twice the number of selection levels. The sliders arrangement can remain unchanged for each machine revolution (fixed arrangement), and in this case the height of the design pattern is given by the number of feed systems of the machine divided by the number of pattern colours.

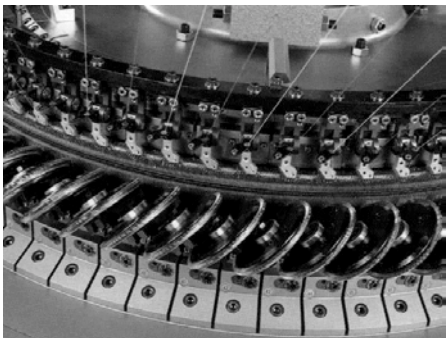
If the operator wishes to modify the height of the pattern, the arrangement of the sliders must be changed after every machine revolution. This operation can be carried out by applying different methods, i.e.:

- Using small cylinders provided with as many holes as the number of selectors; each hole can have a peg to exclude the corresponding selector. These small cylinders can be rotated after each machine revolution to modify the slider selection on a specific feed system.
- Using selection turrets that can be reset and provided with a new selection scheme for each machine revolution.

The mechanical selection system with pattern wheels is based upon the use of a wheel incorporating special grooves on its circumference. The distance between the grooves equals the distance between one needle and the next on the machine bed. Special pegs are positioned into the grooves of the pattern wheel according to the patterns to be carried out.

The wheel is mounted in slant position so that the needle butts can enter the grooves of the wheel and make it rotate. When the needle butt finds an empty space, it is not raised and remains in non-knitting position. When the butt meets a peg, the needle assumes its working position. Pegs have different heights: higher pegs select knitting needles while shorter pegs select tucking needles.

Each feed system of the machine has to be equipped with a pattern wheel, therefore the number of pattern wheels corresponds to the number of feed systems on the machine.



*Picture 94 –Mechanical selection with pattern wheels*

The width of the pattern ratio is strictly related to the number of teeth on the pattern wheel and to the number of machine needles.

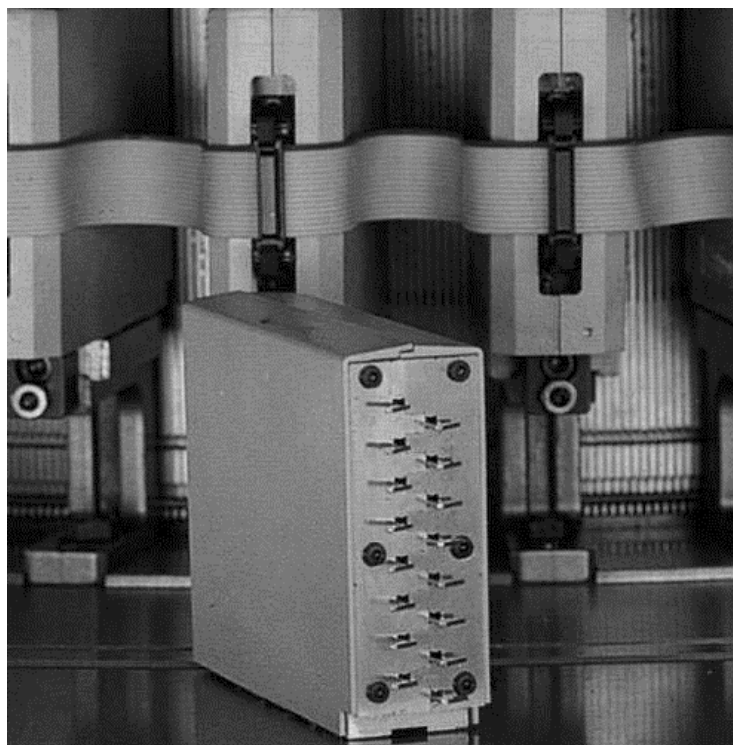
If the number of machine needles is exactly divisible by the number of the teeth on the pattern wheel, the design can be repeated serially lengthwise and crosswise.

However, this solution does not give particularly appreciable results in terms of originality and aesthetics. Therefore, it is advisable that the number of needles be not exactly divisible by the number of the teeth on the pattern wheel, as a result slightly shifting the design pattern position with every revolution of the machine. In this way, the pattern develops diagonally on the fabric giving the impression of a higher covering ratio.

Today, the application scope of pattern wheels has become rather limited compared to the past, yet some manufacturers still offer single and double bed machines equipped with pattern wheels selection above all for the manufacturing of continuous Jacquard fabrics.

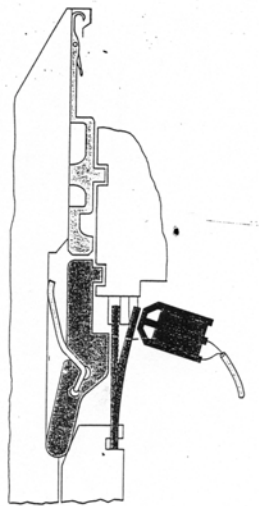
### **Electronic Jacquard Selection System**

The precise definition of this needle selection system for circular knitting machines is “electromechanical selection with electronic control”, based on the use of piezoelectric actuators that act on the selectors, or of a magnet which commands a striker placed under the needle.



*Picture 95 – A 16 (8+8) level piezoelectric actuator*

If the selection is carried out with a single magnet, when the magnet is excited the striker assumes a vertical position thanks to the action of a control spring, then reaches the rising cam and forces the needle in the working position. When the magnet is not excited, the spring withdraws the striker into the groove in the non-knitting position together with the corresponding needle.



The “needle-by-needle” selection allows the knitting of design patterns of almost unlimited size since each needle can be independently set in the knit, tuck or miss position. The electronic selection is now widely used for the needles of the cylinder, while on several double-bed knitting machines, the selection of dial needles is still carried out mechanically with cams and tracks. However, many machine manufacturers also offer electronic dial and cylinder needle selection systems.

*Picture 96 – Electromechanical selection with single magnet*

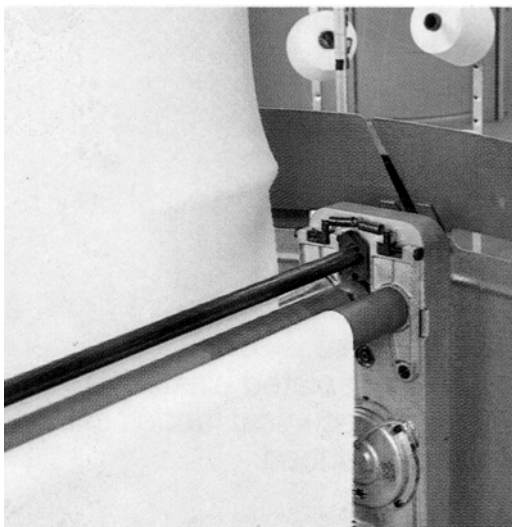
## **Take-down and Winding Motions**

The fabric take-down and winding motions have been designed to facilitate stitch knock-over and fabric take-down procedures. The take-down and winding functions are kept separated in order to allow a smooth running of the machine and avoid possible fabric distortions.

### **Take-down Motion**

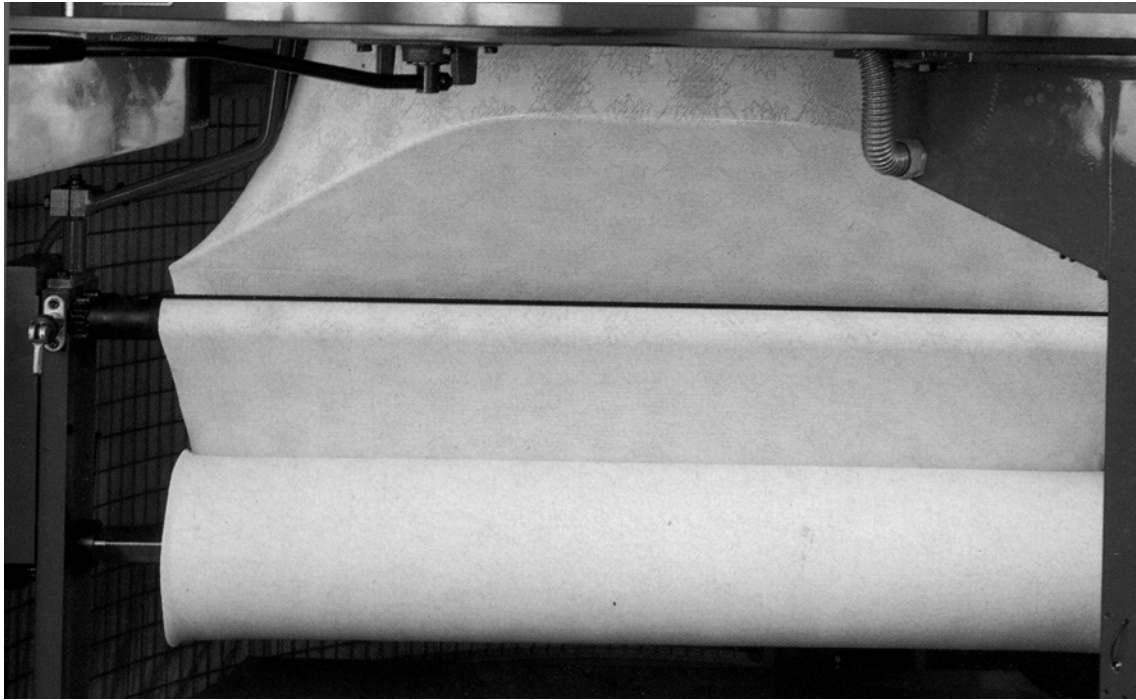
The take-down motion consists of 2 or 3 rollers placed beneath the cylinder. In the simplest system configuration (i.e. the two-roller) the fabric passes between two rollers that stretch it by rotating in opposite directions. Anyway, the best system is the three-roller take-down motion which pulls the fabric without slipping and without exerting too much pressure that could damage the fabric.

From a mechanical point of view, a take-down system can be either equipped with a swivelling arm or with a lever and spring mechanism. Modern take-down systems are motorised and the latest models also incorporate an electronic control.



*Picture 97 – A 2-roller take-down motion*

Circular knitting machines pose some problems as regards the winding of the fabric, as the fabric itself is delivered in tubular form and must be spread flat prior to winding. The spreading of the tubular fabric generates some distortions because of the different distances between the various zones of the tubular fabric emerging from the take-down system and the same zones wound on the fabric roll. These differences reflect into uneven winding tensions (the tension is lower in the fabric centre and higher at its edges). To avoid these problems, a metal frame called “spreader” has been incorporated before the fabric winding system. The spreader increases the width of the tubular fabric by giving it an almost circular shape, equalising the distances between the various zones of the fabric and the nip line of the winding system.



*Picture 98 – Take-up and winding motion with fabric spreader*

A special take-down system has been designed for variable needle-bed machines since these machines do not use the whole needle-bed. This special take-down motion features independent rollers to adjust the tension during the knitting process and differentiate the tension between the central part of the cloth and the edges. On the most recent machines, it is possible to set up to 99 different tension values.

## **Winding Motion**

The fabric winding motion is provided with a clutch. In this way, to grant a steady peripheral speed, the angular speed of the winding roller can be gradually reduced as the diameter of the fabric roll increases.



*Picture 99 – Clutch connection between the winding roller and the take-down motion rollers*

At the ITMA '99 fair in Paris, an Italian manufacturer of circular knitting machines exhibited an innovative winding system mounted on a 30-inch circular knitting machine. In practice, this machine features an “open” base that allows the fabric cutting and opening on only one side prior to winding. Obviously, in order to allow the take-up of the open fabric, the width of the winding roller must be twice the width of a standard one.

The take-up step is carried out on the already opened fabric, and the edges of the fabric are kept tensioned by means of two rollers with worm-screw profiles.

Thanks to this innovative solution, no further rollers squeeze the knit fabric. This avoids the problem of central marks which is particularly serious on elastane fibres.



*Picture 100 – Open-width winding motion*

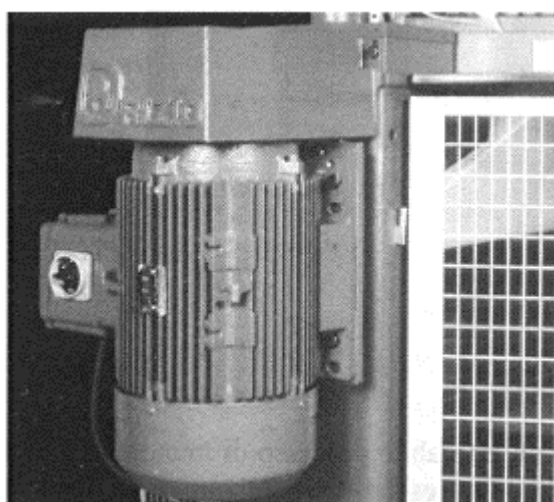
# Drives, Control and Monitoring Systems

## Drives

All the modern circular knitting machines are equipped with inverter drives, ensuring electronic speed variation, to set the optimum working speed and allow the best possible control of machine accelerations and slow-downs.

The drives command the operating speed, the slow speed and, as an alternative to the hand-drive lever, allow a very low speed running with push-button control. The most recent drive models are equipped with visual diagnostic devices for solving problems such as machine stops.

The motion is transmitted to the needle-beds by means of shafts and gears. On single bed machines, the motion transmission is quite simple since there are no alignment problems; on the contrary, double bed machines must incorporate an adjusting device for aligning the needles of one needle-bed to the needles of the opposite one.



*Picture 101- A motor*

## Control and Monitoring System

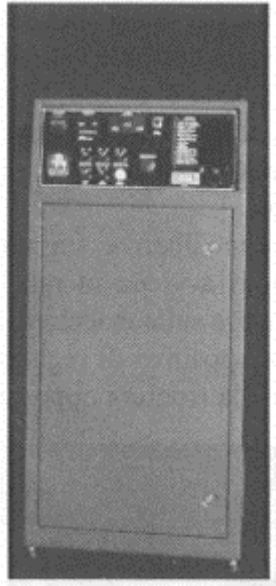
Modern circular knitting machines feature on-board computers (CPU) complete with a display and a keyboard to control and monitor the most important functions:

- speed
- number of machine revolutions
- working hours
- causes of machine stops
- detector of the yarn length fed into the machine

On modern microprocessor-controlled machines, the LCD display is equipped with an alphanumeric keyboard for entering the operator's settings. The whole system is controlled by an electronic circuit which signals the status of the machine and the possible causes of machine stops by means of flashing lights.

All the electronic control components are accommodated in a cubicle linked with the machine by special connectors.

Sometimes, together with these functions, the machine can also carry out needle selection procedures by retrieving the information saved on floppy disks or by means of a direct connection to a dedicated CAD system.

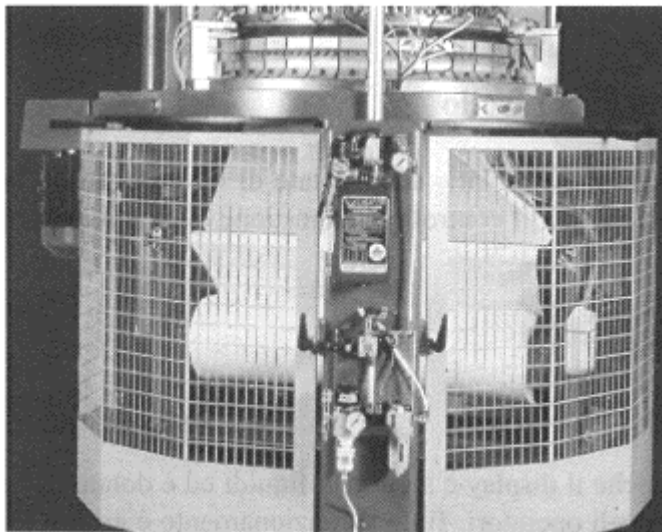


*Picture 102 – Control unit*

## **Ancillary Systems**

### **Lubrication System**

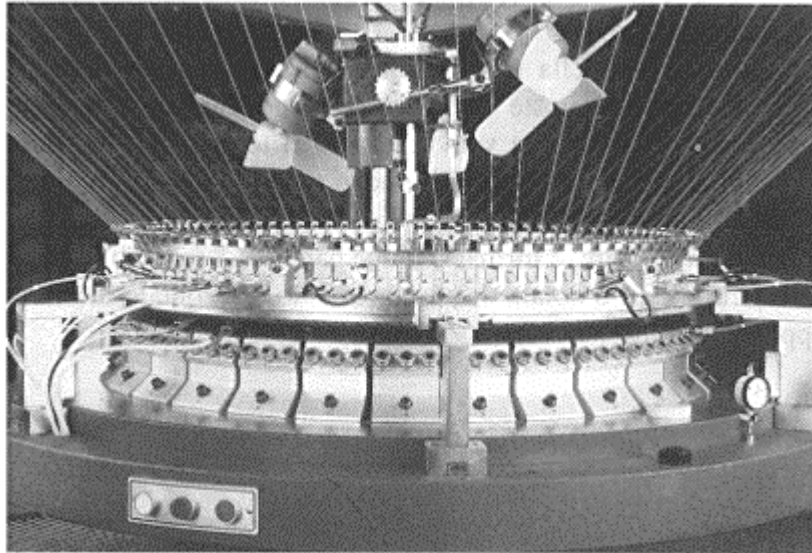
The perfect lubrication of the knitting head is essential for an efficient knitting process; lubrication is usually guaranteed by electronic atomiser pumps.



