Chapter 4

WEAVING

principal fabric constructions

A major method of fabric construction is weaving. The technique probably became known before spinning. Primitive people may have observed the interlaced grasses and twigs in the nests of birds, and thus discovered how they could make clothing for themselves, baskets and nets, and thatchlike huts and fences. Or they may have seen rushes naturally interlacing as they grew. Spinning developed when people discovered that the raw materials could be improved before they were woven. In the course of time, rude looms were made, which were crudely simple and hand-operated. The modern power loom used in the textile industry today essentially performs the same operations as the simple hand-operated loom.

PREPARATION FOR WEAVING

In the weaving operation, the lengthwise yarns, which run from the back to the front of the loom, form the basic structure of the fabric and are called the *warp*. The crosswise yarns are the *filling*, also referred to as the *weft* or the *woof*. The filling yarns undergo less strain in the weaving process. In preparing them for weaving, it is necessary to spin them to the desired size and give them the amount of twist required for the type of fabric for which they will be used.

Yarns intended for the warp must pass through such operations as spooling, warping, and slashing to prepare them to withstand the strain of the weaving process. These operations do not improve the quality of the yarn. In *spooling*, the yarn is wound on larger spools, or cones, which are placed on a rack called a *creel*. From this creel, the yarns are wound on a *warp beam*, which is similar to a huge spool. An uninterrupted length of hundreds of warp yarns results, all lying parallel to one another. These yarns are unwound to be put through a *slashing*, or *sizing*, bath. The slasher machine covers every yarn with a coating to prevent chafing or breaking during the weaving process. The sizing used is either starch-based or a synthetic, such as polyvinyl alcohol or a water-soluble acrylic polymer, depending upon the fiber content of the warp yarns and the kind of loom to be used. The sized yarns are then wound on a final warp beam and are ready for the loom.

ESSENTIAL WEAVING OPERATIONS

On the conventional loom, the warp beam is mounted at the back and the warp yarns are conveyed to a cylinder called the *cloth roll*, which is at the front of the loom and on which the fabric is rolled as it is constructed. Supported on the loom frame between these two cylinders (the warp beam and the cloth beam), the warp yarns are ready to be interlaced by the filling yarns that run in the width of the cloth, thus producing the woven fabric (see Figure 4-1).

In any type of weaving, four operations are fundamental. They are performed in sequence and are constantly repeated:

Shedding—raising specific warp yarns by means of the harness or heddle frame

Picking—inserting filling yarns through the shed

Beating Up (Battening)—pushing filling yarns firmly in place by means of the reed

Taking up and letting off—winding the finished fabric on the cloth beam and releasing more of the warp from the warp beam.

Shedding

On a primitive loom, the weaver had to raise each alternate warp yarn with his finger or with a stick to insert the filling yarns into the warp. Weaving was therefore a very slow process. The raising of the al-

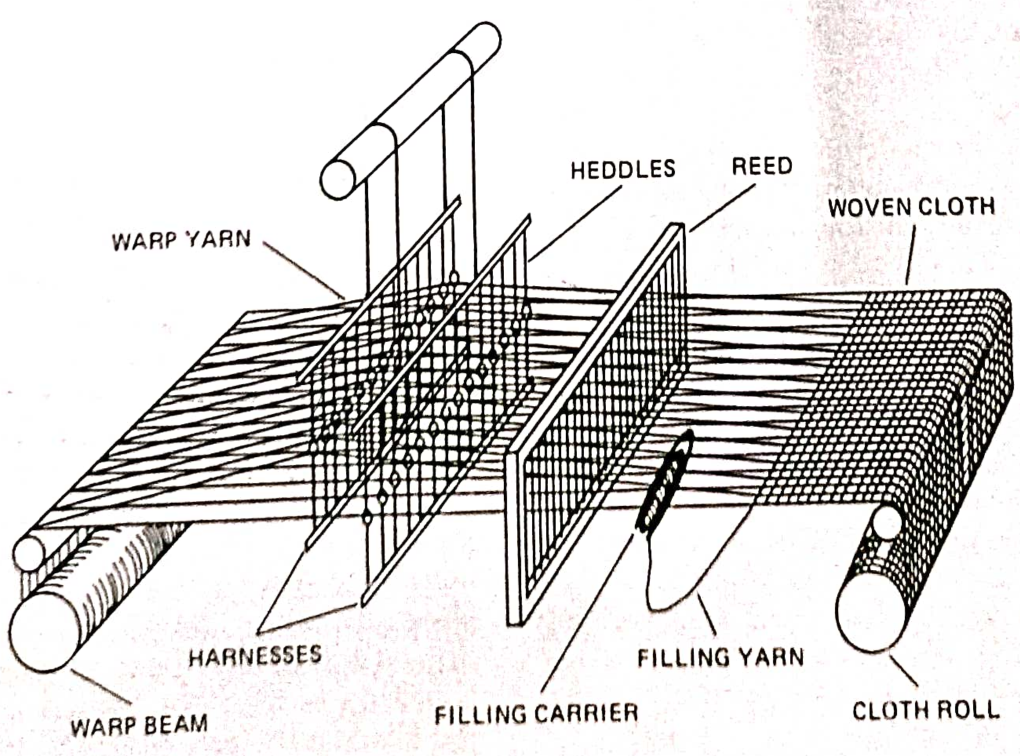
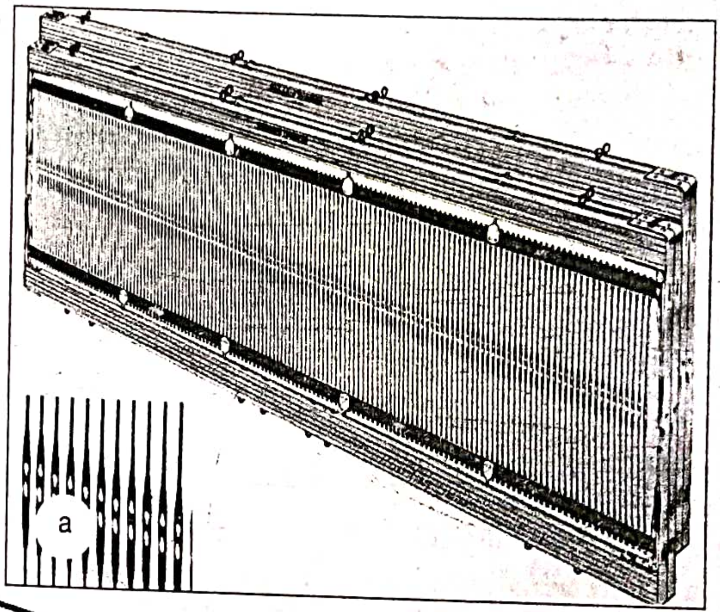
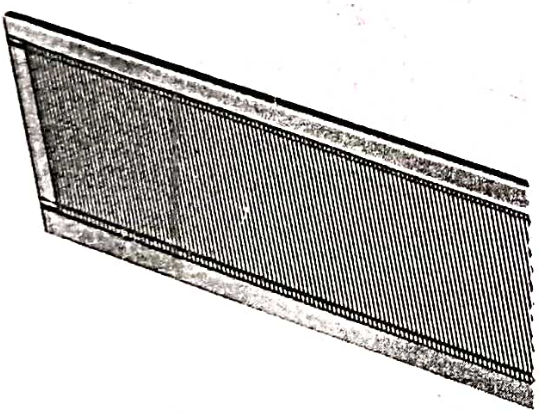


Figure 4-1 Basic structure of a loom.





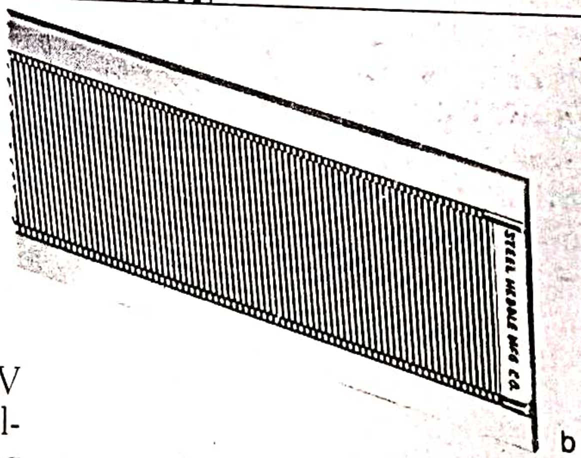


Figure 4-2 (*a*) Warp yarns pass through the eyes of the heddles (see enlargement) and are raised or lowered as one unit. (*b*) Warp yarns are evenly separated and held parallel as they pass between the teeth of the reed. (*Courtesy Draper Division, Rockwell International*)

ternate warp yarns formed an inverted V opening, or shed, through which the filling yarn was inserted. This first weaving operation therefore became known as *shedding*.

On the modern loom, simple and intricate shedding operations are performed automatically by the harness. This is a rectangular frame to which a series of wires, called heddles, are attached. As each warp yarn comes from the warp beam, it must pass through an opening in the heddle (see Figure 4-2). Each opening may be compared to the eye of a needle. The operation of drawing each warp yarn through its appropriate heddle eye is known as *drawing in*.

In the simplest weave construction, the heddle frame raises or lowers certain groups of alternate warp yarns so that the filling yarns alternate in passing under one group of warp yarns and over another.

Picking

As the harnesses raise the heddles, which, in turn, raise the warp yarns, the filling yarn is inserted through the shed by a carrier device. A single crossing of the filling from one side of the loom to the other is known as a *pick*.

The method used for carrying the filling yarn through the shed depends upon the kind of loom employed.

Shuttle Loom. The conventional loom utilizes a *shuttle* that contains a bobbin of filling yarn, which emerges through a hole in the side (see Figure 4-3). As the shuttle is batted across the loom it leaves a trail of the filling at the rate of about 110 to 225 picks per minute (ppm) (see Figure 4-4).

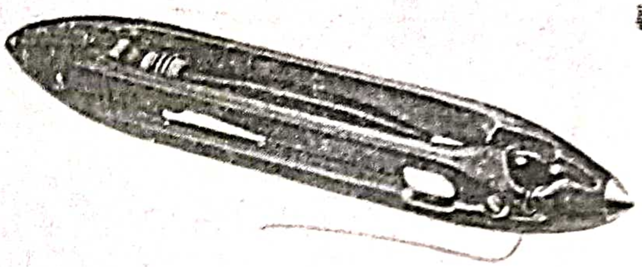


Figure 4-3 The bobbin of filling yarn lies inside the shuttle, and the yarn is pulled through a small opening in the side as the shuttle moves swiftly across the loom. *(Courtesy Steel Heddle Manufacturing Co.)*

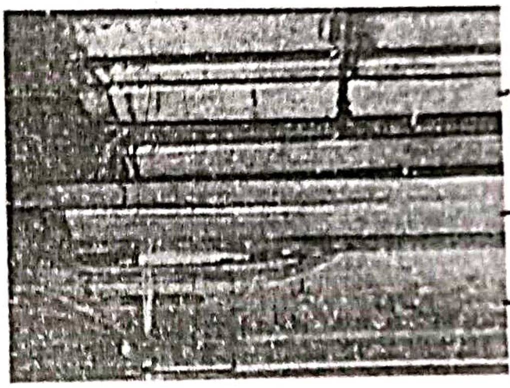


Figure 4-4 This loom in operation shows how the harness and heddles lift and lower units of warp yarns to form the shed through which the shuttle passes. The reed automatically moves forward to batten each newly woven yarn. *(Courtesy Crompton & Knowles Corp.)*

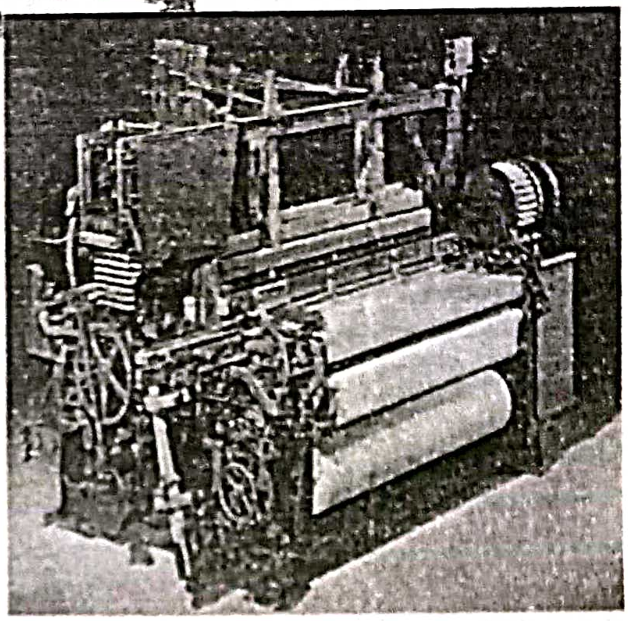


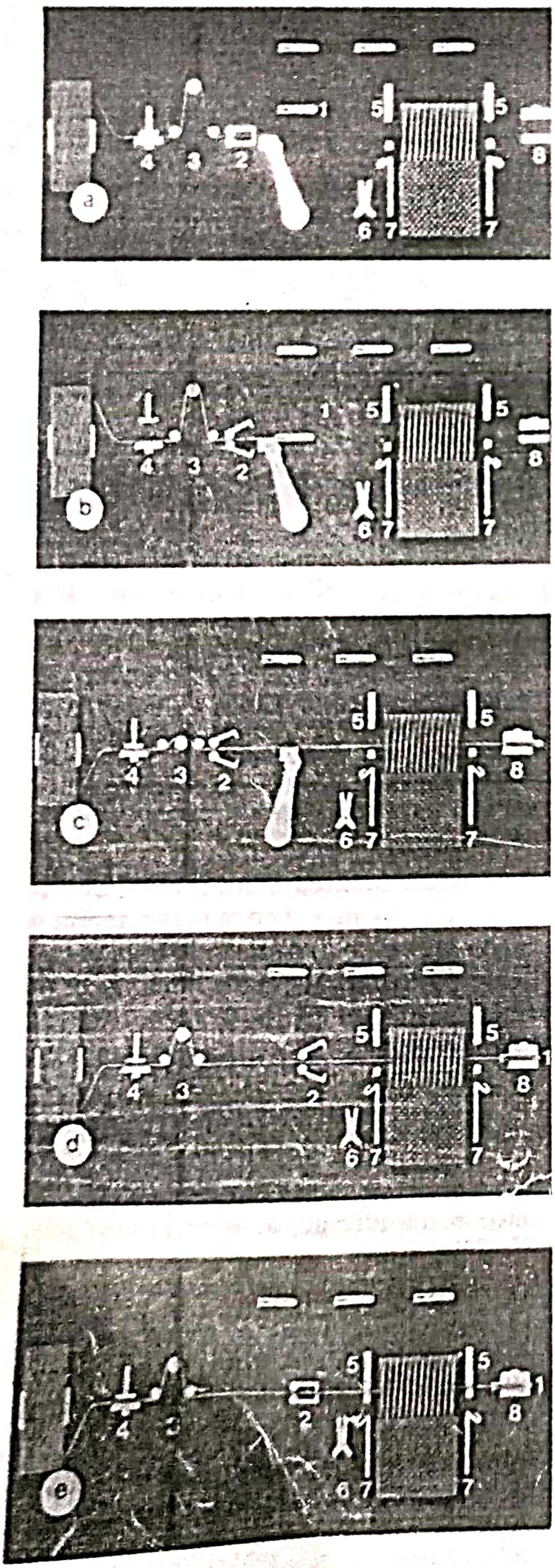
Figure 4-5 Looms such as this are capable of utilizing as many as sixteen harnesses to weave a wide variety of fabrics, e.g., lawn, poplin, oxford, sateen, denim, corduroy, and fancy weaves. Note the harness regulators at the top, the filling bobbins at the right to replace empty shuttle bobbins, and the tilted bar on the lower left for striking the shuttle through the shed. *(Courtesy Draper Division, Rockwell International)*

The shuttle loom is the oldest kind of loom (see Figure 4-5). It is effective and versatile, but it has certain disadvantages. The shuttle sometimes causes abrasion on the warp yarns as it passes over them and sometimes causes thread breaks. This, in turn, results in machine stoppage in order to tie the broken yarns. Shuttle looms operate more slowly than some new types of looms and, they are also noisier.

Shuttleless Looms. To overcome disadvantages of the shuttle loom, several different kinds of shuttleless looms have been developed. Each type uses a different method of picking, which provides specific characteristics and applications.

Missile, or Projectile, Looms. These looms were developed in the 1950s in Switzerland and represent the first proven shuttleless loom. The picking action is accomplished by a series of small bullet-like projectiles which grip the filling yarn and carry it through the shed and then return empty (see Figures 4-6, 4-7, and 4-8). All the filling yarn is inserted from the same side of the loom and a special tucking device is used to hold the ends of the filling in place at the edge of the cloth to form the selvage, or selvedge (see pages 75–76).

