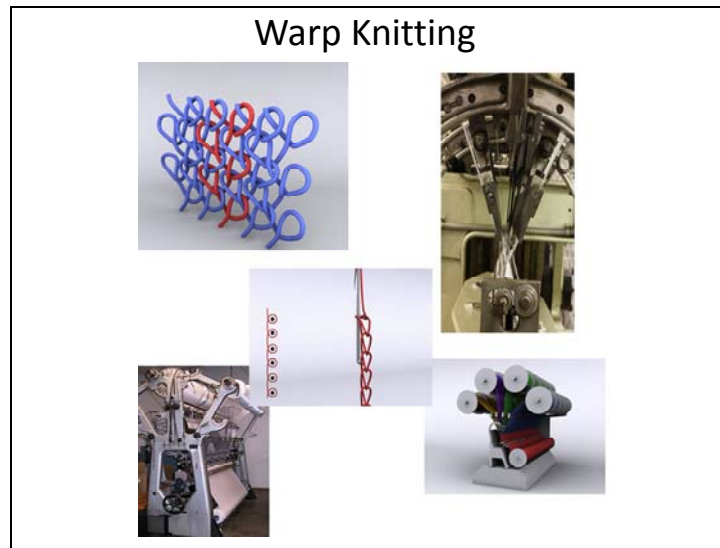
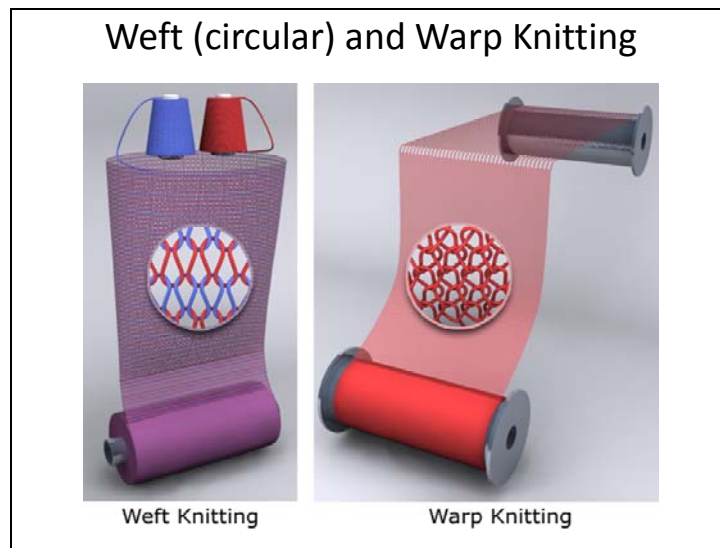


# Warp Knitting

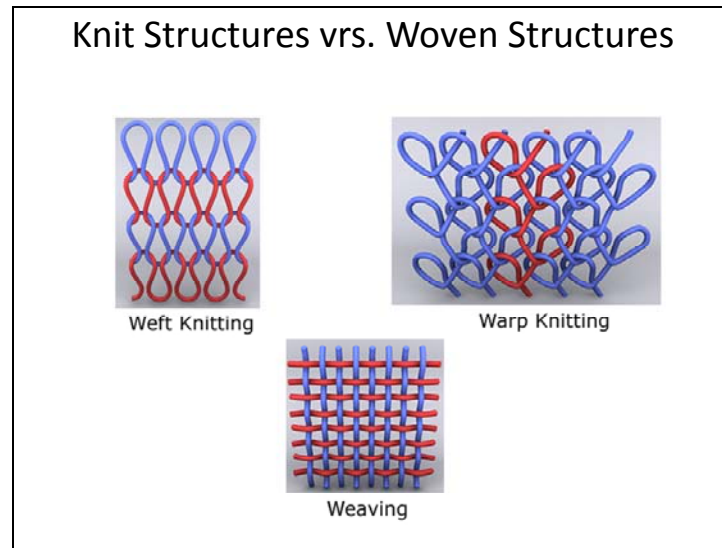
Slide 1



This presentation covers tricot and raschel warp knitting. Topics include the raw materials, fibers and yarns commonly used in warp knitting, preparation of warp beams for knitting, machine types, machine elements and motions, design notations and common warp knit fabrics.



Warp knitting feeds yarns from beams rather than from yarn packages. The beams are called warp beams, hence the term “warp knitting.” All the yarns are knitted simultaneously rather than in a sequence as in weft knitting. Most warp knit fabrics are knitted open width. Because all the needles knit simultaneously across the needle bar(s), warp knitting is more productive compared to weft knitting.



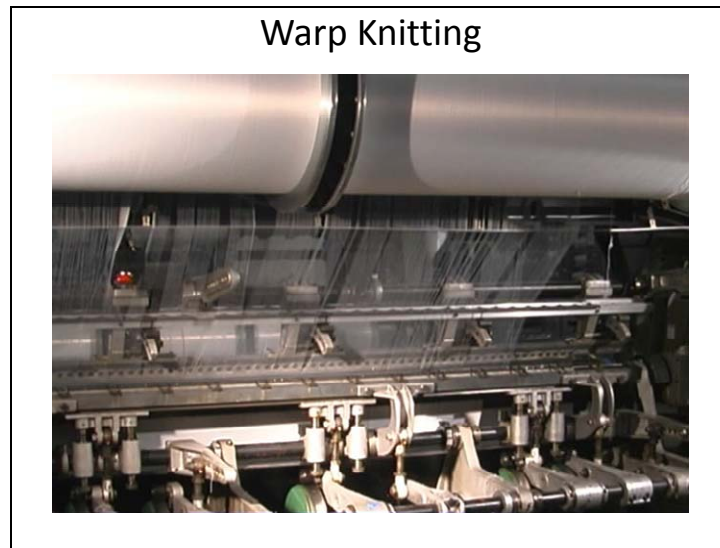
Weft knitting machines feed individual yarns from yarn packages to the knitting needles, each one forming a horizontal row of loops in a width-wise fabric direction. Warp knitting machines, feed yarns from beams, and each yarn is formed into loops as the yarn moves in a vertical direction along the length of the fabric. In the diagrams shown, a given yarn in the weft knit structure, moves in a horizontal direction. However, the red yarn in the warp knit structure moves in the vertical direction. Both types of knitted fabrics are composed of loops of yarns compared to the use of straight yarns in a woven fabric structure. The loop structures have more pliability and elongation than the woven structures. Knitted fabrics are more porous in nature because of their open structure. Knit fabrics are formed by intermeshing loops of yarn and woven fabrics are formed by interlacing straight yarns.

## Warp Knitting

Slide 4



This video compares a circular weft knitting machine with a warp knitting machine. Notice individual yarn packages on the weft knitting machine and multiple beams of yarn on the warp knitting machine. Also notice tubular fabric being formed on the weft knitting machine and open-width fabric being formed on the warp knitting machine.



This is a video of a warp knitting machine in action. Yarns from the beams are formed into loops and the loops engage with one another to form the warp knit fabric. Notice how the loops of yarn are slanted to the left in one course or row and slanted to the right in the subsequent course. The path of the blue yarn is in a vertical direction along the fabric length. The warp beams are precisely formed during a process called warping. Warping takes yarns from individual packages and places those yarns on a beam as shown in this video. Proper tension and alignment of the yarns is critical in forming a good quality beam. From the beams, the yarns pass through small eyelets in elements called guide bars. The movement of guide bars as they wrap the yarns around needles in the needle bar is seen in slow motion. The needle bar is ready to move downward, forming the yarns into knitted loops.

## Fibers and Yarns for Warp Knitting

## Fibers Used

### Man-made Fibers

- Acetate
- Triacetate
- Nylon
- Polyester
- Rayon
- Spandex

### Natural Fibers

- Cotton
- Silk
- Wool

There are various types of man-made fibers used in warp knitting. Acetate is relatively inexpensive, has an excellent hand and drape, is comfortable, and also static and soil resistant. It cannot be successfully heat-set and has poor abrasion resistance. Triacetate can be heat set and has an excellent hand, but is more difficult to dye. It also has low strength and low abrasion resistance. Nylon knits well, is a strong fiber, and is easy to texture and heat set. However it tends to have a poor hand, static problems, soils easily, and has poor wrinkle recovery. Polyester has great wrinkle resistance, knits well, is light resistant, easy to texture and heat set. It has some dyeing, static, and soiling difficulties. Rayon is moisture absorbent, has a good hand, but is weaker under wet conditions. Spandex provides excellent stretch properties to fabrics and can be introduced into the fabric in various forms – bare, corespun, or covered.

Natural fibers such as cotton and wool are staple or short fibers and are not commonly used in warp knitting. These fibers cannot be heat set and, in yarns, tend to shed a significant amount of lint or short fibrous waste. Therefore, spun yarns may be used on raschel machines but not typically on tricot machines. Silk is the only filament type natural fiber but fairly expensive.

### Filament Yarns

- Predominant in Warp Knitting
- Higher Strength than Spun Yarns
- More Uniform with No Fiber Shedding
- Continuous Filaments
- Flat or Textured
- Single Yarns or Plied

Filament yarns are predominantly used in warp knitting due to their high strength and uniformity. These yarns can be in a flat filament form or in a textured filament form. The individual filaments run throughout the entire length of the yarn. Flat filament yarns are left in a straight configuration. Textured filament yarns have been made to loop, curl, or snarl in order to add bulk, softness, reduce luster, and a more textured surface. Filament yarns can be formed into finer yarns compared to spun yarns and, thus, can be used to produce lighter-weight fabrics. Warp knit fabrics may be produced with single filament yarns and plied filament yarns.



### Spun Yarns

- Not Used Very Often
- Short Fibers Twisted Together
- Not As Strong nor Uniform as Filament Yarns
- Produce Contamination
- Mostly Used as A Singles Yarn
- Not as Fine as Filament Yarns

Spun yarns are not used frequently in warp knitting. These yarns are composed of short fibers twisted together to form the structure. The yarn is not as strong or uniform as filament yarn and some of the fibers shed from the yarn and form a contaminant on the warp knitting machine. Single yarns are most commonly used rather than plied yarns. Finer yarns are more difficult to produce and become costly. Knitted fabrics with spun yarns tend to be heavier in weight than most filament yarn fabrics.

## Filament Yarn Numbering

- Denier- Most Common System of Numbering
- Denier Number – Represents the weight of 9,000 meters of yarn in grams
- Lower the yarn denier, finer the yarn
- 1/70/20/1.2 Z/SD
- Denier per filament (dpf) =  $70 \div 20$  which yields a dpf of 3.5

Denier is the most common yarn numbering system used in the United States for filament yarns. The denier yarn number is defined as the weight in grams per 9,000 meters of yarn. Thus a 70 denier yarn indicates a standard length of 9,000 meters weighs 70 grams. The lower the yarn denier, the finer the associated yarn. A common yarn description might be 1/70/20/1.2 Z/SD. This would be described as a singles yarn (one-ply), 70 denier, 20 filaments, 1.2 turns per inch of twist in the Z (clockwise direction), and having a semi-dull luster. The denier per filament (dpf) can be determined by dividing the overall denier (70) by the number of filaments (20). In this case, the dpf would be 3.5. If the dpf calculates to be less than 1.0 denier, then the fiber classification is microdenier or microfiber. Microdenier warp knit fabrics exhibit a very soft and luxurious hand or feel.

## Other Filament Yarn Numbering

**Tex** – yarn number represents the weight in grams of 1,000 meters of yarn

**Example:** a 20 tex yarn weighs 20 grams per a standard length of 1,000 meters

**Decitex (dtex)** – yarn number represents the weight in grams of 10,000 meters of yarn

**Example:** a 200 decitex yarn weighs 200 grams per 10,000 meters

The tex yarn number is based upon the weight in grams of yarn per a standard length of 1,000 meters. Thus, a 20 tex yarn weighs 20 grams per standard length of 1,000 meters. Decitex is based on a standard length of 10,000 meters and thus a 200 decitex yarn weighs 200 grams per 10,000 meters.

## Spun Yarn Numbering

**Metric Count (Nm)** – number of kilometers of yarn weighing one kilogram

**English Cotton Count (Ne)** – number of 840 yard lengths of yarn weighing one pound

**Examples:**

- A 20 (Nm) metric yarn indicates that 20 kilometers weigh one kilogram.
- A 40 (Ne) English cotton count yarn has a yarn length of 33,600 yards (40 x 840) and weighs one pound.

Metric count and English cotton count are the most common numbering systems used with spun yarns. Metric yarn number (Nm) equates to the number of kilometers of yarn that it takes to weigh one kilogram. A 20s (Nm) metric yarn indicates that 20 kilometers weigh one kilogram. English count yarn number (Ne) is the number of 840 yard lengths of yarn that it takes to weigh one pound. A 40 (Ne) english cotton count yarn has a yarn length of 33,600 yards (40 x 840) and weighs one pound. Both of these yarn numbering systems have the characteristic that a larger yarn number represents a finer yarn, this is opposite of the denier system used with filament yarns.

## Yarn Numbering Conversions

- $Nm / 1.69 = Ne$
- $5314 / \text{Denier} = Ne$
- $590.54 / \text{Tex} = Ne$
- $\text{Denier} / 9 = \text{Tex}$
- $\text{Decitex} / 10 = \text{Tex}$
- $Nw / 1.5 = Ne$

A list of common yarn numbering conversions used in the textile industry is given in this slide. Individuals often convert to the system with which they feel more comfortable. What English (Ne) yarn number would be equivalent to 32 Nm? The conversion equations as seen in this slide indicate that to convert a metric yarn to an english cotton count yarn, divide the metric yarn by 1.69.

Answer:  $32 \div 1.69 = 19$

## End Uses by Fiber and Denier

- **Acetate:**
  - 55 denier – dress goods, lingerie, prints
  - 100 denier – loungewear, deep pile fabrics
- **Triacetate:**
  - 55 denier – lingerie, sleepwear, blouses
  - 100 denier – dress goods, shirtings, robes
- **Nylon:**
  - 20 denier – lingerie, sleepwear, prints
  - 70 denier – uniforms, mesh fabrics, lace
- **Polyester:**
  - 40 denier – blouses, prints, uniforms
  - 70 denier – napped robes, uniforms, shirting
- **Spandex:**
  - 70 – 140 denier – low power stretch fabrics
  - 210 – 420 denier – power-net products

Shown in this slide are common end uses based on fiber type and yarn denier. This is not an exhaustive list but only some examples. Nylon is a stronger fiber and can be made into a lower denier, finer yarn for very light weight fabrics. This is reflected by the 20 denier yarn uses of nylon. These end product examples all contain filament yarn. For a comparison, an equivalent spun yarn number for a 55 denier filament yarn would be 97 English cotton count which is very fine in spun yarn and in very limited supply around the world. Polyester is another strong fiber and also can be knitted with lower denier yarns. In low power stretch fabrics, a range of 70 to 140 denier yarn is commonly used with 210 to 420 denier yarn used in power-net products, where a higher stretch and recovery is needed. An example of this is a four guide bar fabric using 4 sets of yarns – 2 sets of nylon yarn and 2 sets of spandex yarn. Whenever these yarns are textured instead of remaining flat, the overall denier could increase by 10 to 20 per cent.

## Yarn Preparation Overview

- Fewer Processes than Used in Weaving
- Warping Is the Main Preparation Step
- Warping Can Have A Crucial Effect on Fabric Quality
- Warping Mistakes Are Difficult to Overcome in Knitting

The use of mainly synthetic yarns and the moderate tensions applied to the knitting yarns, ensures an efficient operation without warp sizing, which has to be applied to most weaving yarns. Yarn preparation is a simple winding of yarn ends onto warp beams in a process called warping. The quality of the warp beam has a crucial effect on the quality of the knitted fabric. In warp knitting, the use of synthetic yarns and the loop formation highlight variations in the yarn. Differences in yarn thickness, tension, twist and other factors can result in a fabric fault. In most cases warping mistakes are hard or impossible to correct during the knitting process. The slogan “well warped is half knitted” is, therefore, very appropriate.

### Warp Beams



Uniform warp yarn feeding and proper yarn tension control is made possible by supplying flanged beams which are attached to shafts that turn to unwind the warp yarns in a parallel arrangement. Each shaft of beams generally feeds its yarns to a separate guide bar which operates independently from other guide bars. This particular warp knit machine has two warp beam shafts in use and, therefore, would use two guide bars to form a given fabric. The warp beam shafts could have the same yarns or different yarns. For space savings during warping and ease of handling, a number of beams may be located on the same beam shaft in order to achieve the full width of the warp sheet. A warp sheet with a width of 84 inches (213 cm), for example, might be supplied as one single beam, two 42 inch (106 cm) beams, or four 21 inch (53 cm) beams.

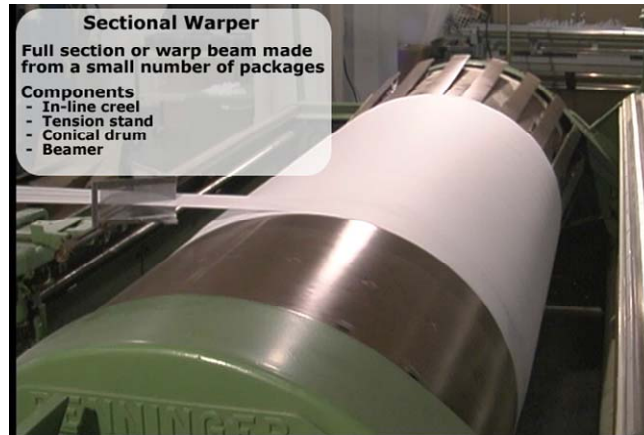


### Direct Warping

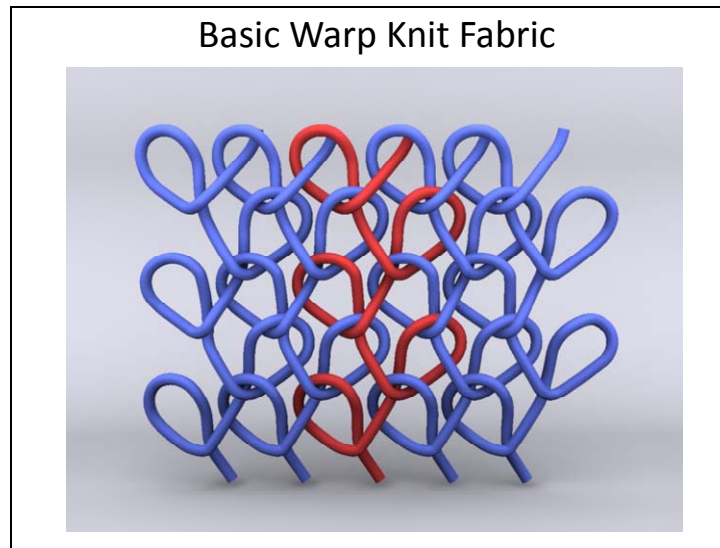


The fastest way to form a warp knitting beam is by direct warping. Packages of yarn are directly fed from a creel to the warping head, which winds the yarns in parallel onto the warp beams. Yarn spacing in the warp sheet to be fed to the knitting machine must be suitable for the machine gauge, and the width of the warp often equals the width of the needle bar in use. Yarns placed on the warp beams must be parallel, not crossed, and be under equal tension. When warping synthetic yarns, static eliminators are needed. The creels are usually straight-line type. When warping spun yarns, lint removal equipment may be needed and possibly the application of a lubricant to the yarn.