*Picture 103 – Lubrication pump*

## Suction and Blowing Systems

These systems allow the abatement of the dust in the working range and the yarn feeding area. Suction and blowing systems usually incorporate a blower in the knitting range and swivelling fans in several points where the yarn passes.

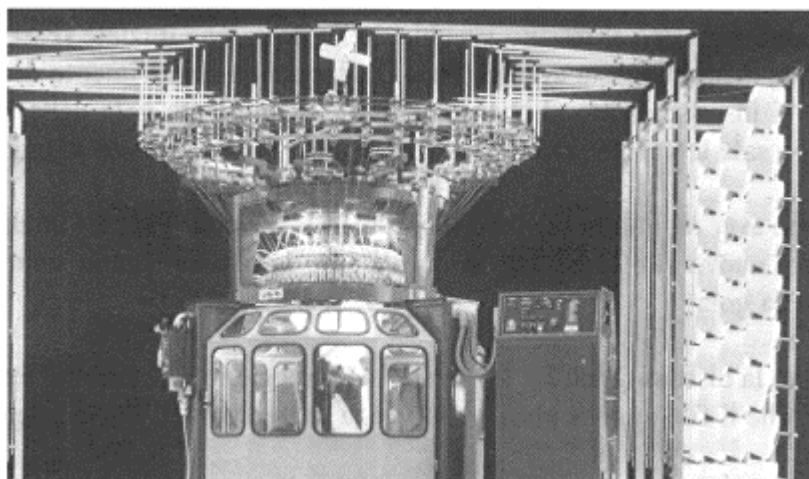


*Picture 104 – Ventilation system*

## Safety Systems

The application of European safety standards and regulations has led manufacturers to design machines featuring safety systems that stop the machine in case of hazard for the machine operator.

To protect the operators from any possible injury, all electric and moving parts are completely enclosed and the machine base is protected by special guards (metal grids or even more complex structures that immediately stop the machine when opened).



*Picture 105 – Safety guards on a circular machine*



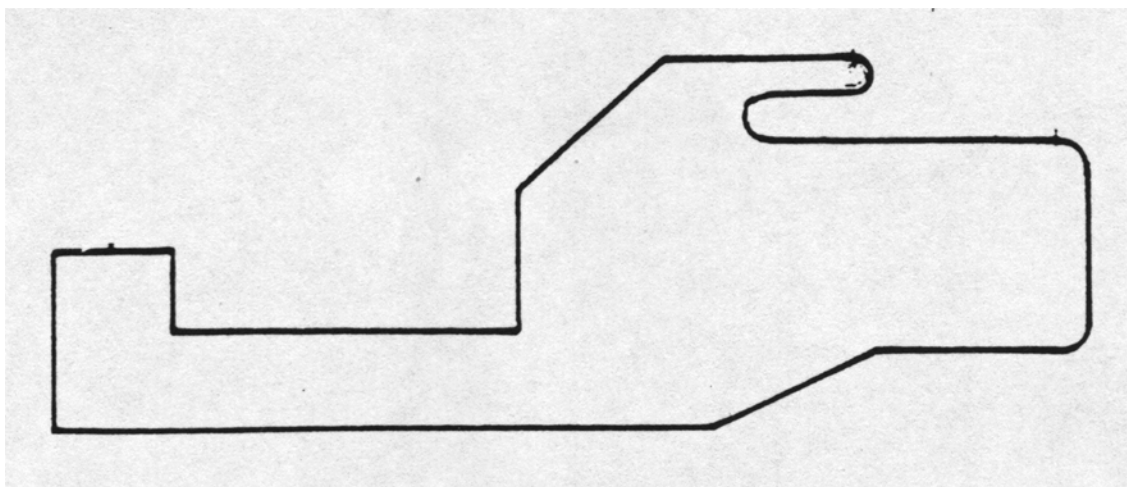
# Large-diameter Circular Knitting Machines

## Single-bed Circular Knitting Machines

Large-diameter single-bed circular machines are equipped with a single circular needle-bed, with vertical grooves where the latch or compound needles can move.

Besides the needles, during the stitch formation cycle special components called “sinkers” also operate that are positioned perpendicularly to the needles. Sinkers play two fundamental roles: they hold the already formed fabric down when the needles rise to knit the new course and support the fabric when the previous course is knocked over.

The sinker, which has a particular shape, has two main parts: the nose (upper section) and the breast (lower section) which can move forward and backward horizontally driven by special cams.



*Picture 106 – A sinker*

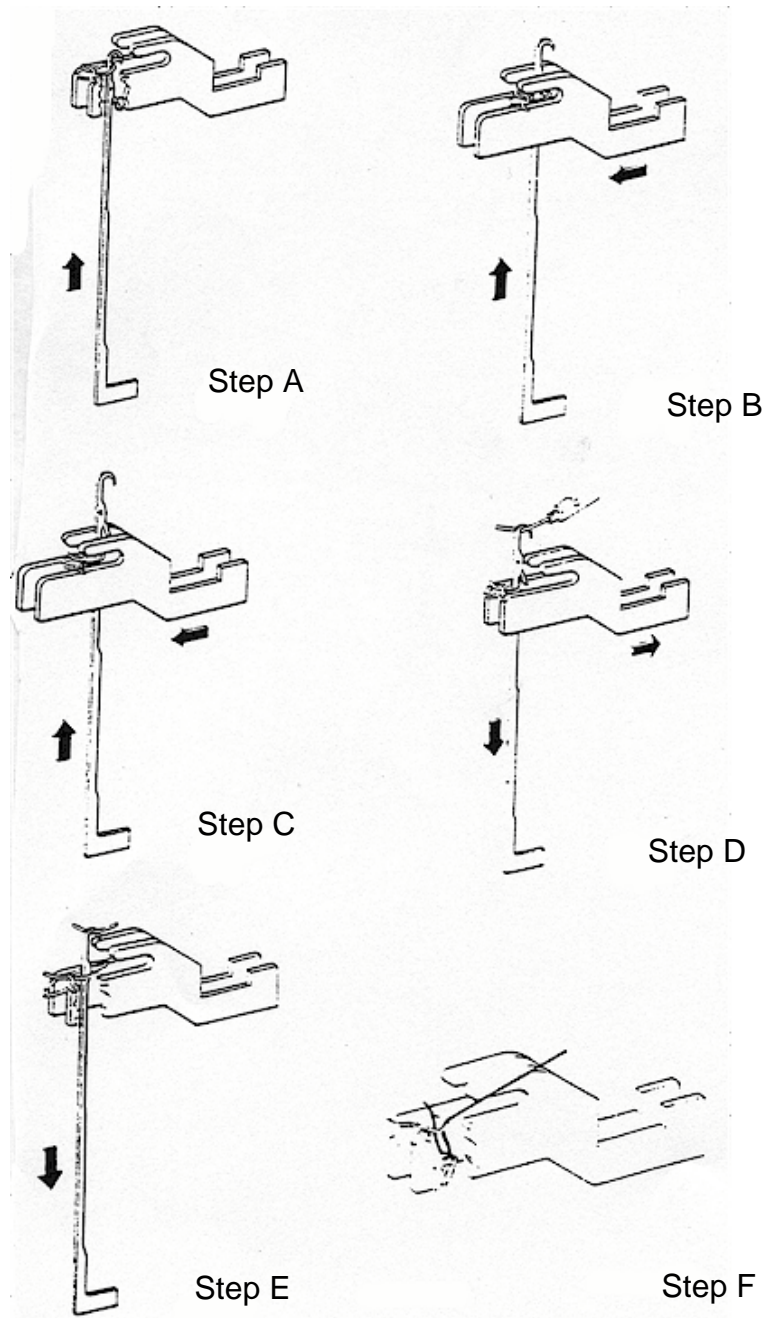
## Stitch Formation Cycle on Single-bed Knitting Machines

As shown in picture 107, the course in its starting position (Step A) lies on the breast of the sinker; when the sinker moves forward (Step B), according to the stitch formation movement, the fabric reaches the zone under the sinker nose called “throat”; when the needle rises, the previous stitches, retained by the sinkers, open the needle latches (Step C).

When the needle, after having reached its highest position (Step C) starts lowering, a new thread is fed (Step D): during this step, the sinkers retain the previous stitches in the sinker throat.

The needles continue their downstroke (Step E), the sinkers draw back and the previous stitches close the latch so that the new thread is retained inside the needle hook.

Finally (Step F) the needles reach their lowest position, the previous stitches slip over the closed hook and knock over at the bottom of the new stitch.



*Picture 107 – Stitch formation steps on single-bed knitting machines*

As previously described in the chapter about the stitch formation motions, the cam-frame is arranged outside the needle-bed; the knitting systems, which transmit the raising and the lowering motions to the needles, are positioned under the cam frame.

In its most simple structure the cam-lock of a single-bed circular knitting machine features a series of raising and lowering cams which form a track where the needle butts slide.

The lowering cam can be adjusted so as to create a different lowering level for the needles and, consequently, the formation of shorter or longer stitches.

To carry out this adjustment, the lowering cam is connected to a micrometric screw which can be controlled by means of a push-button positioned outside the cam frame.

## Jersey Knitting Machines

Since single-bed circular knitting machines are equipped with a single series of needles, they are suitable for jersey manufacturing and, with the necessary mechanical modifications, also for manufacturing jersey-derived fabrics such as terry and fleece. Some machine models are equipped with 4 to 6 colour stripe pattern motions for striped jersey.

On these machines, the selection function can be the track type; some machines can incorporate up to 5 selection tracks, also in electronic version.

The range of diameters is really wide and the maximum size available is normally 30 inches. Some manufacturers even offer versions with a needle-bed diameter of 60 inches (the so-called Jumbo machines) which deliver a fabric wide enough to be cut on the two sides, as a result eliminating the problem of the central fold always present on fabrics with a single lateral cut. On fabrics manufactured with elastane yarn, this fold generates a permanent fault.

The range of gauges offered is also extremely vast, from the coarse E 4 to the fine E 32 gauge. The number of feed systems can reach 3 – 4 feed systems per inch, according to the diameter and to the gauge of the machine. The number of feed systems is lower on machines equipped with stripe pattern motions. The machine speed is approximately 25 to 30 rpm, but recently some machine manufacturers have developed high-speed jersey machines which can even reach 50 rpm.

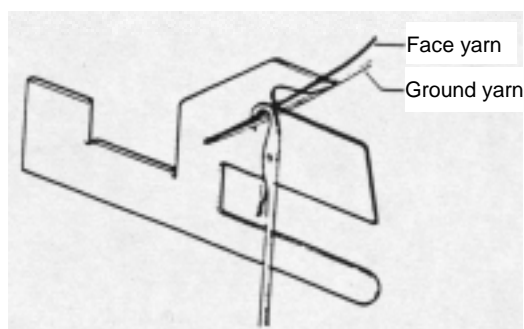
Almost all the machines of new construction are equipped with special devices that allow the use of elastane yarns. Recently, some manufacturers have also introduced machines complete with a conversion kit for the knitting head to rapidly transform the jersey machine into a fleece or terry knitting machine.

## Terry Knitting Machines

For the manufacturing of terry cloth, it is necessary to use single-bed circular knitting machines equipped with special sinkers featuring a longer nose than standard sinkers and special thread guides which feed simultaneously two yarns, one called ground yarn and the other one called face yarn, into the same needle.

During the stitch formation, the sinkers move forward and position themselves between the two yarns. The ground yarn fits under the sinker nose, inside the throat, and carries out a standard stitch formation cycle, while the face yarn is positioned above the sinker nose. Therefore, as the fabric is knitted, the face yarn forms a loop pile, leaving the other yarn to serve as the ground. As a result, the face yarn always appears on the face and the ground yarn always on the back of the cloth.

If the sinker is not pushed forward to reach its maximum forward position, the two yarns fed are both tucked under the nose, with the consequent formation of a double knit stitch of standard length. By exploiting the possibility of moving the sinkers forward completely or only partially, it is possible to create sculptured terry effects, i.e. flat zones alternated with terry knit zones.



*Picture 108 –Terry sinker*

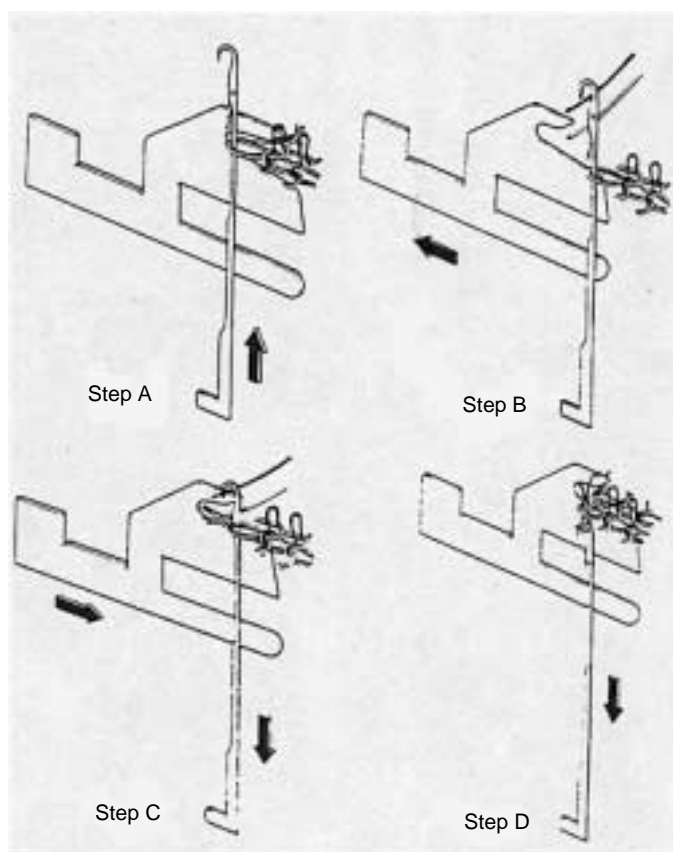
The terry formation steps can be described as follows:

STEP A: the sinkers reach their maximum forward position towards the centre of the cylinder and are momentarily stopped. During this step, they must retain the previous loop on the needle stem and allow the needle to rise, reach the knitting position, and prepare to receive the two yarns fed by the yarn guide. In this starting position the face yarn is on the sinker nib and the interloop is in the throat.

STEP B: the sinkers start their backstroke to allow the yarn guide to feed the needle with the two yarns at different heights. The ground yarn, fed in the lower part of the needle hook, is inserted into the sinker throat while the face yarn, fed in the upper part of the hook, is laid on the sinker nib.

STEP C: the sinkers move toward the centre of the cylinder and the needle starts lowering. During this step, the two yarns remain on the nib and in the throat of the sinkers.

STEP D: the sinkers reach their maximum forward position and stand still; the needle lowers and completely knocks over the previous stitch on the new stitch which has just formed. The new stitch is made up by two yarns (ground yarn and face yarn), while the face yarn of the stitch previously formed is on the sinker nib and the ground yarn forming the interloop is in the sinker throat.



*Picture 109 – Terry formation steps*

Many manufacturers offer terry knitting machines with a 40-inch bed diameter and up to 60 feed systems to carry out both terry and plating, with gauge range from E 14 to E 28.

## **Fleece Knitting Machines**

The fleece fabric is similar to jersey and is obtained by inserting one or more additional yarns which do not form the stitch but only a sort of binding on the ground pattern.

Single-bed circular knitting machines for fleece fabrics are equipped with a special yarn feed system which must feed the additional yarn into the special fleece feed systems before the formation of the ground stitches. The other feed systems operate as usual and form the ground fabric.

From a technical point of view, there are two different types of fleece fabrics, each one requiring a different feed technique:

### **STANDARD FLEECE KNITTING MACHINES**

Require two feed system types for:  
finer and high-twisted ground yarn  
coarser and low-twisted fleece yarn

### **THREE YARN FLEECE KNITTING MACHINES**

Require three feed system types for:  
ground yarn  
fleece yarn  
tie-in yarn with features similar to the ground yarn

The formation steps of a standard fleece fabric can be outlined as follows: the needles specifically selected to receive the fleece yarn raise to their looping position, i.e. they rise until the previous loop withdraws and opens the latch, without however getting past the latch.

The fleece yarn is fed during this step.

The needles start lowering, and bring the fleece yarn which has just been fed into contact with the previous stitches; at the same time the sinkers move forward to hold the previous stitches and the fleece yarn down.