The missile loom has good versatility and is used for a wide variety of basic fabrics ranging from cotton-type goods such as percale and printcloth to worsted-type material. It does require a smooth, uniform yarn that is properly sized to reduce friction. The missile loom has speeds of



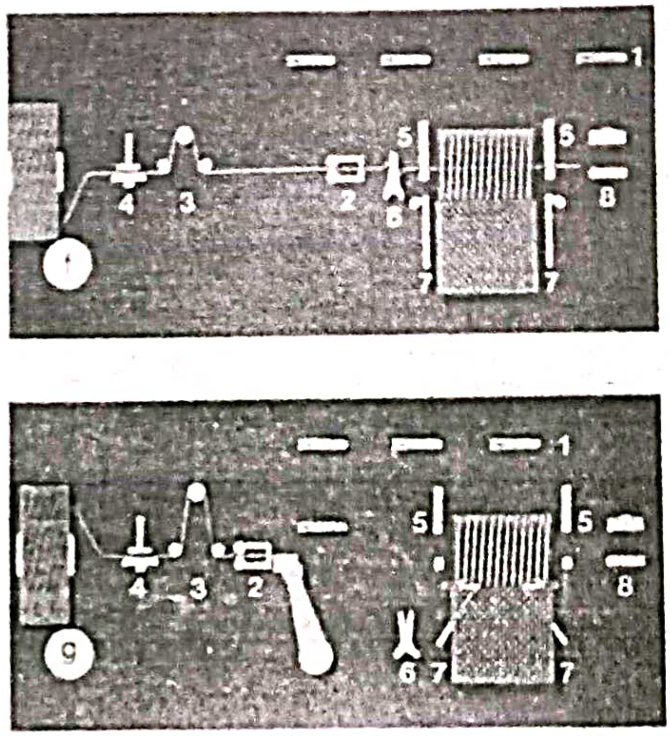


Figure 4-6 Schematic of the weft insertion system of a missile loom. (*a*) Projectile (1) moves into the picking position. (*b*) Projectile feeder (2) opens after the projectile has gripped the end of the weft thread presented to it. (*c*) Projectile has drawn the thread through the shed, during which time the weft tensioner (3) and the adjustable weft brake (4) act to minimize the stress on the thread at the moment of picking. (*d*) Projectile (1) is stopped by the break (8) and pushed back inside the receiving unit housing, while the weft tensioner (3) holds the thread lightly stretched. At the same time, feeder (2) moves close to the edge of the cloth. (*e*) Feeder (2) grips the thread, while the selvedge grippers (5) hold the weft at both sides of the cloth. (*f*) Thread is severed by the scissors (6) on the picking side and released by projectile (1) on the receiving side. The ejected projectile (1) is then placed on the conveyor which carries it outside of the shed back to the picking position. (*g*) Thread has now been beaten up by the reed. The needles (7) tuck the thread ends into the next shed (tucked-in selvedge). The length of thread slackened by the return of projectile feeder (2) is taken up by weft tensioner (3). The next projectile is brought to the picking position. (*Courtesy Sulzer Bros. Inc.*)

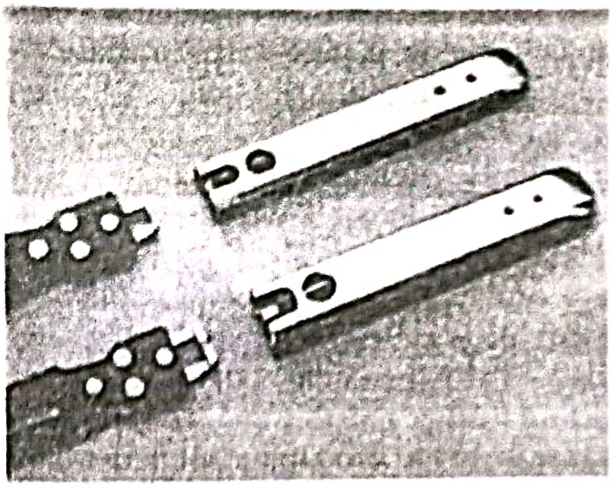


Figure 4-7 Steel gripper projectiles as small as 4 inches (10cm) used to carry the filling yarn in a missile loom. *(Courtesy Sulzer Bros. Inc.)*

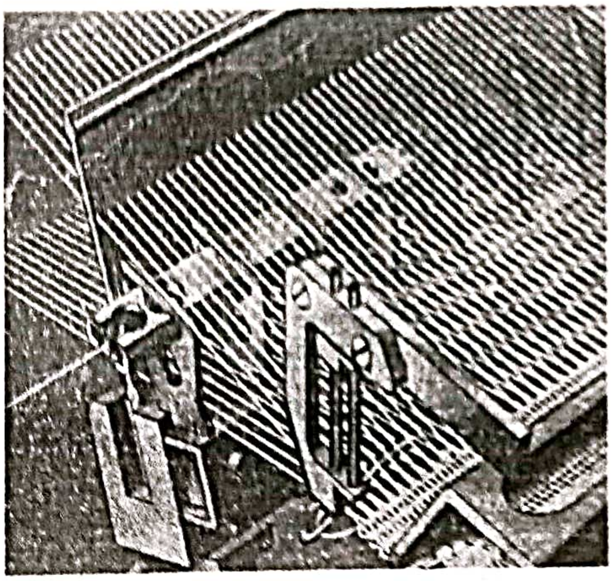


Figure 4-8 Schematic of projectile of filling insertion. Every pick is cut off after complete insertion. The ends are then tucked in the shed and woven in with the next pick. *(Courtesy Sulzer Bros. Inc.)*

up to 300 ppm and yet is less noisy than the shuttle loom (see Figure 4-9).

Rapier Looms. These looms are competitors to the missile loom. There are several kinds which may be subdivided into types. One early model uses one long rapier device that reaches across the width of the loom to carry the filling yarn from one side of the loom to the other.

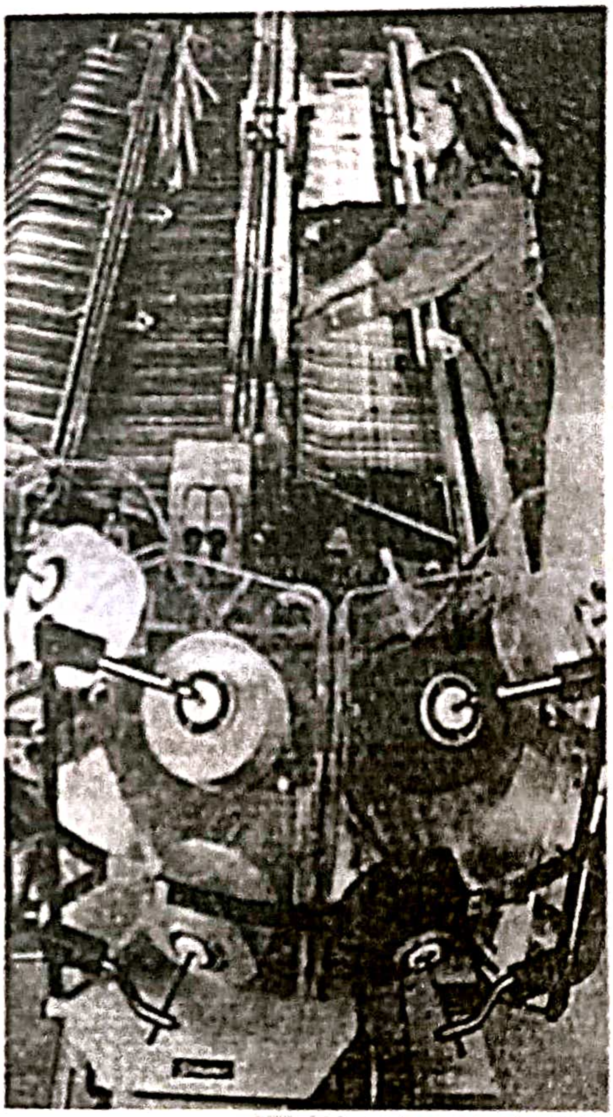


Figure 4-9 This projectile loom accommodates several different colored filling yarns. It can be adapted for such weave variations as dobby, terry, and Jacquard. *(Courtesy Sulzer Bros. Inc.)*

Another type utilizes a double rapier, that is, one on each side of the loom (Figure 4-10). The rapier may be any one of several constructions: rigid, flexible, or telescoping. In every case, one rapier feeds the filling yarn halfway through the shed of warp yarns to the arm on the other side, which reaches in and takes it across the rest of the way (Figure 4-11). These rapier looms are efficient. They operate at speeds ranging from about 200 to 260 ppm at about the noise level of missile looms. They can produce a wide variety

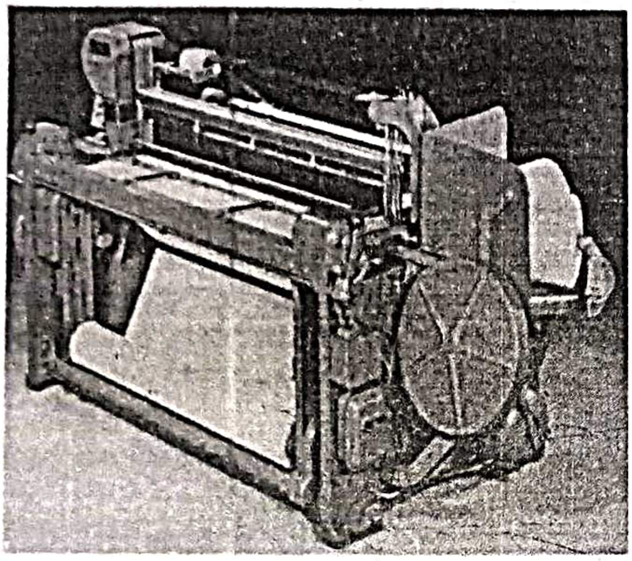


Figure 4-10 This shuttleless loom has fingerlike arms that extend from the disklike compartments on its sides and feed the filling yarn through the shed. Woven cloth is wound on a roll at the bottom front of the loom. *(Courtesy Draper Division, Rockwell International)*

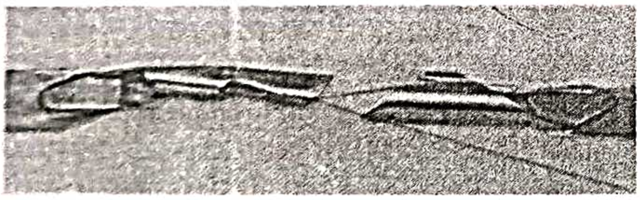


Figure 4-11 Close-up of a filling yarn being transferred from one rapier to another midway across a shuttleless loom. *(Courtesy Draper Division, Rockwell International)*

of fabrics ranging from muslin to drapery and upholstery materials.

Water-Jet Looms. These looms were first developed in Czechoslovakia in the 1950s and subsequently refined by the Japanese in the 1960s. They were designed to weave faster and to relieve the tension on the filling yarn as it is carried through the shed. A premeasured length of filling yarn is carried across the loom by a jet of water. These looms can operate at relatively high speeds of up to about 600 ppm and at noise levels lower than the shuttle, missile, and rapier looms.

Since the pick is tensionless, high quality, almost perfect warp yarns are required for efficient operation. A broken warp could deflect the floating pick out of the shed. Another disadvantage is that the water-jet looms are restricted to production of fabrics made of yarns that are not readily absorbent—such as filament yarns of acetate, nylon, polyester, and glass. Even then, the cloth must be dried before further processing. However, the water-jet looms can produce superior high quality fabrics that have good appearance and feel (hand).

Air-Jet Looms. These looms, invented in Czechoslovakia and later refined by the Swiss, Dutch, and Japanese were designed to retain the tensionless aspect of the picking action of the water jet while eliminating the problems caused by the use of water. These looms use a jet of air to propel the filling yarn through the shed at rates of up to 600 ppm.

Air-jet looms require uniform filling yarns. They are more suitable for use with heavier than lighter yarns because the lighter weight yarns are more difficult to control through the shed. Yet, if the yarn is too heavy, the air jet may not be able to carry the filling across the loom. Within these restraints, the air-jet loom is effective and can produce a wide variety of fabrics. Also, the air-jet loom operates at a lower noise level than the shuttle, missile, or rapier looms.

Circular looms. Circular looms are specifically designed to produce tubular rather than the flat fabrics woven by the looms heretofore discussed. They require the use of a shuttle device that circulates the filling in a shed formed around the machine. The circular loom is used primarily for bagging material.

Beating Up (Battening)

All warp yarns pass through the heddle eyelets and through openings in another frame that resembles a comb and is called a *reed*. With each picking operation, the reed automatically pushes, or beats, each filling yarn against the portion of the fabric that has already been formed. This third essential weaving operation is therefore called *beating up*, or *battening*. It gives the fabric a firm, compact construction.

Secondary

Taking Up and Letting Off

With each shedding, picking, and battening operation, the newly constructed fabric must be wound on the cloth beam. This process is known as *taking up*. At the same time, the warp yarns must be released from the warp beam; this is referred to as *letting off*.

SELVAGES (SELVEDGES)

As the shuttle moves back and forth across the width of the shed, it weaves a self-edge called the *selvage*, or *selvedge*, on each side of the fabric. The selvage prevents the fabric from raveling. It is usually made more compact and stronger than the rest of the fabric by using more or heavier warp yarns or by using a stronger weave. There are different kinds of selvages. The kind of selvage used depends upon economy of production and the expected use of the fabric.

Plain Selvages

These selvages are constructed of the simple plain weave with the same size yarn as the rest of the fabric, but with the threads packed more closely together. Such selvages are fairly durable and firm.

Tape Selvages

The tape selvages are sometimes constructed with the plain weave but often are made of the basket weave, which makes a flatter edge. Tape selvages are made of heavier yarns or ply yarns, which provide greater strength.

Split Selvages

Split selvages are made by weaving a narrow width fabric twice its ordinary width with two selvages in the center. The fabric is then cut between the selvages, and the cut edges are finished with a chain stitch or hem.

Fused Selvages

These selvages are made on fabrics of thermoplastic fibers, such as nylon, by heating the edges of the fabric. The fibers melt and fuse together, sealing the edges. This technique is sometimes used to split wide fabrics into narrower widths.

Leno Selvage

The leno selvage is used on some shuttleless looms (see Figure 4-12). The construction utilizes a narrow leno weave (see page 94) which locks the cut ends along the fabric edge. A loose weave generally requires a tight leno selvage, whereas a light weave may have a leno selvage with less tension.

Tucked Selvage

The tucked selvage is a technique used on some shuttleless looms. A device is used to tuck and hold the cut ends into the fabric edge. The construction of the selvage is dependent upon the particular weave and a number of other factors. A for-

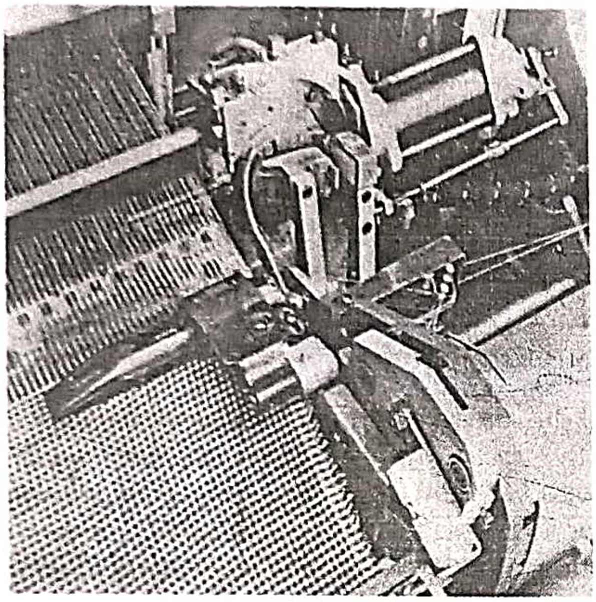


Figure 4-12 Close-up of leno selvage being woven with four ends leaving a fringe which will subsequently be cut to about ⅛ inch (3 mm).

mula for weaving the tucked selvage considers fiber density, the diameter of the yarns (which is also affected by twist, ply, and count variation), as well as the yarn diameter balance, or ratio of the diameter of the filling yarn to that of the warp yarn —in effect, if the diameter of the filling yarn is finer than the diameter of the warp yarn, fewer fillings can be inserted in the fabric selvage, because the warp intersection requires more space between the fillings than one diameter of the filling.

CONSTRUCTION OF CLOTH DESIGNS

A textile designer prepares a pattern of the weave which is put onto cross-sectioned paper called *point paper* in order to indicate the required positions of the yarns for the construction of the fabric. This weave pattern may also be done by computer. A draft of the design is indispensable when setting up a loom for a particular weave or color effect, as it indicates the particular heddle through which each warp yarn is to be drawn. The horizontal squares represent the filling yarns; the vertical squares represent the warp. (The student may obtain a working knowledge of weaves by reproducing such designs on graph paper and then carrying out the actual weaving operations on a miniature loom made of cardboard or a shallow box.)

THREAD COUNT

The durability of a fabric depends on (1) the kind and quality of the fiber, (2) the tensile strength of the yarn, (3) the amount of twist in the yarn, (4) the use of ply yarns as compared with singles, (5) the use of uniform yarns rather than novelty yarns, and (6) compactness of construction. Compactness is one of the most significant factors when considering the durability of a fabric. It is determined by the closeness of the yarns after the fabric is woven. A closely woven fabric has a larger quantity of yarns than a loosely woven one and is therefore more serviceable. A garment made from such a fabric shrinks less in washing, slips less at the seams, and keeps its shape.