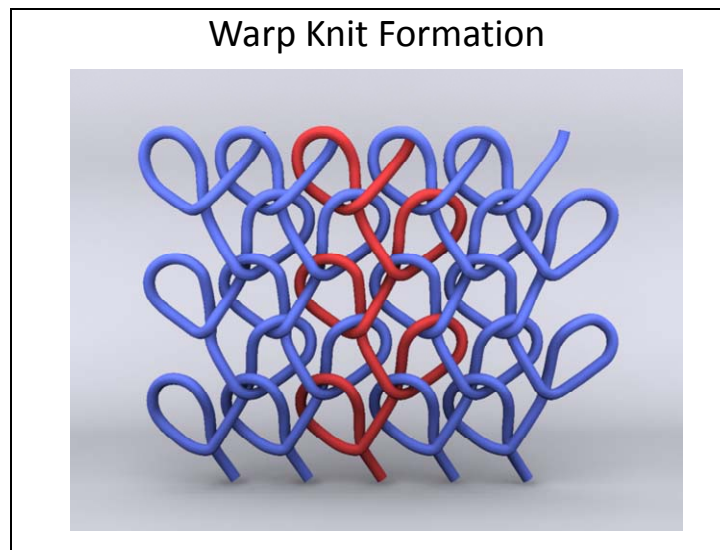
### Indirect Warping



Indirect warping winds small groups, called sections, of yarns onto a type of drum as seen in this photograph. Additional groups of yarns are wound side by side until the required number of yarns is reached. Thus the warp beam is built in sections and then all the sections of yarns are transferred simultaneously to a warp beam with flanges. This type of warping is typically used when floor space is limited or some type of color pattern is formed with the yarns. This type of warping also works well when making samples and short runs. The indirect system is used sparingly for warp knitting and most commonly used in producing warps for weaving.

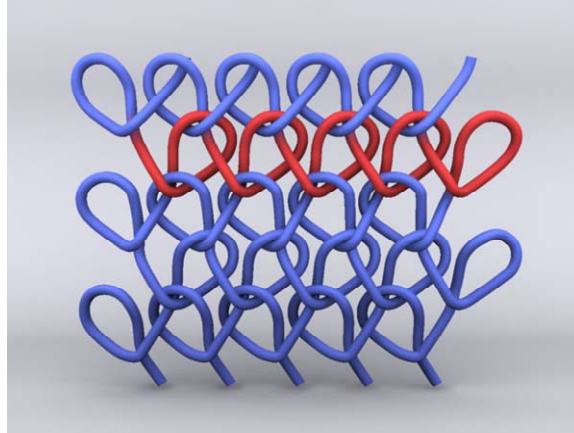


Warp knitting can be defined as a loop-forming process in which the yarn is fed into the knitting zone, parallel to the fabric selvages. The diagram shown illustrates the most basic warp knitted structure made by a single set of ends fed from a single warp. Every needle is fed by a separate end of yarn, from which a loop is formed. In order to connect the loops into a fabric, the ends shog between the needles – meaning that the guide bars through which these yarns are fed move from one needle position to another. In this manner each knitting needle draws a new loop through the loop formed by another end of yarn in the previous knitting cycle. The accompanying diagram shows four complete wales. Notice how the red yarn is knitting in combination with two other yarns. From this basic section of fabric, it can be seen that at least one set of ends of yarns, equaling the number of needles in the machine, is necessary to produce the fabric.



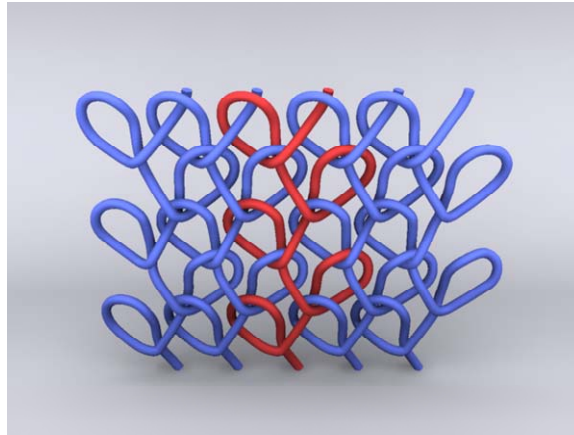
Notice in this animation, how a single end of yarn, red in color, is combining with other ends of yarn, blue in color, as loops are formed along the vertical direction of the fabric. The left and right positioning of the red loops is created by the shogging motion of the guide bar containing that yarn. This motion allows the yarns to form connecting loops, which produces a continuous fabric.

Half Tricot - Course

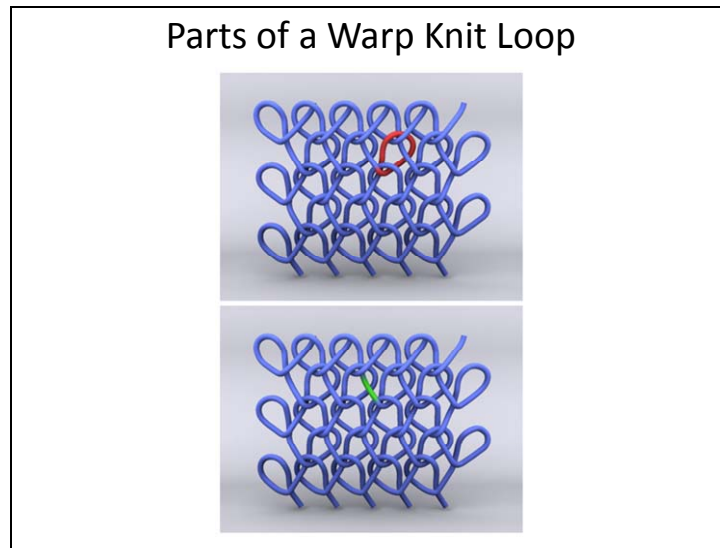


A warp knit course, highlighted in red, is a horizontal row of loops formed by the needles during one knitting cycle. In warp knitting, all the needles perform the same knitting action simultaneously, so that one knitted course is formed across the whole width of the knitting machine for every turn of the main shaft of the machine.

### Half Tricot - Wale



A warp knit wale can be defined as a vertical column of loops formed by a single needle but usually not by a single yarn, as evidenced by the wales containing blue and red yarn. The number of wales in the fabric equals the number of needles across the width of the machine. The fabric structure, seen in this diagram, was formed by the action of six needles since four complete wales and two partially knitted wales can be seen.



The structure of a warp knit loop is very different from that of a weft knit loop. It actually contains two parts. The first is the loop itself, shown in red, which is formed by the yarn being wrapped around the front or hook side of a needle and then drawn through a previously formed loop. This part of the structure is called an overlap. The second part is the length of yarn connecting each formed loop with the next succeeding loop, which is called an underlap, shown in green. It is formed by the shogging or lateral movements of the yarn ends across the back side of the needles. The length of the underlap is defined by needle spaces according to the shogging movement. In this diagram the shogging movement is over only one needle space. The longer the underlap in terms of needle spaces, the more it lies in the weftwise direction of the fabric. This increases the fabric's widthwise stability. A shorter underlap will increase the lengthwise stability.

## Overlap Characteristics

- Shog usually across one needle hook
- Every needle receives an overlapped loop from at least one guide at every knitting cycle
- Two side limbs of the loop are produced
- Rare to shog across two needle hooks due to high yarn tensions and poor fabric appearance

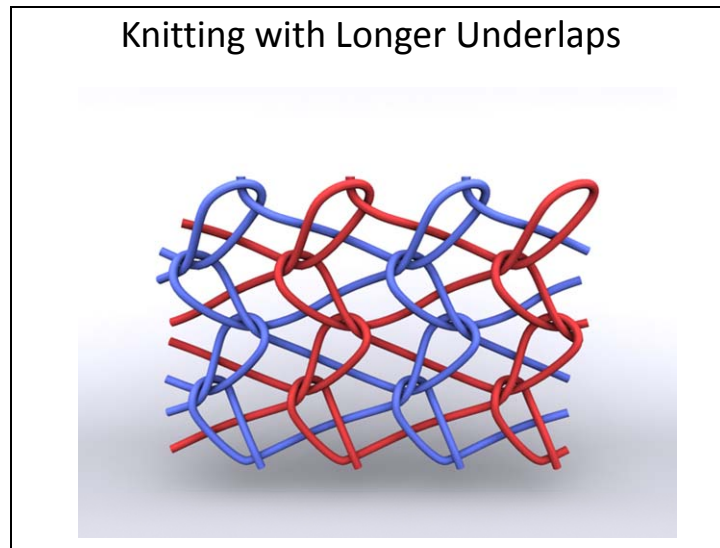
An overlap is a shog, usually across one needle hook. Every needle on a conventional warp knitting machine must receive an overlapped loop from at least one guide at every knitting cycle, otherwise it will press-off, meaning yarns drop off the needles, making a large hole in the fabric. The swinging movement of the guide to the hook side and the return swing after the overlap produce the two side limbs of the loop, which give a similar appearance on the face side of warp knitted fabric as that of a weft knitted needle loop. Very rarely are overlap shogs across two needle hooks, as this produces severe tension on the warp yarn and knitting elements. Two needle overlaps also, generally, have a poor appearance.



## Underlap Characteristics

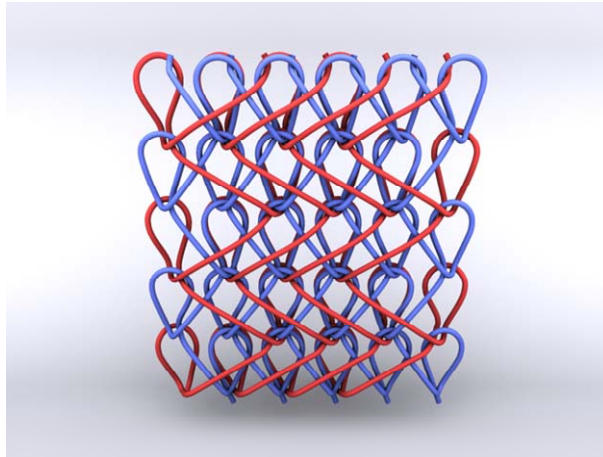
- Generally ranges from 0 to 3 needle spaces
- Could be four or more needle spaces depending on design and fabric structure
- Long under laps cause a reduction in knitting efficiency and production speed
- Underlaps and overlaps are essential in warp knit structures

The underlap shog generally ranges from 0 to 3 needle spaces, but it could be 4 needle spaces or more depending upon the design of the machine and the fabric structure. Efficiency and production speed will be correspondingly reduced with longer underlaps. Underlaps as well as overlaps are essential in warp knitted structures in order to join the wales of loops together, but they may be contributed by different guide bars.



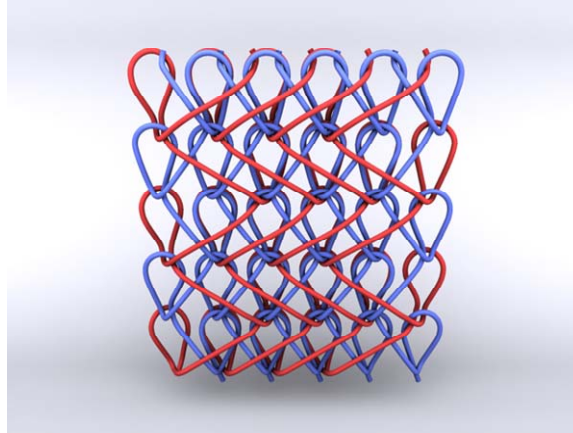
The fabric weight is affected by the length of the underlap. While knitting with longer underlaps as illustrated, more yarn is fed into the fabric. Each underlap crosses over two needle spaces instead of one as in the previous slide. It covers more wales on its way, resulting in heavier, thicker, and denser fabric. Since the underlap is connected to the base of the loop, it causes, due to warp yarn tensions, a slant to the loop structure. The reciprocating movements of the yarn, therefore, cause the loops of each knitted course to slant in the same direction, alternately to the left and to the right as the fabric is being formed.

### Adding another Set of Yarn Ends



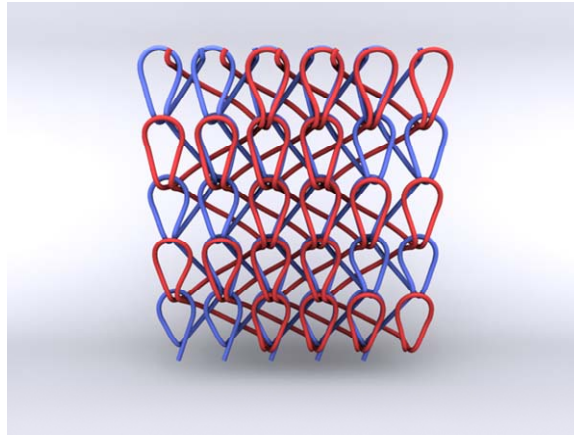
To achieve a better appearance of the fabric with vertical loops as well as controlling the widthwise and lengthwise properties of the fabric, a second set of warp ends can be used. This second set usually makes an opposite shogging movement to the first. The length of the underlaps need not necessarily be the same in the two sets. In the accompanying diagram of a two guide bar fabric structure, one set of ends from the warp (the blue yarns) shog between two adjacent needles while the other set (the red yarns) shog a larger traverse of two needle spaces.

### Technical Back of Warp Knit Fabric

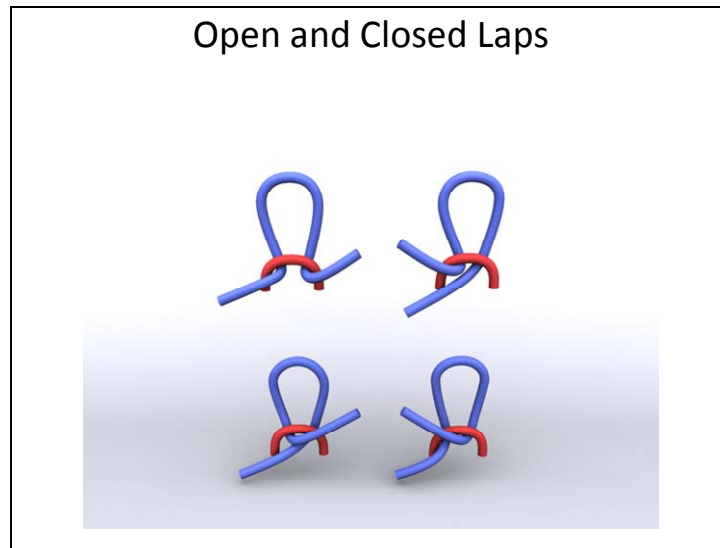


Plain warp knitted fabric is not symmetrical on both sides. This two guide bar structure illustrates the side of the fabric facing the knitter. This side shown is called the “technical back” and can be recognized by the underlaps floating on the surface. When dealing with a fabric made of several sets of ends, fed from different warps, there are several layers of underlaps. The ends fed from the warp closer to the front of the machine, float on the surface of the technical back. The underlaps of the other warps are sandwiched under the underlaps of the former warp in their respective order.

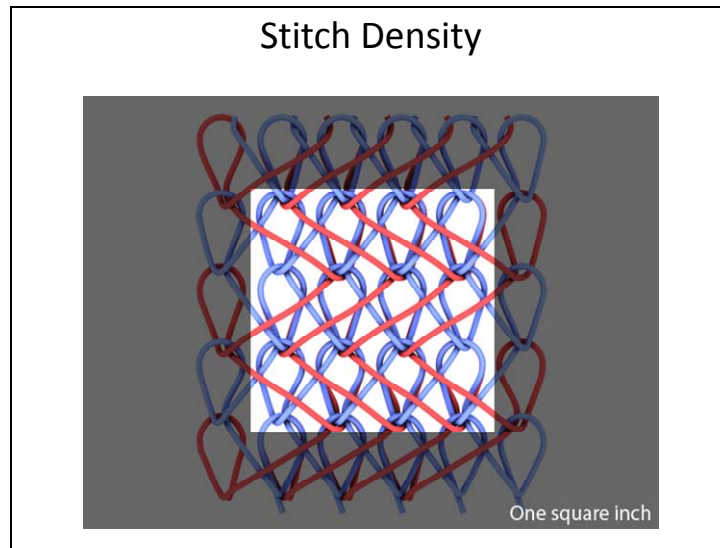
### Technical Face of Warp Knit Fabric



On the technical face, the loop structure formed by the overlaps shows on the surface of the fabric. When the fabric is formed by more than one set of yarn ends, all the yarns which overlap the needle appear in the loop. In most fabrics, the yarns of the warp closest to the front of the machine cover the others, thus forming a plating effect on the technical face. Plating is defined as yarns placed in front of other yarns. The quality of the plating varies with the knitting conditions, the settings of the machine and the yarn used.



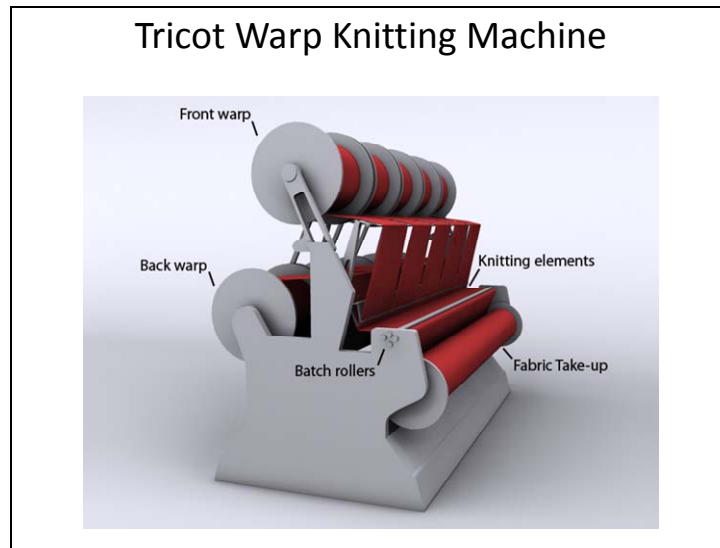
There are two different lap forms used in warp knitting, depending on the way the yarns are wrapped around the needles to produce an overlap. An open lap, illustrated in the top row of loops, is formed when the overlap and the next underlap are made in the same direction. When the overlap and the following underlap are in opposing directions, a closed lap is formed, illustrated in the bottom row of loops. The most common lap used, in most warp knit structures, is the closed lap. The open lap is used when special fabric properties are needed or when technical limitations exist. Special attention must be paid to the overlap direction because it affects the fabric properties significantly.