During the following step, all the needles rise to their looping position; when they start lowering, the thread guide feeds the ground yarn. The knitting cycle is completed once the needles have reached their lowest position, and the previous stitches and the fleece yarn have been knocked over.

Standard fleece fabrics are manufactured on standard jersey machines with suitable equipment, while the three yarn fleece fabrics can be manufactured on machines with special diameters up to 40 inches, 3 feed systems per inch and gauge from E 12 to E 24.

## **Double-bed Circular Knitting Machines**

The most widespread version of double-bed circular knitting machine is equipped with two needle-beds positioned at 90°; the vertical needle-bed is called cylinder while the horizontal one is called dial.

Another version of double-bed circular knitting machines features needle-beds positioned at 180°; these machines are called double-cylinder machines (or links-links machines). They incorporate two needle-beds called lower and upper cylinder with the grooves of the two cylinders aligned to one another. These machines feature special double latch needles that can be racked from one needle-bed to the other one to knit the stitch on the lower or on the upper cylinder.

### **Dial-cylinder Knitting Machines**

On dial-cylinder circular knitting machines the cylinder is considered the front needle-bed while the dial is considered the rear needle-bed. Both needle-beds feature grooves guiding the needle movements. The needles used for dial-cylinder circular knitting machines are mainly latch needles; some manufacturers however use compound needles.

Large-diameter dial-cylinder knitting machines can be divided into different categories according to the knitted good they manufacture:

- circular knitting machines for rib fabrics
- circular knitting machines for interlock fabrics
- circular knitting machines with variable needle-bed for fabrics of variable width

The dial-cylinder circular knitting machines can be built in such a way that the cams rotate together with the spool rack. In this case it is possible to modify the position of the cams at each machine cycle and at each passage in front of the machine head. Dial-cylinder circular knitting machines can also be built with the cams and the spool rack standing still while the dial and the cylinder rotate with the fabric take-down system. The fixed cam system with rotating needle-beds is mainly used for the production of continuous fabrics while the mobile cams system with fixed needle-beds is mostly used for the production of cloths.

On large-diameter circular knitting machines, cams are subdivided into sections – corresponding to a group of cams that can be removed from the machine at a time – and can incorporate one or more feed systems, depending of the machine model.

In addition, the cams have different profiles according to the type of machine and to the type of fabric to be produced.

On circular knitting machines with fixed diameter – or with variable needle-beds for the production of cloths – there are several needle drive options to carry out different operations: needles can work in knit position (raising cam and tucking cam in a knit position) or in tuck position (raising cam in knit position and tucking cam in non-knit position).

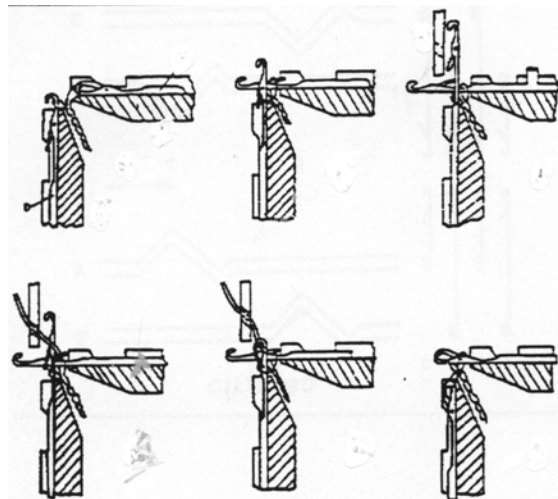
To prevent cams from hitting the needle butts and breaking, the control area is normally free from needles; as a consequence, the fabric emerging from the machine will have a 2-3 cm non-knitted area.

The stitch length is adjusted by means of micrometric screws on each feed system. To modify the length of the stitch, the machine includes different pre-set positions that can be retrieved from the head according to the design pattern to be carried out.

## Stitch Formation on Dial-cylinder Knitting Machines

The stitch formation cycle on double-bed dial-cylinder machines is similar to that of flat knitting machines. The needles start rising from their lowest position; the previous stitch slips along the needle stem and opens the latch; when the needle reaches its highest position the previous course is on the stem, beyond the open latch.

The needle starts lowering and the thread guide feeds the thread for the new stitch which is seized by the hook; at the same time the previous one slips forward on the stem and closes the latch. Once the previous course has been knocked over on the new course, the cycle is completed. The same movements are carried out by the needles in the dial. Here, however, the dial needles move on a horizontal plane, so instead of raising and lowering movements, we will have forward and backward needle movements.



*Picture 110 – The various steps of stitch formation on dial-cylinder knitting machines*

Several machine models allow the variation of the stitch knocking over in order to have either a simultaneous or a differentiated knocking-over operation.

In the former case, the needles of the cylinder and the needles of the dial form the stitch simultaneously; in the latter case, by varying some controls or by racking the dial by five or six needles with respect to the cylinder, it is possible to knock over first the needles of the cylinder and then the needles of the dial. With the simultaneous knocking-over technique, the resulting fabric will be more consistent, soft and stretchable since the two series of needles can take up the quantity of thread necessary to form the stitch. On the contrary, with the differentiated knocking-over technique, in order to take up the quantity of thread necessary for the stitch formation, the needles in the dial have to make the thread slip with respect to the needles of the cylinder that have already been lowered. In fact, it is easier to take up part of the thread from the stitches already formed on the cylinder. In this way, the fabric formation will require less thread, resulting in a denser and less stretchable construction.

On dial-cylinder circular knitting machines it is also possible to transfer the stitches from a needle-bed to the opposite one to create complicated design patterns. The stitch transfer is carried out usually from the cylinder to the dial to exploit the wider possibilities for selection

offered by the cylinder needle bed. Obviously, the stitch transfer in the opposite direction is also possible.

To carry out the stitch transfer on mechanically controlled machines, it is necessary to replace some of the knitting feed systems with special feed systems equipped with transfer cams on the cylinder and receiving cams on the dial. In general, there is one transfer system for every two knitting feed systems. Obviously, the replacement of these knitting feed systems with transfer systems causes a reduction of output rates. Besides the transfer cams, it is also necessary to provide the machine with special needles with opening spring, like that of flat-bed knitting machines.

## Rib-stitch Machines

Rib-stitch machines constitute the most typical category of double-bed machines. The dial needles of rib-stitch machines are arranged in staggered position with respect to the cylinder needles.

These machines are mainly used for manufacturing continuous tubular fabric with rib-stitch or derived patterns.

Manufacturers offer rib-stitch machines in a wide range of models with diameters up to 40 inches; the most common models are however the 30, 34 and 36 inches, with gauge from E 10 to 28.

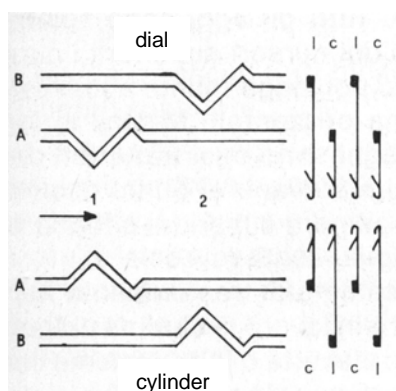
The models with multi-track selection feature up to 5 tracks on the cylinder and up to 2 tracks on the dial.

## Interlock Machines

Interlock machines are dial-cylinder machines of special design. In fact, the cylinder needles and the dial needles are arranged in front of each other.

Obviously, in order to achieve different needle motions, the needles themselves must be of different types: on interlock machines, needles are generally arranged in such a way that a short needle is alternated with a long one in the cylinder, and a long needle is alternated with a short one in the dial. To drive short and long needles, two cam tracks are necessary on both the cylinder and the dial.

On one feed system, the short needles of a needle-bed and the long needles of the opposite one operate alternately and form a half-course of rib stitches; in the next feed system, the needles operate inversely and form a second half-course of rib stitches interknitted with the previous one. In interlock fabrics, a knit stitch course is therefore made up by two interknitted half-courses of rib stitches.



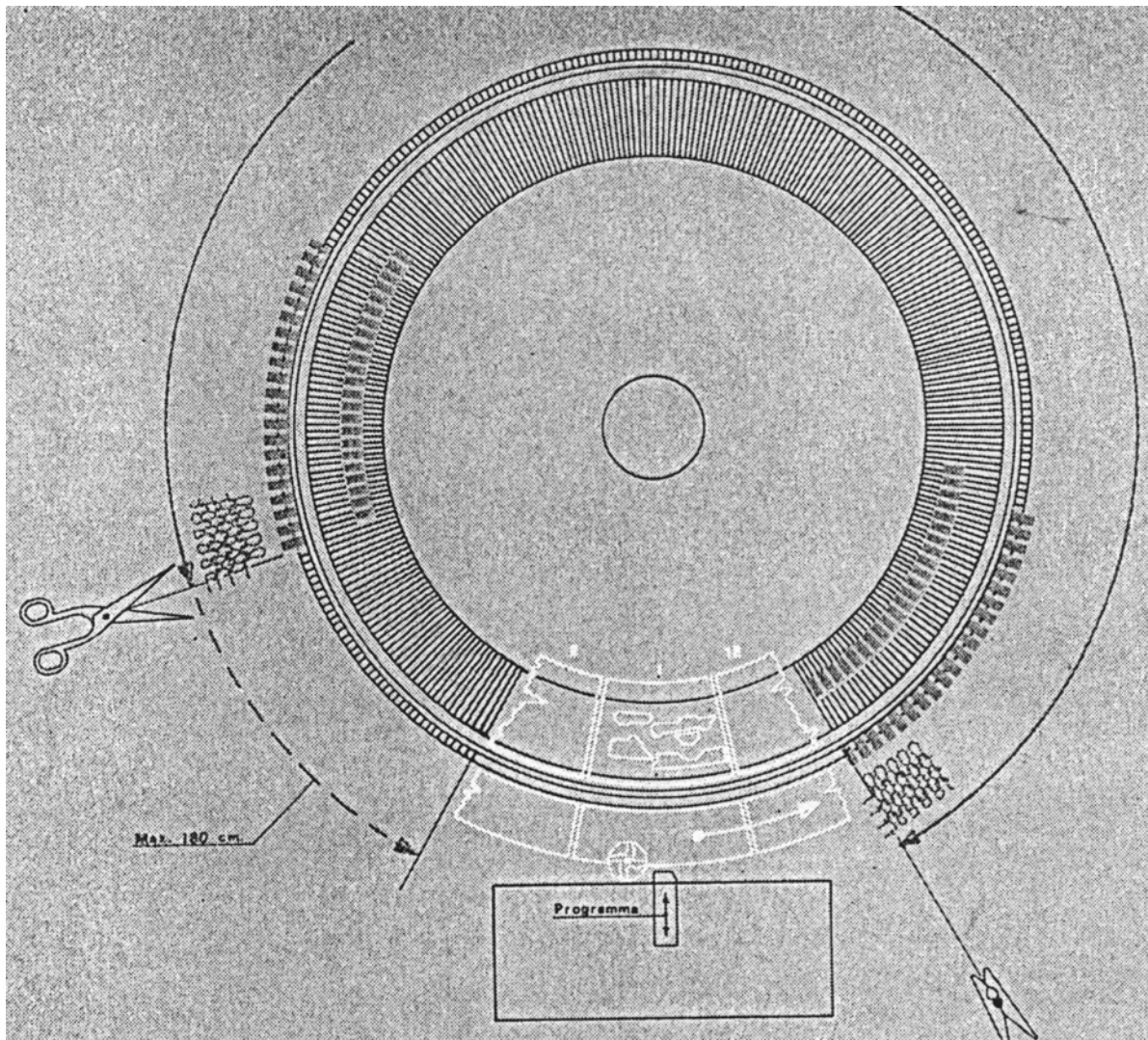
Interlock machines, built mainly in the 30-inch diameter version, and E 18 to E 32 gauges, feature a huge number of feed systems (up to 108) and are designed mainly for the production of cloths with interlock patterns.

*Picture 111 – Arrangement of needles and tracks on interlock machines*



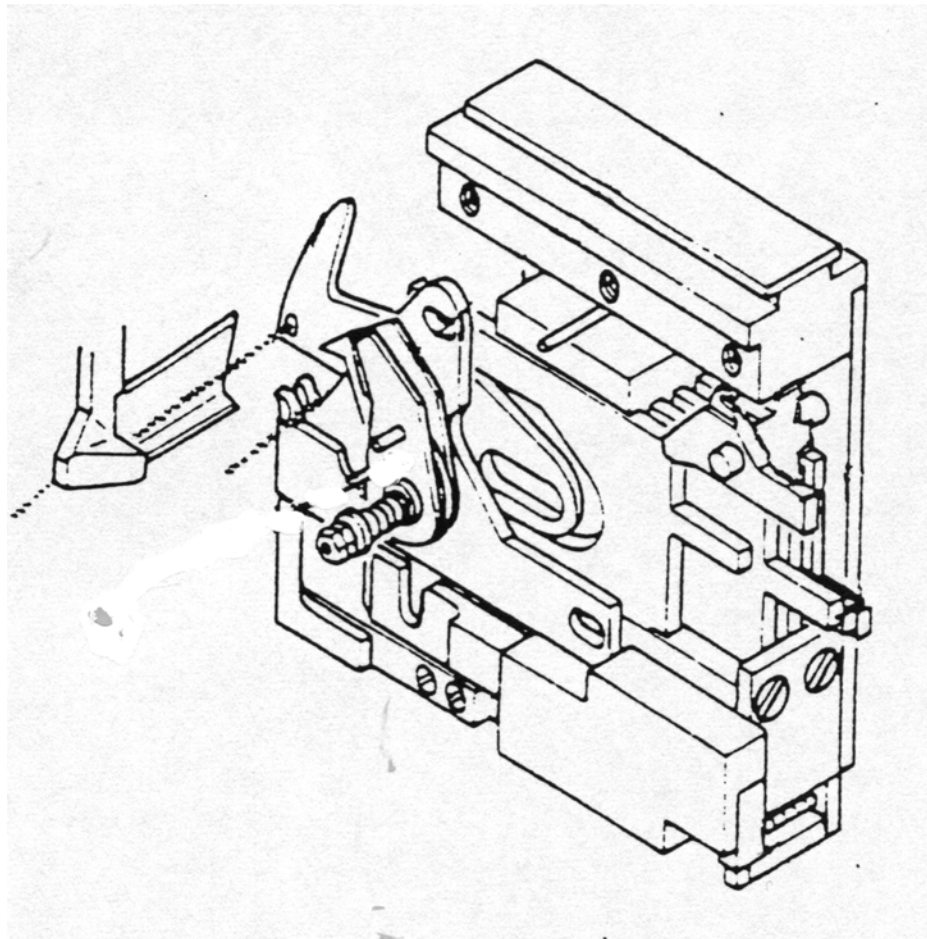
## Variable Needle-bed Machines

The main difference between fixed and variable needle-bed machines is due to the fact that in fixed needle-bed machines the needles occupy the whole bed and must all and always be used to manufacture a tubular fabric. In variable needle-bed machines the needles do not cover the whole bed; needles are incorporated only in a specific area of the machine bed. In practice, the dial and the cylinder have a section of 50-60° without needles: this empty area accommodates a control unit which transmits the mechanic and electrical commands to all the motions operating during the stitch formation.



*Picture 112 – Variable needle-bed arrangement*

When reaching this control area, the knitting process is interrupted. The thread is cut and retained until, at the end of the control area, the knitting process is resumed. The gripper starts operating before the first needle and retains the thread at the beginning of the work process. Another tool (a cutter) is placed after the last operating needle; the cutter cuts the thread at the end of the course. To increase the number of non-knitting needles, it is sufficient to move the cutters towards the grippers; in this way the knitting area will be varied as desired.



*Picture 113 – Thread cutting and retaining system*

The main characteristic of variable needle-bed machines is the possibility of varying the number of operating needles and, by using special thread cutting and retaining tools, of manufacturing an open cloth whose width can be pre-set according to the desired size; this entails considerable yarn saving.

In practice, these machines create knit products similar to those manufactured on flat bed machines, with a definitely higher output, thanks to a greater number of feed systems compared to the flat bed machines.

From a technical point of view, these machines are offered with 40 or 42-inch diameters for the manufacturing of 277 and 291-cm open cloths, respectively; the available gauges range from E 5 to 18, and the number of stripe pattern motions varies from 4 to 5.

The base number of feed systems is 18 or 24, which can be differently combined in knitting and transfer feed systems: for example 18 knitting feed systems, and a fixed double transfer feed system and extra feed systems replacing the knitting feed systems with the transfer feed systems, or 12 knitting feed systems and 6 transfer feed systems or even 24 feed systems for both knitting and transferring tasks.

The early models of these machines incorporated rotating cam frame and fixed needle-beds. On more recent machine models, however, thanks to the electronic programming systems, the cam frame rotation has been eliminated since machine control is possible without obliging all the feed systems to pass through the head. In the latest versions, the cylinder and dial turn while the cam frames stand still. Stepper motors drive the lowering cams; they adjust the length of the knit stitch which can vary for each course.