A fabric of compact construction has a high thread count. *Thread count*, also known as *cloth count*, is determined by counting the number of warp yarns and filling yarns in a square inch of fabric. These yarns are commonly referred to as *ends* and *picks*, terms that are synonymous with *warp* and *filling*, respectively. To ascertain the thread count, one may use a pick glass, or thread counter, which is a magnifying glass mounted on a small stand with a square opening in its base. Through this opening, warp and filling yarns are magnified and counted. If the square opening is a ¼-inch size, the number of yarns counted in the quarter inch, when multiplied by 4, gives the number of yarns in 1 inch of the fabric. Some pick glasses have a ½-inch square opening; others have a full square inch. If the square opening has millimeter markings, then 5 mm multiplied by 2 gives the number of yarns in 1 centimeter of fabric. Most metric pick glasses have a 1 cm square opening; some have a 2.5 square centimeter opening. The largest size minimizes the possibility of error in computation.

Another and faster means of determining thread count is with a transparent plastic plate of line gratings, which are a sequence of parallel lines set with mathematical precision at decreasing distances from each other. When the instrument is placed on the fabric so that the yarns are parallel to the line gratings, light passing through produces a wave pattern (moiré effect) that is interrupted by an harmonic effect image of a cross or an oval form. The center of this area is a point which indicates the *interference figure* where the waves converge into a straight line and the threads per inch can be read on the scale along the edge of the plate (see Figure 4-13*a* and *b*).

Thread count should not be confused with yarn count. Yarn count measures the degree of fineness in yarns; thread count measures the number of warp and filling yarns in a square inch (or cm) of fabric. While these counts are separate devices of measurement, there is a direct relationship between them. Thick or coarse yarns will be used if coarse sheeting with a low thread count is to be constructed. These give the fabric greater resistance to hard wear.

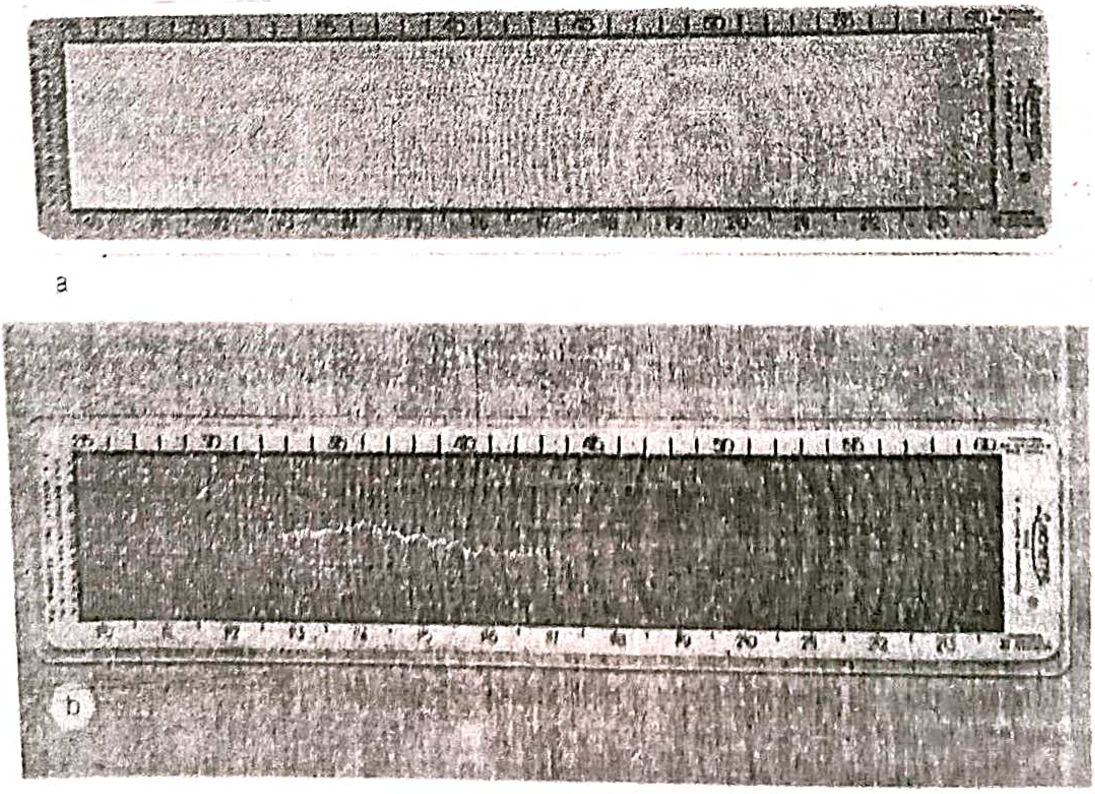


Figure 4-13 The Lunometer, a line grating device used for measuring thread count, (*a*) showing the scale of graduated decreasingly spaced parallel lines, (*b*) set over a fabric and displaying the harmonic effect image of an oval with the line at its center indicating the interference figure of 49, the thread count per inch. (*Courtesy John A. Eberly, Inc.*)

Typical Thread Counts

Thread counts range from as low as 20 threads to the inch (8 to 10 cm), used in tobacco cloth, to as high as 350 threads to the inch (138/cm), found in typewriter-ribbon fabrics. An example of thread count used as a standard is illustrated by the summary of types of muslin and percale sheets in Chapter 31. With some finished goods, such as sheeting, thread count is sometimes given as a single number, which is the addition of warp and filling. A total thread count of 140 threads to the square inch, for example, means that each sheet must have 74 warp yarns and 66 filling yarns to the square inch. The first number indicates the warp; the second is the filling. Thus a 74 × 66 is described as a 140. (In metric equivalent, that would be 55/cm² having 29 warp yarns and 26 filling yarns to the square centimeter. Therefore, a 29 × 26 is described as a 55.)

Balanced Construction

A fabric is said to be well balanced if the number of warp yarns and filling yarns are almost equal. For example, a piece of muslin with a thread count of 64 × 60 (25 × 24/cm²) is considered well balanced. A piece of gauze with a thread count of 28 × 24 (11 × 9/cm²) is also well balanced. In contrast, a broadcloth with a count of 100 × 60 (40 × 25/cm²) has poor balance. Although good balance of warp and filling produces a fabric with good wearing qualities, a balanced construction is not always obtainable with certain fabrics. Broadcloth shirting, for example, uses approximately twice as many warp yarns as filling yarns. The nature of its construction, therefore, makes it impossible for it to be well balanced according to thread count; yet, it is a durable fabric if its thread count is high.

Sometimes, a fabric may have good balance in its thread count, but it may be altogether unsatisfactory because of weakness in either warp or filling yarns. The factor of tensile strength of both sets of yarns must, therefore, always be taken into consideration when a fabric is being judged. Both yarn count and thread count determine the suitability and value of finished goods. A safe rule to remember is that a high-count fabric even with poor balance will give better wear than a low-count fabric with good balance.

A fabric's strength can be tested by grasping the fabric with both hands and pressing down and apart with the thumbs close together and parallel. This should be tried in both directions of the cloth. If the yarns are weak, the fabric will split, indicating low durability. If the count is low, the yarns will slide or spread apart into an elliptical opening, indicating weakness under strain or tension at points of stress, such as the seams.

CLASSIFICATION OF WEAVES

The manner in which groups of warp yarns are raised by the harnesses to permit the insertion of the filling yarn determines the pattern of the weave, and in large measure the kind of fabric produced. Weave patterns can create varying degrees of durability in fabrics, adding to their usefulness and also to their appearance. In a simple weave construction, consisting of the filling going under one warp and over the next, two harnesses are needed: one to lift the odd-numbered warp yarns, and a second to lift the even-numbered warp yarns. More than two harnesses are required for advanced weaves, and as many as forty for figured weaves.

The three basic weaves in common use for the majority of fabrics are plain, twill, and satin, with some variations.

Important constructions are also obtained from the following weaves: pile, double cloth, gauze, swivel, lappet, dobby, and Jacquard (see Table 4-1).

Plain Weave

The plain weave is sometimes referred to as the tabby, homespun, or taffeta weave. It is the simplest type of construction and is consequently inexpensive to produce. On the loom, the plain weave requires only two harnesses. Each filling yarn goes alternately under and over the warp yarns across the width of the fabric (see Figure 4-14). On its return, the yarn alternates the pattern of interlacing. If the yarns are close together, the plain weave has a high thread count, and the fabric is therefore firm and will accordingly wear well.

As the manufacture of the plain weave is relatively inexpensive, it is used extensively for cotton fabrics and for fabrics that are to be decorated with printed designs, because the surface that it produces is receptive to a direct print. The appearance of the plain weave may be varied by differences in the closeness of the weave, by different thicknesses of yarn, or by the use of contrasting colors in the warp and filling. The last method gives the effect of a design. In addition, two variations of the plain weave afford simple decorative effects: the basket weave and the ribbed, or corded, weave.

Fabrics in Plain Weave. There is a wide variety of fabrics made of the plain weave constructed from every type of yarn composed of every kind of fiber. Plain woven fabrics range in weight and compactness from thin lightweights to compact heavyweights. (For descriptions of fabrics cited here and on following pages, see the Glossary of Fabrics.)

a

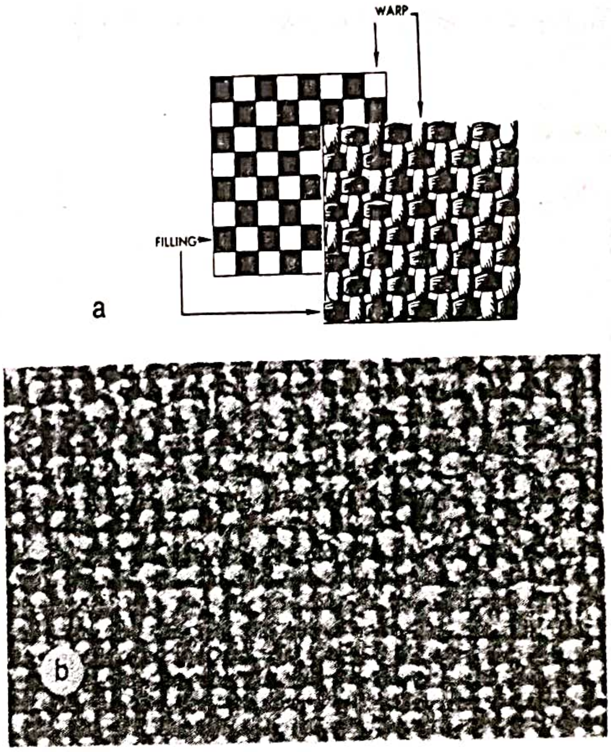


Figure 4-14 The construction design for the plain weave resembles the familiar checkerboard. (*a*) The way in which filling yarns (black squares and yarns) pass under and over alternate warp yarns (white squares and yarns) is shown. (*b*) When fabric is closely constructed in the plain weave, there is no distinct pattern, as shown in this muslin.

Lightweight fabrics, such as cheese cloth, crinoline, and tobacco cloth are *low count sheers*. They are woven of coarse, carded yarns with thread counts ranging from about 10 × 12 to 48 × 44, producing an open construction. The texture and hand depend upon the finish. Low count sheer fabrics are not strong or durable and are limited in use for such purposes as screening and backing materials.

Sheer fabrics, such as batiste, cambric, lawn, mousseline de soie, chiffon, ninon, organdy, and voile, are *high count sheers*. They are woven of fine combed or filament yarns with a thread count of about 88 × 80, producing thin, transparent material. The texture and hand depend upon the kind of yarn, the yarn

TABLE 4-1 *WEAVES AND THEIR CHARACTERISTICS*

WEAVE	STRUCTURE	APPEARANCE	PROPERTIES	TYPICAL FABRICS
Plain	Each filling passes alternately over and under each warp in a square pattern.	Flat; no distinct design unless yarns have contrasting colors or thicknesses.	Easily produced; maximum yardage; inexpensive; relative durability depends on yarn count and balance; adaptable for printing and other finishing processes.	Batiste; cheesecloth; cretonne; gingham; percale; voile.
Basket	Two or more warps simultaneously interlaced with one or more fillings giving balanced structure.	Variation of plain weave; basket or checkerboard pattern; contrasting colors often used; attractive.	Inexpensive; drapable; somewhat flexible and resilient; absorbent; less durable than plain weave; soils more easily.	Monk's cloth; oxford.
Ribbed	Plain weave with wales or cords in warp or filling.	Variation of plain weave; ribs or cords provide texture and design.	Drapes well; durability affected by pronounced ribs; possible yarn slippage from tension.	Bengaline; broadcloth; dimity; faille; poplin; rep; taffeta.
Twill	Three (or more) shaft; warp or filling floats over two or more counterpart yarns in progressively stepped up right or left direction.	Left- or righthand diagonal; variations provide chevron (herringbone), corkscrew, houndstooth, or other designs; enhanced by colored yarns.	Strong, firm texture; increased drapability and resilience; interesting designs; may develop shine.	Cheviot; covert; denim; drill; foulard; gabardine; serge; surah; tweed; whipcord.
Satin	Four (or more) shaft with warp floats in interrupted diagonal.	Compact; smooth; interrupted diagonal discernible with magnifying glass.	Lustrous; excellent drapability; floats subject to snagging.	Satin; slipper satin; crepe-back satin.
Sateen	Four (or more) shaft with filling floats in interrupted diagonal.	Variation of satin weave; compact, smooth.	Similar to satin; may be of staple yarns and Schreinerized	Sateen.
Crepe	Combination of plain and satin or sateen weave.	Irregular, indistinct pattern with pebbly, textured surface.	Interesting hand; could have good strength, resilience, drapability, and serviceability depending upon fiber, yarn twist, compactness, structure.	Granite; moss crepe; sand crepe; wool crepe.
Pile	Extra set of warps or fillings woven over ground yarns of plain or twill weave to form loops.	Three-dimensional effect formed by yarns entering perpendicularly into the ground weave.	Soft, warm, resilient, absorbent; interesting surface effects.	Cut and uncut pile fabrics ranging from toweling to rugs.
Cut Pile	Pile loops cut.	Soft, brushlike surface; may have rows of cut pile.	As above.	Corduroy; velvet; velveteen.

WEAVE	STRUCTURE	APPEARANCE	PROPERTIES	TYPICAL FABRICS
Uncut Pile	Pile loops intact.	Soft, though rougher than cut pile; loops apparent and close together, covering ground weave; loops may be on both sides.	As above. Softness and absorbency depend upon compactness of loops and twist of pile yarn.	Frieze; terry.
Double-Cloth	Two fabrics of independent weaves woven together with extra set of yarns.	Two different surfaces, sometimes reversible; thick; heavy.	Strong; warm; may be bulky.	Blanket cloth; coatings; upholstery.
Gauze (Leno)	Pairs of warps twisted over each other with each passing of filling.	Open-mesh with yarns securely held; variations produce corded effects.	Sheer but durable for its weight.	Grenadine; marquisette.
Swivel	Small designs interwoven on surface of fabric with extra filling yarn insertion mechanism.	Decorative designs, sometimes multi-colored; extra yarns forming design are cut on reverse side.	Attractive; design yarns tend to roughen on back and may pull out.	Dotted swiss; madras.
Lappet	Small designs stitched into fabric during weaving.	Decorative designs limited to one color; extra yarns of design are cut on reverse side but held firmly.	Attractive; design more durable than swivel.	Grenadine; madras.
Dobby	Small, geometric designs composed of short floats created by dobby loom attachment.	Decorative designs, often with corded effect which may give textured surface.	Attractive; generally good body.	Huckaback; granite cloth; piqué.
Jacquard	Any combination of weaves and patterns possible since each warp is individually controlled with each pick passage.	Unlimited range of intricate designs on all types of backgrounds; multicolor effects.	Attractive; drapes well; serviceable but durability dependent upon weave and yarn.	Brocade; brocatelle; damask; matelassé; tapestry.
Triaxial	Three yarn construction at various angles.	Porous, canelike patterns.	Strong; stable; minimum stretch.	Industrial uses and home furnishings

twist, and the finish. For their weight, high count sheers are reasonably durable and serviceable. They are used for such purposes as blouses, dresses, shirts, and for such home furnishings as curtains.

Medium-weight fabrics represent a very large group of materials. They are woven of medium size carded, combed, or filament yarns with thread counts ranging from about 44 × 48 to about 96 × 80. Medium-weight plain woven carded yarn fabrics include such materials as calico, chintz, longcloth, madras, and muslin. Combed yarn fabrics in this group include such materials as challis, chambray, dress linen, and percale. Medium-weight plain woven filament yarn fabrics include habutai, radium, and various crepes. These fabrics are given a variety of finishes and have a wide range of texture, hand, and appearance. They are serviceable; care of treatment depends upon the fiber, yarn, and finish used. They are used for all types of apparel and for home furnishings.

Bottom-weight fabrics are the heavier materials woven of thicker yarns but have about the same range of thread count as medium-weight goods. These fabrics include canvas, crash, cretonne, flannel, homespun, and tweed. The construction may be very compact and, depending upon the kind of yarn and finish, can be quite durable. Bottom-weight plain wovens are used for apparel and for such home furnishings as drapery and upholstery.