Stitch density is the total number of loops in a given area of fabric. The area is usually a square inch or centimeter and the density is obtained by multiplying the number of courses by the number of wales in the given area. If the part of the fabric highlighted in this sketch is a perfect square inch, the stitch density, would be 12 loops per square inch, three courses per inch multiplied by four wales per inch. Because many fabrics shrink widthwise after leaving the warp knitting machine, it is not possible to determine the machine gauge or needles per inch by analyzing the fabric. The count of fabric courses is determined by machine settings and knitting conditions. The loops can be knitted long to produce slacker fabric or small to produce a tighter fabric. Since the wale density is almost exclusively determined by the machine gauge and fabric construction, the knitter can more easily control the loop size or course density. For this reason, in some parts of the industry, the main fabric parameter considered is the course count.

## Machine Types



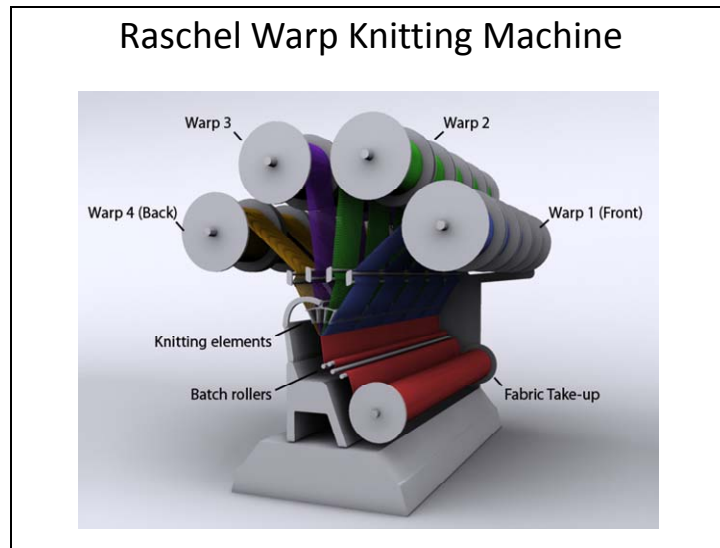


Tricot warp knitting machines typically employ either spring-bearded types of needles or compound needles. These needle types will be discussed later. The machine gauge is typically expressed as needles per inch. The fabric is drawn towards the batching roller, almost at right angles to the needle bar. Warp beams are inclined in an arc towards the back of the machine, with the top beam supplying the front guide bar, and the bottom beam supplying the back guide bar. The machines have a simple construction and a short yarn path from the beams. Guide bars are numbered from the back of the machine towards the front of the machine. Tricot beam arrangement generally restricts the maximum number of beams and guide bars to four. This is not of major importance because the majority of tricot machines operate with only two guide bars. Tricot warp knitting creates a gentle and low tension on the fabric being knitted due to the small angle of fabric take-away, as seen in this diagram, and the type of knitting action employed. This makes it ideal for the high speed production of simple, fine gauge (28-44 needles per inch), close-knitted, plain and pattern work. For that reason, many lingerie and apparel fabrics are knitted using two guide bar structures with both bars overlapping and underlapping.

### Key Tricot Machine Characteristics

- 28 and 32 gauge machines popular for two bar tricot and locknit structures with machine widths of 84 and 168 inches (213 and 426 cm) and using 40-denier nylon
- Possible to knit from 10-denier nylon up to 20/1 cotton count
- Machine gauges can range from 10 needles per inch for coarse spun yarns to 20-24 needles per inch for textured yarn fabrics
- 36-44 gauge (needles per inch) for fine fabrics with knitting widths up to 260 inches (660 cm)

In the past, 28 and 32 gauge machines have been popular for two-bar tricot and locknit structures with machine widths of 84 and 168 inches (213 and 426 cm) while using 40-denier nylon. Currently, it is possible to knit from a fine 10-denier nylon filament, up to a heavier 20/1 cotton count spun yarn. Machine gauges can range from 10 needles per inch, for coarse spun yarns, to 20-24 needles per inch for, textured yarn fabrics. For fine fabrics, 36-44 gauge machines are available in knitting widths up to 260 inches (660 cm).



Fabric on raschel machines is drawn downward from the needles almost parallel to the needle bar, at an angle of 120-160 degrees. This angle creates a high take-up tension, particularly suitable for open fabric structures such as laces and nets. The warp beams are arranged above the needle bar and centered over the top of the machine so that the warp yarns pass down to the guide bars on either side of them. The guide bars are numbered from the front of the machine. Raschel machines can accommodate at least four 32-inch diameter beams or a large number of small diameter beams.

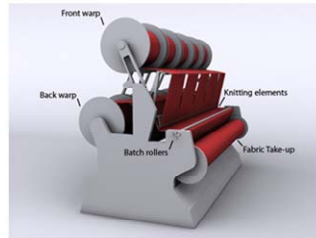
### Key Raschel Machine Characteristics

- Typically knit with latch needles or compound needles
- Machine Gauge – needles per inch
- 1 to 32 gauge range
- Suitable for coarse gauge open-work
- Open-work utilizes pillar stitches, inlay lapping variations, and partly-threaded guide bars.
- Raschel arrangement of sinkers makes this possible.

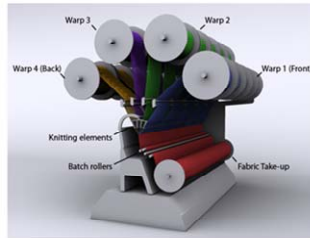
Raschel machines typically knit with latch needles or compound needles. Machine gauge is expressed as needles per inch. The gauge range can be from 1 to 32. The simple knitting action and the strong and efficient take-down tension makes the raschel machine well suited for the production of coarse gauge open-work structures using pillar stitch, inlay lapping variations and partly-threaded guide bars. Raschel sinkers perform the function of holding down the loops while the needles rise. These types of knitting actions will be discussed later in the presentation.

## Machine Elements and Actions

### Yarn Path in Warp Knitting



**Tricot**



**Raschel**

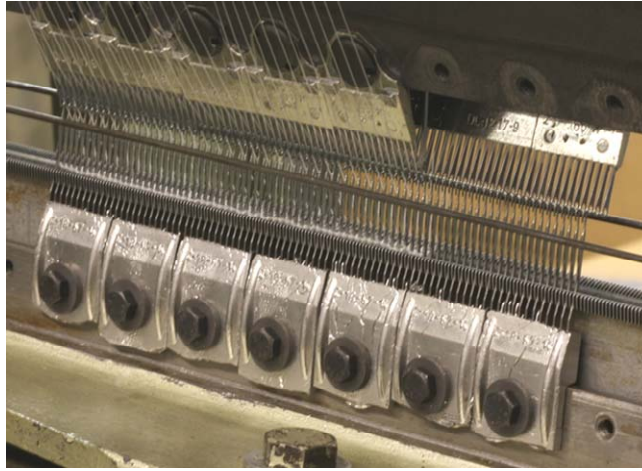
The yarn path is similar in both raschel and tricot warp knitting. The yarns leave the warp beams and are tensioned before moving down to the knitting elements. The knitting elements are composed of guide bars and the needle bar. The movement of the guide bars and needle bar are shown in following slides. Once the yarns are knitted into fabric, a take-up roller system pulls the fabric away from the knitting needles and delivers the fabric to the fabric roll.

### Guide Bars



Guide bars are supplied with yarn from each warp beam shaft. All the yarns from one row or shaft of beams is typically threaded through one individual guide bar. Therefore, if a machine has three shafts or rows of beams, it will also have three guide bars. Conversely, if a machine has four rows of beams, then it will have four guide bars. Shown is a section of a guide bar in a metal lead placed in the foreground of the picture. A number of metal leads seen in the background of the photograph are attached to each guide bar and the guide eyelets are spaced to the same gauge as the needles on the machine. Each guide eyelet occupies a position, when at rest, midway between two adjacent needles. All guides in a conventional guide bar produce an identical lapping movement at the same time and, therefore, have identical requirements of warp tension and rate of feed, although the yarns may differ in color or composition from each other. Occasionally, two partly-threaded guide bars may be supplied from the same fully-threaded beam, provided they make lapping movements of the same extent to each other while moving in opposite directions. The minimum number of guide bars and warp sheets for commercially acceptable structures is usually two.

### Needle Bars

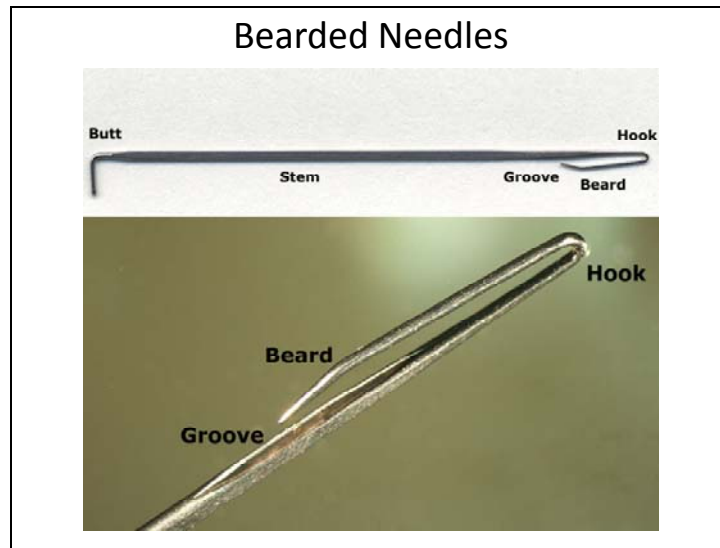


The needle bar is composed of leads containing needles. A sufficient number of leads will be attached to the needle bar to establish a certain fabric width. Shown are seven leads containing needles, but only five guide bar leads are being used. All the needles in a given needle bar will rise and descend simultaneously to produce a new course in the warp knit fabric. During machine operation, a needle bar will be rising to engage the yarns and then descends to form the yarn into knit loops.

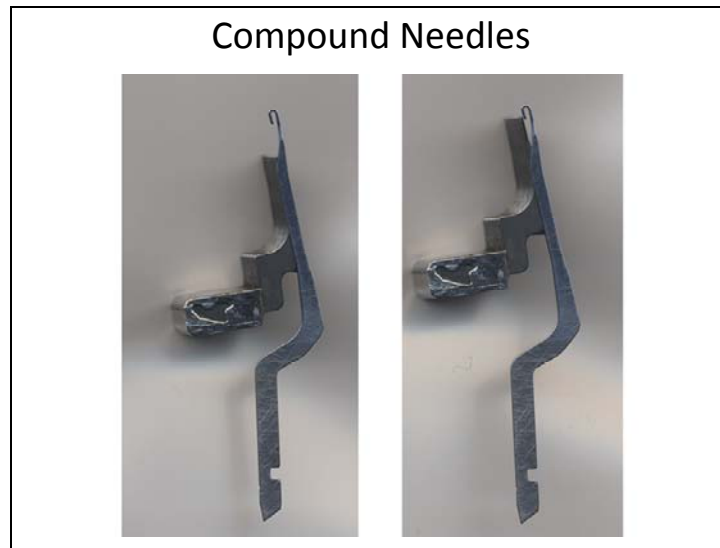




Different warp knitting machines may use different types of needles located on the needle bar. Most modern Raschel knitting machines use compound needles. Many machines, however, are still equipped with latch needles as shown in this photograph. The latch needles are cast in units or leads, one inch long. The latch of the needle depends, for its knitting operation, on the yarn. The loop within the hook opens the latch when the needle rises to the clearing position and closes it when the needle descends for knockover. A broken yarn causes a needle to be void of yarn, and hence, the latch stays closed, so that no loops can be formed. Such a needle has to be opened manually in order to allow loop formation to resume. Raschel machines are constructed in different gauges, ranging from 6 to 32 needles per inch.



The bearded needle is used on many older tricot machines and has an extended hook or beard that is pressed to enclose the newly-formed loop so that this loop can be drawn through the previously-formed loop as the latter is being released. It is the cheapest and simplest type of needle to manufacture and commonly found in machine gauges as fine as 60 needles per inch. The bearded needle has a stem, around which the needle loop is formed. The needle head is where the stem is turned into a hook to draw the new loop through the old loop. The beard is the curved downward continuation of the hook that is used to separate the trapped new loop inside from the old loop as it slides off the needle beard. The eye or groove of the needle is cut in the stem to receive the pointed tip of the beard when it is pressed, thus enclosing the new loop. The needle shank may be bent for individual location in the machine or cast with others in a metal lead.

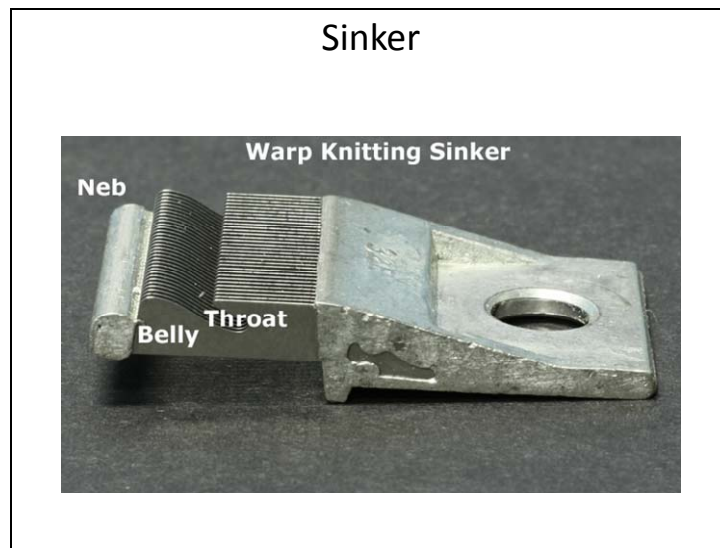


Compound needles consist of two separately controlled parts – the open hook and the sliding closing element. The two parts rise and fall as a single unit but, at the top of the rise, the hook moves faster to open the hook and at the start of the fall the hook descends faster to close the hook. The preferred type of compound needle is the open-stem slide needle which has a closing tongue that slides externally along a groove on the edge of the flat hook member. This type of compound needle is cheaper, more compact and each of the two parts can be replaced separately. The slim construction and short hook of the compound needle make it particularly suitable for producing fine warp knitted structures at high speed. It can knit chain stitches without the loops rising up the needles, and its sturdy construction resists the deflection generated by elastic yarns or thick places in spun yarns.

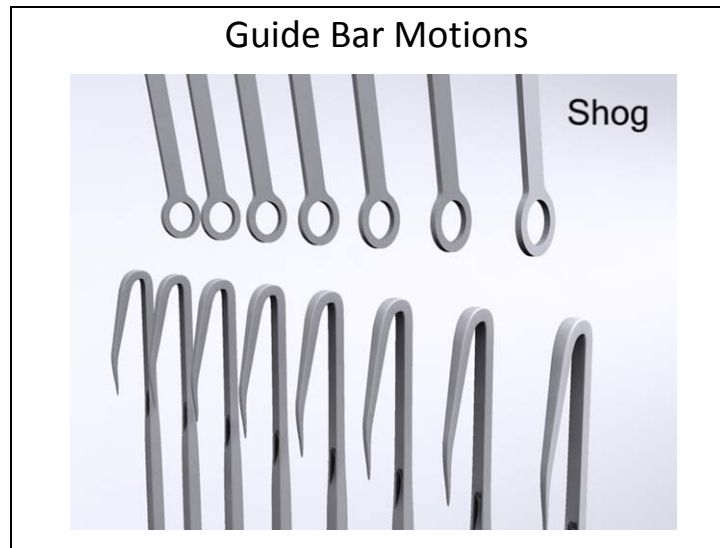
### Compound Needles Type 2



Some types of compound needles have the sliding element in a lead and they protrude through hollow stems in the needle hooks, which are also contained in leads.



The sinker is a thin plate of metal which is placed between each needle. The sinkers are usually cast in units one inch long which in turn are screwed into the sinker bar. The sinker has various parts with individual functions. This photograph shows the neb of the sinker and the throat which is used to hold down the fabric. The belly of the sinker is used as a knocking-over platform.



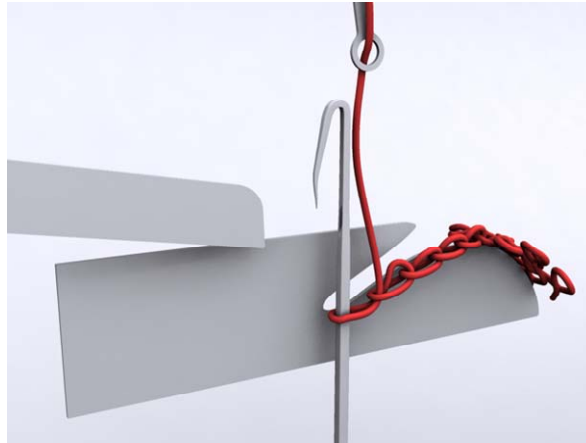
For simplicity, the animation shows only one needle bar being used, and in this case it contains bearded needles. The principles illustrated remain the same for double needle bar machines which will be described later. As shown, the guides of the guide bar are required to execute a compound movement, composed of two separately derived motions. A swinging motion and a shogging movement act at right-angles to each other in order for their yarns to form overlap and underlap paths that combine as one yarn path around the needles. The swinging motion is in an arc from the front of the machine to the hook or bearded side of the needles and a later return swing. It occurs between adjacent needles and is a fixed, collective, and automatic action for all the guide bars as they pivot on a common rocker-shaft. The sideways shogging movement that occurs parallel to the needle bar produces the underlaps and overlaps. The occurrence, timing, direction and extent of each shog is separately controlled for each guide bar by a pattern chain or pattern wheel. A shogging movement can occur when the guides have swung clear of the needle heads on the back or front of the machine. On the hook side, it produces an overlap and on the side remote from the hook it produces an underlap. The timing of the shog during the 360 degree of the main cam-shaft revolution determines whether an overlap or underlap is produced.

### Overlaps and Underlaps



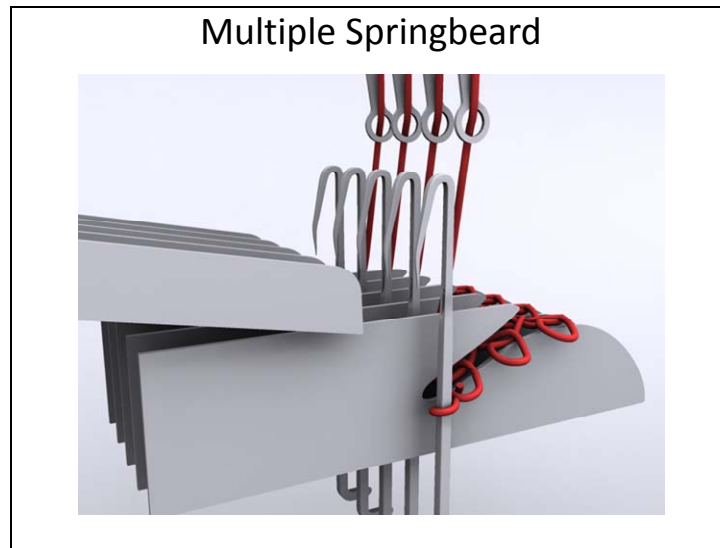
The first part of this video views the knitting action from the machine front in slow motion. The guide bars swing between the needles, overlap yarns by shogging on the hook-side of the needles, swing back between the needles towards the machine front and then form the underlap by shogging on the back side of the needles which faces the machine front. The latter part of the video shows the machine running at a faster pace. Notice how the sinker plate containing the sinkers moves into position before the needles rise, preventing the fabric from rising up on the needles as they ascend.