Modern machines can grant up to 60 different positions of the lowering cams with an accuracy of 0.1 mm.

To make patterns similar to those obtained from flat bed knitting machines, and typical of outdoor knitted goods (cable, pointed patterns, etc.) these machines must be able to transfer the knit stitches as broadly as possible.

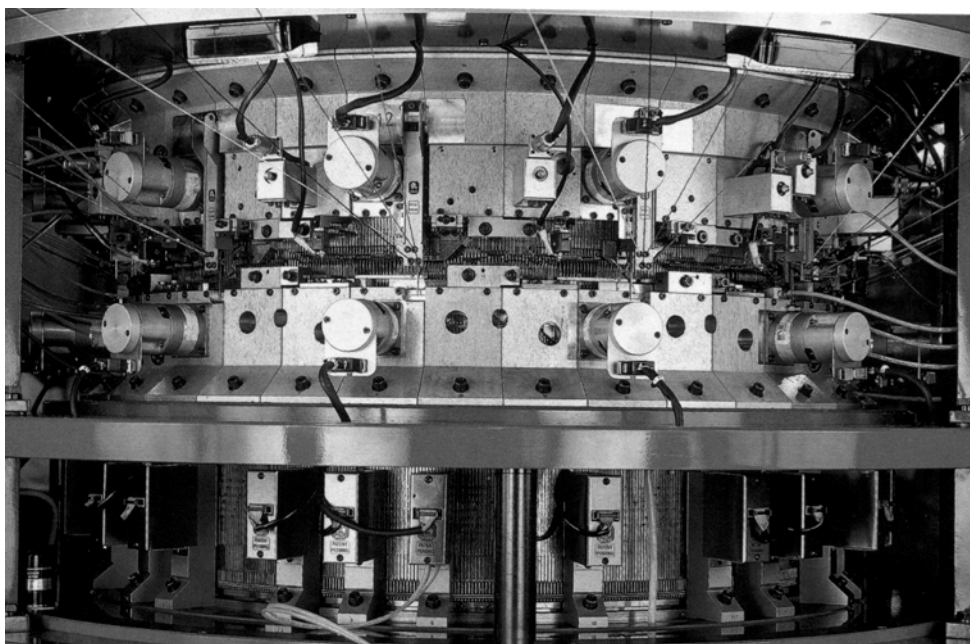
Recent models are equipped with double-direction transfer systems, i.e. from the cylinder to the dial and vice-versa. These machines also allow a quick change-over of all the operating systems, thanks to which the knitting systems can be alternated with the transfer systems. It is also possible to rack the needles of the dial in relation to the needles of the cylinder; some machines even can carry out differentiated transfer techniques.

As far as the needle selection is concerned, some machines allow the 3-way working technique (i.e. knit, tuck and miss stitches) only on the cylinder while more sophisticated models allow the 3-way working technique on both needle-beds, thus increasing the machine versatility.

On the latest machines, electronic needle-by-needle Jacquard selection is carried out by means of piezoelectric actuators.

## Double-cylinder Machines

Double-cylinder circular knitting machines are made up by a base whose central zone houses two circular needle-beds positioned vertically at 180°; the two needle-beds are called lower and upper cylinder.

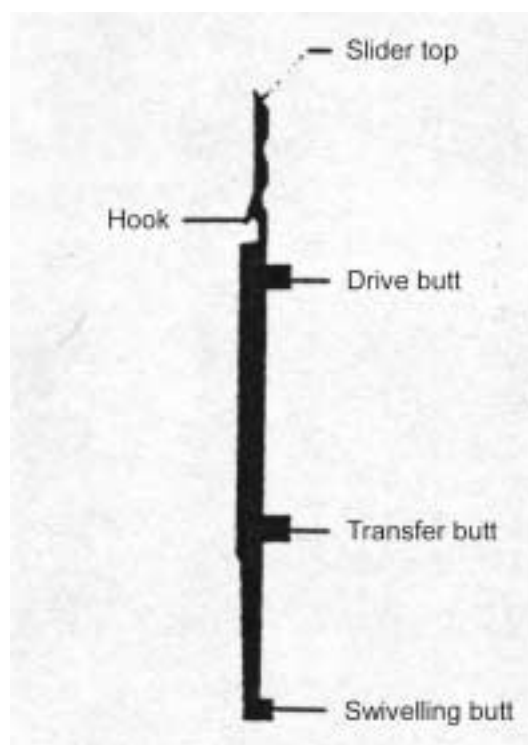


*Picture 114 – Knitting head of a double-cylinder machine (with fixed cam frames and rotating needle-beds)*

The needles are arranged in opposite grooves; these machines feature a single series of double latch needles.

Double latch needles have no butt; therefore an external element must control the needle and drive its movement. This element is called slider. The machine incorporates two series of sliders: one is positioned on the lower cylinder and another one is positioned on the upper cylinder; both series are driven by cams.

The main elements making up the slider are shown in the following picture:



*Picture 115 – Slider for a links links machine*

The feed systems are so arranged to cover the whole profile of the cylinders; each feed system is equipped with its yarn guide.

In these large-diameter circular machines generally the cam frame rotates while the needle-bed and the spool rack stand still.

The technical characteristic of this machine is that, to realize the knit stitch structures, the needles can be transferred from one needle-bed to the other one, instead of transferring the loop from one needle to another one.

Double-cylinder circular knitting machines have been specifically designed to manufacture patterns with plain and purl knitting effects, the latter also called links-links effects.

The most usual types of stitch carried out on these machines is the plain stitch – that can be obtained by making all the needles operate on the lower cylinder – and the purl stitch, obtained by making all the needles operate on the upper cylinder. The base links links stitch pattern is obtained by alternating one plain stitch course with a purl stitch one; in this case the needle passes from the lower cylinder to the upper one and vice versa after knitting each course.

### **Stitch Formation and Needle Transfer**

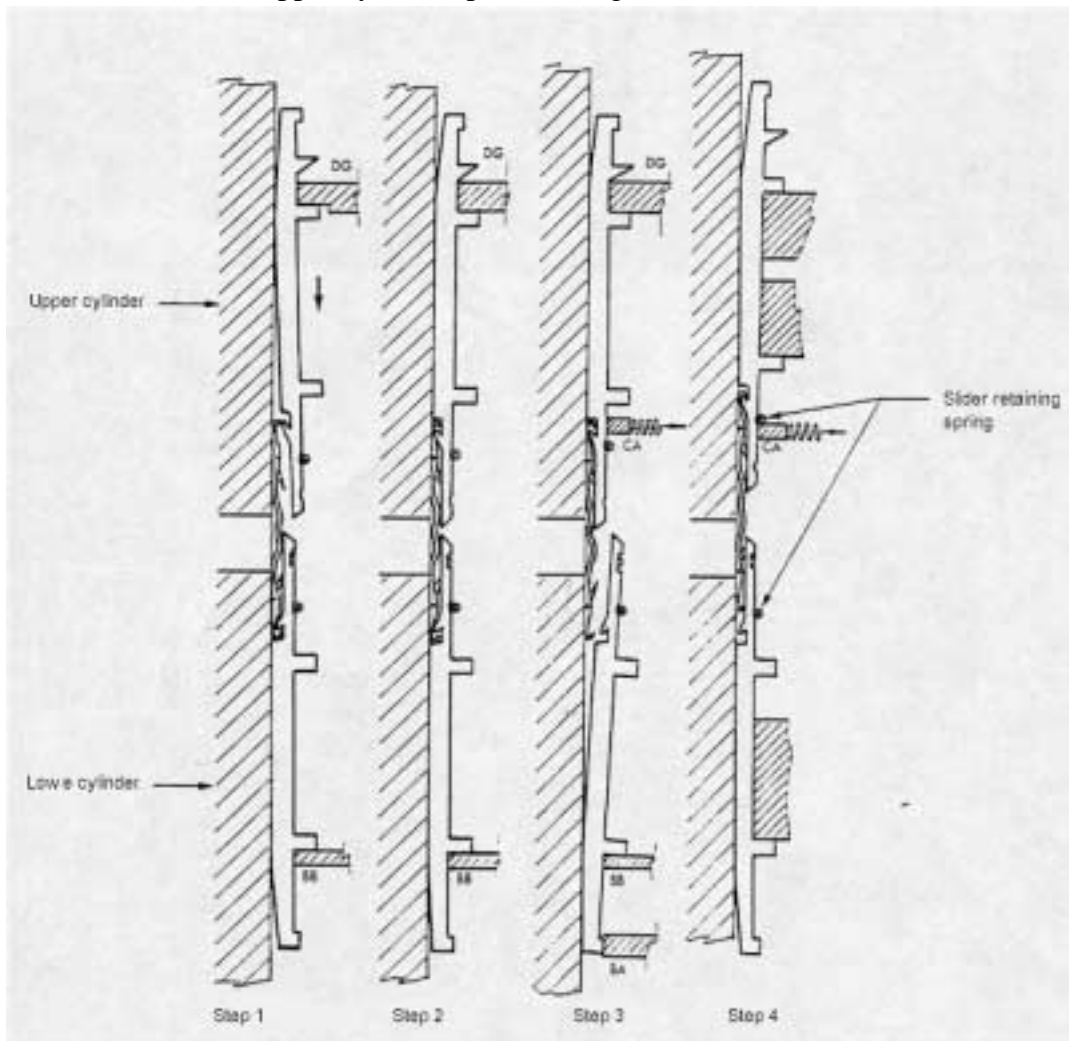
The movements necessary for the stitch formation and for transferring the needle from one cylinder to the other can be briefly outlined as follows (picture 116):

STEP 1: The double latch needle is locked by the slider on the lower cylinder and starts rising driven by the butt of the slider.

STEP 2: The needle reaches a position that allows the slider of the upper cylinder to lock its head.

STEP 3: The needle taken by the upper cylinder is released from the slider of the lower cylinder.

STEP 4: The needle is transferred to the upper cylinder; the thread fed by the thread guide is received under the hook; the knocking-over of the previous stitch and the formation of the new one are carried out on the upper cylinder (purl knitting).



Picture 116 – Needle transfer on links links machines

All the commands on this type of machine can be mechanically or electronically controlled. The mechanical control unit frequently relies on punched cards which store all the information necessary for controlling all the machine motions, for example the cam locks, the stripe pattern motions etc. The needle selection is performed by means of the butt sliders; many machines offer the possibility of controlling the needle selection by means of turrets that can drive the jacks arranged on the lower cylinder below the sliders. The arrangement of the jacks can be the symmetrical or the diagonal type; the width of the pattern area is strictly related to number of jacks.

On electronically controlled machines, needle-by-needle selection is carried out by means of individual magnets that drive the slider butts. These machines are now offered in a restricted number of versions for the manufacturing of cloths and fabrics with welt and separation thread. The diameter is usually 33 inches, the gauge ranges from E 4 to 14 and the number of feed systems is generally limited to 12.

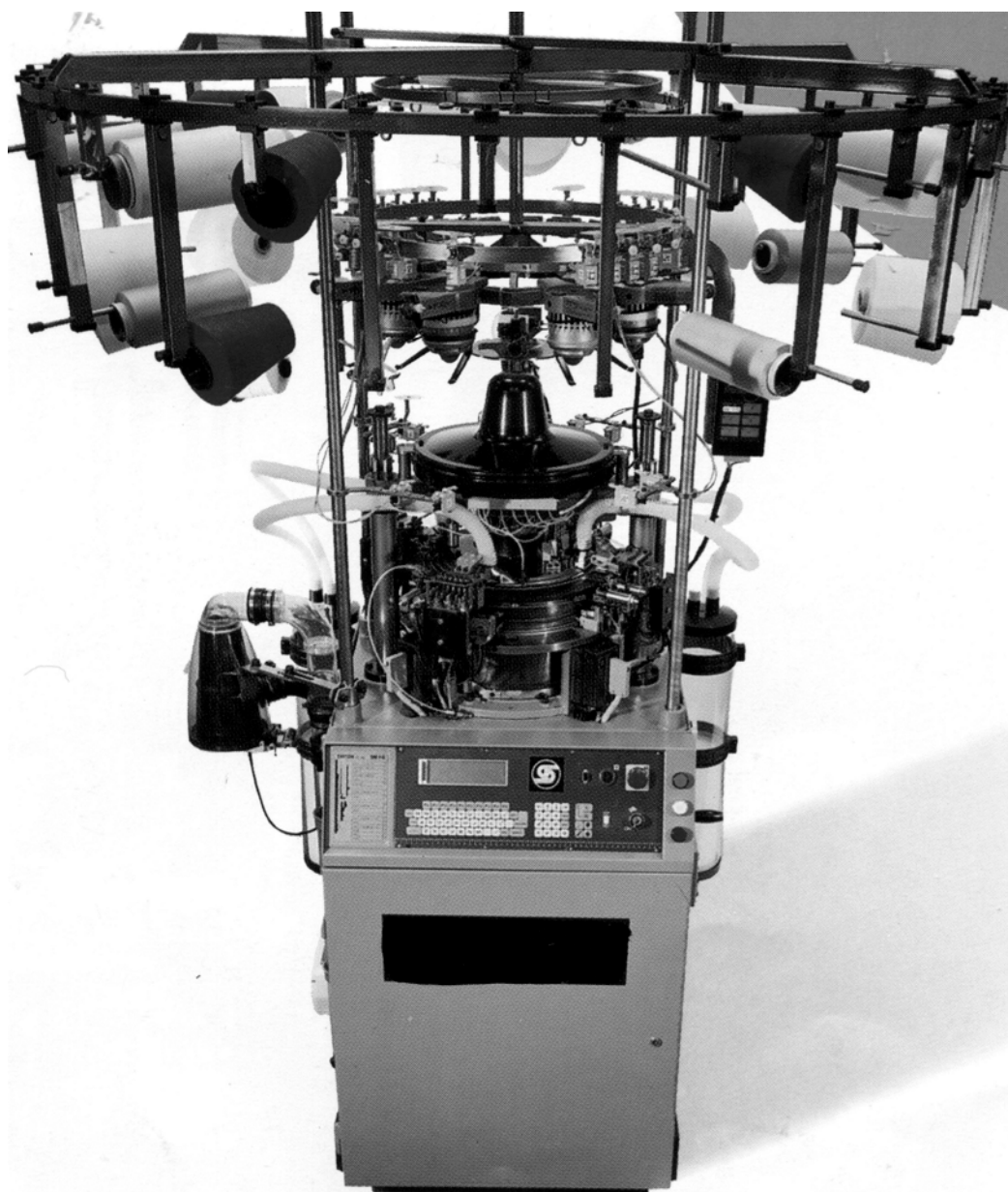
## Medium-diameter Knitting Machines

### Medium-diameter Cloth-manufacturing Machines

From a technical point of view, all the machines with a diameter ranging from 8 to 24 inches must be considered medium-diameter knitting machines.

Many manufacturers of circular knitting machines offer single and double-bed machines, special versions whose diameter allows them to be classified as medium-diameter circular knitting machines. Obviously, from many points of view, these machines are quite identical (engineering solutions, operating mode, types of product) with large-diameter models.

### Bodysize / Seamlesswear Machines



*Picture 117 – A medium-diameter circular knitting machine*

Bodysize machines represent a particular and fundamental category of medium-diameter machines, as they can manufacture full-fashioned and separated tubular cloths with simple, double or elastic welt or continuous fabrics with diameter specifically set according to the desired size, for the production of seamless knit fabric, mostly for underwear, bathing suits and medicalwear.

To be more precise, the most common technical features of the latest single-bed machines are: 10 to 24-inch diameter, gauge ranging from E 7 to 32, 8 feed systems, stripe pattern motions with 7 thread guides, adjustment of the stitch formation by means of stepper motors operating separately on each feed system, possibility of 2-way working technique on 8 feed systems and 3-way working technique on 4 feed systems, 8 selection actuators with 16 operating levels.

Furthermore, all these machines are equipped with positive yarn feeders for standard and elastane yarns (for elastic welt manufacturing). The machines for the manufacturing of separated cloths incorporate suction systems for thread-to-thread separation while machines that manufacture seamless knitted goods incorporate electronically-programmable take-down and winding systems and also an electronic control system.