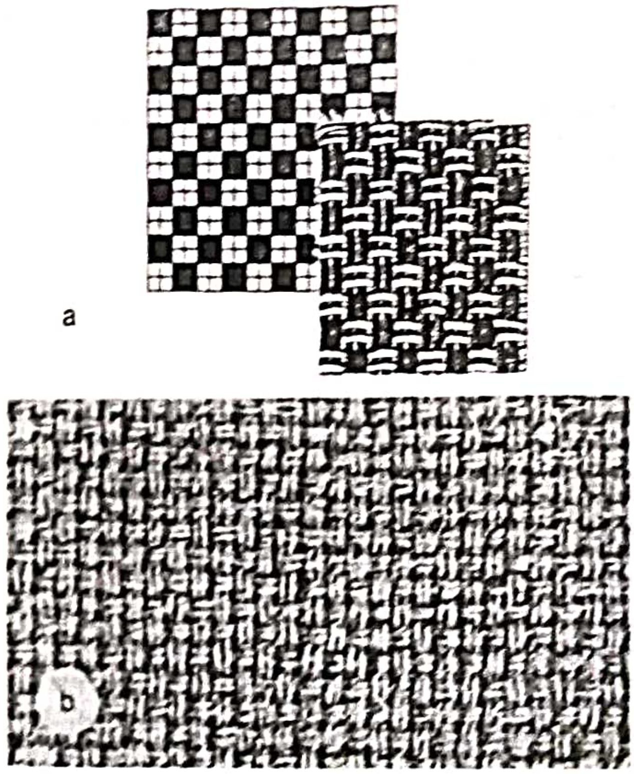


Figure 4-15 (a) The basket weave is a variation of the plain weave. Two (instead of one) filling yarns pass under and over two (instead of one) warp yarns. This weaving method results in a simple, attractive pattern, so named because baskets have long been woven in this manner. *(b)* Monk's cloth shows how the interweaving of two filling yarns with two warp yarns constructs a loosely woven fabric with an attractive basket-weave pattern.

Basket Weave. The variation of the plain weave known as the *basket weave* uses doubled yarns to produce the design that resembles the familiar pattern of a basket. Two or more filling yarns with little or no twist are interlaced with a corresponding number of warp yarns. They are woven in a pattern of 2 × 2, 3 × 3, or 4 × 4, instead of 1 × 1, which is the plain weave (see Figure 4-15).

The weave used in oxford shirting varies slightly from the regular basket weave in that it has a 2 × 1 construction; but the size of the single yarn—a coarser yarn used as the filling—is approximately equivalent in size to the two separate warp yarns. As the coarser yarn has low twist, the fabric is of soft texture and has a degree of luster (see Figure 4-16).

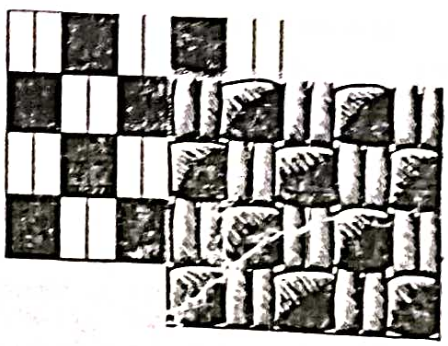


Figure 4-16 The design for oxford cloth shows how a large filling yarn having no twist is woven under and over two single, twisted warp yarns.

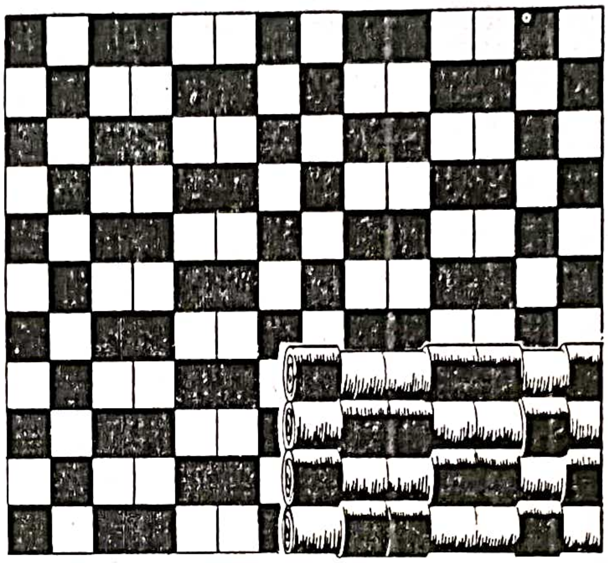
Many variations of the yarn construction of the basket weave are possible. For example, there may be a 3 × 2 or a 5 × 3, and so on. The size or thickness of the combined warp yarns will, however, always equal the size or thickness of the corresponding filling yarns. This provides a certain degree of balance and pattern to the fabric.

The basket weave produces an attractive, loosely woven fabric that is flexible, somewhat wrinkle resistant, and hangs well. It is therefore suitable for drapery and covering fabrics such as monk's cloth. Due to the characteristic looseness of construction and the low tensile strength of yarns that have little or no twist, this weave is not considered desirable for clothing purposes where the factor of durability is a primary consideration.

Fabrics in Basket Weave. All types of fiber are used in yarn used in the basket weave. The cloth may be in the medium- to bottom-weight category and include such materials as monk's cloth, oxford, and shepherd's check. Basket weave fabrics are used for suiting, outerwear, and such home furnishings as drapery.

Ribbed Effects. Ribbed, or corded, effects are further variations of the plain weave. The rib may be produced in the warp or in the filling by alternating fine yarns with coarse yarns, or single yarns with doubled yarns (see Figure 4-17). Warp-ribbed fabrics are usually referred to as *waled* or *corded.*

Ribbed effects are popular, but the consumer should remember that sometimes inferior yarns are used in their manufacture, especially when the yarns that make the rib are hidden in the thickness of the cloth. As these yarns do not show on either side of the fabric, sometimes extremely short-staple yarns or yarns with insufficient twist are used. A ribbed fabric will not be durable if the ribs are too pronounced, because the coarse yarns that produce the rib tend to pull away from adjacent fine yarns. Yarn separation, or slippage, may occur where there is tension, such as at seams. Also, in ribbed effects, an entire yarn is exposed to friction, thus lessening the durability of the fabric (see Figure 4-18).



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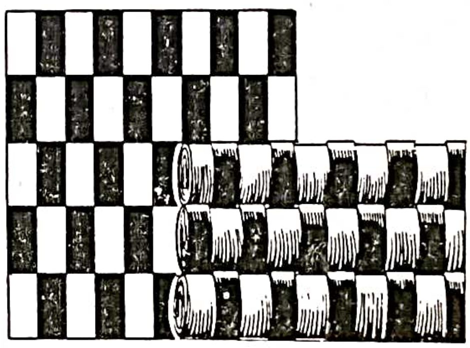


b

Figure 4-17 (*a*) Drawing of a ribbed, or corded, effect running in the direction of the warp. (*b*) Drawing of a ribbed effect running in the direction of the filling.

Fabrics in Ribbed Effects. Lightweight sheer fabrics sometimes are woven with ribbed and/or corded effects to produce a pattern and provide some body. Dimity, which is used for curtains, blouses, and dresses, is such a material.

Most ribbed effects are medium-weight. The ribbed, compact structure generally provides greater drapability than the plain weave. The cloth may be smoother and softer, depending upon the yarn and finish used. Filling-ribbed fabrics in this group include broadcloth, faille, poplin, and taffeta, which are used for a variety of apparel.

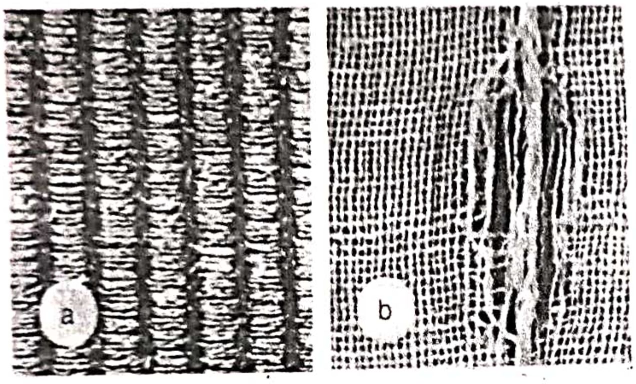


Figure 4-18 (*a*) An example of a well-constructed ribbed fabric. (*b*) When too coarse a yarn is combined with fine yarns for a ribbed effect, the fine yarns adjacent to the rib soon break when subjected to strain or to heavy wear. (*Courtesy U.S. Department of Agriculture*)

Bottom-weight ribbed fabrics use heavier filling yarns of staple fiber, usually have very low-twisted filament warp, and tend to be more compact. Typical materials are bengaline, ottoman, and rep.

Twill Weave

A distinct design in the form of diagonals is characteristic of the second basic weave, called the *twill*. Changes in the direction of the diagonal lines produce variations, such as the herringbone, corkscrew, entwining, and fancy twills (Figure 4-19). Increased ornamentation may be obtained by varying the slant of the diagonal and yarn colors. The values of the twill weave include its strength and drapability. The diagonally arranged interlacings of the warp and filling provide greater pliability and resilience than the plain weave. Also, twill fabrics are frequently more tightly woven and will not get dirty as quickly as the plain weave, though twills are more difficult to clean when they do get soiled. The yarns are usually closely beaten, making an especially durable fabric. Twill weaves are therefore commonly used in men's suit and coat fabrics and for workclothes, where strong construction is essential.

In the twill weave, the filling yarn interlaces more than one warp yarn but never more than four, as strength would be sacrificed by so doing. On each successive line, or pick, the filling yarn moves the design one step to the right or to the left, thus forming the diagonal. Whichever the direction of the diagonal on the face of the fabric, the design runs in the opposite direction on the reverse side.

When the direction of the diagonal starts from the upper left-hand side of the fabric and moves down toward the lower right, it is called a *left-hand twill*. When the direction of the diagonal starts from the upper right-hand side of the fabric and moves down toward the lower left, it is called a *right-hand twill*. Although there is no advantage of one over the other, the direction of the diagonal can aid in the recognition of the face of the fabric.

The *steepness* of the diagonal can indicate strength and durability in the fabric. In order to obtain a steep twill, more warp yarns must be used than filling yarns. And since warp yarns have a higher twist and are stronger than filling yarns, the steeper the twill the stronger the fabric is likely to be.

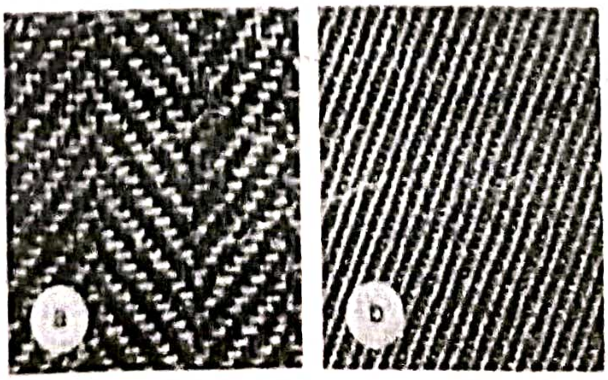
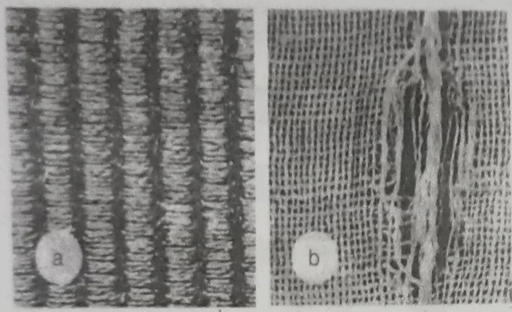


Figure 4-19 (*a*) The common herringbone twill. (*b*) The characteristic diagonal of the twill weave. (*Courtesy National Association of Wool Manufacturers*)



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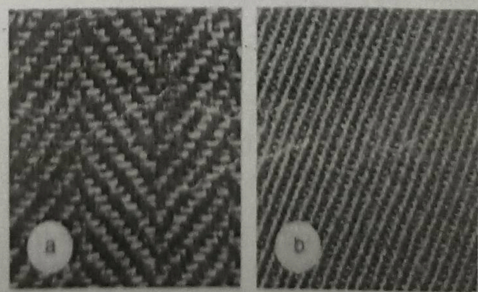

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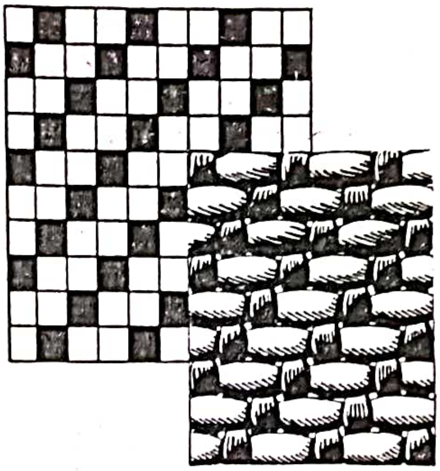


Figure 4-20 Drawing shows a three-shaft twill—two warp yarns are interlaced with one filling yarn in each repeat. This is a right-hand, filling-faced twill because the diagonal moves from the upper right down to the lower left, and more filling than warp appears on the face of the fabric. It is also referred to as a one-up-and-two-down twill ($\frac{1}{2}$) because the warp goes over one and under two filling yarns.

Twill weaves are named according to the number of harnesses required to make the design. A three- or four-harness twill is frequently used. The word "shaft" may be substituted for "harness," as in *three-shaft* or *four-shaft twill* (see Figure 4-20).

Twill weaves are also classified as *even* or *uneven* according to the number of warp and filling yarns that are visible on the face of the fabric. The even twill, for example, shows an equal number of warp and filling yarns in the recurring design, such as two over and two under. This pattern makes what is called a four-shaft twill, and it requires four harnesses.

Most twill weaves are uneven. An uneven twill may show more warp than filling yarns in the recurring design; this is called a *warp-face twill.* If more filling yarns than warp yarns show on the face, the weave is called a *filling-face twill.* Warp-face twills are generally stronger than filling-face twills because the stronger warp yarns on the face of the fabric can take more abrasion and wear. Warp-face twills generally have much more warp than filling yarns; consequently, such fabrics hold their shape better and drape better due to the warp's greater twist and resilience.

Although one may readily think of the interlacing of the filling yarn as going over and under the warp threads as the filling passes through the shed of the loom, twills are described in terms of the interlacing of the warp yarns over and under the filling yarns. An uneven four-shaft twill, for example, that has one warp yarn riding over three filling yarns is referred to as a three up and one down, or $\frac{3}{1}$. On the other hand, a three-shaft twill that has one warp yarn riding under two filling yarns is referred to as a one up and two down, or $\frac{1}{2}$ (see Figures 4-21 and 4-22).

Many combinations and variations of twill constructions are possible. These produce interesting pattern effects, which can be further enhanced by yarns of different colors and textures (Figure 4-23).

Fabrics in Twill Weave. Although there are lightweight twills, the majority of fabrics in twill weave are medium weight, and there is a substantial variety of bottom-weights. Depending upon fiber, yarn, construction, and finish, they are used for a wide range of apparel, such as dresses, suits and coats, and home furnishings, such as drapery and upholstery.

Cloth made of staple yarns are usually left-hand twills. They include canton flannel, covert cloth, coutil, denim, drill, gabardine, hickory shirting or hickory stripe, jean, khaki, middle twill, outing flannel, silesia, ticking, venetian cloth, and whipcord.

The twill weave is not used much in the production of linen, as linen yarns make a naturally strong fabric. However,

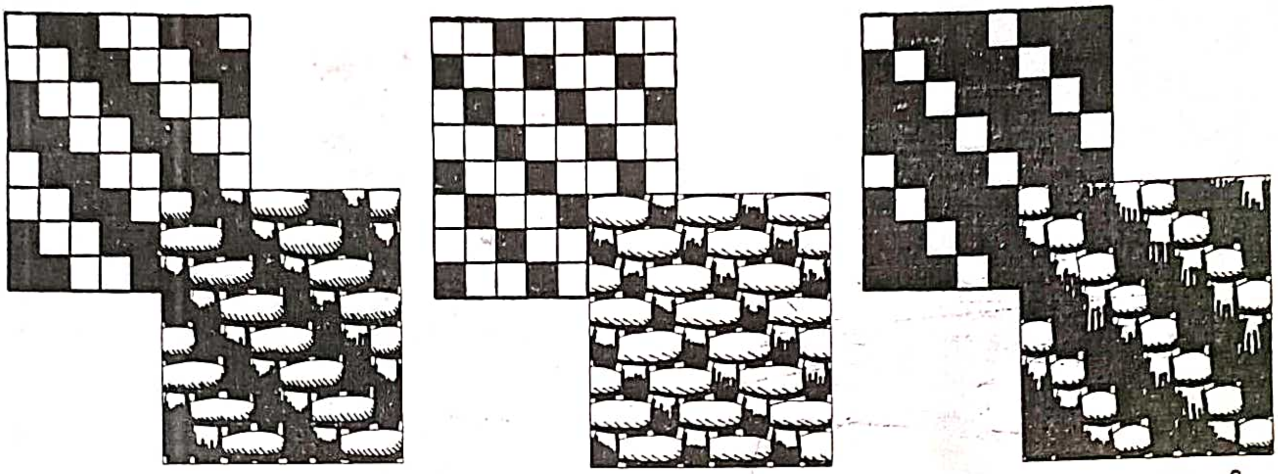


Figure 4-21 The basic diagonal of the left-hand twill weave. The direction of the diagonal and the number of harnesses used produce different surface designs.