### Single Springbeard Needle



This animation shows how a single yarn guide in a guide bar swings in with a given yarn, shogs on the bearded side of the needle to form the overlap, swings out towards the back side of the needles and then shogs to form the underlap. Keep in mind, that if you were standing at the machine front, you would be facing the back of the needles. The needle rises to place the new loop of yarn within the beard. At this point, the needle starts to descend and the presser bar closes the beard. The descending needle then pulls the new loop of yarn through the previous loop, which was resting on the needle stem. The previous loop is then “knocked over” the top of the needle and is placed in the delivered fabric. Notice the action of the sinker as the needle moves up and down and the belly of the sinker acting as a platform for pulling the new loop of yarn through a previous loop.

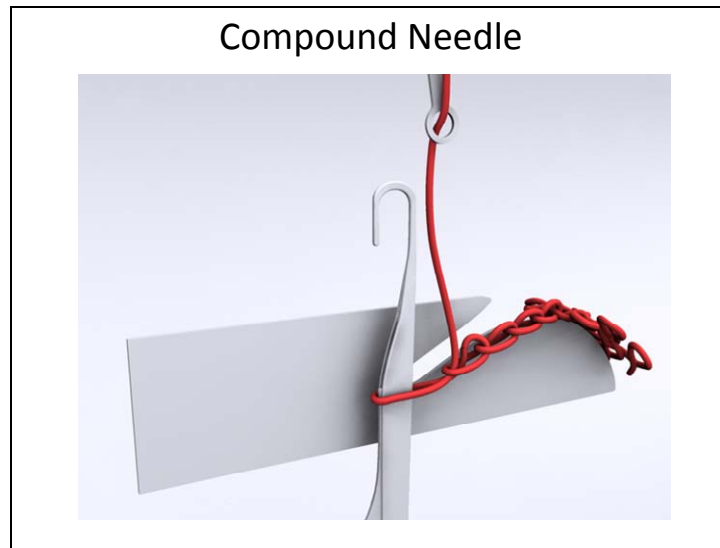




This animation shows multiple bearded needles and multiple yarn guides swinging in and shogging to form the overlaps and then swinging out and shogging to form the underlaps. Notice that the underlap shogging moves back and forth, left and right, one needle space on successive courses. As mentioned earlier, this helps to bind the wales together to form the fabric.



This animation begins with a latch needle in the yarn feeding position with the latch open. The sinker bar is in position to hold down the fabric. The needle then descends, allowing the old loop to close the latch as the new loop is pulled through it. The old loop is knocked over the needle hook and placed into the fabric.



In this animation the yarn is overlapping a compound needle which uses the sliding tongue to close the hook and allow the old loop to be knocked over. The more confined movement of the compound needles with a shorter stroke allows higher production.

## Yarn Consumption for Guide Bars

- Run-in – yarn consumption of each guide bar
- Rack – the length of yarn consumed in 480 knitting cycles used as a measurement for run-in
- Each guide bar knits the same construction and fed equally
- A longer run-in produces longer loops and slacker fabric
- A shorter run-in produces shorter loops and tighter fabric

The yarn consumption of each guide bar is called “run-in” and is measured as the length of each yarn knitted into the fabric during 480 knitting cycles. In warp knitting, all the yarn ends threaded through the guides of one guide bar knit the same construction and are fed equally. The working cycle of 480 knit courses is called a “rack”. A longer run-in knits longer loops and slacker fabric with fewer courses per inch. A shorter run-in produces shorter loops and tighter fabric with more courses per inch.

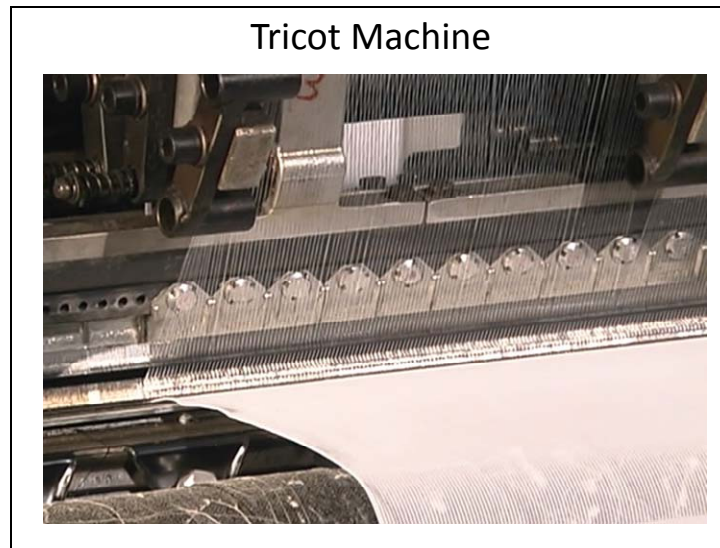
## Run-in Ratio

- Term used when knitting with more than one guide bar
- It is the relative amount of yarn fed from each warp and written as a ratio
- Ratio is different for different fabric constructions and qualities

### Examples

- |                           |     |
|---------------------------|-----|
| • Locknit                 | 3:4 |
| • Reverse Locknit         | 4:3 |
| • Standard Two Bar Tricot | 1:1 |
| • Sharkskin               | 5:3 |
| • Satin                   | 5:9 |

Run-in ratio is a term used when knitting with more than one guide bar. Run-in ratio is the relative amount of yarn fed from each warp and written as a ratio. The ratio is different for different fabric constructions and qualities. When running standard flat nylon yarns, the run-in ratio for a locknit construction might be a 3:4 back bar to front bar ratio. However, when running reverse locknit with the same yarn, the run-in ratio might be 4:3. With a standard two-bar tricot, the run-in ratio would be 1:1. To get the effect of sharkskin, the run-in ratio might be 5:3. For longer underlaps contained in a satin construction, the run-in ratio might be 5:9.



The Tricot warp knitting machine shown in this video is knitting a two guide bar fabric. The guide bars are creating the necessary overlaps and underlaps to produce the delivered fabric. The fabric comes off the machine at 90 degree angle with respect to the needle bar. The machine has four shafts for holding 4 sets of beams, but only two are being used. Only a small number of needles are being used to knit the narrow width of fabric. On the right side of the machine is a pattern chain used to control the motions of the guide bars. Observe the overlapping motion of the guide bars, the lateral shogging movements, and the action of the sinker bar as the fabric is being formed. The pattern chain rotates, directing the shogging motions of the guide bars, to create the fabric design. The chain has the necessary links which are of slightly different heights which controls the guide bars.

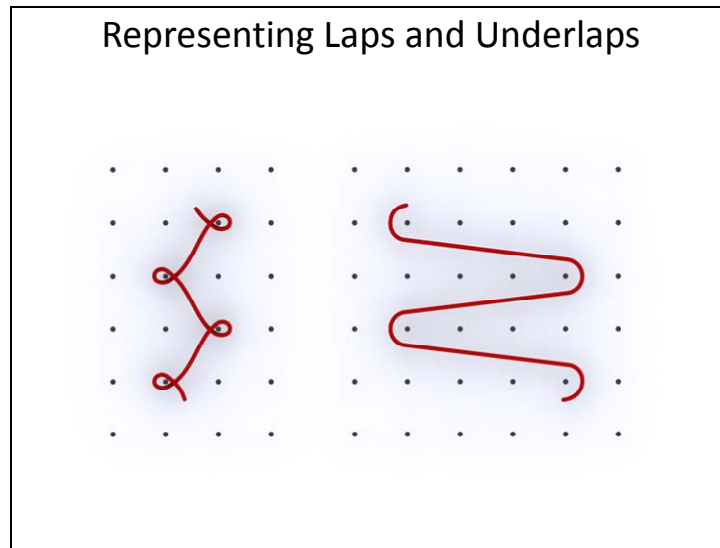
### Two Guide Bar Raschel Machine



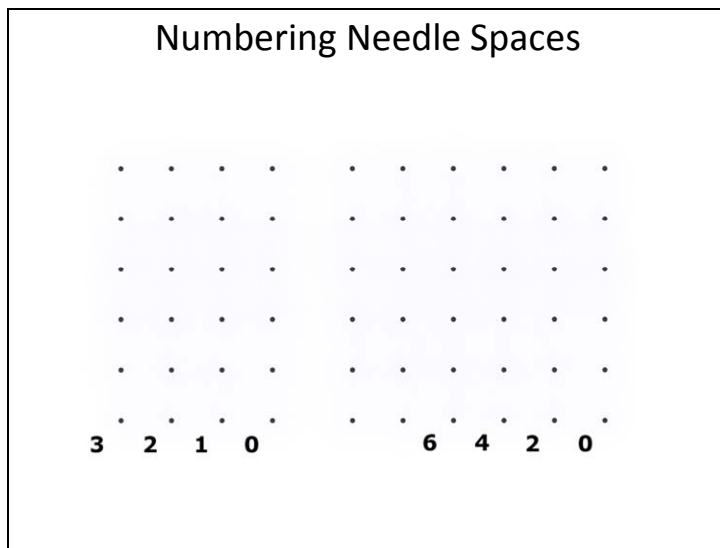
This Raschel machine has four large beams with two beam shafts to support yarns going through two guide bars. Notice the up and down movement of the needle bar as you view the back of the machine along with the swing and shogging motions of the two guide bars. As seen, there are rotating cams which control the up and down movement of the needle bar. The pattern device initiates the movement of the two guide bars, which dictates the design of the fabric. The different heights of the chain links and the different shogging motions created can be seen. Zooming in on the guide bar and needle bar movements, one can see the lateral back and forth movements as overlaps and underlaps are placed into the fabric.

## Warp Knitting Design Principles

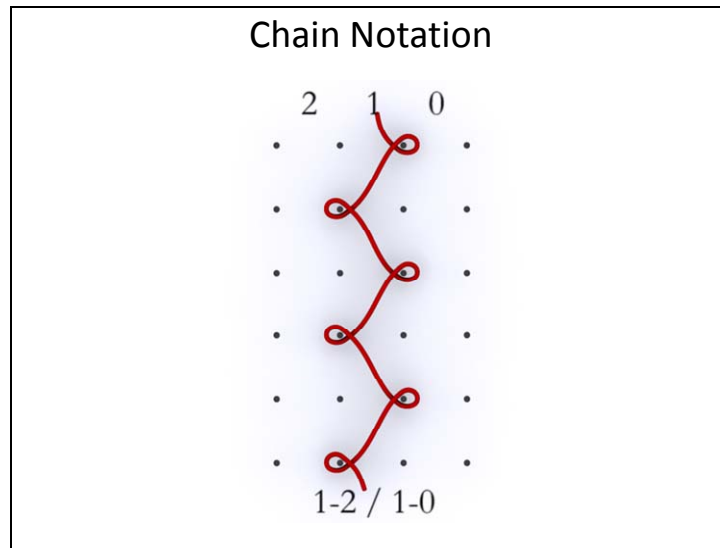




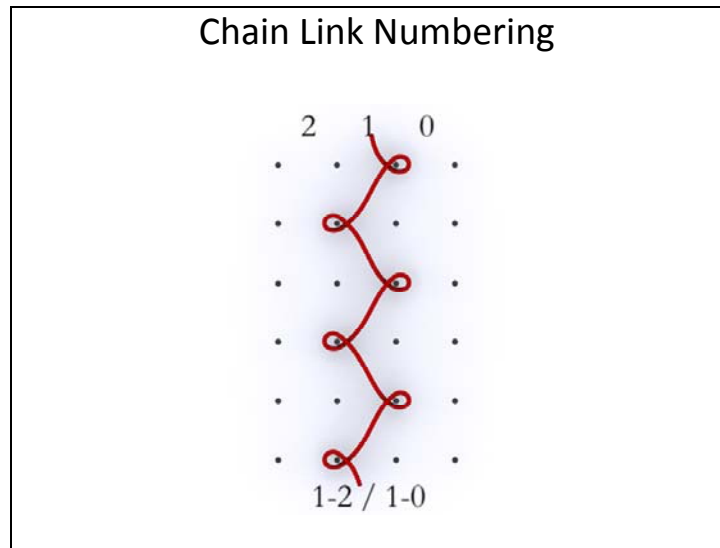
The movement of the guide bars can be represented or plotted on paper containing small dots placed an equal distance apart. Each horizontal row of dots represents the needles or needle bar at one course of the fabric. Each vertical line of dots represents a wale. The design is created by working up the paper from the bottom to the top for each successive course. The path of each guide is shown by drawing a line around the dots as if looking down on the needle from above. If a line is drawn for each threaded guide, then the design of the fabric can be developed. Since all the guides in a given guide bar must move in the same manner, showing the motions of one guide bar and its associated yarn is sufficient for representing the movements of all guides and their associated yarns along the entire width of the guide bar. For multiple guide bar fabrics, a separate notation or drawing must be shown for the movements of each guide bar. One must realize that the lapping movement on “point paper” not only shows the movement of the guides on the machine, but also gives a diagrammatic representation of the path of the yarn in the fabric.



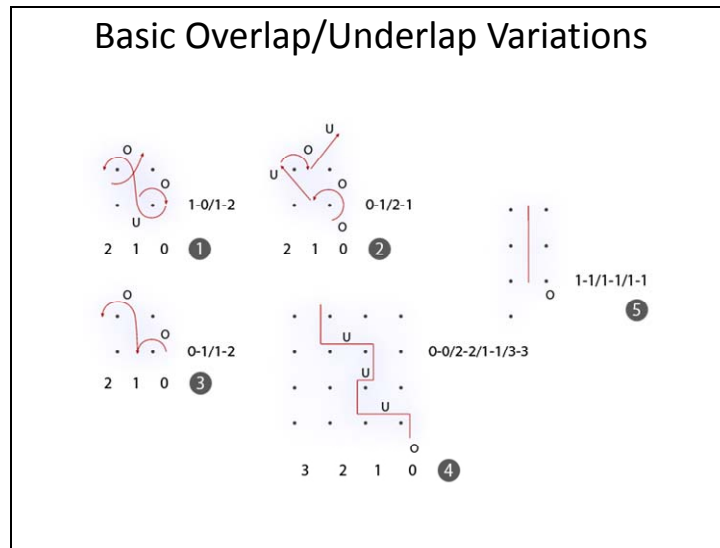
On point paper notation, the needle spaces are numbered from the right hand side for a machine which has its pattern mechanism on the right hand side. The opposite would be true for a machine having its pattern mechanism on the left side of the machine. On tricot machines, needle spaces are numbered using whole numbers beginning with 0. Occasionally, on Raschel machines, the needle spaces are numbered beginning with 0 and using only even whole numbers such as 2, 4, 6, etc. after that.



The chain notation is the description of the fabric construction in numbers and symbols. It is the basis for the technical conversion of the construction via a given pattern chain. Numbers represent needle spaces, corresponding to the numbers at the top of the accompanying sketch, and the symbols represent overlaps and underlaps. A – symbol represents an overlap and a / symbol represents an underlap. In this chain notation, a single guide bar swings in at needle space 1 and then overlaps by shogging over to needle space 2, at which point it swings back out. This movement forms an overlap, meaning overlapping from needle space 1 over to needle space 2. At this point, after swinging out at needle space 2, the guide bar shogs behind the needle and forms the underlap. The next overlap is produced as the guide swings in at needle space 1, shogs over one needle, and then swings out at needle space 0. Thus the chain notation is 1-2 / 1-0 and repeats on every two courses. The notation indicates that each yarn in each guide bar eyelet is overlapping around an individual needle from right to left and then an under lap is formed between two adjacent wales as the yarns are knitting to form a loop of yarn on the next course. The path of the yarn takes it in a zigzag direction from one wale to another.



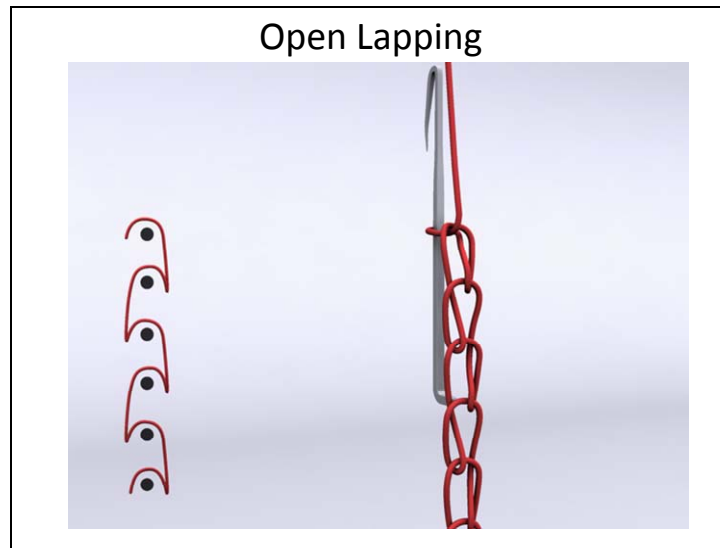
The numbers representing the needle spaces correspond with the height of different links in a pattern chain for a given design. In the previous example, the guide bar formed an overlap as it shogged from needle space 1 to needle space 2. Thus the 1 corresponds to a thinner link in the pattern chain and the 2 corresponds with a thicker link in the pattern chain. The thicker link causes the guide bar to shog over to the left one needle space. In a 28 gauge machine, meaning 28 needles per inch, the guide bar shogs over 1/28 of an inch meaning that the associated chain link is 1/28 inch thicker than the previous chain link. In shogging from needle space 1 to needle space 0 to form the next overlap in the design repeat, the chain link goes from 1 to 0. This means that the 0 link is 1/28 inch thinner than the 1 link. This drives the guide bar to the right towards the side of the machine containing the pattern mechanism. It can be seen that it takes 2 links per course to produce this design. Also note that the underlap movements would be 2/1 and then 0/1.



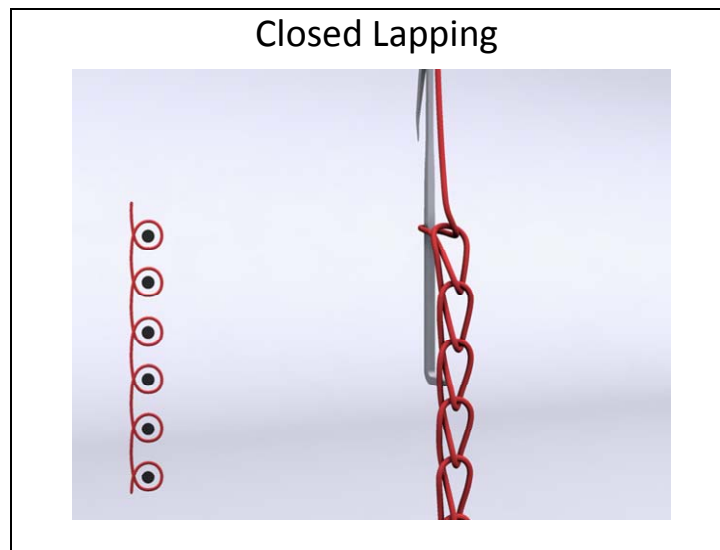
One or more of the following lapping variations are generally included in most guide bar lapping movements.