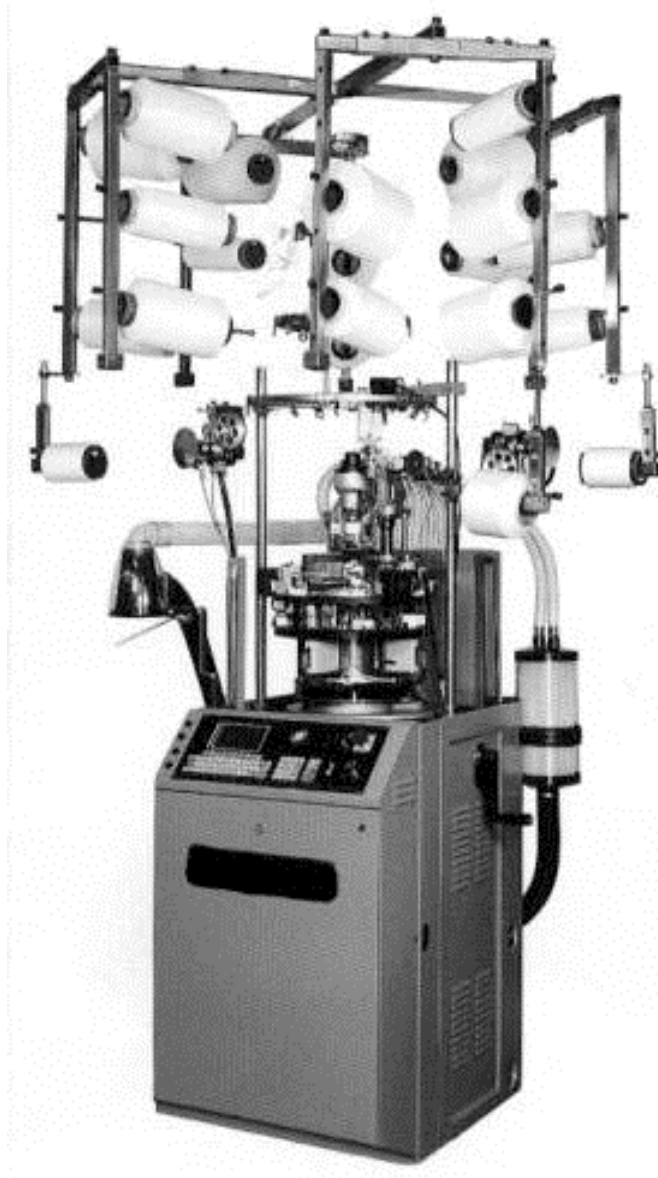
Double-bed bodysize machines generally feature a diameter of 14 to 22 inches, E 12 to 15 gauge, a number of feed systems varying according to the diameter (but always resulting from the combination of the feed systems to knit or to transfer the stitch – e.g. 8+4T, 12+6T), 4-colour stripe pattern motions, electronic selection by means of individual magnets that in some models can be only attached to the cylinder, and in others to both the dial and the cylinder, the possibility of racking the needles of the dial with the needles of the cylinder, positive yarn feeders and electronic take-down motion.

## **Small-diameter Circular Knitting Machines**

All the machines with a diameter ranging from 3 to 5 inches and which are mainly used for hosiery production are classified as small-diameter circular knitting machines.

There are many types of machines in the hosiery field, but basically they can be subdivided into two main categories in relation to the goods they manufacture:

1. Machines for fine stocking and tights
  - single-cylinder machines
  
2. Machines for men's socks
  - single-cylinder machines
  - single-cylinder machines with needles in the dial (rib machines)
  - double-cylinder machines



*Picture 118 – Overall view of a hosiery machine*

The fundamental construction elements of a hosiery knitting machine are usually:

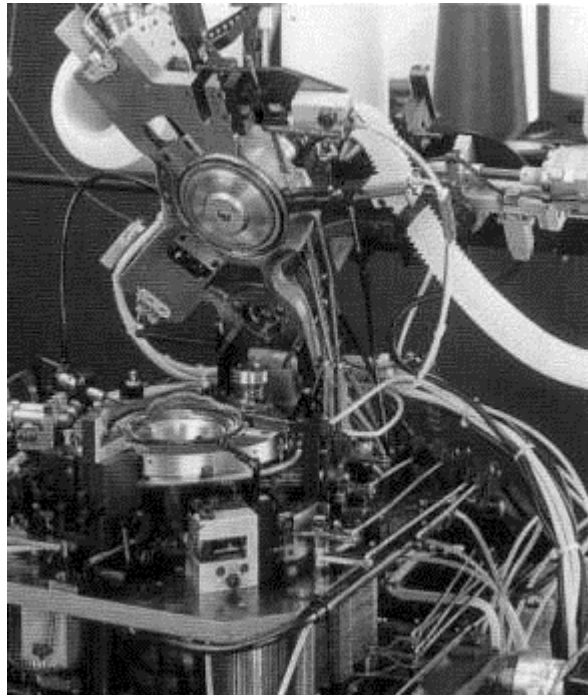
- a spool rack and the ground and elastane yarn feeding system, generally equipped with a separate control system
- knitting head including the needle-bed and the motions that command the elements operating during the stitch formation
- pneumatic system to recall the hosiery models
- machine base with drive, control and command systems. On modern machines, the mechanically control system with cam drum and chain has been superseded by electronic control systems with actuators.



## Single-cylinder Machines

From a technical point of view, these machines should be classified as single-bed machines since they incorporate only one series of needles assembled in a cylindrical needle-bed and a series of sinkers which operate, together with the needles, during the stitch formation process. The selection is carried out by means of sliders and the movements are transmitted to the stitch formation motions by means of cams.

A special motion called “dial” is assembled above the cylinder; the dial integrates special hooks which operate during the formation of the double welt and the automatic closing of toe.



*Picture 119 – Knitting head of a single-cylinder machine with the needles in the dial*

These machines are available in fine gauges for the manufacturing of women’s fine stockings and tights, as well as in coarse gauges for the manufacturing of sports and men’s socks.

The most recent technological trend aims to standardise the models of all manufacturers, i.e. manufacture fully electronic machines and simplify the machine by reducing the number of feed systems, making it faster and more cost-effective.

The basic technical features of these machines are: 4 to 6-inch diameter, 4 to 6 feed systems, completely electronic needle-by-needle selection by means of 16-level actuators, possibility of knitting heel and toe with a reciprocating motion, speed up to 1,000 rpm for simple patterns and 500 rpm for more complicated patterns.

Hosiery items can be manufactured in two different ways: the traditional cycle is based on full-fashioned heel and toe: in this case, when knitting the heel and the toe, only some needles operate along with one or two feed systems, and the cylinder rotates with a reciprocating motion.

The machines operating this way usually incorporate 4 feed systems, generally the first one works during the formation of the leg and the foot and when knitting the full-fashioned heel and toe, and has a larger number of thread guides (up to 7) while the other feed systems only work during the leg and foot formation and have less thread-guides (up to 5).

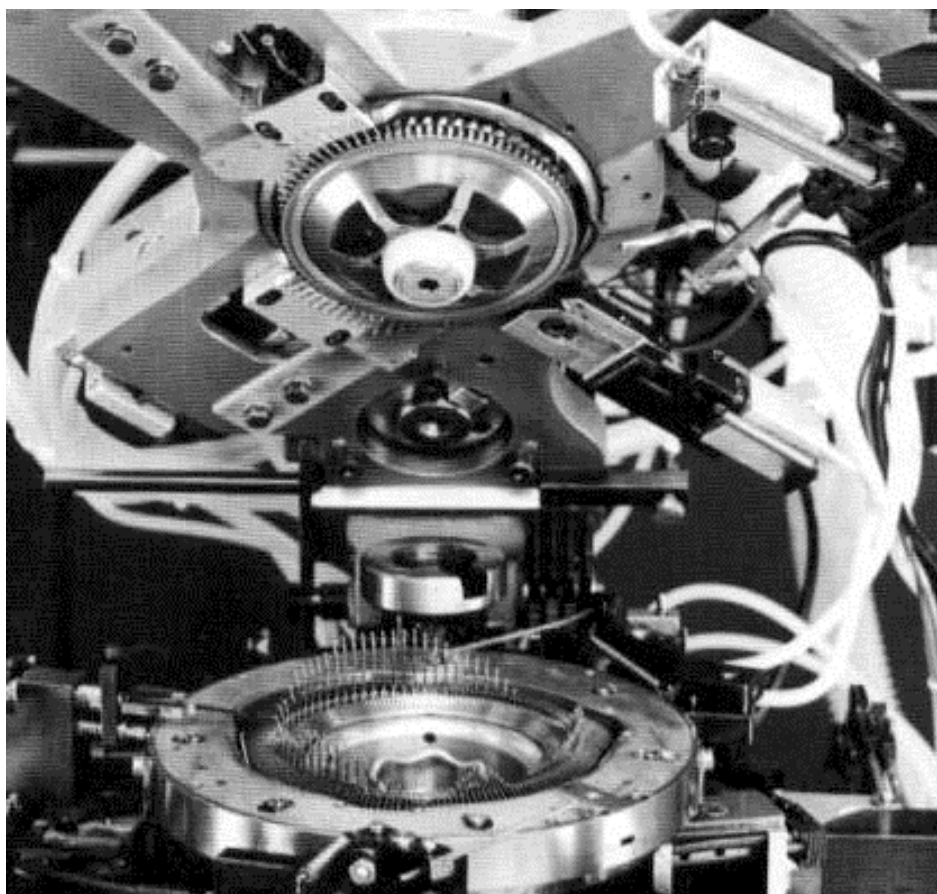
An alternative solution to this knitting technique is “tubular” knitting, i.e. the manufacturing of hosiery without toe or heel. Thanks to this process the toe is originally open and sewn at a later stage; on modern machines, the toe can be also sewn automatically during the production process. These machines are less complicated from a mechanical point of view and allow a higher throughput speed over the whole knitting cycle. However, the quality of hosiery produced on these machines is poorer if compared to the quality of articles with full-fashioned heel and toe.

On many single-cylinder models the number of colours of the pattern designs are strictly related to the number of feed systems assembled on the machine; several machine models can also carry out terry stitches.

### **Single-cylinder Machines with Needles in the Dial (Rib Stitch)**

The design of single-cylinder machines with needles in the dial partly reflects the design of single-cylinder machines: in these machines the hooks in the dial have been replaced with needles to obtain a structure of the knitting head similar to the one of the dial-cylinder machines which produce rib knit patterns.

From a technical point of view, the main limit of these machines is represented by the restricted possibility of selecting the needles in the dial as a result of the smaller diameter of the dial, allowing the use of needles with a single butt level with different heights and then the possibility of making only a few rib stitch patterns (1x1, 1x3, 1x5).



*Picture 120 –Knitting head with single cylinder and needles in the dial*

The basic features of these machines are 3 to 5-inch diameter, 2 to 4 feed systems, average E 6 to 16 gauge with minimum E 3.5 and maximum E 22, electronic needle-by-needle selection by means of 16-level actuators, possibility – on a lot of machine versions – of knitting plain terry, plating and Jacquard designs, of knitting heel and toe with reciprocating motion virtually on all the most recent machine models, 300 rpm maximum speed with simple patterns and 200 rpm with more elaborated patterns.

## **Double-cylinder Machines**

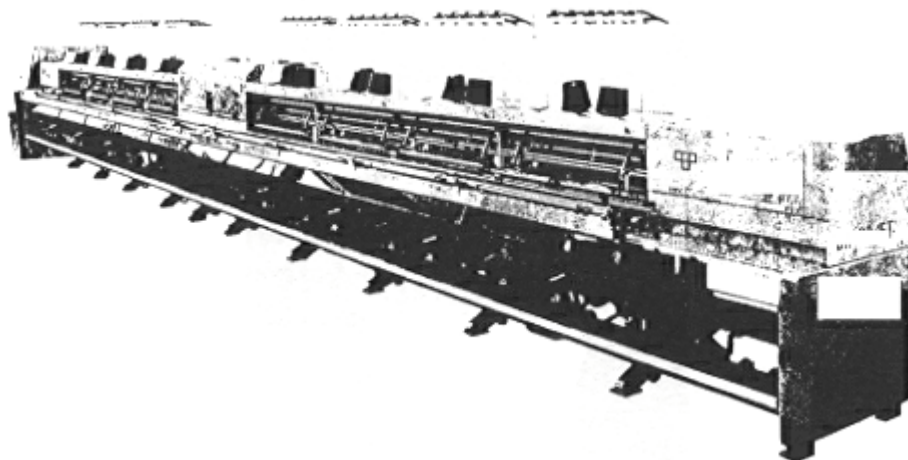
These machines for the manufacturing of men's socks have had to face tough competition from simpler single-cylinder machines with needles in the dial; in fact, now only a few machine manufacturers offer double-cylinder machines, despite the indisputable excellent quality of the rib socks they produce.

From a technical point of view, small-diameter/double-cylinder machines feature one series of double latch needles which can work either in the lower or in the upper cylinder. The stitch formation and the needle transfer are carried out the same way as on double-cylinder/large-diameter machines.

Technical development in this field points towards higher throughput speeds with the same number of the feed systems (from 2 to 3). Usually, these machines too incorporate electronic drive and needle-by-needle selection systems.

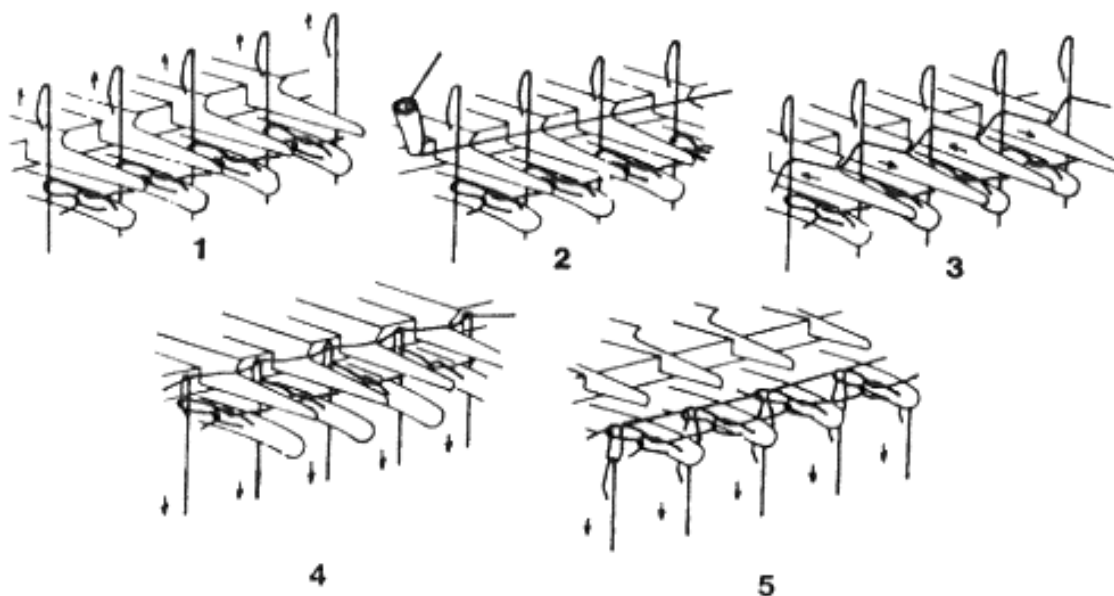
## Full-fashioned Knitting Machines

The full-fashioned knitting machine in picture 121 features from 4 to 12 sections. This machine has a single needle-bed provided with spring beard needles.



*Picture 121- Full-fashioned knitting machine*

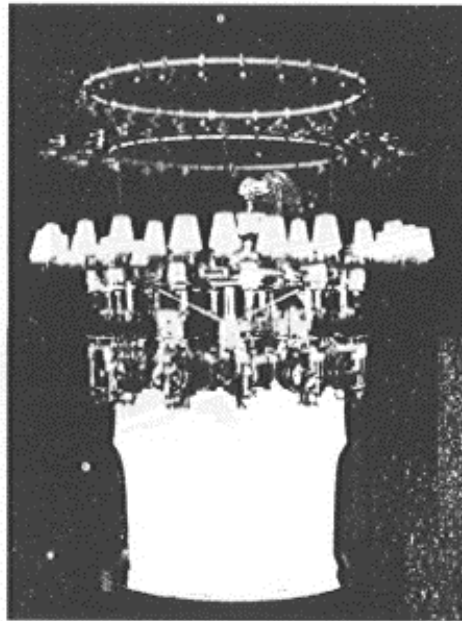
During the stitch formation cycle (picture 122) the needle bar rises while the fabric is held down by the nose of the sinkers. After being fed by the thread guides, the needles lower while the presser closes their hooks. In the meantime the separation and float sinkers withdraw. The already formed course slips out over the closed hook and a further downward stroke of the needles knocks over the previous stitches forming a new course.



*Picture 122 – Stitch formation cycle on a full-fashioned knitting machine*

## Loop-wheel Circular Knitting Machines

Loop-wheel circular knitting machines, or “mailluse” in French (picture 123), incorporate a circular needle bed in which spring beard needles are arranged horizontally.