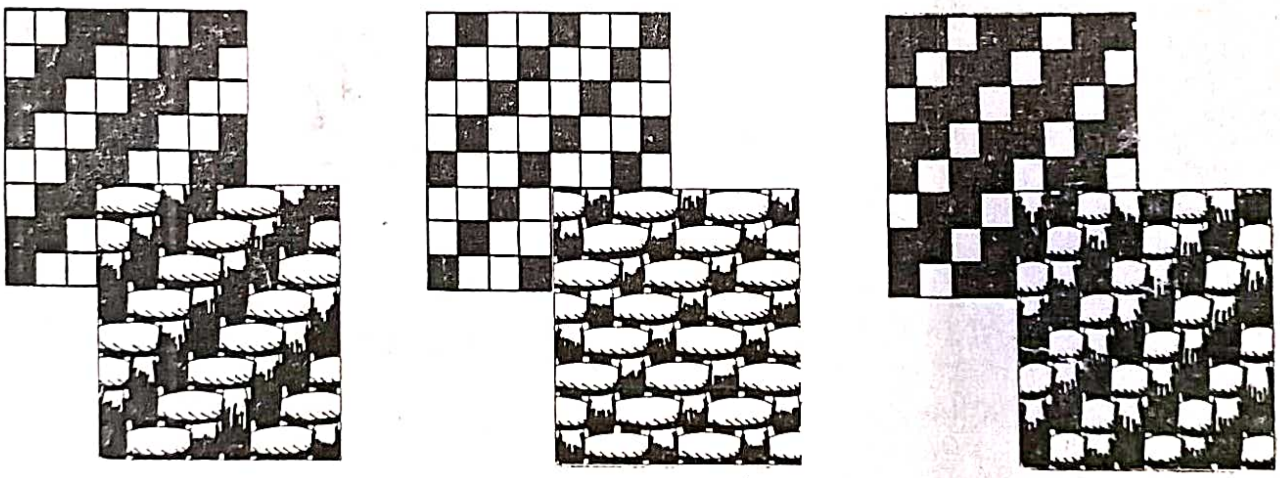


Figure 4-22 Right-hand twills.

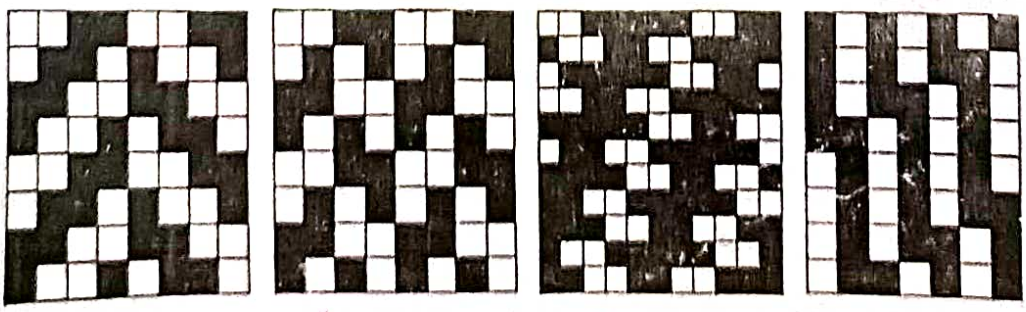


Figure 4-23 These variations of the twill weave show (*a*) and (*b*) broken twills (herringbone), (c) gabardine, and (*d*) corkscrew twill.

it may be found in linen ticking, twill toweling, and towel drills.

Wool-type fabrics are usually right-hand twills, such as broadcloth, cashmere, cheviot, covert, flannel, gabardine, mackinaw, melton, pilot cloth, serge, tweed, whipcord, and worsted cheviot.

Fabrics made of filament yarns are also righthand twills. They include foulard, merveilleux, silk serge, and surah.

Satin Weave

In basic construction, the satin weave is similar to the twill weave but generally uses from five to as many as twelve harnesses, producing a five- to twelve-shaft construction. It differs in appearance from the twill weave because the diagonal of the satin weave is not visible; it is purposely interrupted in order to contribute to the flat, smooth, lustrous surface desired. There is no visible design on the face of the fabric because the yarns that are to be thrown to the surface are greater in number and finer in count than the yarns that form the reverse of the fabric. The satin weave may have a warp-face or filling-face construction.

Warp-Face Satin Weave. Warp-face satin is woven so that the warp may be seen on the surface of the fabric. For example, in a five-shaft construction, the warp may pass over four filling yarns and under one; in a twelve-shaft construction, the warp may pass over eleven filling yarns and under one. Since the warp lies on the surface and interlaces only one filling at a time, the lengths of warp between the filling are called *floats*. These floats lie compactly on the surface with very little interruption from the yarns going at right angles to them. Reflection of light on the floats gives satin fabric its primary characteristic of luster, which appears in the direction of the warp (see Figure 4-24).

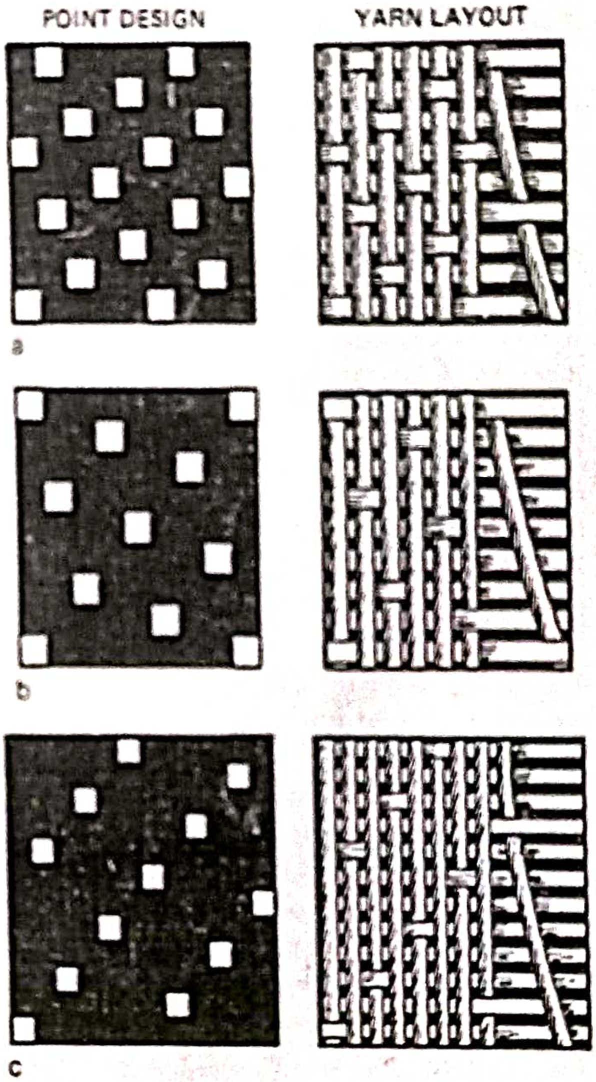


Figure 4-24 Warp-face satin weave. Point design (white squares indicate where warp yarns pass under filling yarns) and yarn layout of (a) five-shaft construction, warp floats interlace every fifth filling; (b) eight-shaft construction, warp floats interlace every eighth filling; and (c) twelve-shaft construction, warp floats interlace every twelfth filling.

The long floats found in the satin weave might be considered a disadvantage because they represent a minimum of interlacings, and therefore a potential weakness in the fabric. Furthermore, to increase the smoothness and luster of the fabric, the yarns are given a minimum of twist and are therefore relatively weak. The longer the float, the greater the chance that the surface of the fabric will snag, roughen, and show signs of wear. However, the luster makes the fabric suitable for dressy wear and the smoothness, for use as lining.

Satin-weave fabrics drape well because the weave is heavier than the twill weave, which, in turn, is heavier than the plain weave. More harnesses are used for satin weave, thus compressing a greater amount of fine yarn into a given space of cloth. This compactness gives the fabric more body as well as less porosity, which makes the fabric warmer. The quality of drapability also makes satin fabrics preferable for evening wear, and the warmth contributes to its value as lining material.

Designing a Satin Construction. When making a design for a satin construction, the interlacings on successive lines must be separated by a proper interval to avoid forming the contiguous diagonal. When the proper interval for any shaft construction is selected, the design will not repeat itself until the number of successive picks that make up the desired shaft have been interlaced. In a five-shaft construction, for example, the design begins to repeat on the sixth line; in an eight-shaft, on the ninth line; in a twelve-shaft, on the thirteenth line.

Fabrics in Warp-Face Satin Weave. Most fabrics made with the satin weave are medium weight; a lesser number are heavier weights. Both staple fiber and filament yarns are used.

The staple fibers most frequently used are cotton and rayon for such fabrics as damask, sateen, ticking, and venetian cloth for use in apparel and home furnishings.

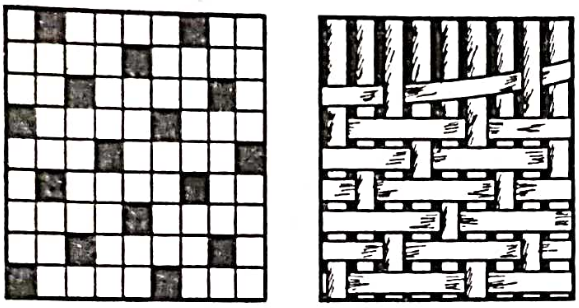
Linen is used for damask home furnishings, principally table cloths.

Silk, rayon, acetate, and nylon filament yarns are usually used for such material as brocade, damask, merveilleux, and satin.

Filling-Face Satin Weave. The filling-face satin weave is also called the *sateen weave*; however, this sometimes causes confusion because some cotton and rayon fabrics are also identified as sateen. In this construction, the filling yarn lies on the surface of the fabric as it passes regularly over and under the warp yarns. For instance, a filling yarn may pass over four warp yarns and under one. The floats are consequently made up of the filling yarns, and the luster appears in the filling direction (see Figure 4-25).

Designing a Filling-face Satin Construction. An eight-shaft construction illustrates here the rules that must be followed to select a suitable interval.

1. Arrange in pairs the numbers that will add up to the desired shaft number. For an eight-shaft filling-face satin, the shaft number is 8. The pairs are 1 and 7, 2 and 6, 3 and 5, 4 and 4.
2. Eliminate the pair that contains the number 1 and the number below the shaft number, which is 7 in this case. A contiguous diagonal would result if these intervals were used, producing the conventional twill weave.
3. Next, eliminate the pairs that have a common divisor and those that are divisible into the shaft number. This step eliminates 2 and 6, 4 and 4. The pair 3 and 5 remains. These numbers are the only intervals that can be used in an eight-shaft construction. If any of the eliminated numbers were used as an interval, the fabric would show no interlacing whatever for one or more warp yarns; in fact, there would be no fabric because it would fall apart.



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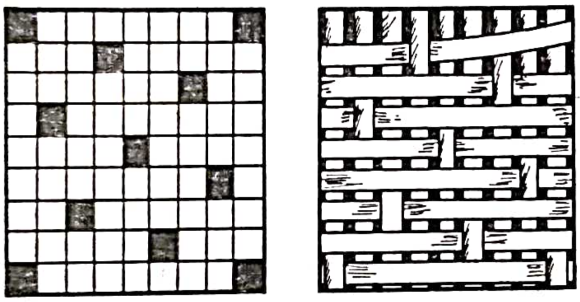

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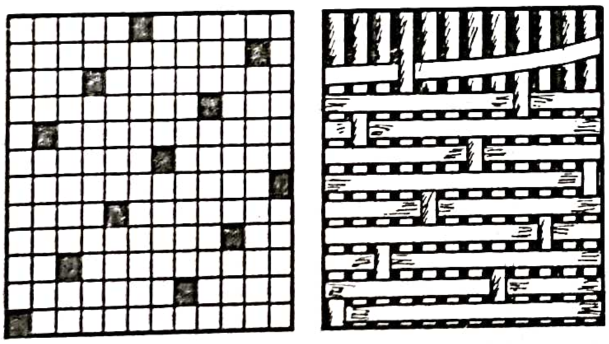

c

Figure 4-25 (*left*) Filling-face satin weave. Point design (black squares indicate where filling yarns pass under warp yarns) and yarn layout of (*a*) five-shaft construction, filling floats interlace every fifth warp; (*b*) eight-shaft construction, filling floats interlace every eighth warp; and (*c*) twelve-shaft construction, filling floats interlace every twelfth warp.

Now that the only possible interlacings have been worked out, the design can be constructed (see Figure 4-26). For convenience, here the interlacing begins in the lower left square, at *A*. The horizontal rows of squares represent filling yarns—that is, the successive picks on the loom. The vertical rows represent the warp yarns.

The interval to be used for this particular design could be 3 or 5; in this case, 5 has been selected. As this is to be an eight-shaft construction, the interlacing on the first pick will be 7 squares (warp yarns) apart at *B* and *C*.

To find the warp yarn that will interlace on the second pick, count 5 to the right, beginning with the square above the interlacing that is already started at *A*; thus, the interlacing occurs at *D*. Adja-

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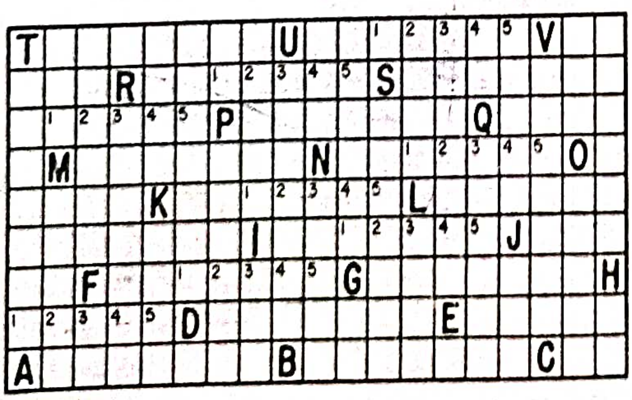


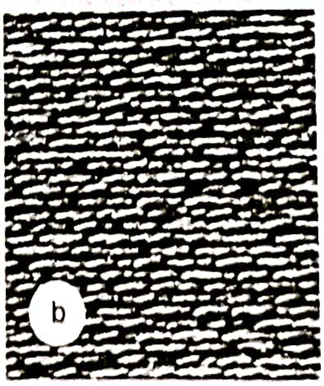


Figure 4-26 (*a*) Diagram of an eight-shaft filling-face satin construction. Each horizontal line of blocks represents a filling yarn or pick. The blocks covered by letters are the points at which the filling yarns interlace the warp yarns on each successive pick. In the eight-shaft warp-face satin construction, the filling is carried across the back, creating the float in the warp. The basic idea of warp-face satin can be seen when this diagram is turned sideways. (*b*) Satin cloth.

cent interlacing on the same line will be 7 squares apart, at *E*.

To find the warp yarn that will interlace on the third pick, start with the square above *D*. Count 5 to the right, and interlacing G is plotted. Adjacent interlacings will be 7 squares apart.

On the fourth pick, interlacing *I* is found by counting 5 to the right of the square above *F*; *J* is found by counting 5 to the right of the square above G, or 7 squares from *I*.

This same procedure determines the interlacing points on successive picks, additional interlacings always being 7 squares apart.

On the ninth pick, the design starts to repeat, which proves the accuracy of the construction of an eight-shaft weave.

Where it is not possible to plot subsequent interlacing by continuing to count to the right, because of the small area of the design, interlacings on successive picks can be determined by counting 3 to the left instead of 5 to the right. If the interval 3 had been used to count to the right, 5 would have been used to count to the left.

Fabrics in Filling-face Satin Weave. Filling-face satin fabrics are generally of medium-weight and made of staple fiber yarns. They are usually made of cotton or rayon into damask, sateen, and ticking. When linen is used, the cloth is likely to be a damask.

Crepe Weave

Reference has been made previously to the use of hard-twist and textured yarns for making crepe fabrics that have rough, pebbly surfaces. Embossing finishes are also used to produce crinkled effects (see pages 177–179). These fabrics are made with the plain weave.

Similar effects can be obtained by variations in the plain and satin weaves with the use of a dobby attachment on the loom (see page 96). Irregular, indistinct patterns utilizing both the plain weave and varied lengths of satin floats in the warp and/or filling are used to produce the *crepe weave* (sometimes called a *granite weave*). The result is a somewhat rough-textured material. Such crepe fabrics can be made either of yarns that ordinarily would not provide a crepe effect or of a combination of such yarns and hard-twist or textured yarns.

The characteristics of crepe-weave fabrics depend largely upon the kind of yarn used. If ordinary yarns are used and the crepe weave is employed to give a crepe appearance, then the fabric will have little drapability, low strength, and limited durability. Some crepe fabrics tend to stretch, and some may shrink when subjected to wetting. On the other hand, combinations of yarns and weave construction can produce fabrics of interesting appearance and texture that have good drapability, resilience, stretch, and serviceability.

Fabrics in Crepe Weave. As has been noted, many crepe fabrics are constructed in the plain weave of either hard-twist or textured yarns. However, not all fabrics of the crepe weave use such yarns.

Examples of fabrics made of a crepe weave of spun or filament yarns are granite, or momie cloth, and sand crepe. An example of a fabric made of a crepe weave of hard-twisted filament yarn is moss crepe. These kinds of materials are used mainly for blouses and dresses.

Pile Weave

The pile weave is a fancy weave that also includes a plain or a twill construction.

In contrast to the three basic weaves that produce a flat surface on a fabric, the pile weave introduces a decorative third dimension, creating an effect of depth. Its construction is especially desirable when softness, warmth, and absorbency are desired. Pile-weave fabrics are also durable if the proper yarns and adequate compact construction are used. In the manufacture of rugs, for example, a strong, tightly twisted yarn with compact construction in the base cloth will withstand long wear.