1. 1-0/1-2 (An overlap followed by an underlap in the opposite direction – forming a closed loop.)
2. 0-1/2-1 (An overlap followed by an underlap in the same direction – forming an open loop.)
3. 0-1/1-2 (Only overlaps and no underlaps – forming open laps.)
4. 0-0/2-2/1-1/3-3 (Only underlaps and no overlaps – referred to as laying-in.)
5. 1-1/1-1/1-1 (Neither overlaps nor underlaps – referred to as miss-lapping.)

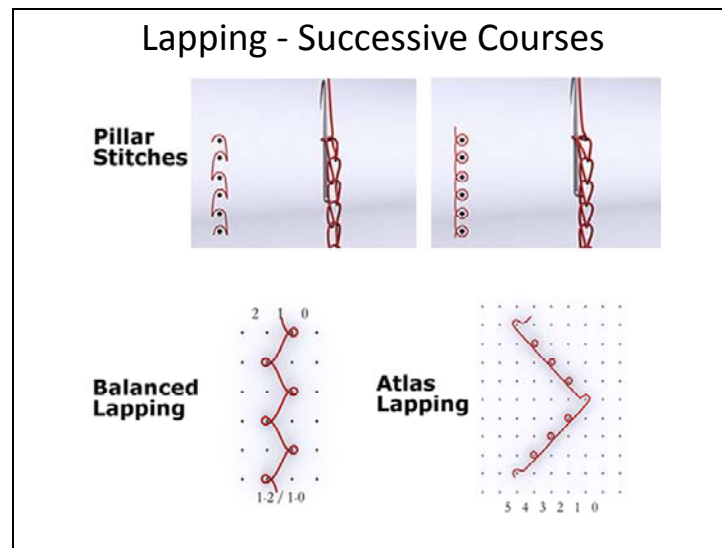
Movements 4 and 5 require the overlaps of another guide bar in front in order to hold them into the structure.



Open lapping is one of two lap forms used in warp knitting. When the overlap and the next underlap are made in the same direction, an open lap is formed, as seen in this animation. Open laps are commonly used in open-lap pillar stitches. The open lap is used when special needs arise or when technical limitations are imposed. They can be unraveled from the end of the yarn knitted last.



A closed lap is formed when the overlap and the following underlap are in opposition to one another as depicted in this animation. The closed lap is commonly used in most warp knitted structures. Closed-lap pillar stitches are used in crochet knitting because the lapping movement is simple to achieve.



When using either open or closed laps, there are three possible arrangements of lapping at successive courses, which may be used alone or in combination:

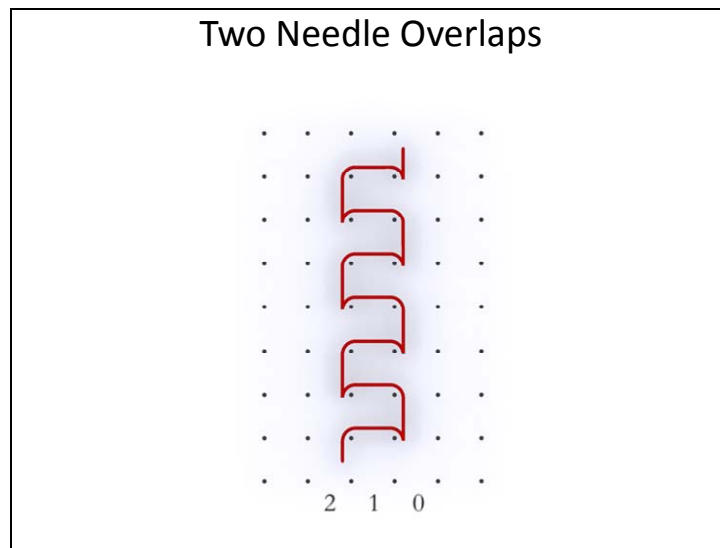
1. The Pillar Stitch: In the pillar or chain stitch, the same guide always overlaps the same needle. This lapping movement produces chains of loops in unconnected wales, which must be connected together by the underlaps of a second guide bar. Shown in this diagram are opens and closed lap pillar stitches.

2. Balanced Lapping: Tricot lapping or 1 x 1 is the simplest of these movements, producing overlaps in alternate wales at alternate courses with only one yarn crossing between adjacent wales. Two yarns will cross between wales with a 2x1 or cord lap, three yarns with a 3x1 or satin lap, four yarns with a 4x1 or velvet lap, etc.

Note: Each increase in the extent of the underlap tends to make the structure stronger, more opaque and heavier. The increasing float of the underlap has a more horizontal appearance, while overlaps produced by the same yarn will be separated from each other at successive courses by an extra wale in width.

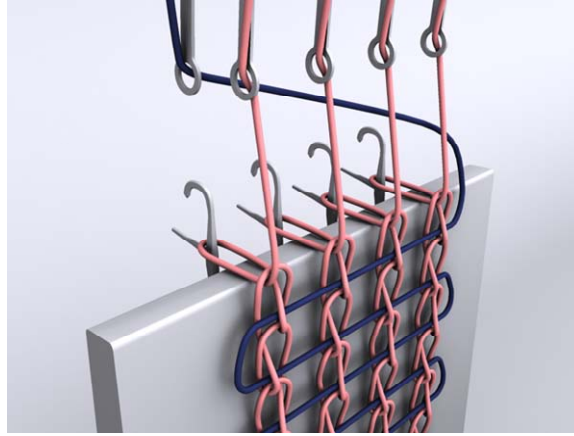
3. Atlas Lapping: This is a movement where the guide bar laps progressively in the same direction for a minimum of two consecutive courses, normally followed by an identical lapping movement in the opposite direction.



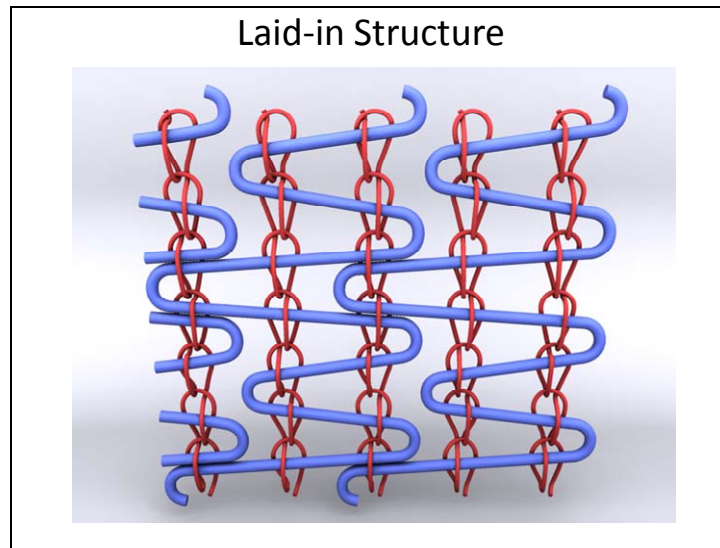


Guide bars can be shogged over two needle spaces on the hook-side of the needles during an overlap. When this happens, two needles are wrapped by each yarn and both will draw the loops simultaneously, as shown in the animated point diagram. This lapping motion is mostly used in order to provide body and stability to a single guide bar fabric. Due to excessive tension on the yarns poor appearance of the produced loops, this is usually undesirable. In two guide bar fabrics, the two-needle overlap is usually formed by the front guide bar where the yarns are more free to float on the fabric surface and form more easily into the knitted loop.

### Basic Principles of Laying-in



Another design tool in warp knitting is laying-in. For some design purposes, some of the guide bars do not knit the yarn into the fabric. The yarns are threaded through guide bars but the bars only insert the yarn ends into the fabric and are referred to as laid-in. This procedure is more prominent on Raschel machines. The accompanying figure shows the dark yarn as the laid-in yarn. Laying-in is usually produced by the back bar in two guide bar fabrics and when using more than two bars, all the guide bars, excluding the front one, can inlay their yarns into the fabric. At least one fully threaded guide bar is positioned at the front of the laying-in bars to produce the ground structure of the fabric. Fully threaded guide bars increase fabric stability when the yarn is inlaid and partly threaded guide bars are usually used to pattern the fabric. The inlaid yarn shows only on the back side of the needle; thus, an underlap is produced but the yarn does not enter the hook of the needle.

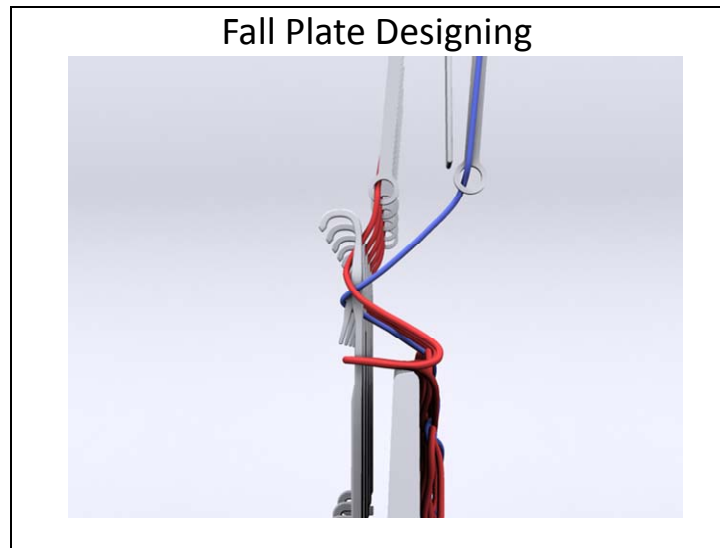


In this laid-in structure, the front bar is fully threaded with the red yarn to produce the open lap pillar stitches, while the back bar is threaded only by the blue yarn. The in-laid yarn is more visible on the technical back of the fabric than it is on the technical face.

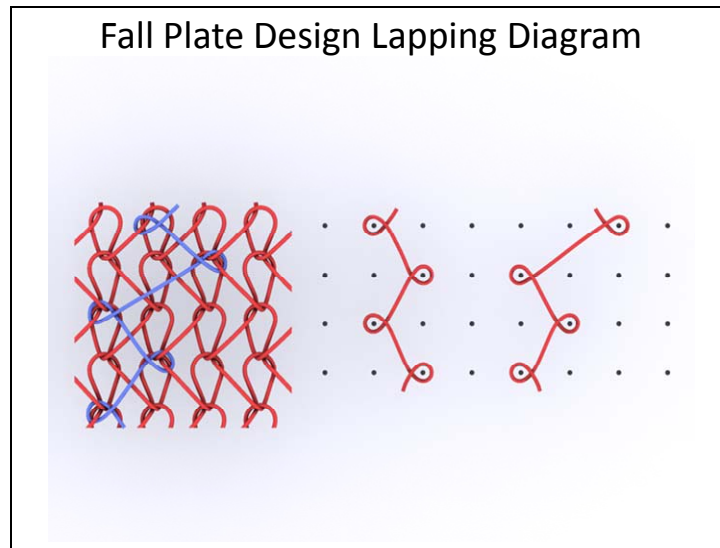
### Advantages of Laid-in Yarns

- Can allow yarns that cannot be knitted into loops to be used.
- Can lay-in yarns that are coarser and exceed the limits dictated by the machine gauge.
- Less yarn is used when it is laid-in and thus more expensive patterning yarns can be used in this way.
- Range of design can be broadened with less yarn limitations when yarn is laid-in.

Novelty or fancy yarns can be used as laid-in yarns since they are not formed into loops. Coarser yarns that exceed the limitations set by the machine gauge can be laid-in and utilized for design purposes. Any yarn capable of passing freely through the eyelet of the guides and between the needles during the swing, can be inserted into the fabric. An inlay yarn may have a yarn count that is 6-8 times heavier than the optimum count for that machine type and gauge. Since the laid-in yarns are not formed into loops, less yarn is needed. Therefore pattern yarns, which tend to be more expensive, can be used to a greater extent. In general, the designer has more yarns available for design purposes because of fewer limitations. In summary, laying-in allows the introduction of fancy, unusual, and/or inferior or superior yarns whose physical properties such as thickness, low strength, irregular surface, elasticity or lack of elasticity render them difficult to knit into regular intermeshed loops.

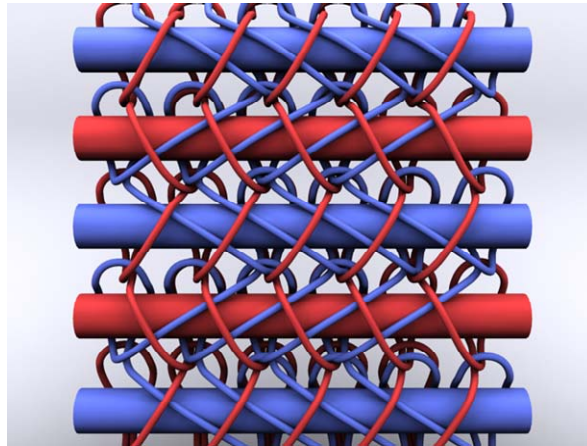


Laid-in yarns are always locked under the underlaps of the ground construction and do not produce a surface effect. A fall-plate can be mounted onto the knitting machine and consists of a thin metal plate, extending across the width of the machine and positioned between the guide bars. The fall-plate technique combines the advantages of laying-in with the possibility of producing the effect superimposed on the surface of the technical back of the fabric. The fall-plate mechanism is exclusive to latch needle raschel machines, although a similar effect to fall-plate loop structure, termed plaiting, can be achieved on crochet machines. In this animation, the fall plate moves down vertically, behind the back of the needles and the patterning yarn which is threaded in the front guide bar is pushed under the needle latch, to be cast into the fabric together with the previous course. Since fall-plate yarn is not knitted by the needle hook, fancy or heavy yarns may be used in partly or fully-threaded guide bars. Fall-plate designs use either open or closed lap movements to produce attractive relief designs whose overlaps as well as underlaps show clearly on the technical back of the fabric.

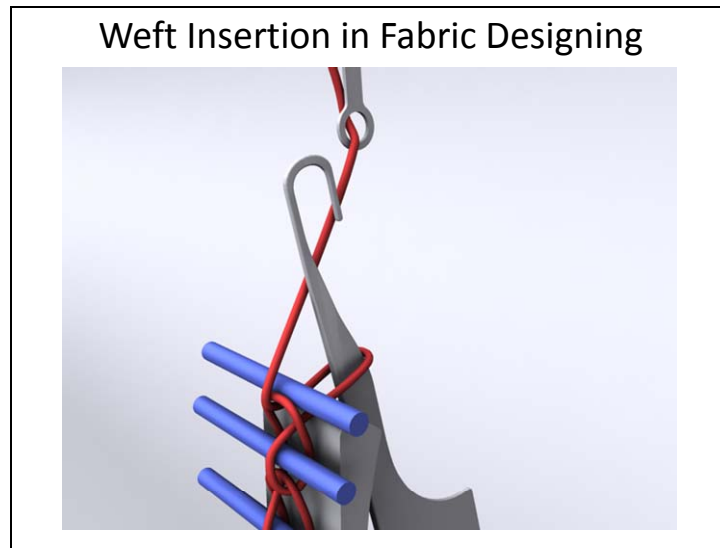


A diagram of a loop structure produced by a fall-plate mechanism is illustrated in this figure. The back bar producing the ground structure is fully threaded while only one pattering yarn is threaded in the front guide bar. Contrary to inlaid yarns, which are always locked under the underlaps of the ground construction and do not produce a surface effect, the pattering yarn lies on top of the technical back of the fabric. As already mentioned, since the yarn does not stay in the needle hooks and does not form a loop, most of the limiting factors of yarn structure are eliminated as they were with the use of laid-in yarns. The key advantage over the laid-in yarns is the fact that the effect yarns, being situated in the front guide bars, float freely on the technical back fabric surface, giving the fabric a three-dimensional appearance.

### Weft Inserted Warp Knit Fabrics

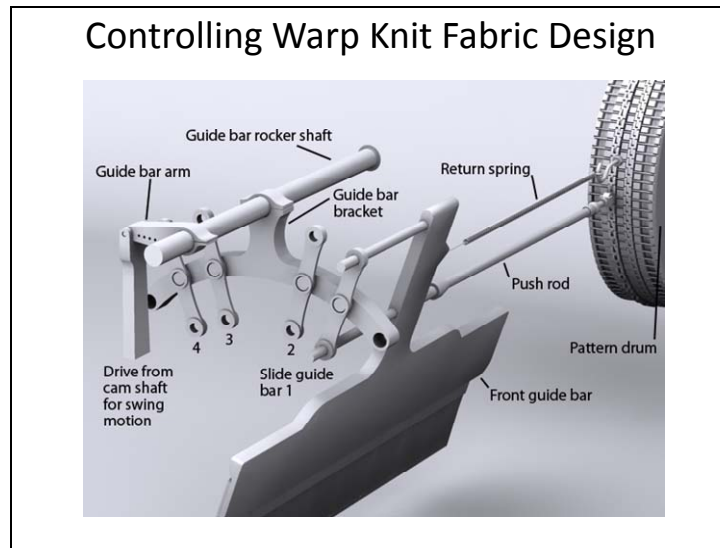


In this simulated weft-inserted warp knit structure, the weft yarn is deposited on top of the overlaps on the needles and against the yarn passing down to them from the guide bars. In this way, the inserted weft becomes trapped between the overlaps and underlaps in the same manner as an inlay yarn when the needles rise. However unlike inlay yarn, the weft will run horizontally across the complete course of loops.

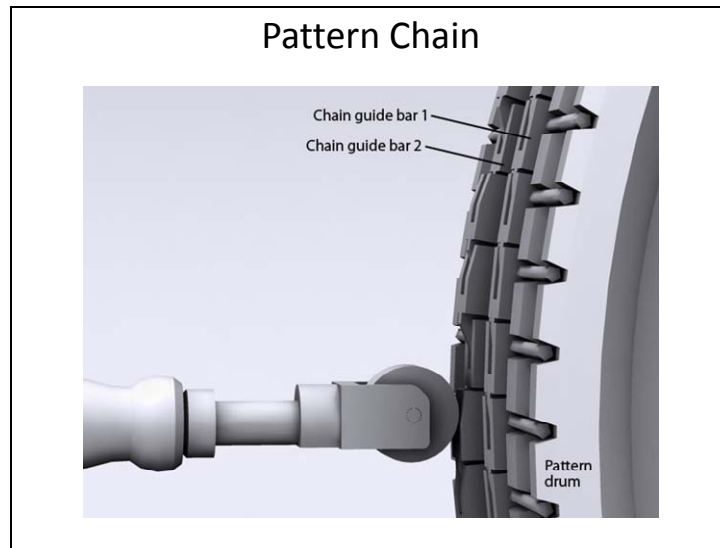


In weft-inserted warp knit fabrics, straight yarns are laid in the fabric in a horizontal fashion from selvage to selvage and perform as weft yarns in a woven fabric. Therefore the widthwise properties of the knitted fabric are similar to those of a woven fabric. High quality tricot and Raschel fabrics can be produced using weft insertion. The accompanying diagram shows the incorporation of the weft yarn into the warp knit structure. As in the use of laid-in yarns and fall-plate designing, yarn limitations are overcome using this technique. Weft-inserted warp knitting machines operate with two rotating chains, one on each side of the machine. The chains contain hooks whereby each weft yarn can be stretched out from respective hooks in each chain. As many as 24 yarns are simultaneously stretched across hooks in a magazine type system, allowing yarns to be always available for high speed insertion. The weft yarns are placed behind the needles. After being placed into the fabric, the weft yarns must be separated from the chains and trimmed by automatic scissors at the selvage.