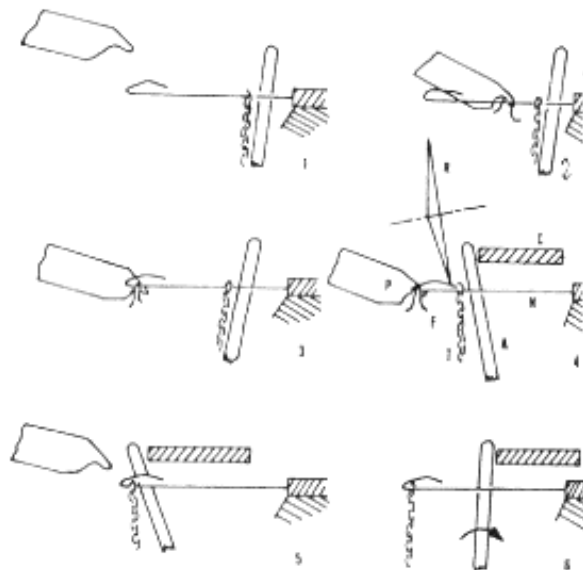


*Picture 123 – A loop-wheel circular knitting machine*

During the stitch formation cycle (picture 124) the needle moves close to the looping wheel. The corresponding sinker lowers and lays the thread on the needle stem; the sinker then moves outwards bringing the loop inside the hook.

The needle reaches the presser which closes the hook.

The loop on the stem is pushed by vertical sinkers upwards until it reaches the closed hook and is knocked over on the new thread.

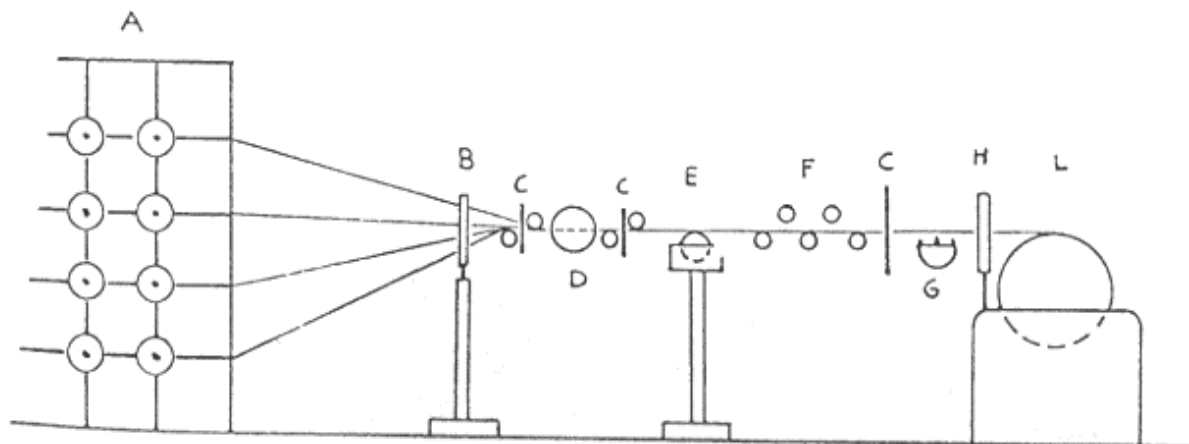


*Picture 124 – Stitch formation cycle on a loop-wheel circular knitting machine*

## Warping

The yarn to be used on warp knitting machines is wound on cylindrical elements, called warp beams, provided with two lateral flanges.

The preparation of warp beams (i.e. warping) is performed upstream to the knitting stage (picture 125).



*Picture 125 – Layout of a direct warping system*

The single threads are unwound from packages or cops placed on a creel (A), and then conveyed through a reed (B) while special eyelets keep them separated. Thereafter, they pass through two toothed reeds (C) monitored by a photoelectric instrument (D) that detects the presence of broken filaments or detached fibres.

The system also incorporates an oiling system (E) and a buffer device (F) for the yarn which stores the warp when the beam is counter-rotated to find a broken filament.

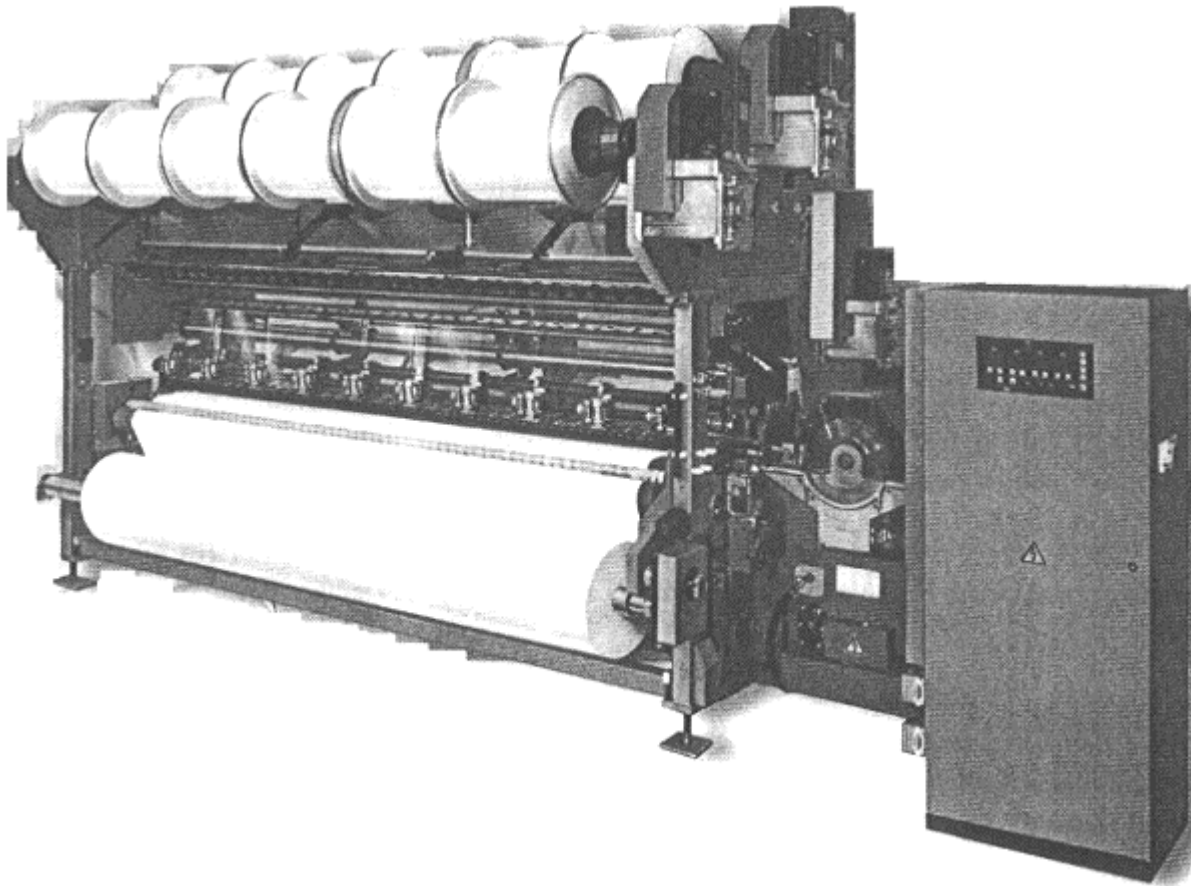
The threads pass through a ionising apparatus (G) which eliminates electrostatic charges, then through a reduction reed (H). Finally, the warp threads are wound on the warp beam (L): in this last stage, the threads run very close to one another in overlapping layers of uniform density and tension prior to being wound onto the beam.

## Warp Knitting Machines

Warp knitting machines (picture 126) are used in the production of run-proof fabrics. The frame of a warp knitting machine must be particularly sturdy and resistant since it must accommodate a number of moving components.

All the motions that operate during the stitch formation process are driven by a shaft: each driving shaft revolution corresponds to the formation of a course of stitches.

The needles can be fed with different yarns, taken up from the warp beams placed above the machine.



*Picture 126 – A typical warp knitting machine*

## The Guide Bar

The threads are unwound from the beam and pass first through the tensioning bars and then through special holes called “guides”, that are all positioned on the same “guide bar”.

The number of guides depends on the number of needles on the knitting machine; the guides can be threaded-in or not. The threading-in can be either the full or the varied type according to the pattern to be knitted.

The guides are raised and moved sidewise to form a course of loops simultaneously when the needles are drawn down through the loops of the previous course.

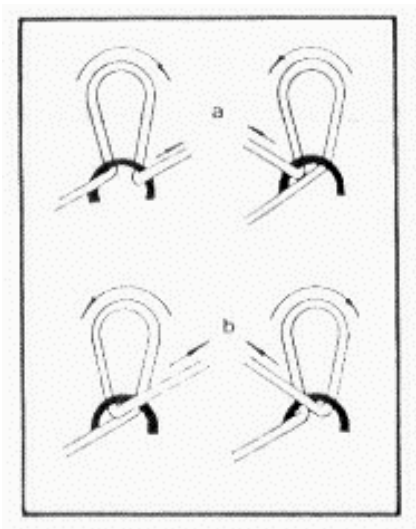
In detail, when the knitting process begins, the guides are behind the needles. By moving sidewise, they pass between one needle and the next, positioning themselves in front of the needles. Then the guides move laterally, usually by one needle, or by two needles in case of double stitch patterns.

This movement can be carried out in both directions and therefore the thread, driven by the guide, can feed the needle either on its left or on its right.

After laying the thread over the needle stop, the guides swivel and perform the return travel taking the needles back with them.

At this point, the guide can stand still to make an open stitch (picture 127a) or float laterally by one or more needles.

When this movement is made in opposite direction with respect to the thread feed movement, the resulting stitch will be a closed one (picture 127b), whereas if both movements have the same direction, the resulting stitch will be an open one.



*Picture 127 – Open (a) and closed (b) stitches*



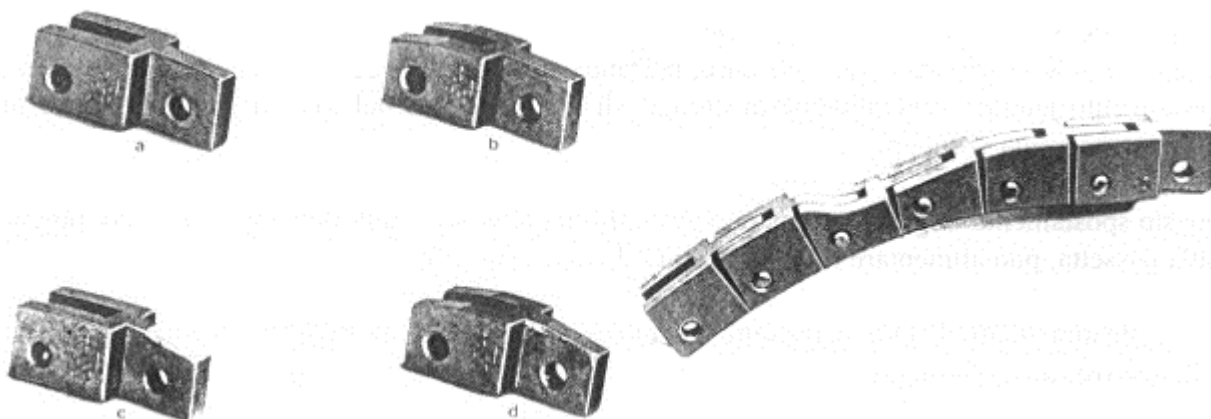
Since the yarn guides are built into the same guide bar, they all make the same movements simultaneously.

The machine incorporates several guide bars (or bars); the knitting process can be carried out with a single bar or with several bars which move independently of one another.

### The Guide Bar Chain

The lateral movement of the bars that impart the float and overlay movements to the guides can be also obtained using profiled discs or a special chain with links of various heights (the so-called “glider chain”).

The chain links can have different heights and lateral radii with respect to one another (picture 128)



*Picture 128 – A chain link*

*Picture 129 – Chain with links of different height*

The radii grant a smooth changeover from one link to another (picture 129) and avoid great differences in the acceleration of bars, thus granting higher operating speeds.

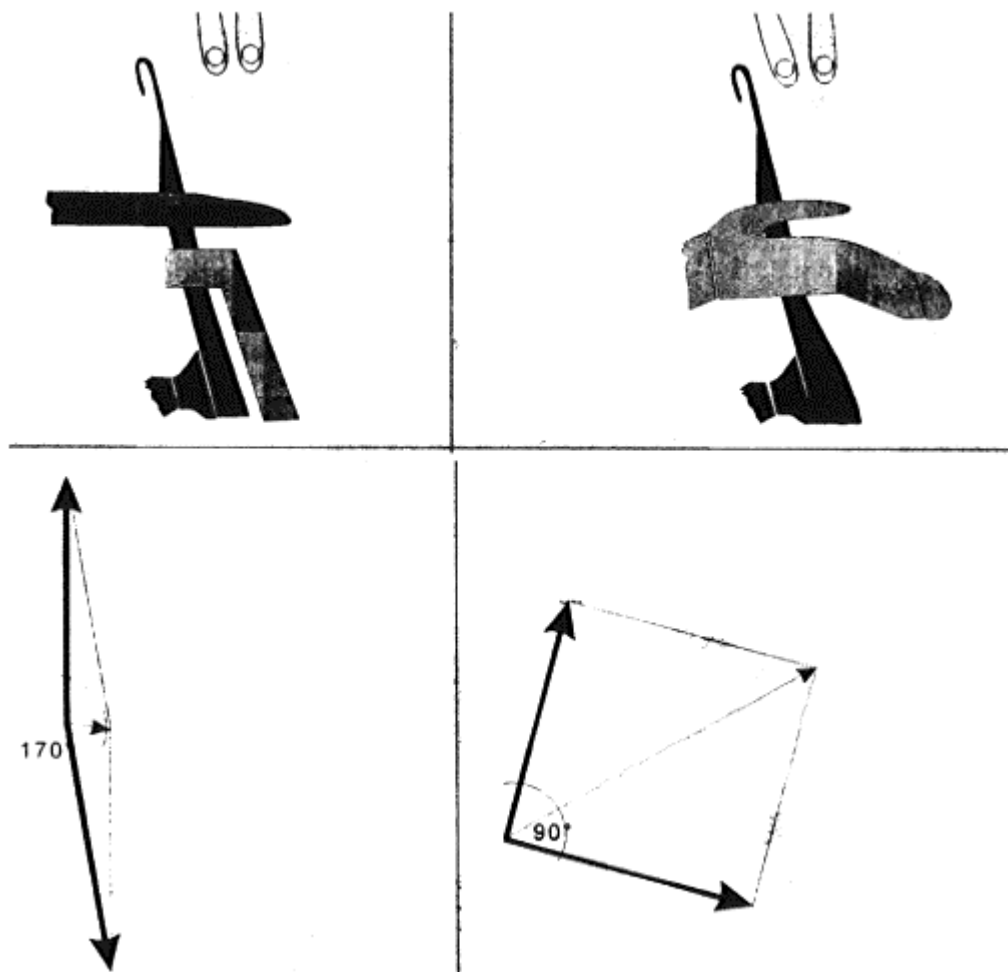
## Classification of Warp Knitting Machines

Warp knitting machines can be divided into flat warp knitting machines and Raschel machines. They can have a single or a double needle-bed.

Flat warp knitting machines are equipped with spring beard needles or compound needles, while Raschel machines incorporate latch needles or compound needles.

The sinkers of flat warp knitting machines feature a nose, a throat and a breast, and pull the fabric perpendicularly to the needle direction.

Raschel machines incorporate sinkers with nose only; as the fabric is manufactured, it is dropped in a direction almost parallel to the needle direction (picture 130).