The pile is produced by weaving an additional warp yarn or filling yarn into the basic structure. The additional yarn, which forms loops at regular intervals, is drawn away from the surface of the fabric by thick wires. These loops may be cut or closely sheared, or left uncut if a loop surface is desired (see Figure 4-27).

When the pile is produced by an extra warp yarn, the result is a warp-pile fabric, of which terry and plush are two examples. Fabrics are classified as plush when the pile is ⅛ inch (3 mm) high. When the pile is produced by an extra filling yarn, the result is a filling-pile fabric, of which velveteen and corduroy are examples.

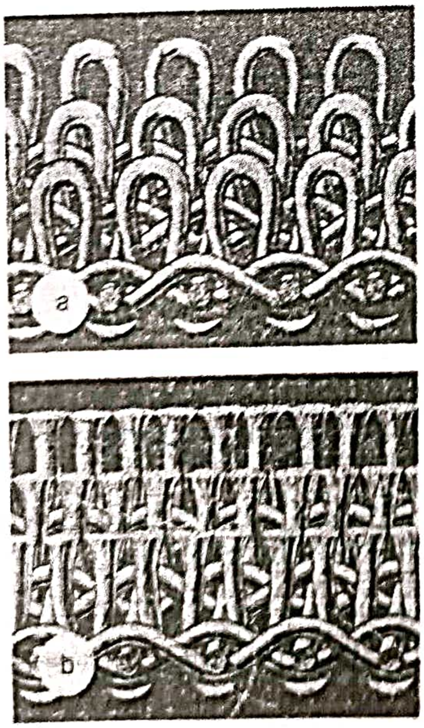


Figure 4-27 (*a*) Drawing of pile weave as it looks after the wires that have raised the filling yarns have been withdrawn. (*b*) Drawing of cut pile which can be produced by using wires equipped with razorlike ends that cut the loops as the wires are withdrawn.

Cut Pile. There are several methods of producing cut pile. One technique is to weave an extra set of yarns that will float across several ground, or binder, yarns to form rows of loops to be subsequently cut. For example, corduroy is woven with extra filling yarns that float in uniform rows over groups of three or more warps to form parallel rows of loops running the length of the cloth. After weaving, a machine is used to lift the floats and cut them with a row of revolving knives, thus raising a pile from the ground fabric; the width of pile is determined by the length of the floats. For a close, dense pile as in velveteen, the floats are woven over the ground cloth in a manner that will cause a compact pile structure when the loops are cut and sheared for uniform height. Cut-pile fabrics may be woven on looms equipped with wires that have knife edges to cut the extra set of warp yarns which float over predetermined numbers of filling yarns. As the wires are withdrawn across the loom, the floats are cut to produce the cut pile.

Another method of producing cut pile is by cutting apart the two layers of a double cloth (see pages 93–94). Two pile fabrics are formed simultaneously as the extra set of yarns, which hold the two cloths together, is cut by a knife traveling across the loom. The height of the pile is determined by the distance between the two cloths. This technique may be used to make such fabrics as velvet. The W method produces a more durable fabric

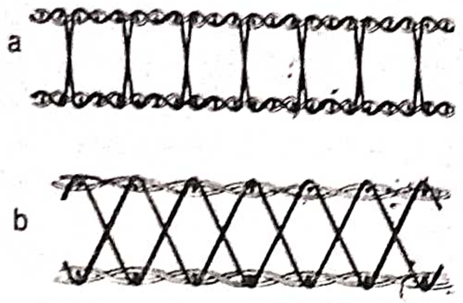


Figure 4-28 The double-cloth weave can be produced by either of two methods: (*a*) the V method or (*b*) the W method. Cutting the yarn that holds the two cloths together makes two separate cut-pile fabrics.

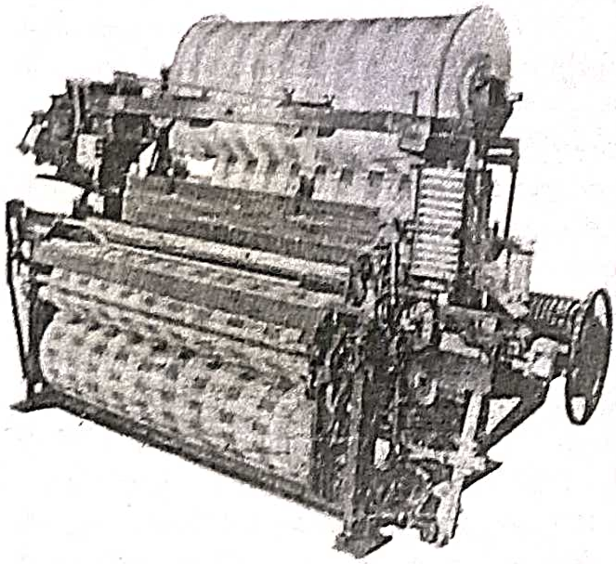


Figure 4-29 A terry loom with the additional warp beam above to provide the extra set of ground warp yarns. *(Courtesy Crompton & Knowles Corp.)*

and one less likely to develop bald spots because the pile is held in place by three yarns rather than the one yarn used in the V method (see Figure 4-28).

Cut-pile fabrics have certain limitations. They catch lint and spot easily. Although the pile is constructed perpendicularly to the ground fabric, the finishing processes of singeing, waxing, and/or pressing may cause the pile to slant and give it either an up or down direction. This will cause light reflection to give the material shading, depending upon how it is held or brushed. It is therefore important to note the direction of the pile for consistency of color appearance in the construction of garments or use in home furnishings. Some cut-pile fabrics may be laundered, depending upon the fiber used, but they must be thoroughly rinsed so that they will not be stiffened by soaps or detergents. If they need to be ironed, they should be pressed with a steam iron. To avoid crushing, ironing should be done on the wrong side.

Uncut Pile. There are two methods of producing uncut-pile fabrics. One is with the use of wires but without knife edges as described above. When the wires on the loom are withdrawn, the loops formed from the extra set of floats remain intact. Frisé is generally made in this manner.

The other method is to weave an extra set of warp yarns into the fabric from a warp pile beam (see Figure 4-29). For example, a loom can be constructed to accommodate the extra warp pile beam and groups of three fillings to be inserted and beaten up with a single reed motion. After the second filling is inserted, the let-off motion causes the yarns from the warp pile beam to slacken, while those on the ground warp beam remain under tension. Following insertion of the third filling in the set, the reed beats up firmly all three picks causing the slackened warp to form the pile loops. The height of the pile is dependent upon the distance that the first two fillings are held back from the fell of the fabric (see Figure 4-30). The pile can be produced on one or both sides of the cloth. A typical fabric woven this way is terry.

Uncut pile fabrics may wear better than cut pile. However, the loops may catch and tear. They are also not as soft, warm, or absorbent as cut-pile materials.

Fabrics in Pile Weave. Pile fabrics may be woven entirely of either spun or filament

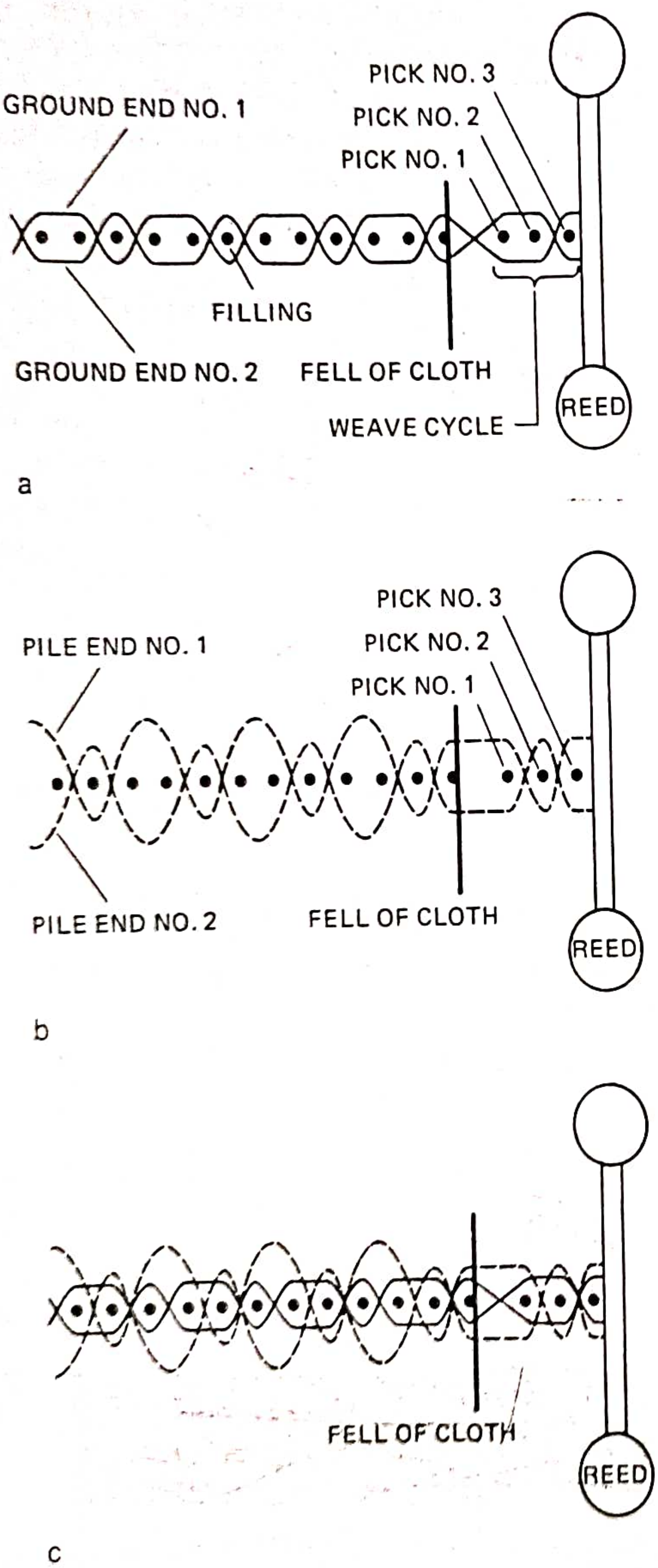


Figure 4-30 (*left*) Schematic of terry weave principles. Terry cloth consists of a ground and pile weave. The ground weave (yarn from bottom beam) interlaces with the filling to form a firm supporting structure for the terry cloth and the pile weave (yarn from top beam) interlaces with the filling to produce the loops. (*a*) Illustration of how the ground ends interlace with the filling on a three-pick terry weave. The three picks near the reed are waiting to be moved to the fell of cloth and beat-up as were the twelve previously inserted picks shown at left. It should be noted that the ground ends interlace only once with the three picks of the weave cycle. Note that ground end No. 1 is made to operate 2 up, 1 down; whereas ground end No. 2 is 1 up, 2 down. (*b*) Illustrations of how the pile ends interlace with the filling on a three-pick terry weave. Notice pile end over the first pick will form a loop on the top while the pile end under the first pick will form a loop on bottom of the cloth. (*c*) Shows the combined ground and pile weave for the three-pick terry weaves. The pile ends are shown dotted to aid the reader in distinguishing between the two weaves. The loops are formed when the yarn is beat-up directly after the third pick has been inserted. *(Courtesy Draper Division, Rockwell International.)*

yarns. Or they may be made of spun yarn in the ground and filament yarn in the pile.

The pile construction limits the possibilities for producing lightweight materials. Two such fabrics are transparent velvet made with a relatively open ground construction and etched velvet which is made of a cut-pile design separated by sheer ground areas. The pile of these materials are of lustrous filament yarn. These fabrics are generally used for evening gowns and fancy dress goods.

Most pile fabrics are in the medium- and heavyweight categories. They range from velvet and velour for apparel, to plush and frisé for upholstery, to a variety of rugs.

Fabrics in Pile Effect. The pile structure is also achieved by techniques other than weaving. Descriptions of these are provided in the sections dealing with knitting, tufting, and flocking.

Double-cloth Weave

In the double-cloth weave, two fabrics are woven on the loom at the same time, one on top of the other. The fabric may have a plain weave on one side and a twill weave on the other. Each of the fabrics requires its separate sets of warp and filling yarns. They are combined by interlacing some of the warp or filling yarns or by means of a complete fifth set of stitching yarns. The surfaces of such fabrics may show different patterns or color on each side by varying the yarns as to color and size. A true double-cloth weave is never a pasted construction.

Because the double-cloth weave produces two pieces of fabric combined into one, fabrics so woven are commonly regarded as strong and warm. Warmth, however, is due primarily to the insulative properties inherent in a fiber; bulk and thickness alone do not give warmth. Also, strength cannot be judged by mere thickness or weight. It cannot be assumed that a double-cloth weave will have the qualities of warmth and strength; on the contrary, the fabric may be heavy, bulky, and needlessly expensive. Sometimes, this method of construction is chosen to use a cheaper material on the reverse side of the fabric, thus reducing the cost of a heavy fabric.

Fabrics in Double-cloth Weave. Double-cloth fabrics are by their very nature heavier weight materials. They may be made of spun yarns or of spun and filament yarns. Depending upon their composition and construction, they can be used for robes, blankets, coat materials, and a variety of upholstery fabrics.

Gauze Weave

The gauze weave must not be confused with the weave used in manufacturing gauze bandages or cheesecloth; these materials are made with the plain weave. The true gauze weave construction produces a fabric very light in weight and with an open-mesh effect. Curtain materials and some shirting and dress goods are woven with this weave. Such lightweight fabrics have a strength that could not be provided by the plain weave. In the gauze weave, strength is gained by the manner in which the yarns are intertwisted: each filling yarn is encircled by two warp yarns twisted about each other.

The gauze weave is sometimes referred to as the *leno weave* because it is made on a leno loom, but the true leno weave is a variation of the gauze weave (see Figure 4-31).

On the leno loom, the action of one warp yarn is similar to the action of the warp in the plain weave. The *doup attachment*, a hairpin-like device at the heddle, alternately pulls the second warp

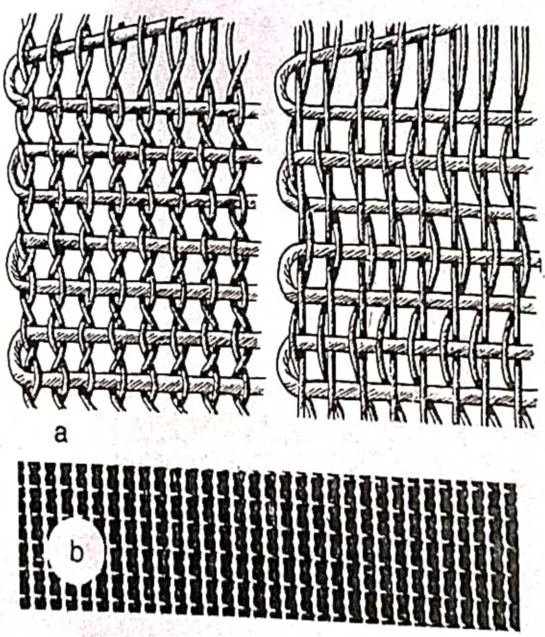


Figure 4-31 (*a*) Gauze weave (left) and leno weave (right). Note how the filling yarns in the gauze weave are encircled by two warp yarns twisting around each other, a construction that gives strength although the mesh is open. In the leno weave, the second of each of two warp yarns merely passes around the first yarn. (*b*) Marquisette, which is constructed with a leno weave. (*Courtesy U.S. Department of Agriculture*) yarn up or down to the right or left with each pick passage. This causes the pair of warps to be twisted, in effect, around each filling yarn. The leno is sometimes used in combination with the plain weave to produce a stripe or figure on a plain background. Generally, the term "leno" is used synonymously with "gauze."

Fabrics in Gauze Weave. Fabrics made with the gauze weave are manifestly sheer. Yet, their weights vary depending upon the thickness of the yarns, which could be of spun, filament, or combinations of these yarns.

Typical materials are grenadine and marquisette which are used for curtains, shirtings, and blouses.

Swivel Weave

The swivel weave is the method by which decorative effects, such as dots, circles, or other figures, are interwoven on the surface of a fabric while it is being constructed on the loom. The weaving of the design requires an extra filling yarn and additional small shuttles or insertion devices. A separate shed is made for them. While the fabric is being constructed, the row of small shuttles drops across the width of the loom, and each interweaves its separate design with a circular motion on a small area of the warp. A long thread is carried on the undersurface of the fabric from one design to the next. Different colors may be used in each of the designs because each figure is woven with its own specific bobbin (Figure 4-32).

The decoration produced by the swivel weave is not considered durable, because the swivel yarns are cut when the fabric is completed and cannot be securely fastened. The cut ends roughen the undersurface of the fabric and may pull out if it is handled roughly, as may happen in laundering. However, clipped spot construction, which appears to be similar to swivel weave, is less durable because the floated extra filling yarns that form the spots are merely cut and the spots are not anchored.