To produce different warp knit designs, one must control the shogging movements of the guide bars. Different shogging movements are initiated by varying the radius of a continuously turning pattern shaft, either in the form of different heights of pattern links that pass over a pattern drum attached to the shaft, or in the form of carefully shaped solid metal circular cams, termed pattern wheels. The accompanying diagram shows a pattern drum that can be rotating with different links of different heights controlling the shogging movements of an associated guide bar. Each separate guide bar has separate chain links to guide its movement. An increase in height from one link to the next produces a thrust against the end of the guide bar, shogging it positively in a direction away from the pattern device. A decrease in height from one link to the next produces a negative shog in a direction towards the pattern device. A constant height will produce no shog and the guide bar will continue to swing through the same needle space.



As seen in this diagram, Y-shaped chain links are similar in appearance to a tuning fork with the fork end leading. The tail of the preceding link fits into the fork of the succeeding link. The links are held together by pins that are pushed through holes in the sides of the fork and tail. Tricot links are numbered 0, 1, 2, 3, 4, 5, etc. As noted earlier, with direct shogging, each successive number is one needle space higher than the previous link. It must be understood that the height of a link, for example "0", does not represent a fixed position between two needle spaces because all the guides in the same guide bar will have been positioned by the same "0" link, but each will be between a different pair of needles across the knitting width.

## Electronic Guide Bar Control

- Pattern wheels and chain links are ground to match a specific design that is desired in a fabric.
- A new pattern chain or new set of pattern wheels is required when a different design is placed on the machine.
- In electronic pattern systems, a separate linear motor to directly shog each guide bar is used.

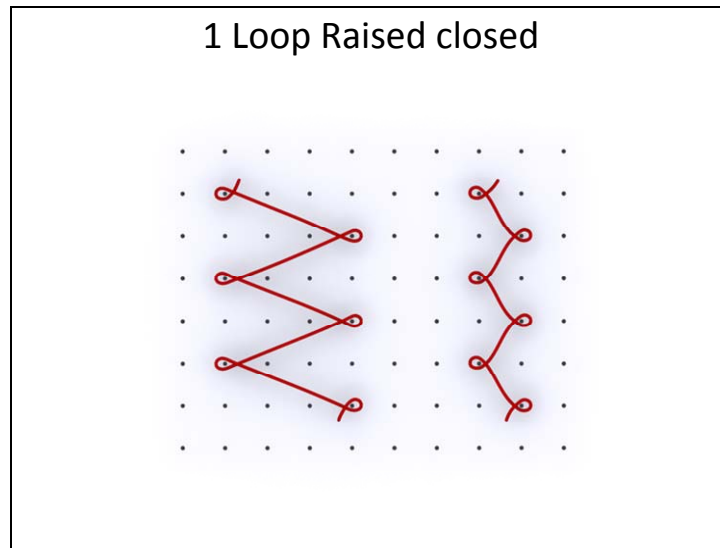
Pattern wheels and chain links have to match up with a specific design for a warp knit fabric. Every time a new fabric is desired, a new pattern chain or new set of pattern wheels is needed. In electronic pattern systems, a separate linear motor to directly shog each guide bar is used. Different designs can, therefore, be developed on a CAD system and then downloaded to the warp knitting machines.

## Typical Tricot Designs

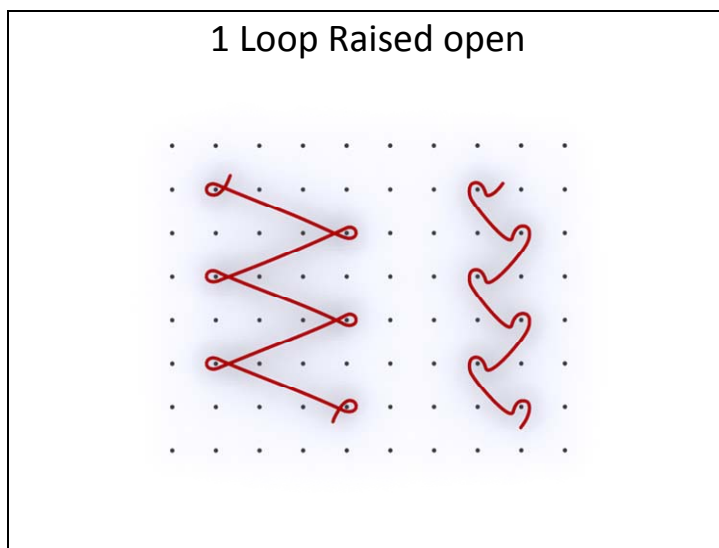
### Tricot Two Bar Fabric Characteristics

- Single bar fabrics tend to be dimensionally unstable.
- Single bar fabrics exhibit an unbalanced loop structure and loop inclination.
- Most tricot fabrics are two bar with fully threaded guides.
- Two separate warps feed into these fabrics, each going through different lapping motions.
- The relative movement of the two guide bars along with the magnitude of shogging, determines the appearance and properties of the fabrics.
- Each guide bar contributes a yarn to every overlap and the two underlaps lap to a different angle, extent, or direction.
- Normally the yarns of the front guide bar tend to dominate the face as well as the back of the fabric.

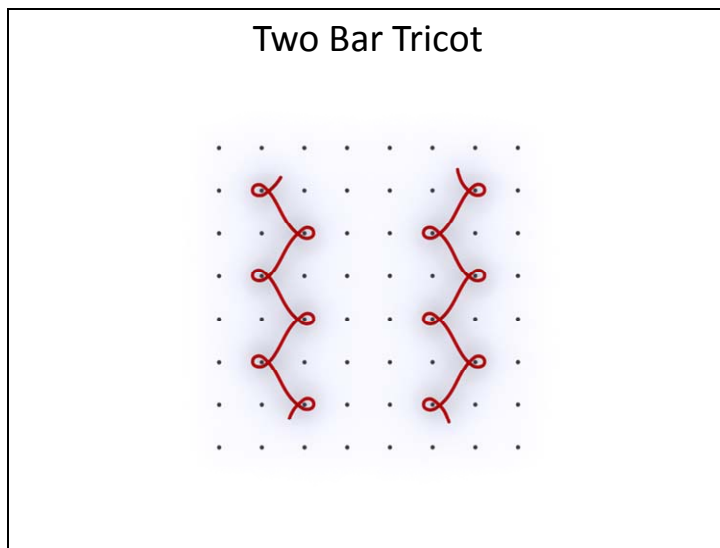
Single-bar structures are usually unstable dimensionally. Many of them exhibit an unbalanced loop structure and loop inclination is very pronounced. Currently, most fabrics produced on tricot machines are constructed by two fully threaded guide bars which are fed from two separate warps which go through different lapping motions. If the lapping movements were the same, the structure would have similar characteristics as single guide bar fabrics. The relative movement of the two guide bars in combination with the magnitude of the shogging, determines the appearance as well as the properties of the fabrics. Each guide bar contributes a yarn to every overlap and the two underlaps can be clearly distinguished as they lap to a different angle, extent, or direction. Under normal conditions, the yarns of the front guide bar tend to dominate the face as well as the back of the fabric.



To produce a loop raised design, the underlaps of the two bars move together, as seen in this animation. The loops will lie at an angle in the fabric, the direction of inclination depending on the direction of movement of the underlaps. In this diagram the back bar loops are closed.

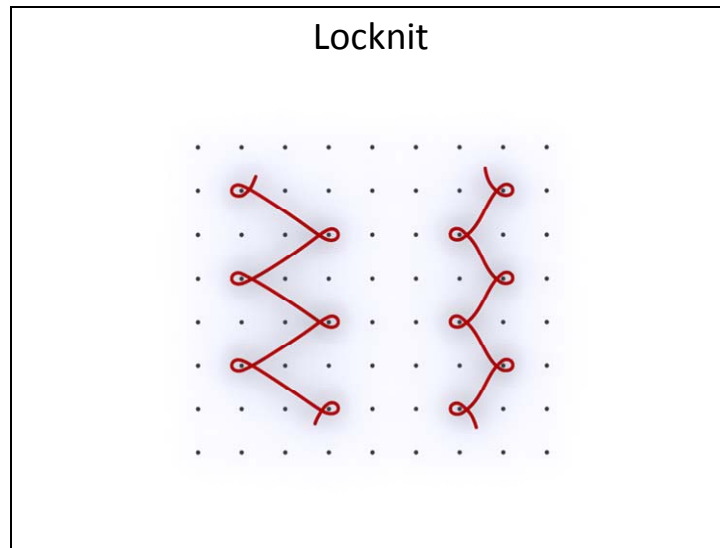


In this diagram the back bar loops are open.

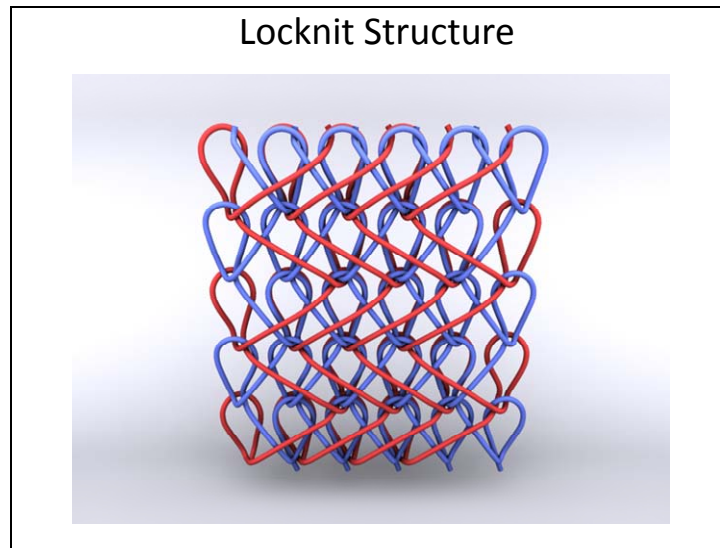


This two bar tricot is the simplest two bar structure and uses a minimum amount of yarn. As seen in this animated diagram, the two laps balance each other exactly as they cross diagonally in between each wale, producing upright overlaps. However this fabric tends to have poor cover and, in fine denier continuous filament yarns, the fabric tends to split between the wales in some finishing processes. This is particularly true with acetate and triacetate yarns.

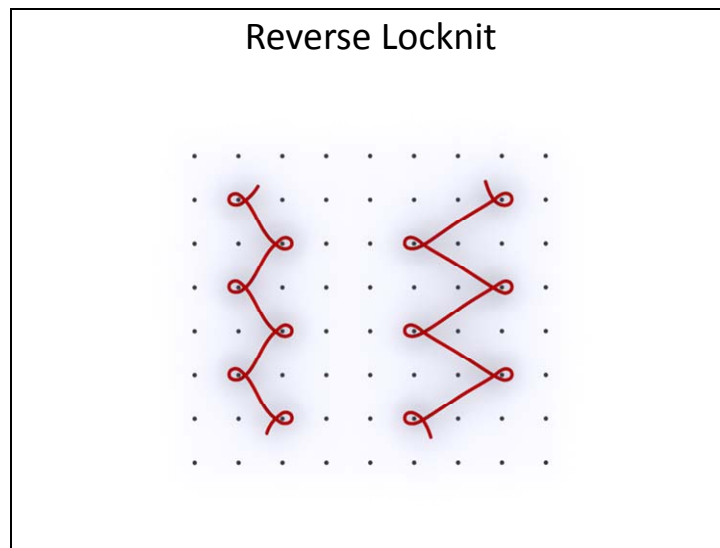




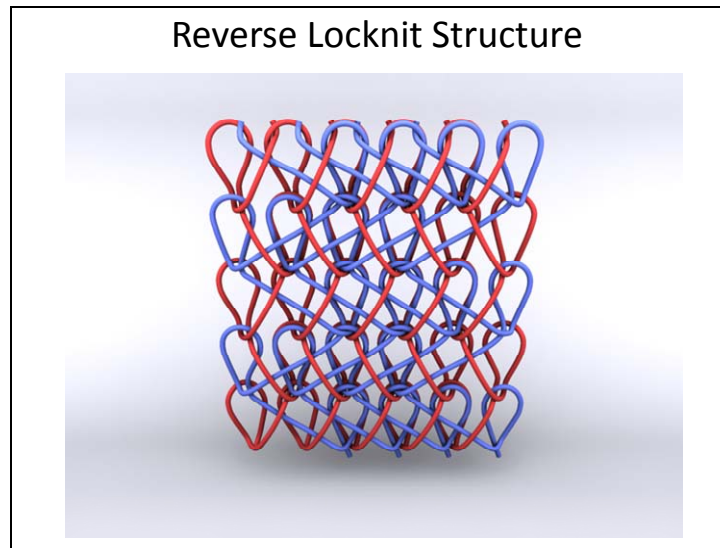
The most widely used of all warp knit structures is locknit. As seen in the accompanying animated design, the longer underlaps of the front bar appear on the back of the fabric and help to improve widthwise extensibility, cover, opacity, and give a smooth, soft hand and good drapability to the fabric. In the US, some refer to this structure as jersey and in Germany and France it is called charmeuse. The elasticity of locknit makes it particularly suitable for lingerie and intimate apparel. The free-floating underlaps that are superimposed on the technical back also contribute to a very pleasant touch which is desirable in lingerie. Popularity of this design is also due to it being the lightest non-splitting fabric. Contraction of this fabric, once it leaves the knitting machine, can exceed 30%, depending on the knitting conditions, yarn type, and yarn tension. Traditionally produced on 28 gauge machines, the trend is to produce locknit on 32 to 40 needles per inch.



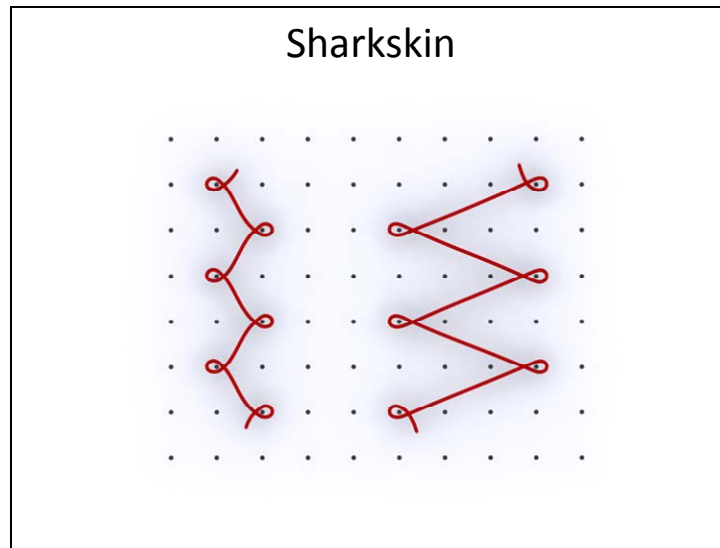
To produce the locknit structure as shown in this diagram, the back bar, with blue yarns, shogs a 1-and-1 lapping movement, as in tricot fabric structures, but the front guide bar, with red yarns, shogs two needle spaces. The yarn consumption of the two guide bars depends on fabric quality, machine gauge, yarn type, and knitting conditions.



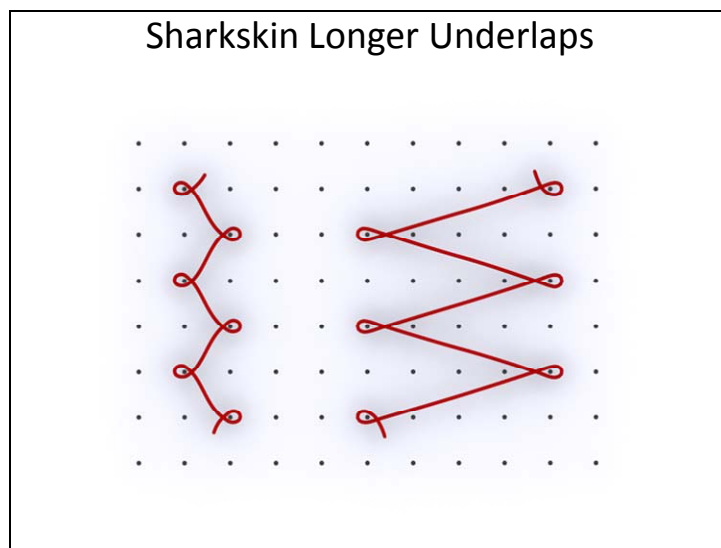
Reverse locknit is used to a lesser extent than locknit. It is sometimes called reverse jersey in the US. It has reduced extensibility and no curling, and because of the short front guide bar underlaps, it has a lower shrinkage in finished width. This fabric design is named because it is made with a longer underlap on the back bar and a shorter one on the front guide bar, which is opposite or reversed of what is found in the locknit design.



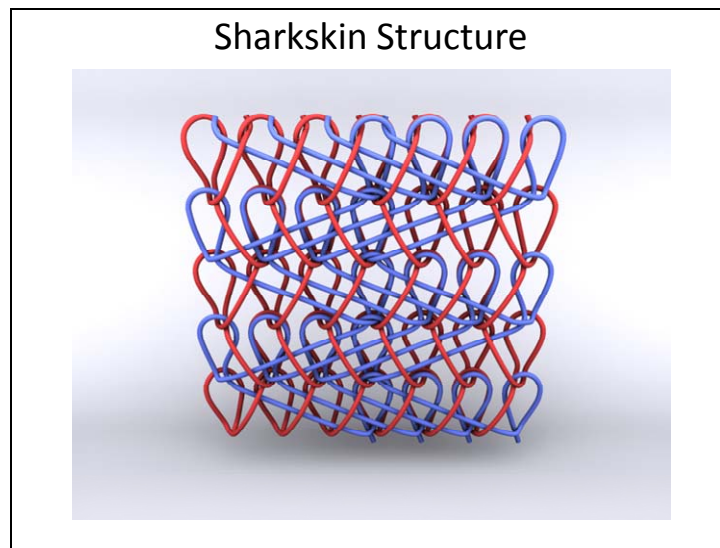
A reverse locknit structure can be seen in this diagram. The longer underlaps, with blue yarns, were produced on the back bar and the shorter underlaps, with red yarns, were produced on the front guide bar.