*Picture 130 – Pulling direction of the fabric on a Raschel machine (left) and on a flat warp knitting machine (right)*

## Stitch Formation on Flat Warp Knitting Machines

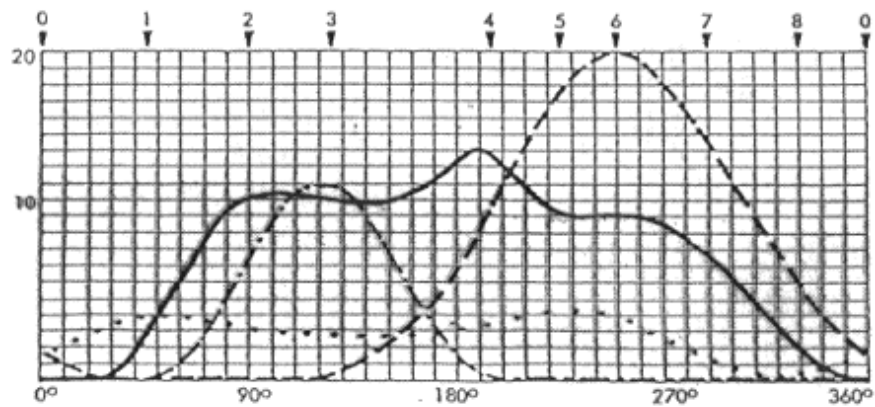
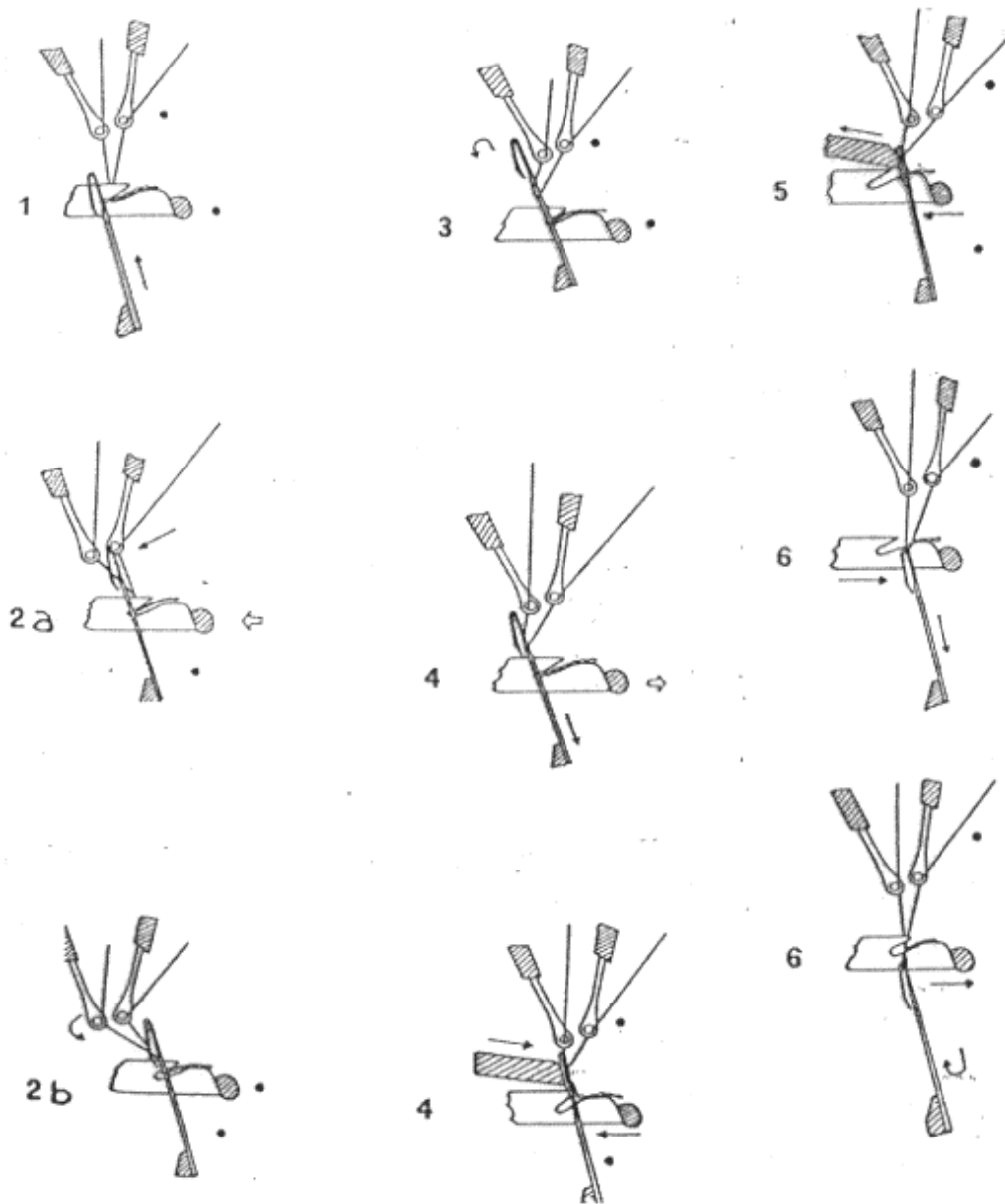
### Flat Single-bed Warp Knitting Machines with Spring Beard Needles

The components operating during the stitch formation cycle on flat single-bed warp knitting machines with spring beard needles are the following:

the needles – the guide bars – the sinkers – the presser.

Picture 131 shows the various steps of the stitch formation cycle and the diagram of the machine movements, which shows the paths of the various components operating during a single revolution of the driving shaft.

1. The needle is in its knock-over position and starts rising; the sinker approaches and holds the stitch in the throat; the guide, initially positioned behind the needle, starts moving.
2. The needle reaches its relative maximum height and stops to let the guide pass and position in front of the needle.  
With the needle in its standstill position, the thread is fed and laid over the needle stop; the sinker withdraws slightly to reduce the thread tension during the feeding step.
3. Since the feeding operation has been carried out above the spring beard of the needle, the needle rises further and reaches its absolute maximum height to let the thread slip on the stem; in the meantime the guide returns behind the needle while the sinker is approaching the needle.
4. The needle starts lowering and the thread enters the hook; at this point the presser closes the needle hook, which is now in its standstill position.
5. Now the previous stitch, which is still on the needle stem, must be knocked over on the next thread.  
The needle cannot lower since it is still touching the presser; therefore the sinker is withdrawn so that the stitch in the throat can move upwards along the slant section of the throat and above the hook.
6. The presser withdraws and the needle starts lowering again; the stitch moves above the hook and once the needle has reached its bottom position, it knocks over on the next yarn, thus creating a new stitch. In the meantime the sinker has withdrawn and now holds the fabric with its breast.  
The guide can now move sidewise for the floating movement.



Picture 131 – Stitch formation cycle on a flat single-bed warp knitting machine equipped with spring beard needles

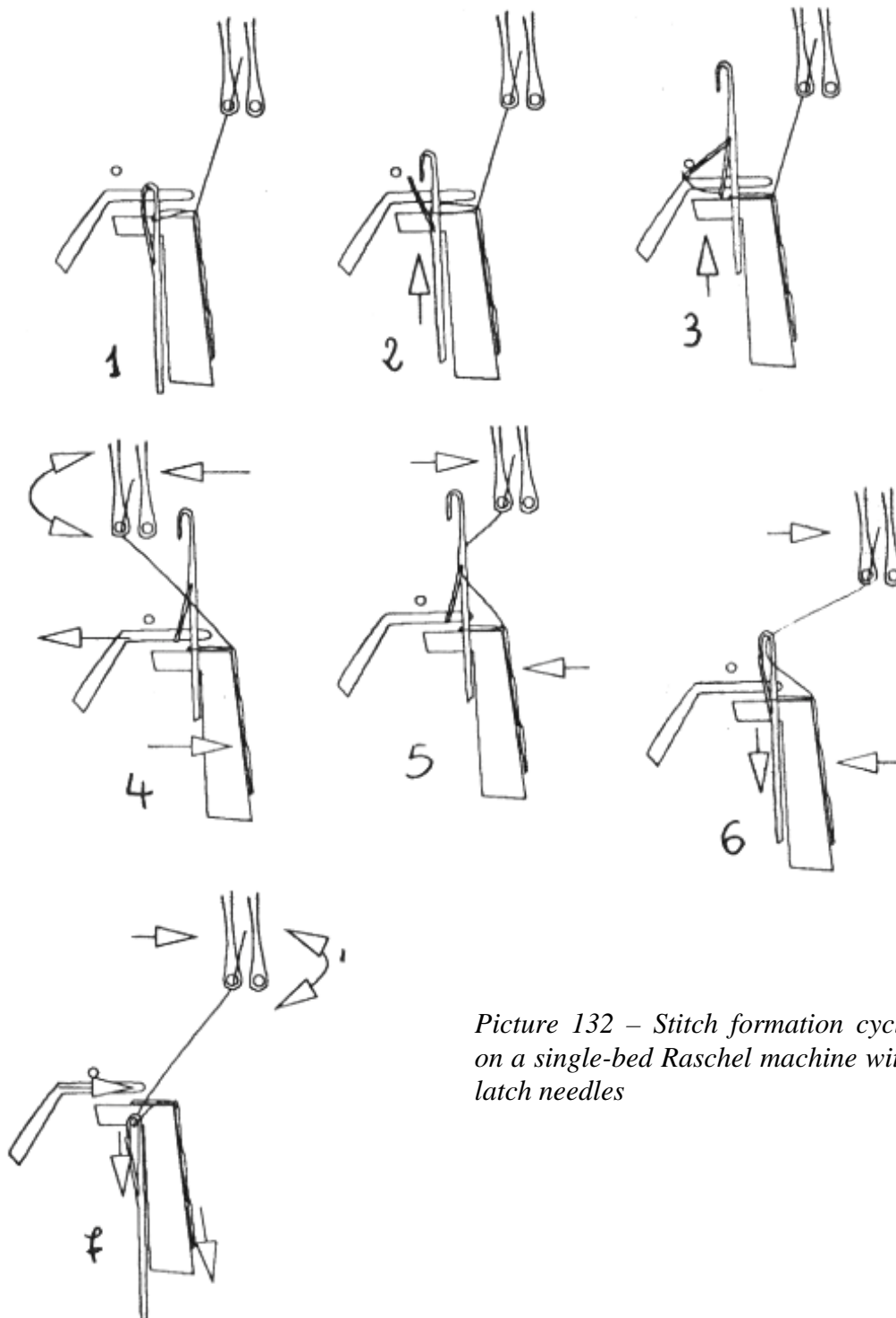
## Single-bed Raschel Machines with Latch Needles

The stitch formation on these machines (picture 132) differs slightly from the stitch formation on flat warp knitting machines with spring beard needles.

Single-bed Raschel machines with latch needles incorporate the following working components: the needles – the guide bars – the sinkers.

Sinkers only feature a nose, which retains the stitch while the needle is rising.

The fabric is sustained by a plate and is delivered in a direction almost parallel to the needle.

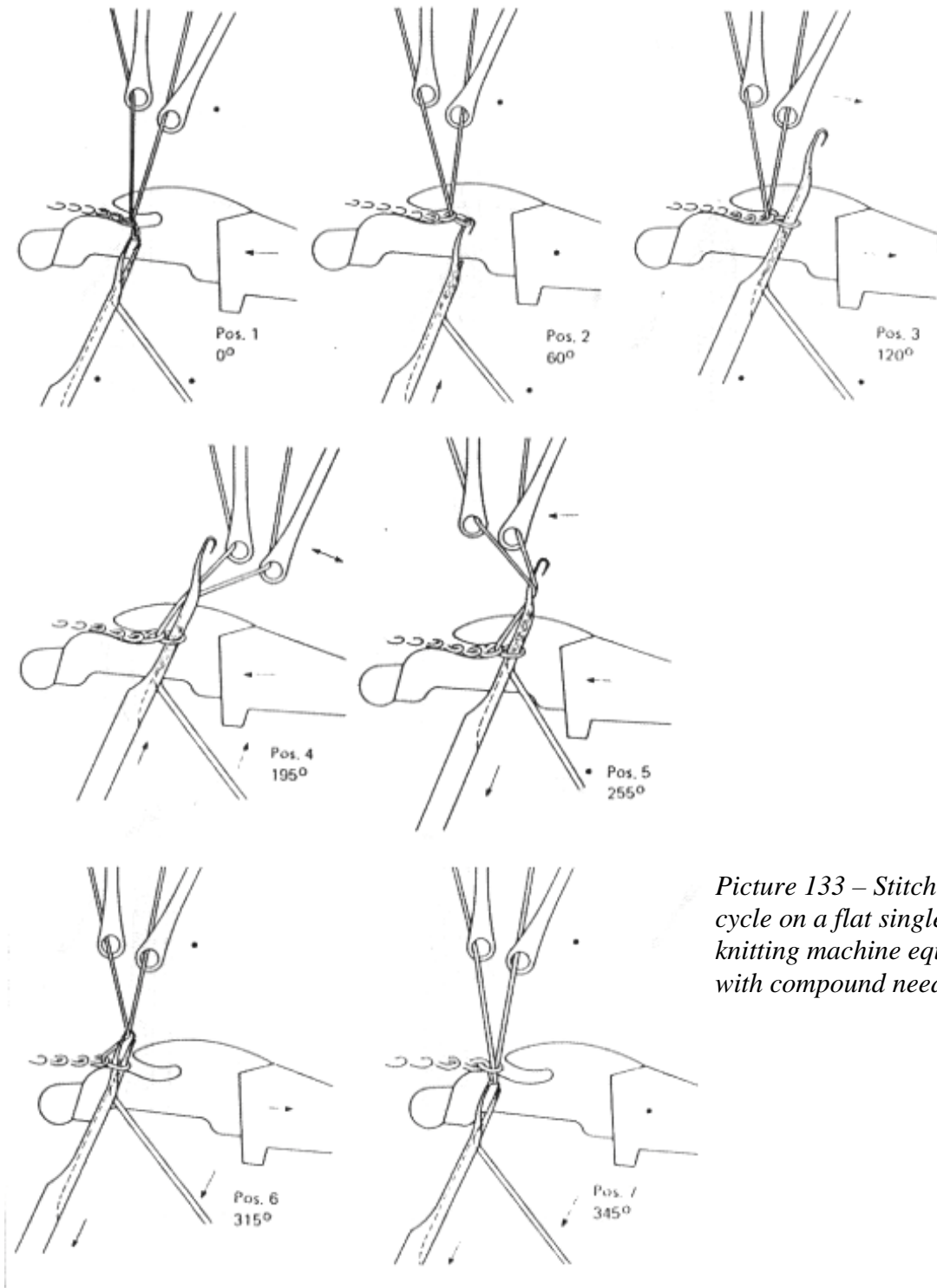


*Picture 132 – Stitch formation cycle on a single-bed Raschel machine with latch needles*

## Flat Single-bed Warp Knitting Machines and Single-bed Raschel Machines with Compound Needles

Pictures 133 and 134 show the stitch formation cycle on single-bed machines equipped with compound needles.

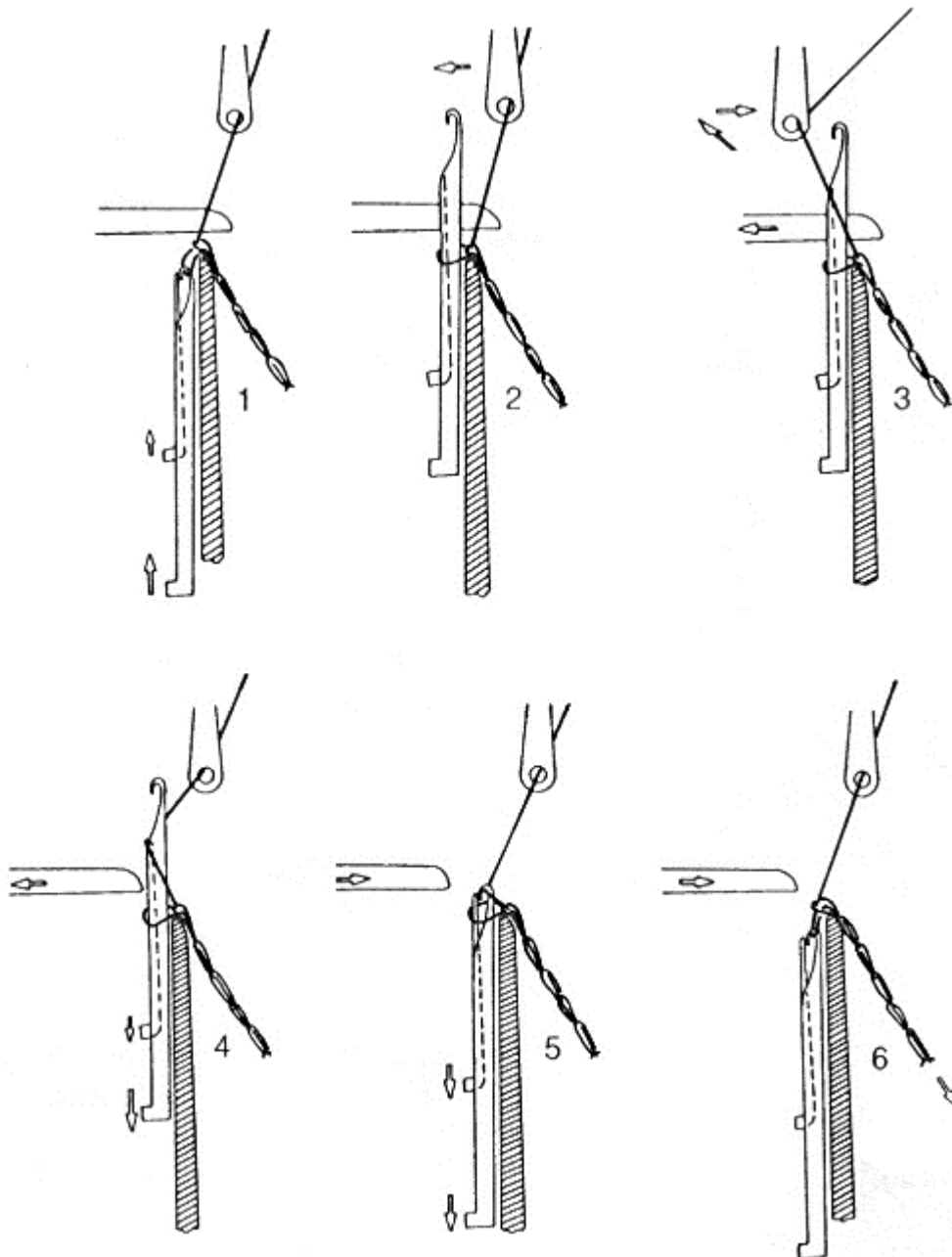
These machines feature the following working components: the needles – the compound needle sliders – the sinkers – the guide bars



*Picture 133 – Stitch formation cycle on a flat single-bed warp knitting machine equipped with compound needles*

The different shape of sinkers, which pull the fabric in different directions, is a distinguishing feature for these two types of warp knitting machine.