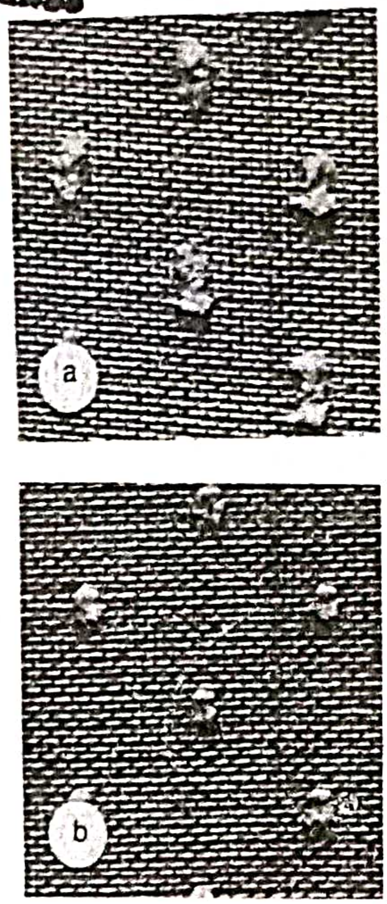


Figure 4-32 Dotted swiss has a swivel-weave construction into which an additional warp thread is interwoven and subsequently clipped on (*a*) the reverse side of the fabric, producing intermittent dots on (*b*) the face.

Fabrics in Swivel Weave. The swivel weave is employed with sheer lightweights, such as dotted swiss and grenadine, and medium-weights, such as madras.

Lappet Weave

The lappet weave is also used to superimpose a small design on the surface of a fabric while it is being woven. In the lappet weave, the design is stitched into the fabric by needles that operate at right angles to the construction. Thus, the lappet weave is very similar to embroidery.

The lappet design is made with one continuous additional yarn carried on the back of the fabric from one design to the next. The floating threads on the back may be cut away when the fabric is completed, but the ends are fastened securely and will not pull out easily. Therefore, fabrics made with the lappet weave are superior to similar ones made with the swivel weave.

Fabrics in the Lappet Weave. The lappet weave is employed on a variety of fabrics where novelty patterns are desired.

Dobby Weave

The dobby weave is a patterned weave used to construct designs that cannot be produced by the plain, twill, or satin weaves. The designs are simple, limited in size, and usually geometric in form. They are found in shirtings and tie fabrics. The dobby weave is created on a plain loom by means of a mechanical attachment, called a *dobby* or *cam*, which raises or lowers as many as twenty-four to forty harnesses containing the series of warp yarns that form the pattern (see Figure 4-33). Although a large number of harnesses is used in this construction, the design is always small and does not make use of long floats. The most familiar type of dobby weave is bird's-eye, the small diamond pattern made with short floats that give the impression of an eye.

Fabrics in Dobby Weave. Fabrics made with a dobby weave are generally of spun yarn and of medium-weight. They may have a rough or pebbly surface imparted by the particular design. Typical fabrics are bird's-eye, huckaback, and granite cloth.

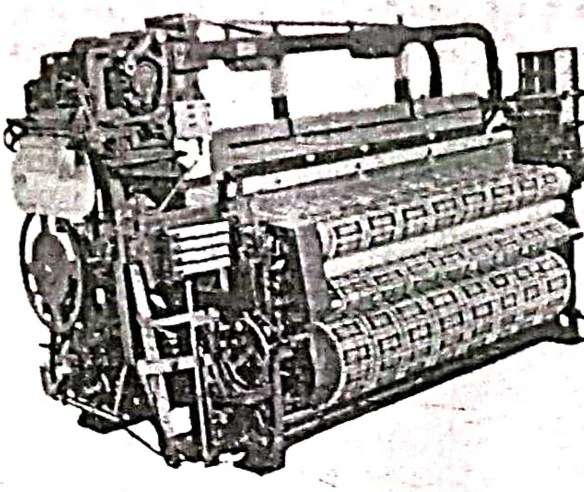


Figure 4-33 A loom with a dobby attachment. Note the punched pattern indication control on the left for the dobby movement to obtain the desired design to be woven into the fabric. (*Courtesy Crompton & Knowles Corporation*)

Jacquard Weave

In any of the weaves that have been described, the number of harnesses determines the construction. For example, two harnesses are required for the plain weave, three or more for the twill, and five to twelve for the satin weave. As many as forty can be manipulated by the special attachment of the dobby. The dobby designs are not intricate, however. They are limited to straight lines, edges, steps, or small circular lines.

For curves, swirls, and large-sized figures, it was necessary to devise a different mechanism that would allow an unlimited range of intricate designs. This need is met by the Jacquard attachment, named after its developer, Joseph Marie Jacquard, a Frenchman. The Jacquard mechanism controls thousands of heddles, which lift one or more warp yarns independently of others without the use of

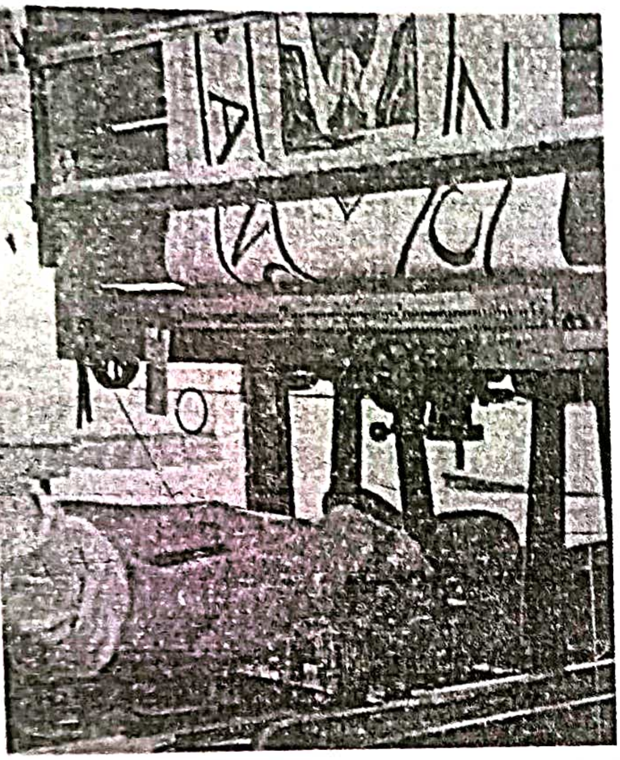


Figure 4-34 The card puncher has a paper design before him. Following a line of checks across the design paper, he inserts steel punches in the cardboards specified on the paper design. Each hole in the card controls the loom mechanism that raises the desired warp yarns in the fabric surface, thus producing the weaving design. (*Courtesy* Textile World)

harnesses. Its action is similar to that of the player piano, where each note is governed by a hole on the music roll and is sounded when the hole passes over a certain opening.

The Jacquard design is first worked out on squared paper. Cards are then perforated to correspond with the design; they are laced together, looking somewhat like a chain of punched data processing cards, and placed on the Jacquard attachment (see Figure 4-34). The moving cards pass over a battery of needles mounted on top of the loom. Each needle controls a string, which, when released, picks up the heddle to which it is tied. The perforations on the cards allow the needles to drop through, and lift certain strings, which, in turn, lift single heddles independently of others (see Figure 4-35). The preparation of a Jacquard weave is the most expensive part of its construction. Setting up the loom may take several weeks or months; but once set, the pattern to be produced can be used and reused for different materials. This is the most expensive form of weaving. However, computerized versions now permit patterns to be programmed, readily modified, and stored, which facilitates operations.

Floats are inevitable in the Jacquard weave because of the elaborate designs. As in the satin weave, long floats may affect the wearing quality of the fabric; also, long yarns exposed to friction cause lint. Compact construction of the fabric, however, offsets the tendency to friction and wear. The consumer should select accordingly when purchasing fabrics having the Jacquard weave, especially damask table cloths which receive hard wear and repeated washings.

Fabrics in Jacquard Weave. The Jacquard weave is used in light-, medium-, and heavyweight cloths made of spun and filament yarns to produce a range of decorative fabrics including brocade, brocatelle, damask, matelassé, and tapestry (see Figure 4-36). Depending upon the yarn, pattern, and weight, they are used for such apparel as dinner jackets and evening gowns and for such home furnishings as table cloths, drapery, and upholstery.

DISTINGUISHING WARP AND FILLING

Persons who deal with fabrics, as well as the home sewing consumer, must be able to identify the warp and the filling yarns, because the direction of the warp determines the way in which the fabric should

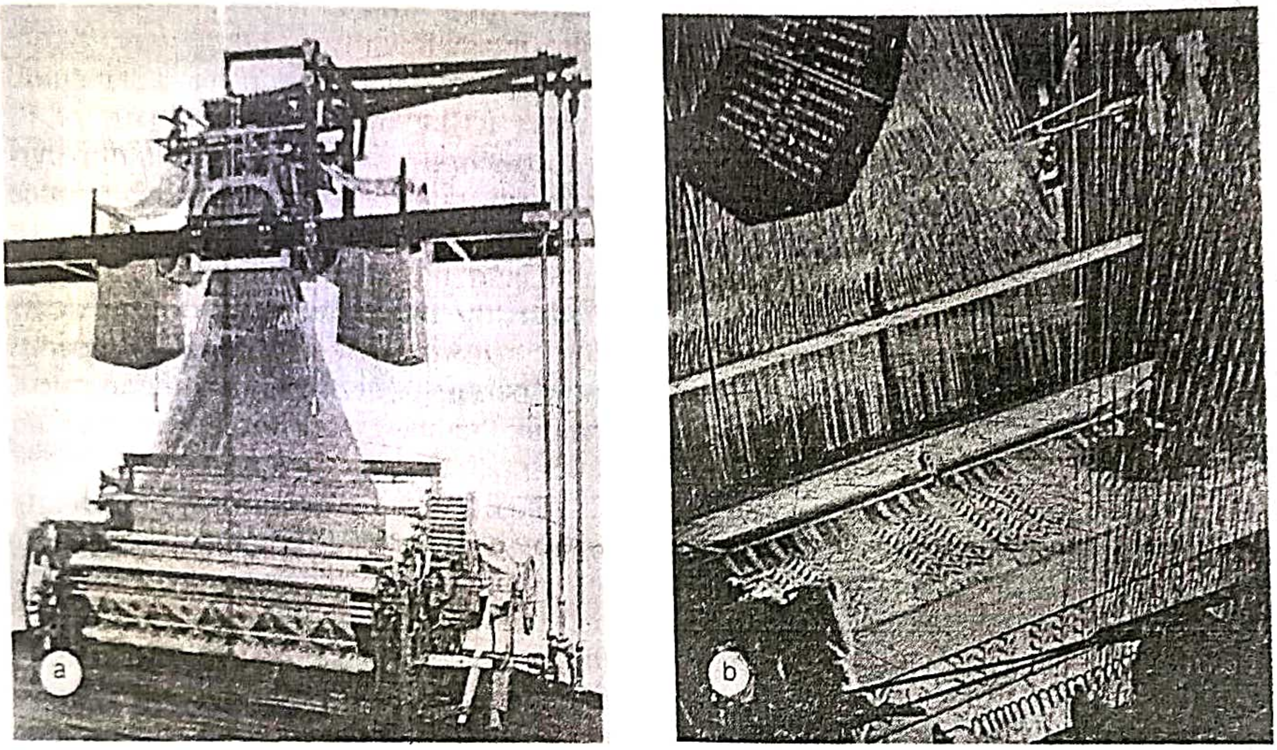


Figure 4-35 (*a*) This Jacquard head loom in operation shows the laced cards at the top of the loom. The long, slanting strings control the heddles immediately below the cards. The heddles raise and lower the warp yarns in accordance with the pattern punched on the cards above; the filling yarns make the design as the shuttle passes across the loom. (*b*) Close-up of Jacquard loom weaving a pile fabric. *(Courtesy Crompton & Knowles Corp.)*

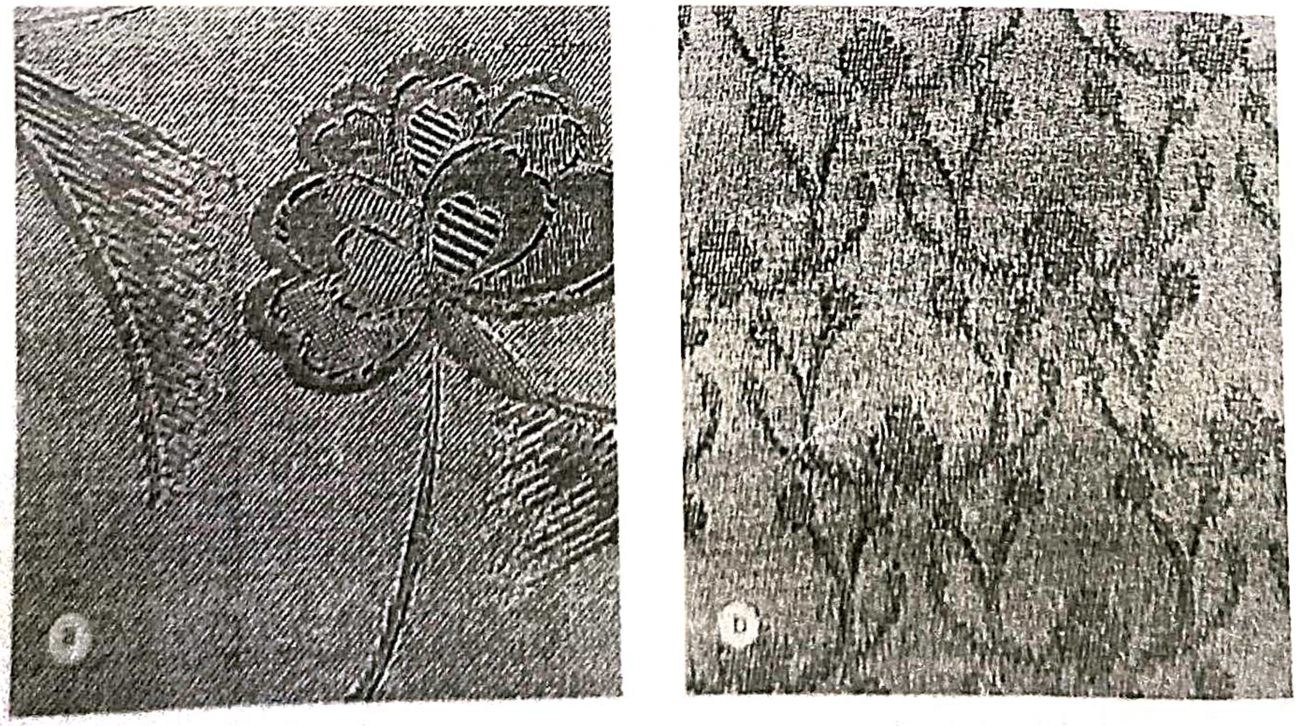


Figure 4-36 (*a*) Damask and (*b*) brocade fabrics produced on the Jacquard loom. *(Courtesy American Viscose Corp.)*

be cut when a garment is made from it. In a new piece of cloth, the direction of the warp is easily distinguished. The length of the fabric indicates the warp yarns. Also, if a piece of the fabric shows part of the selvage, which is the firm edge of the cloth, then the yarns parallel to the selvage are warp yarns. The opposite yarns are the filling yarns. When a sample of fabric contains no selvage, the warp and filling may be identified by observation of the weave:

1. In plain weaves, a greater number of yarns running in one direction indicates the warp.
2. In twill weaves, the filling yarns run in the direction of the diagonal, which may be toward the right or toward the left.
3. In satin weaves, the floating yarns are more likely to be the warp yarns. When one runs a finger over the fabric in both directions, the finger will slide more easily in the direction of the floats. Usually the floats will be in the warp, unless the fabric is cotton. Cotton is more likely to have the floats in the filling.

When the name of the fabric is known, its characteristic features aid in distinguishing the warp and filling. For example, the ribs of dimity and of piqué run in the direction of the warp; the ribs of rep, faille, bengaline, and poplin in the direction of the filling. When colored stripes show in such fabrics as chambray, madras shirtings, and in some dress goods, the direction in which the stripe runs usually indicates the warp.

When the warp and the filling cannot be identified by the foregoing aids, the sets of yarns may be examined for the following characteristics:

1. Exerting tension on a sample by holding it in both hands and pulling, at the same time pressing with the thumbs and forefingers, will show which set of yarns is stronger. The stronger set will be the warp, because warp yarns have to withstand the tension of the heddles in the weaving process. The filling yarn, which travels through the shed and across warp yarns to form the fabric, is under little tension.
2. When one set contains yarns of varying sizes, this set is usually the warp. Filling yarns are usually of the same size.
3. The set of yarns that can be more easily stretched is the filling.
4. Yarns of inferior quality are commonly used as filling in inexpensive fabrics. When both sets of yarns are carefully compared, the inferior yarn is usually the filling.
5. When a yarn has a hard twist, as in serges and overcoatings, it is generally the warp yarn.
6. Yarns with slack twist usually are the filling yarns. Yarns with little twist are used as filling when a soft, lustrous effect is desired.
7. If one set consists of thicker yarns, this indicates the filling, as the bulk produced by heavier yarns dispenses with the need for a great amount of twist.
8. If ply yarns are used, they probably indicate the warp.
9. In a napped fabric, the warp runs in the direction of the napping, because the fabric has been run through the machine in the direction of its length.
10. In lightweight fabrics, a marked evenness between the yarns indicates the warp. This evenness is the result of the mechanical movement of the reed as it battens the filling yarns when the cloth is constructed. In patterned weaves, such as herringbone twill, the impact of the battening operation leaves small reed marks that distinguish filling from warp yarns.