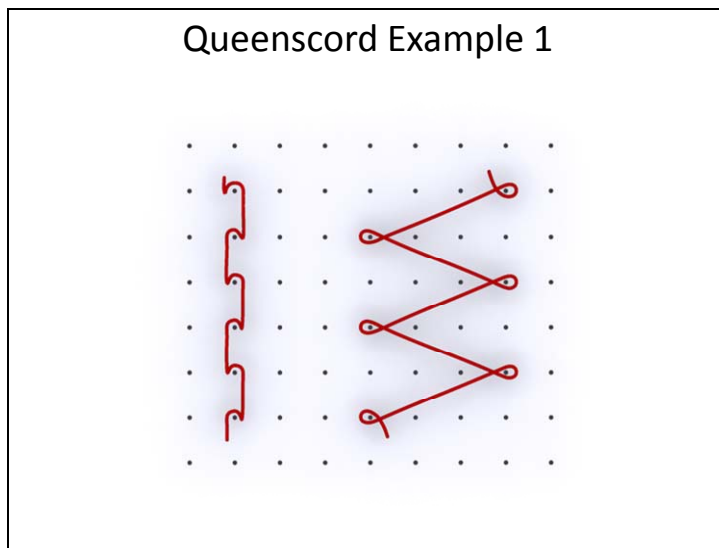
Sharkskin design produces a warp knit fabric with more rigidity and a heavier weight. These characteristics are produced in the fabric by increasing the back guide bar underlap to three or four needle spaces. This diagram shows the back bar underlap is three needle spaces. Sharkskin is constructed as a reverse version of satin, having longer underlaps on the back bar instead of the front bar.



Another sharkskin design shows the back bar underlap covering four needle spaces. The front guide bar design remains the same.



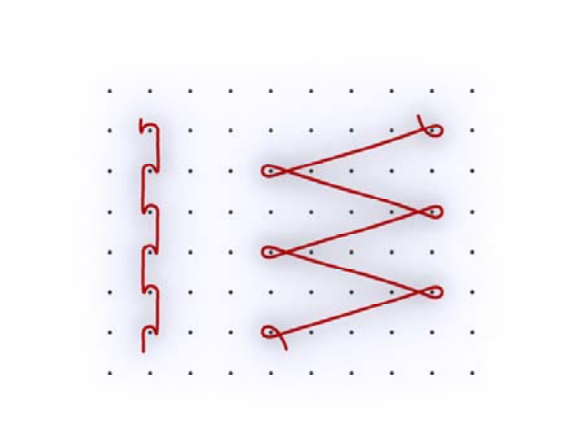
This sharkskin loop drawing shows the red yarn on the front bar and the blue yarn, with the longer underlaps, being knitted on the back bar. The back bar underlaps are over a span of three needle spaces. The loop structure shows the longer underlaps of the back guide bar locked under the short underlaps of the front guide bar. The trapped underlaps restrict the shrinking potential of the fabric which is therefore more rigid and more stable than those described previously.



The Queenscord has even more rigidity than sharkskin. Because the front guide bar makes the shortest possible underlap as seen in this diagram, the pillar stitch tightly ties-in the back bar underlaps, producing a fabric with less shrinkage than Sharkskin. The pillar stitch yarn as it passes up the wale tends to give the fabric appearance a slight cord effect and the underlaps of the pillar are unable to balance the underlaps of the back bar so they show inclined slanted stitches. The queenscord illustrated is constructed with a chaining front bar and a reciprocating 3-and-1 movement on the back bar. In other words, each underlap spans three needle spaces.



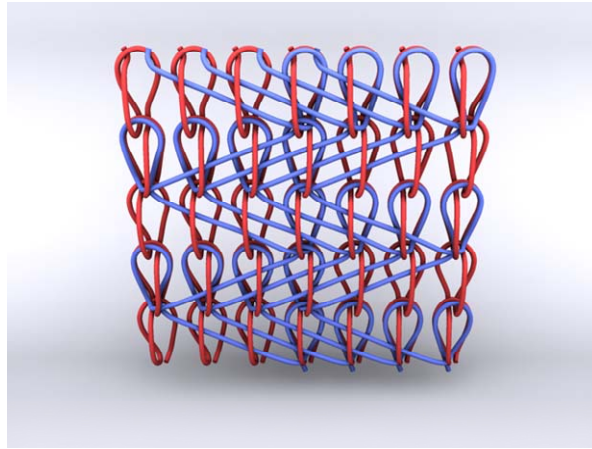
## Queenscord Example 2



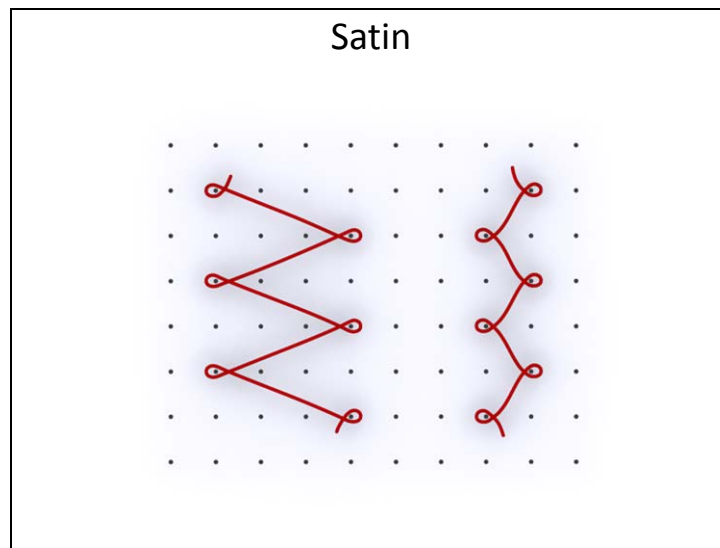
The diagram illustrates a Queenscord configuration on an 8x8 grid. The queens are positioned at (1,1), (2,2), (3,3), (4,4), (5,5), (6,6), (7,7), and (8,8), forming a main diagonal. A red line highlights the path of the queens from (1,1) to (8,8). The queens are numbered 1 through 8, corresponding to their row and column indices.

The queenscord illustrated in this point diagram is constructed with a chaining front bar and a reciprocating 4-and-1 movement on the back guide bar. In other words, each underlap spans four needle spaces. When knitting queenscord, a pin-stripe effect can be produced by threading the front guide bar with colored yarns. This fact, together with the superior stability of queenscord, has made it very popular for the production of shirting fabrics.

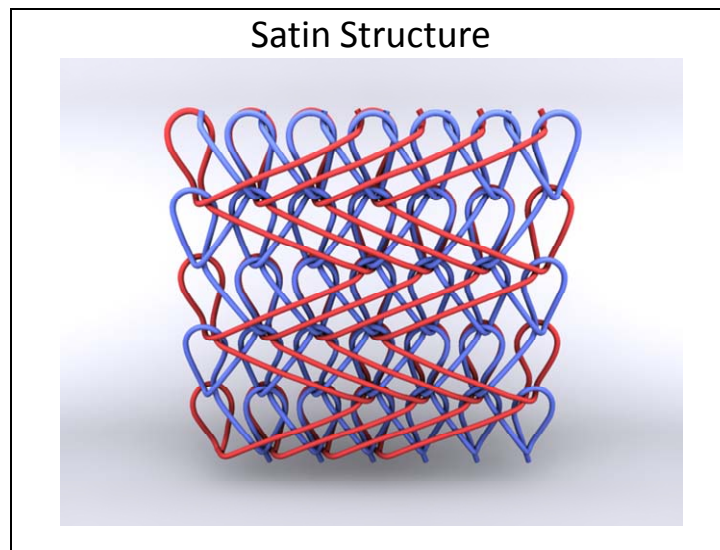
### Simulated Queenscord Construction



In this diagram of a queenscord fabric construction, the red yarns form the pillar stitches produced by the front guide bar and the blue yarns represent the long underlaps produced by the back guide bar. As can be seen, the longer back bar underlaps cover three needle spaces and are trapped in the center of the fabric by the front bar underlaps.



The lapping movement for a satin warp knit fabric is shown in this point diagram. The front bar shows one needle space longer than in locknit. The technical face is similar to locknit but the technical back is smoother and shinier due to the underlaps of the front guide bar, which are longer and more parallel to each other. The fabric is elastic and very comfortable to wear. The long underlaps on the front guide bar cause the fabric to shrink considerably after leaving the needles of the machine.



The loop diagram shown is a three-needle satin structure. The red yarns are knit on the front guide bar and the underlaps of the front guide bar show up on the technical back of the fabric, making it smooth and more lustrous, especially when knitting with continuous filament yarn.

## Fabrics with Uniform Appearance

A regular warp knit fabric surface can be produced when the following criteria are met:

1. Each guide bar is fully threaded and every guide in a particular bar has the same yarn threaded through it.
2. Each guide bar makes a regular lapping movement of similar extent at each course.
3. When a weft yarn is inserted, it occurs with a similar yarn at regular intervals.
4. Warp yarns are supplied to each guide bar at a constant tension and at a uniform rate from course to course.

A regular warp knit fabric surface can be produced when the following criteria are met:

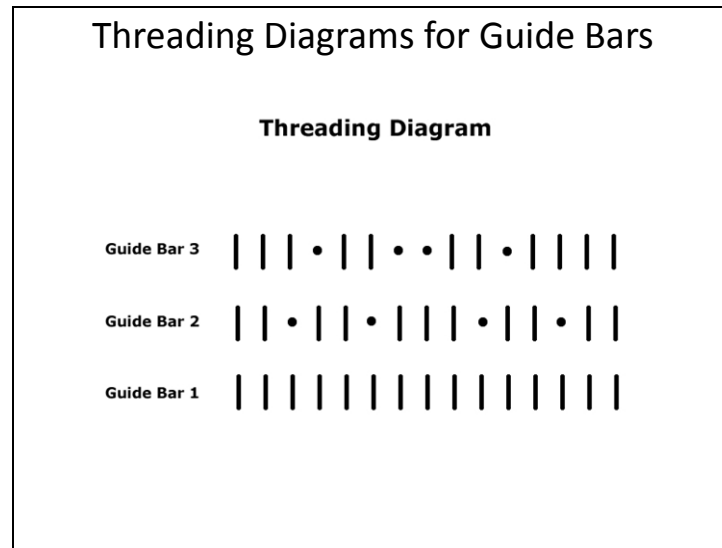
1. Each guide bar is fully threaded and every guide in a particular bar has the same yarn threaded through it.
2. Each guide bar makes a regular lapping movement of similar extent at each course.
3. When a weft yarn is inserted, it occurs with a similar yarn at regular intervals.
4. Warp yarns are supplied to each guide bar at a constant tension and at a uniform rate from course to course.

### Non-uniform Appearance Fabrics

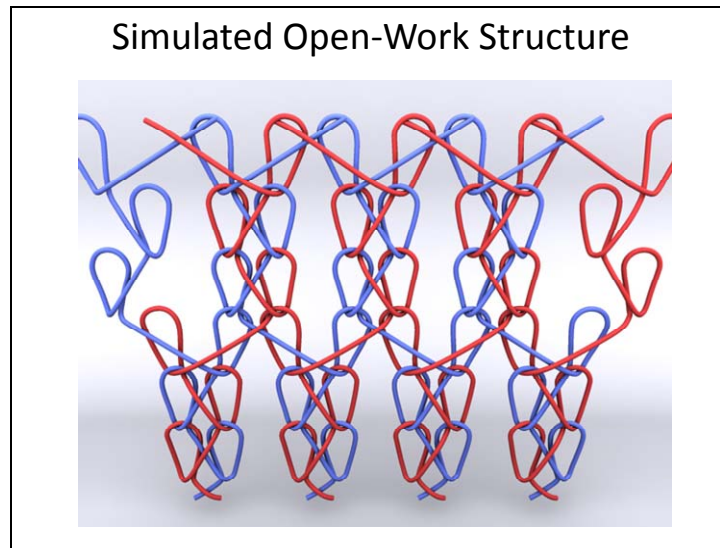
1. Guides can be threaded with different types of yarn or they can be left empty without yarn. This will alter the appearance of the particular wales lapped by the guides.
2. The extent of underlaps can be varied by a guide bar which affects the appearance of those courses where the variation occurs. If the guide bar is fully threaded, the effect will run across the width of the fabric. Similar effects can be obtained using weft insertion and different types of yarn, or by varying the frequency of the insertion.
3. Fabric appearance can also be changed at certain courses by varying the rate of warp supply or selectively tensioning the warp yarns and thus influencing the length of yarn in the underlaps.

An irregular warp knit fabric surface can be produced by varying one or more of the criteria to produce surface interest and open-work.

1. Guides can be threaded with different types of yarn or they can be left empty without yarn. This will alter the appearance of the particular wales lapped by the guides.
2. The extent of underlaps can be varied by a guide bar which affects the appearance of those courses where the variation occurs. If the guide bar is fully threaded, the effect will run across the width of the fabric. Similar effects can be obtained using weft insertion and different types of yarn, or by varying the frequency of the insertion.
3. Fabric appearance can also be changed at certain courses by varying the rate of warp supply or selectively tensioning the warp yarns and thus influencing the length of yarn in the underlaps.



The guide bars used in the production of some warp knit fabrics are only partly threaded in a predetermined sequence, and some of the guides are empty of yarn. When this happens, openings in the fabric structure can be created. This method is used for the production of net fabrics, meshes, laces and curtains. It is sometimes useful to illustrate the threading arrangement in the guide bars by using numbers to describe the sequence of empty and threaded guides. For example: guide bar 1 fully threaded, guide bar 2 threaded 2 in and 2 out, and guide bar 3 is 1 out, 2 in, and 1 out. A threading diagram can also be employed to describe a more complex sequence. Such a structure is seen in this diagram. Each horizontal row represents a guide bar. Short vertical lines represent guides where a yarn is threaded and dots indicate an empty guide eye. Guide bar 1 is fully threaded. Guide bar 2 is 2 in, 1 out, 2 in, 1 out, 3 in, 1 out, 2 in, 1 out, and 2 in. Guide bar 3 is 3 in, 1 out, 2 in, 2 out, 2 in, 1 out, and 4 in. When knitting with different yarn types or different colors, the full lines can be substituted with alphabetic letters, numbers or other symbols to represent each yarn type or color.



The simulated open work structure seen in this example demonstrates how open-work structures can be produced by using different threading techniques including leaving some guide eyelets vacant of yarn. Thus, instead of using full set threading, partial set threading is used. This technique is mainly used for the production of net fabrics with a variety of mesh openings. In two-bar tricot fabrics, an opening is formed in the fabric structure when two wales do not connect. With full set threading, the only way to prevent the wales from connecting is to produce a pillar stitch. It is common practice in Raschel knitting to form nets in such a manner. Tricot knitting, however, is not equipped to knit single, unconnected chains since the sinker, as a major participant in loop formation, must hold an underlap to prevent the fabric from rising with the needles. Therefore in tricot knitting, the narrowest possible continuous fabric between two openings is made of two wales. The sinker can then hold the fabric between these two needles which allows the needles to clear. A fabric knitted in this way is shown in the diagram. Notice the double wale on each side of the opening.



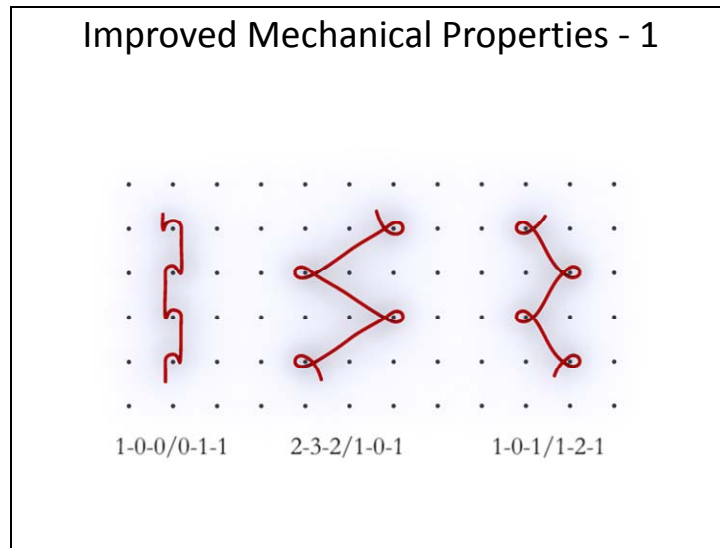
## Multi-Guide Bar Designs

### Additional Guide Bar Advantages

- Better control of dimensional and mechanical properties
- Improved pile fabrics
- Greater use of color
- More elaborate part set threading designs
- Improved elasticated fabrics

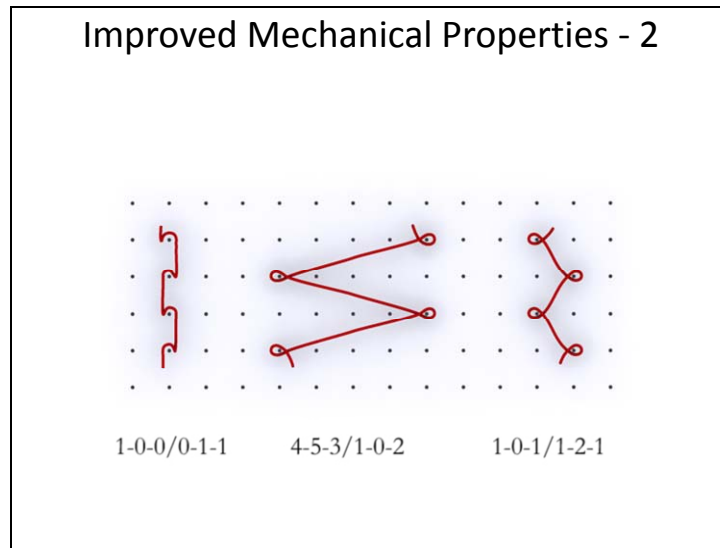
“Three or more guide bars” usually refers to tricot machines with three and four guide bars. The construction of these types of fabrics increases the versatility and enlarges the pattern scope of the tricot machine. The increasing swinging movement of the guide bars decreases the production of these machines. However, the increased patterning possibilities offer important advantages:

1. Better control of dimensional and mechanical properties.
2. Improved pile fabrics because of a more stable ground structure.
3. Greater use of color and visibility of color on the fabric surface.
4. More elaborate part set threading designs to produce a wide range of mesh and lace-like fabrics.
5. Improved elasticated fabrics with more patterning possibilities and less transparency of the fabric knitted.



As seen in the animated point diagram, the chaining front bar is responsible for a very high lengthwise stability, while the remaining two bars, with varying underlaps, impart widthwise stability.

Notice that 3 pattern links per knit course are used. This is indicated by the use of three numbers instead of two. This is used on many modern tricot machines because the guides spend very little time on the hook-side of the needles during the overlap and a much larger proportion of the knitting cycle is spent when they are on the front side. The 3 links per course movement distributes the time allotted for each shogging movement in a better way.