The motion of the compound needle slider with respect to the needle limits the maximum raising height of the needle itself, and therefore allows a consistent increase in throughput speeds. Furthermore, compound needles reduce the thread tension and therefore the stitch is more balanced and uniform.

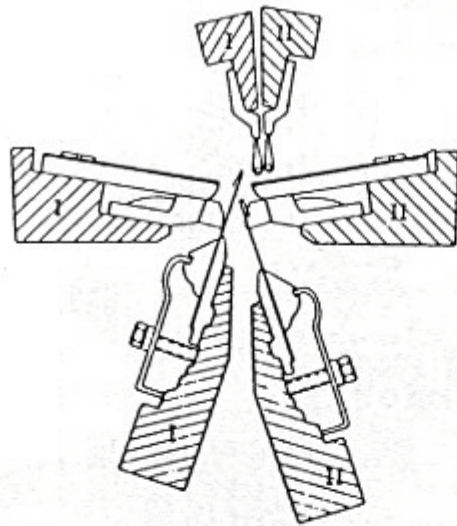


*Picture 134 – Stitch formation cycle on a single-bed Raschel machine equipped with compound needles*

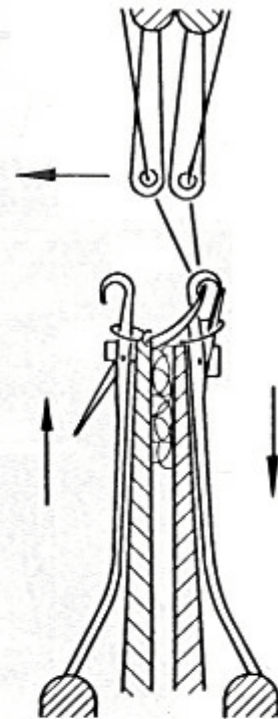
## Flat Double-bed Warp Knitting Machines and Double-bed Raschel machines

The stitch formation cycle on double-bed machines is similar to single-bed machines. The difference is that these machines incorporate two needle beds with their hook turned outwards, two grooved plates supporting the fabric and a single group of bars working alternatively with both the needle-beds, forming the stitch first with the needles of one bed and then with the needles of the other.

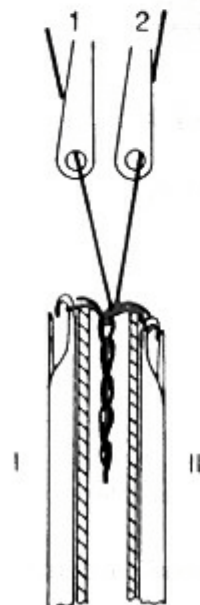
Double-bed machines can incorporate spring beard needles (picture 135), in this case they produce Simplex fabrics, latch needles (picture 136) or compound needles (picture 137).



*Picture 135 – Stitch formation cycle on a flat double-bed warp knitting machine equipped with spring beard needles*



*Picture 136 – Stitch formation cycle on a double-bed Raschel machine equipped with compound needles*

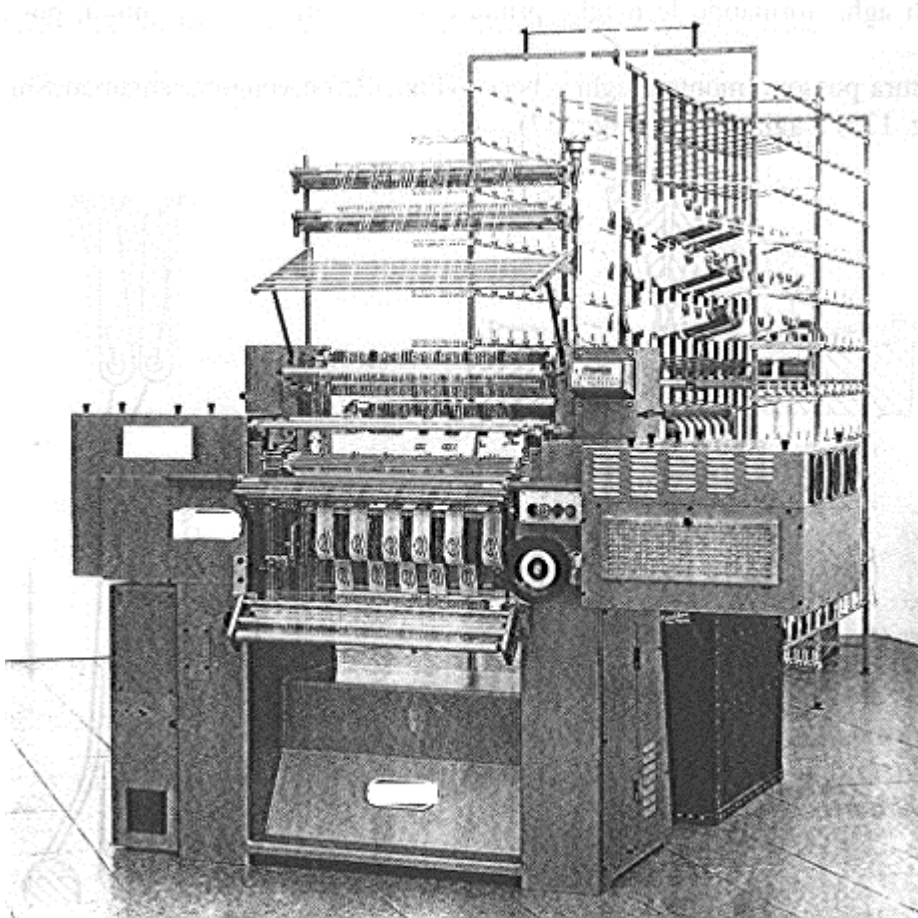


*Picture 137 – Stitch formation cycle on a double-bed machine equipped with compound needles*



## Crochet Machines

Crochet machines are a category of warp knitting machines as they deliver warp knit fabrics.



*Picture 138 – Electronic crochet machine for laces*

These machines create products with different features and applications:

- narrow fabrics such as laces, bandages and ribbons
- trimmings
- technical and medical textiles
- underwear and outerwear fabrics
- furnishing fabrics

According to their engineering features, crochet machines can be divided into:

- conventional machines driven by glider chain
- machines with weft bar driven by a weft insertion system, without glider chain
- machines with microprocessor-controlled weft bars

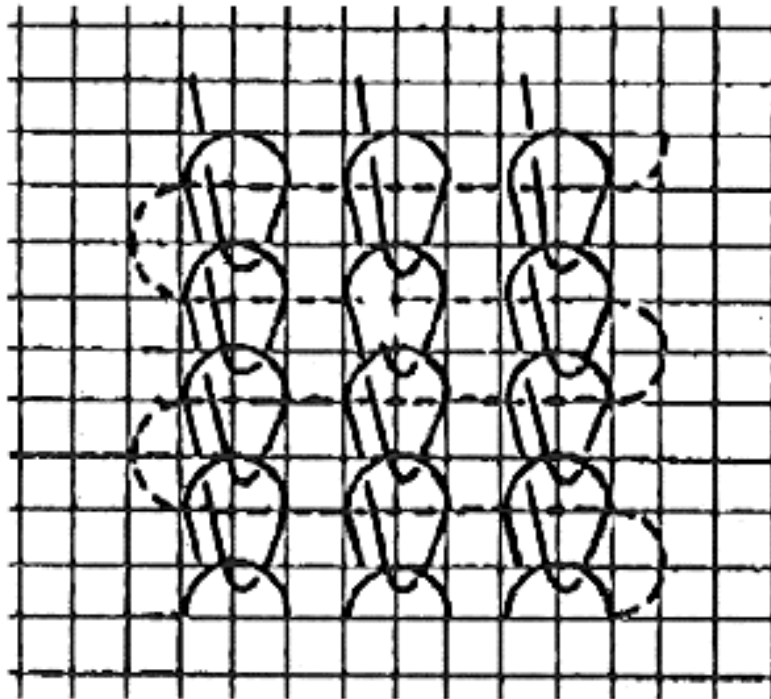
Crochet machines can incorporate spring beard needles, latch needles or compound needles.

The most recent electronic models include up to 16 weft bars to create elaborated patterns; the pins that in the past were used for driving the bars of conventional machines have been first replaced with glider chains, and then with electronic control systems.

The operating speed of these machines can reach 2,000 rpm.

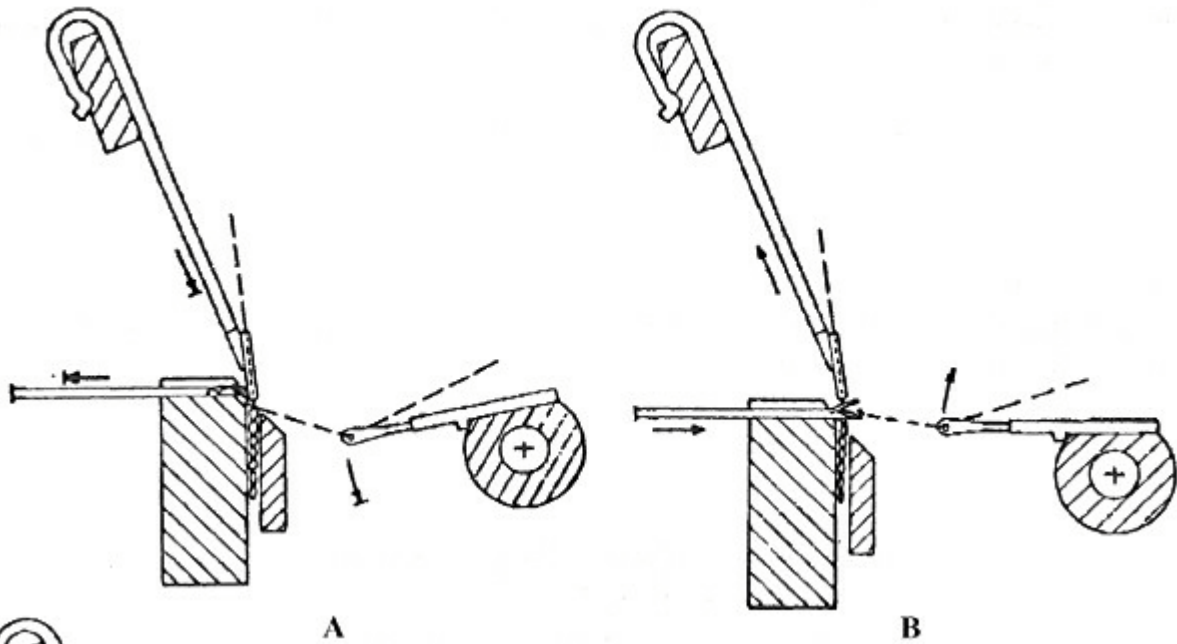
The single warp threads always feed the same needles with a bar motion that generates separated pillars of chain stitches.

At each revolution of the machine, a inlay weft thread is inserted between the loop sides and the interloops, as a result tying the pillars and creating the fabric (picture 139).



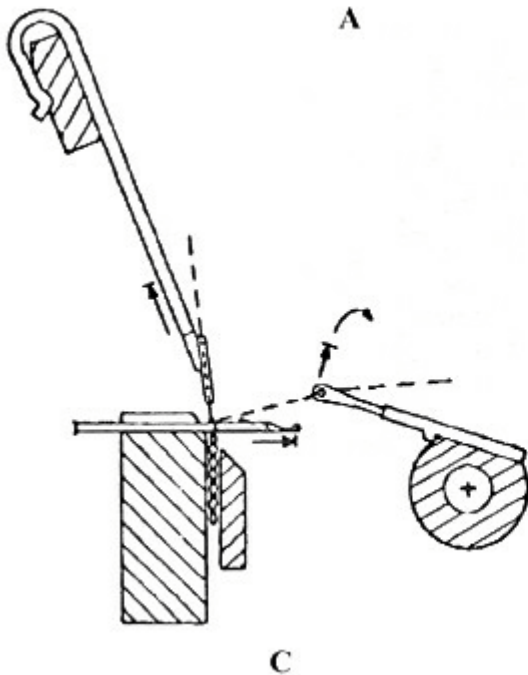
*Picture 139 – Fabric pattern that can be carried out on crochet machines: the dashed line symbolises the inlay thread connecting the pillars.*

## Stitch Formation with Latch Needles

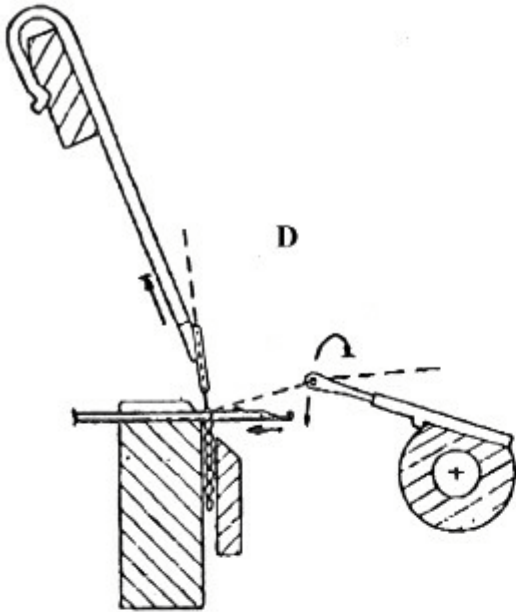


*Picture 140 - Step A - The needle is sunk into the needle bed. The tube is completely lowered. The guide is in its bottom position.*

*Picture 141 - Step B - The needle starts coming out. The tube starts rising and the guide carries out its forward travel.*

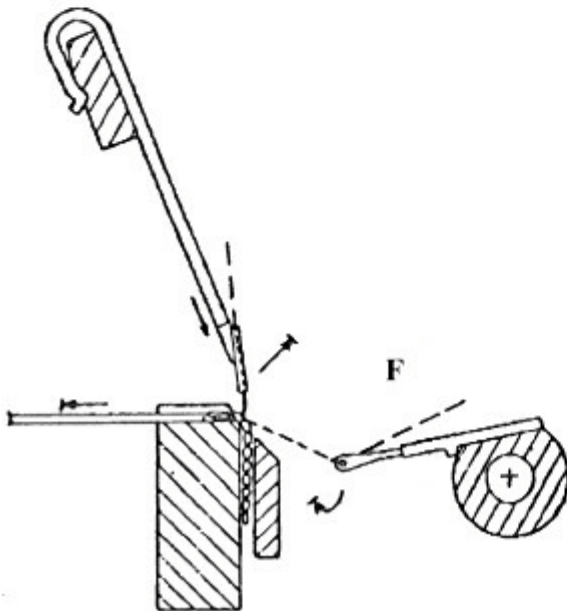
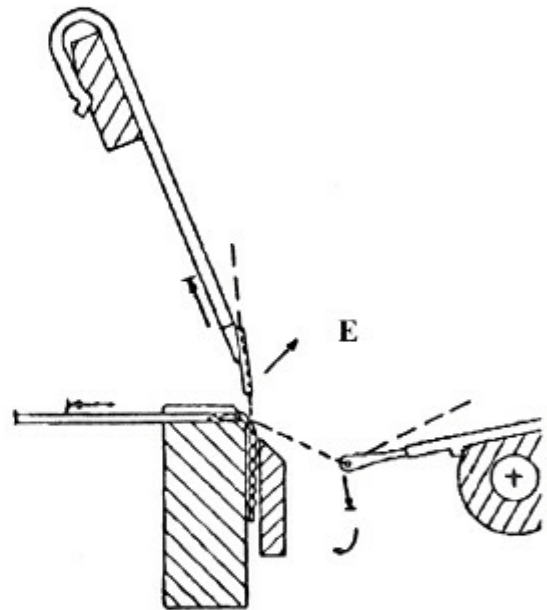


*Picture 142 - Step C - The needle reaches the end of the stroke. The tube and the guide are raised in their top position. The guide starts its lateral overlay movement.*



Picture 143 – Step D – The needle starts withdrawing. The guide moves horizontally and after laying the thread on the needle, it starts lowering for its return travel.

Picture 144 - Step E –The needle is withdrawn completely and the previous stitch has been knocked over. The tube moves laterally. The guide takes its initial position again after having carried out the floating motion.



Picture 145 - Step F – Once the lateral movement has been carried out, the tube starts lowering.