The lapping movement shown in this diagram produces a heavier and more stable fabric, due to the longer shogging movement of the middle bar.

## Raschel Warp Knit Structures

### Knitting Elements of Raschel Machines

- Most equipped with compound needles
- High speed production
- Gauges between 6 and 32 needles per inch
- Guide bars range from 2 to 10 normally
- Includes fully threaded guide bars or a combination of fully threaded and pattern bars in a nesting arrangement

Most standard Raschel machines are equipped with compound needles. Hook size and needle stroke are designed as short as possible to allow high-speed production. Usual gauges are between 6 and 32 needles per inch and in some cases the gauge is even coarser due to part set threading. Normally, the number of guide bars range from 2 to 10 and their assembly includes fully threaded guide bars or a combination of fully threaded and pattern bars in a nesting arrangement.

## Net Fabrics Raschel Machines

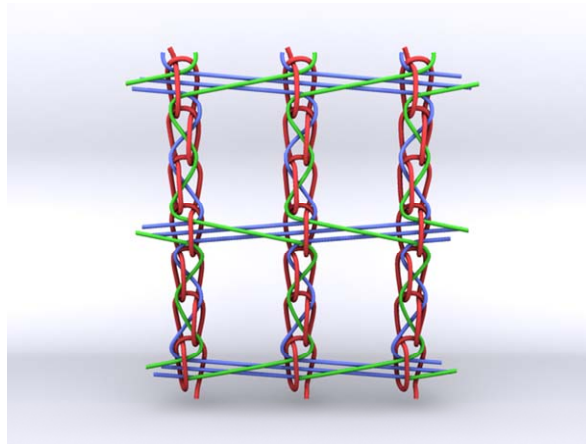
- Use of unconnected chain lappings to produce open work
- Differences in net structures result of:
  - different loop constructions
  - different sizes of openings
  - different types of yarns

### **Examples**

- Shade nets
- Fish Nets
- Camouflage Nets

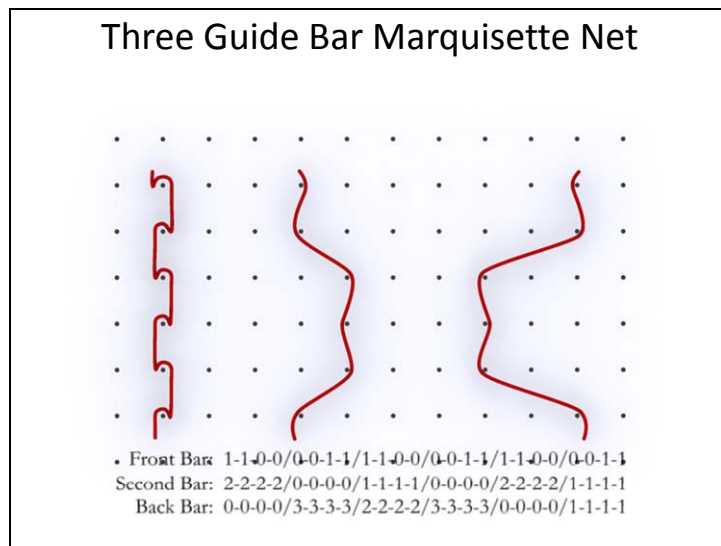
Net fabrics are produced in very large quantities. The Raschel machine is equipped to produce unconnected chain lappings and is thus capable of producing a multitude of net structures. Differences in net structures are the result of different loop constructions, different sizes of openings and different types of yarns. Nets are produced for a variety of end uses, ranging from shade nets to fishing nets, and from wrapping to camouflage nets.

## Common Net Structure - Marquisette

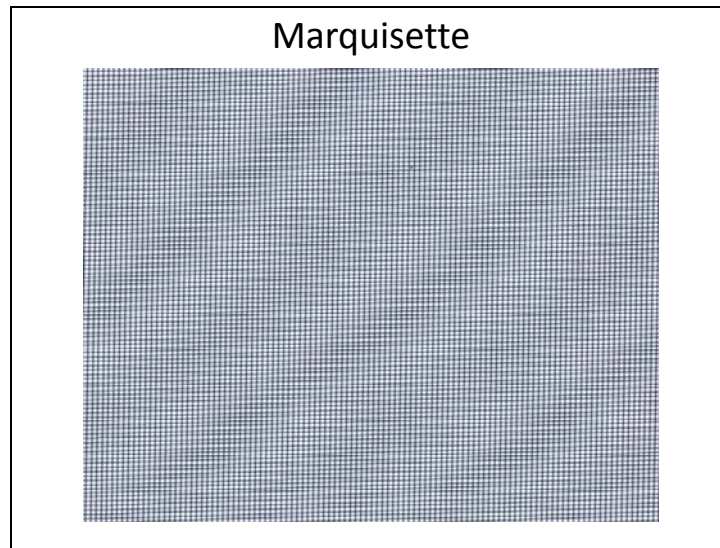


The marquisette net structure is one of the most popular net structures. Notice how the side connections by the inlay yarns do not appear in each knitted course. Marquisette structures are popular in net curtains. The loop structure of a three-guide bar marquisette is shown in this diagram. The front guide bar is constantly chaining to produce the vertical pillars while the horizontal connections are produced by the inlay yarns which are threaded in the back guide bars.



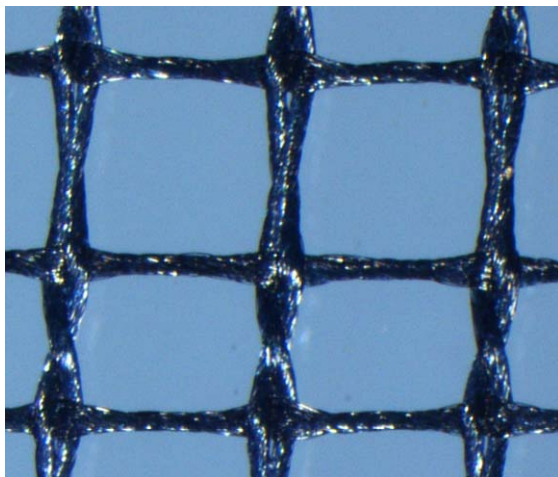


This point diagram illustrates the lapping movement of a three guide bar marquisette along with the associated chain notations. As can be seen, the chain notations can be rather complex as one deals with more guide bars and open structures.

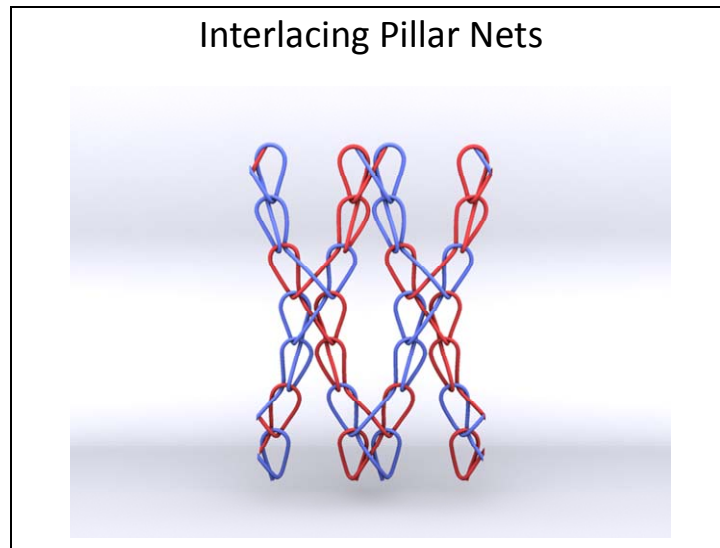


As seen in this photograph of a marquisette net, the fabric is a very open and transparent structure.

Marquisette - magnified



This magnified view of a marquisette fabric highlights the chain stitches and the connecting inlay yarns.



Occasionally nets are formed by interlacing pillars in the structure to produce various shapes of openings. The opening in this simulated fabric is diamond-shaped. To produce the connections between the pillars, after a predetermined number of courses, the guide bars are shogged in opposition to one needle space. During this course, each of the guide bars draws its new loops through the loop previously made by the adjacent yarns. When the connection is made, each guide bar is shogged to its original position and resumes the chaining lapping movement. The next connection is carried out in the opposite direction to the first and so the diamond shaped openings are formed.

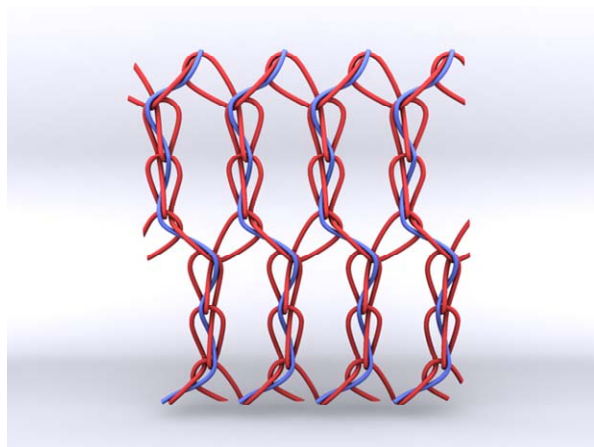
## Other Raschel Knit Fabrics

- Net Curtains and Drapes
  - using inlay techniques
  - using weft-inserted yarns
  - using fall-plate technology
  - using tulle net loop structures
  - using multi-guide-bar machines
- Heavier Fabrics for Outerwear and Upholstery
- Elasticated Fabrics

Other examples of raschel knit fabrics are:

1. Net Curtains and Drapes
  - using inlay techniques
  - using weft-inserted yarns
  - using fall-plate technology
  - using tulle net loop structures (illustrated on next slide)
  - using multi-guide-bar machines
2. Heavier Fabrics for Outerwear and Upholstery
3. Elasticated Fabrics

### Tulle Net Curtain Nets



This is a loop structure diagram of a tulle net loop design. It is sometimes used as a ground structure for curtain fabrics. Some tulle structures are used for raschel lace and bridal veil net products.

## Double Needle Bar Machines

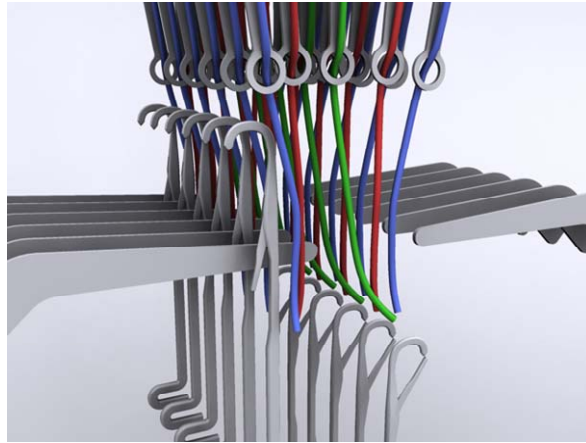
## Double Needle Bar Tricot

- Production of double-face fabrics
- Two sets of needles arranged back to back
- Technical face of the fabric shows on both sides
- Underlaps are locked within the structure
- Used in knitting glove fabrics, outerwear, and underwear.
- Sometimes called a Simplex machine
- Fine gauge, spring bearded needles
- Gauges from 28 to 32 needles per inch
- Machine widths typically 84, 93, 138, and 168 inches

Double needle bar tricot machines were developed for the production of double-face fabrics. By placing two sets of needles back to back, the technical face of the fabric shows on both sides, while the underlaps are locked within the structure. The double needle bar tricot fabrics can be used in the glove industry and also suitable for outerwear and underwear. The machine, also called a Simplex machine, typically uses two guide bars, is fine gauge, and uses bearded needles. Gauges range from 28 to 32 needles per inch in each needle bed and machines are typically in widths of 84, 93, 138, and 168 inches. On these machines, both guide bars wrap each needle bar in turn and thus produce one double-sided fabric.

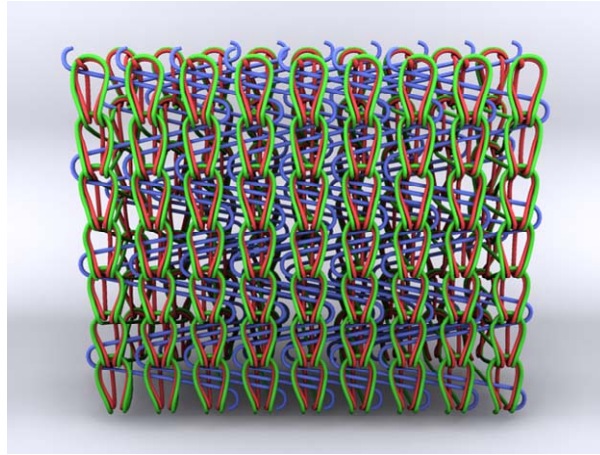


### Double Needle Bar Animation



Machine types are built with varying numbers of guide bars, for the production of a wide variety of products ranging from packing sacks to artificial blood vessels. On these machines, as can be seen in the animation, the needle bars are independently operated in an up-and-down movement while the guide bars swing alternately among the needles of each bar. On the conventional double needle bar machine, each needle bar in turn is active only for half of the 360 degrees of the knitting cycle. Two sinker bars are shown, each one operating with its associated needle bar.

### Double Needle Bar Structure



This double needle bar simulated structure reveals all the connecting yarns between two faces of the fabric. As such, a knitted sandwich structure can be formed. Two guide bars form the front fabric, two guide bars form the back fabric and one guide bar knits on both the needle bars to produce the floating yarns. The diagram shows the pile yarns anchored in both fabrics and also connecting both fabrics. After the knitting operation, the fabric is separated into two pile fabrics by cutting the float or connecting yarns between the two fabric faces. Thus two identical fabrics come off the machine after cutting and the pile yarn is apparent on both fabrics. Upholstery fabrics form one of the largest markets for these fabrics and a large share of automotive textile products are produced in this way. The machines that make these fabrics are sometimes referred to as plush Raschel machines.

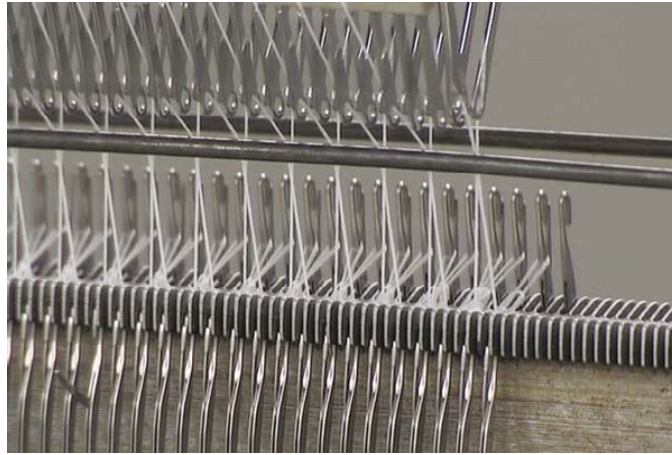
## Double Bar Products

- Tubular Articles
- Packing Sacks
- Pile Fabrics
- Branching Tubular Fabrics
- Pattern Fabrics
- Spacer Fabrics
- Geotextiles
- Safety Textiles

Typical products made on double bar raschel machines are as follows:

1. Tubular Articles – including seamless panties, brassieres, and pocketings.
2. Packing Sacks for fruit and vegetables knit from polyolefin in fibrillated tape or mono-filament form.
3. Pile Fabrics – including cut pile fabrics made by joining fabrics made on each needle bar with a connecting yarn which when cut produces two pile fabrics. Examples of these fabrics are simulated fur fabrics, upholstery and coat linings.
4. Branching Tubular Fabrics – such as artificial blood vessels.
5. Patterned Lace Panty Hose, Curtains, and Pile Fabrics – which are made on machines with up to 36 guide bars or more and equipped with a jacquard mechanism.
6. Spacer Fabrics – which are manufactured so the distance between the two fabric surfaces is retained even after compression by the resilience of the pile or connecting yarns which can be stiffer yarns such as monofilament synthetic yarns. Spacer fabrics have a hollow center which may be filled with solid, liquid, or gaseous material. The hollow center can also be filled with air for good insulation properties. End-uses for spacer fabrics include molded bra cups, padding, and linings along with many medical applications.
7. Geotextiles – for drainage, filter, and membrane materials, road and tunnel reinforcement, and erosion protection.
8. Safety Textiles – such as heat and flame-resistant protective clothing for civil and military purposes.

### Four Guide Bar Two Needle Bar



This Raschel machine is equipped with two needle bars, which operate independently of one another. It has two beam shafts feeding yarns to four of the guide bars. Two of the guide bars knit the main body of the fabric while the other two guide bars knit in the selvage or edge of the fabric. Rotating cams cause the needle bars to ascend in order to be in a position for overlapping and shogging and then descend to form the knit loops. Pattern chains are employed to create the fabric design. Four rows of links provide the necessary movement of the guide bars. The different profiles of the links create the necessary shogging movements. A round metal wheel called a follower, traces the profile of the links in the pattern chain. Lower profile links shog an associated guide bar to the right for overlapping and underlapping and higher profile links shog an associated guide bar to the left for overlapping and underlapping. Each follower wheel is connected to one of the guide bars. Notice the four guide bars in use and the heavy-duty springs used to bring the guide bars back to the right after extension or movement to the left away from the pattern mechanism. Two needle bars are knitting, each alternating with the other. One needle bar moves upward as guide bars swing forward and then shog for the formation of the overlaps and then underlaps. The needle bar then recedes and the other needle bar is raised to pick up yarns from the guide bars and then it recedes. This alternating movement of the two needle bars continues as the fabric is knitted, each needle bar knitting once during each 360-degree revolution of the machine's cam-shaft. Thus the production rate is approximately cut in half. The use of the two needle bars can create tubular fabrics, each needle bar knitting a single-faced fabric. Pile fabrics can also be produced as connecting yarns between the two needle bars are slit later and two pile fabrics are the result. Spacer fabrics can be manufactured when the connecting yarns are uncut resulting in a double-faced fabric.

### Warp Knitting Capabilities Summary

Warp knitting has many unique advantages over other fabric formation systems. Some of these are highlighted below as a summary for the warp knitting module.

1. Higher production rates than weaving .
2. A wide variety of fabric constructions.
3. Large working widths.
4. A low stress rate on the yarns which allows the use of fibers such as glass, aramid, and carbon, particularly in weft-inserted fabrics.
5. Fabrics can be directionally structured.
6. Three dimensional structures can be knitted on double needle bar raschel machines.
7. With weft-insertion, uni-axial, multi-axial, and composite structures can be produced on single needle bar Raschel machines.

Warp knitting has many unique advantages over other fabric formation systems. Some of these are highlighted below as a summary for the warp knitting module.

1. Higher production rates than weaving .
2. A wide variety of fabric constructions.
3. Large working widths.
4. A low stress rate on the yarns which allows the use of fibers such as glass, aramid, and carbon, particularly in weft-inserted fabrics.
5. Fabrics can be directionally structured.
6. Three dimensional structures can be knitted on double needle bar raschel machines.
7. With weft-insertion, uni-axial, multi-axial, and composite structures can be produced on single needle bar Raschel machines.