IDENTIFYING THE RIGHT SIDE OF A FABRIC

For cutting and sewing purposes, it is necessary to identify the face, or right side, of a fabric. When the cloth is on a bolt, identification is easy because the fabric is wound or folded with the right side inside to keep it clean. Off the bolt, other characteristics may be observed. If one side of the fabric is shinier than the other, the more lustrous side is the face. If a printed fabric has a more distinct design on one side, that is the right side. When the fabric has a nap, the face is, as a rule, the fuzzier side. When slub yarns are used, they tend to be more outstanding on the right side. Recognition of the weave characteristics also helps.

Twill Weave

Since twills often have a diagonal with a distinct wale or ridge on the face, the right side may be identified in this manner. Even when there is no wale, the diagonal of the twill is likely to be more discernible on the face of the fabric. The cloth should be held so that the warp yarns run up and down.

Satin Weave

If the fabric is very smooth and lustrous, the fabric should be examined closely for floats, which would be on the face. By partially separating out a thread along the edge of the material, one could observe whether the yarn forms the characteristic floats of the satin weave. A magnifying glass will help.

Pile Weave

The prime purpose of the pile weave is to provide textural interest to the fabric. Therefore, the pile will be on the face of the fabric.

Fancy Weaves

The smoother sides of swivel and clip-spot weaves are the right sides. The back of the cloth will show the ends of the clipped yarns used for the design. The lappet weave usually has a trail thread passing on the back of the fabric from one design to the next in the row. The dobby designs, including piqués, are clearer and more outstanding on the face. Jacquard patterns stand out from the background although the pattern is not always raised.

IDENTIFYING WOVEN FABRIC DEFECTS

In the course of making fabrics, imperfections occur. Fabrics should be examined for yarn and weave defects.

Yarn Defects

A *slub* caused by uneven spinning or by waste caught during the spinning would indicate a weak spot in the yarn as well as an area for possible fabric abrasion and wear. There could be a *broken or missing end or pick*, thereby resulting in fabric weakness and pattern imperfection. Sometimes there may be a *mixed end or pick*, that is a yarn different in size, twist, number of plies, or color, which would affect the wear or appearance.

Weave Defects

A *slack yarn* due to insufficient tension in weaving or a *tight end or pick* caused by excessive tension is also a defect. An uneven space between ends may be caused by a *misdraw*, where one or more warps were incorrectly drawn through a harness or the reed. There may be a *mispick* due to improper weaving of a filling yarn as the result of restarting the loom on the incorrect pick after an interruption.

There may be *reed marks*, or spaces between groups of warps at intervals or continuously, due to crowding or improper spacing of the warp yarns as they pass through the reed. A *tight selvage*, indicated by a puckered or wavy edge, may be caused by excessive tension in the warp yarns.

Streaks across the width of the fabric may occur. A *barré mark*, which gives the effect of a stripe with shaded edges, may be caused by faulty loom functioning, yarn variations, or faulty dye absorption. A *filling bar*, which is a pronounced crosswise band, may be due to a group of picks of a different size or a section with a different number of picks than are in the rest of the fabric, possibly due to improper restarting of the loom.

TRIAXIAL WEAVE

In the late 1960s, Norris F. Dow of Pennsylvania developed a weaving system utilizing three sets of yarns instead of the customary two. The technique is based upon a method of weaving cane for such purposes as chair backs and seats. His system was sufficiently unique to warrant a United States patent, which he called Doweave. The rights were eventually sold and the technique ultimately became known as *triaxial* weaving. Fabrics of specific yarns and types of triaxial weave are now sold under a number of trademarks.

Methods of Construction

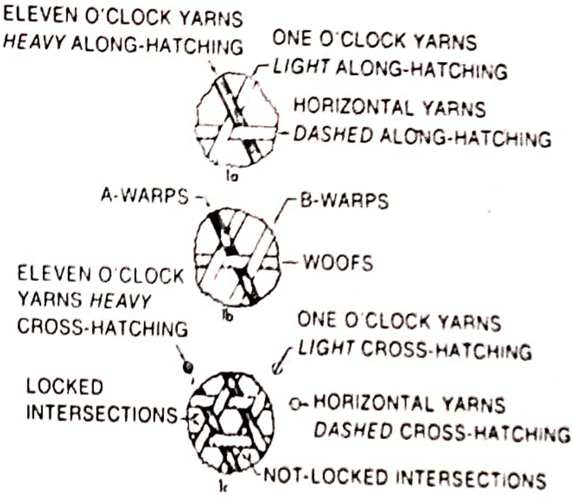
In the basic construction of a triaxial fabric, one yarn runs horizontally, the second yarn runs on a bias at a 60 degree angle to the first, and the third yarn runs in the opposite direction of the second and also at a 60 degree angle to the first, forming a triaxial interlocking, as opposed to the 90 degree biaxial interlocking of the conventional weaving technique. As the process is repeated, hexagonal interstices are formed rather than the squares of the conventional construction.

Variations of the basic construction are possible. For example, the horizontal yarn may be woven over and under alternate pairs of parallel bias yarns. The effect produces interstices that are parallelogram in shape. This variation produces a closer construction. Other variations produce fabrics of even closer constructions and different appearances (Figures 4-37 and 4-38).

Fabric Characteristics of Triaxial Weave

Fabrics constructed of the basic triaxial weave are very stable. For example, fabrics made of glass fiber cannot slip or slide. The porosity of the fabric will be determined by the diameter of the yarns and the closeness of the construction. When the fabric is constructed of yarns snugly compacted together, the hexagonal interstices are approximately twice the diameter of the yarn. Therefore, minimum porosity is about one-third of the fabric area. The weave imparts uniform resistance to stretch in all directions. However, if the yarns are very greatly compacted together, they tend to bend or crimp, and this gives the fabric some degree of stretchability.

The variations in construction alter the fabric characteristics. Surface appearance, porosity, and stretchability can be changed. For example, the variation which produces a parallelogram effect has



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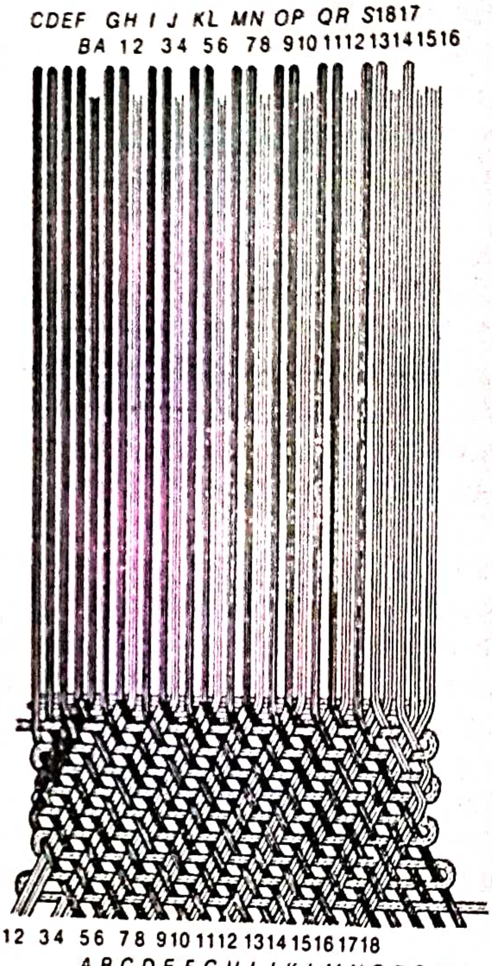

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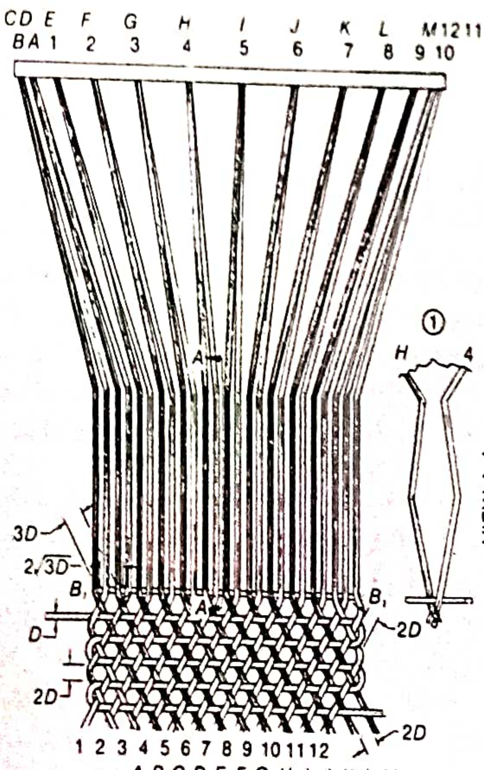

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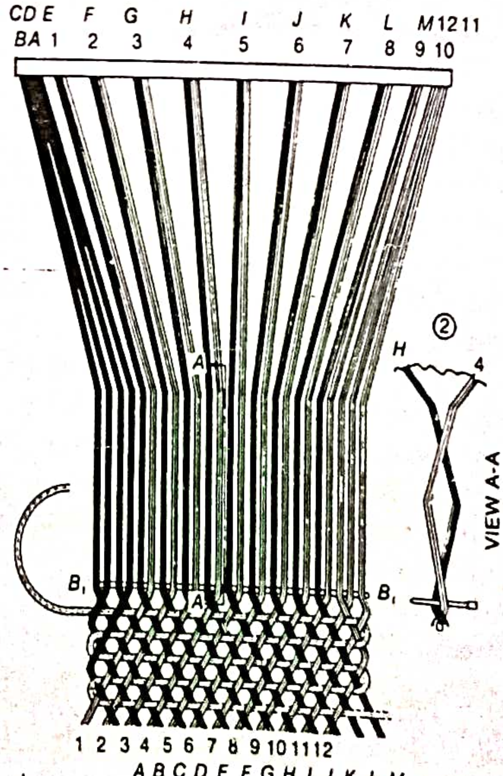

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Figure 4-37 *(a)* Illustrations of locked-intersection characteristics of triaxial weave fabrics, and conventions used for yarn identifications as seen from obverse side. *(b)* Plan view of the first basic position for weaving the first-variant weave. *(c)* Plan view of the first basic position for weaving the basic weave; alignment of warp yarns preparatory to shed formation. *(d)* Plan view of second step in weaving cycle for basic weave; shed formation. *(Courtesy Textile Research Institute)*

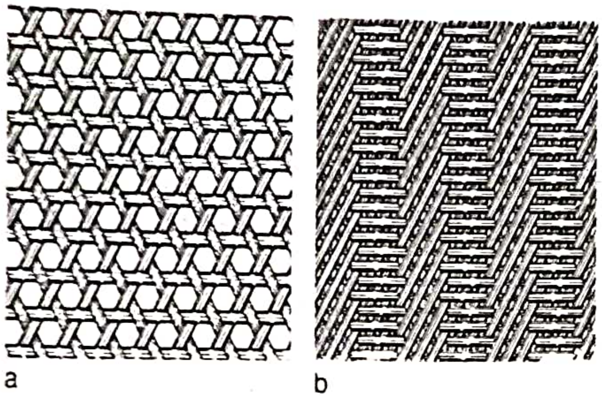


Figure 4-38 Diagrams of triaxial weave fabrics: (*a*) basic weave; (*b*) variant weave. (*Courtesy Doweave, Inc.*)

a porosity of about 12½ percent, stability in the horizontal direction, and stretch in the vertical direction.

Uses of Triaxial Fabrics

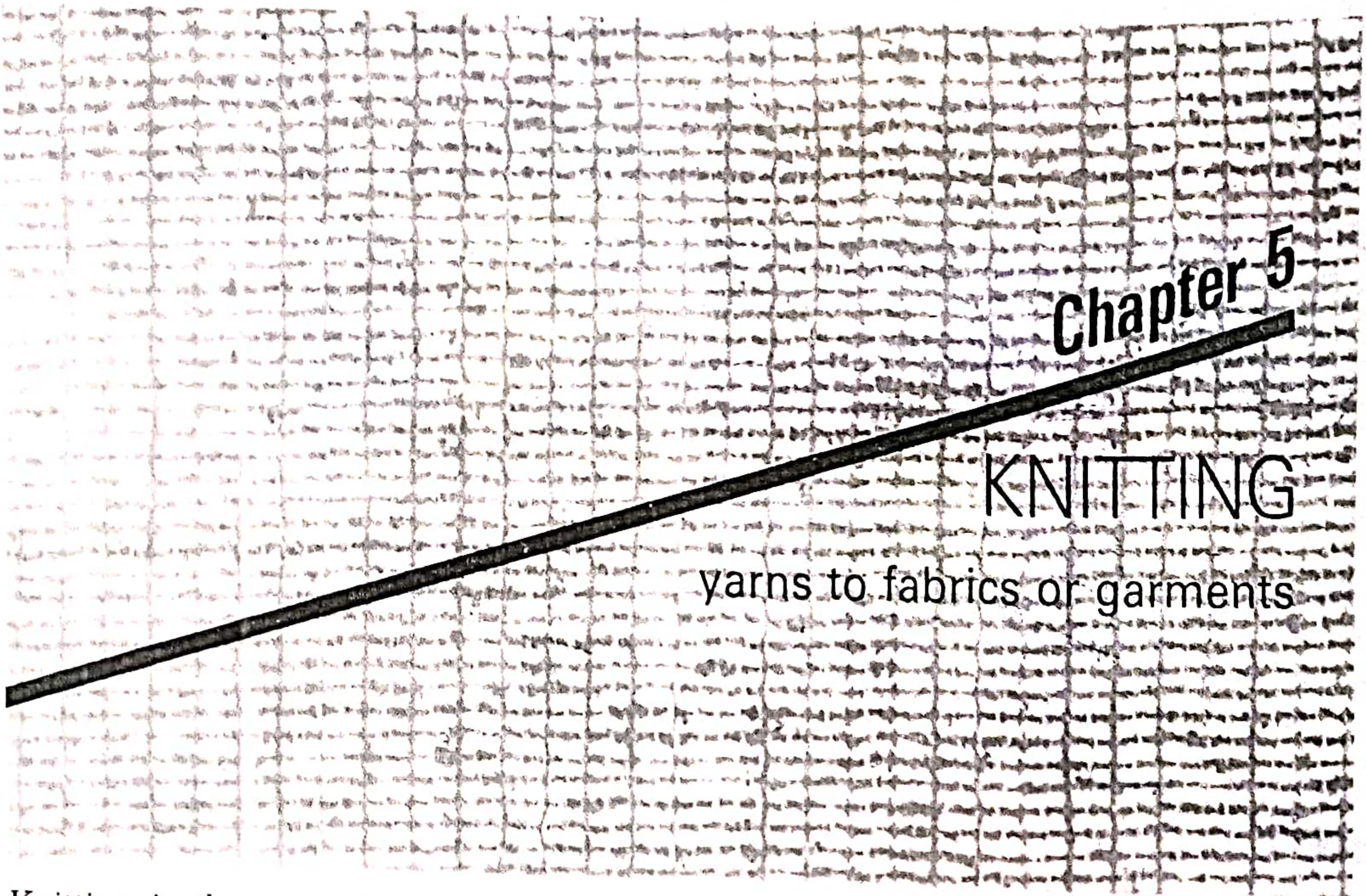
Fabrics of triaxial weave construction are primarily used for industrial purposes, such as conveyor belts, reinforcements for plastics, and aerospace accessories. Its various design and stretch properties suggest apparel and home furnishings applications.

REVIEW QUESTIONS

1. Explain why lappet ornamentation is permanent and swivel is not.
2. Why are harnesses not required in the Jacquard weave?
3. Describe the basic operations of the weaving process, naming specific parts of the loom.
4. Compare the pile weave and its uses with the double-cloth weave and its uses.
5. Differentiate between plain weave, ribbed weave, basket weave, and twill.
6. Compare the advantages and disadvantages of the twill and satin weaves.
7. Which of the three basic weaves is (a) the more durable, (b) the most beautiful, (c) the most inexpensive to produce? Give reasons for the answers.
8. What weave would you prefer in a shirt, suit, curtains? Why?
9. Why was the Jacquard weave revolutionary in the weaving industry?
10. Contrary to common belief, why does the gauze weave embody strength?
11. Differentiate between damask and a fabric made by the dobby weave.
12. How can one identify the face of a fabric?
13. How can the warp be differentiated from the filling in a fabric?
14. (a) What is a swivel design? (b) On what kinds of garments would it be used?
15. (a) What is the selvage? (b) What are the types? (c) Which is best? Why?
16. Is it of any advantage to the consumer to know the basic differences between the three foundation weaves? Why?
17. What is triaxial construction?

SUGGESTED ACTIVITIES

1. Construct designs for variations of the plain and the twill weaves.
2. Construct a design for producing a ribbed effect in the warp.
3. Wind a piece of yarn or string around a square piece of cardboard so that on each side of the cardboard there are vertical parallel yarns in close rows. These are similar to the warp yarns on a loom. Thread another piece of yarn of a contrasting color in a large needle. Insert it through the parallel rows to produce the pattern of the three foundation weaves.
4. Identify three defects in fabrics found in your household.



Chapter 5

KNITTING

yarns to fabrics or garments

Knitting is the second most frequently used method of fabric construction. The popularity of knitting has grown tremendously within recent years because of the increased versatility of techniques, the adaptability of the many new manmade fibers, and the growth in consumer demand for wrinkle-resistant, stretchable, snug-fitting fabrics, particularly in the greatly expanding areas of sportswear and other casual wearing apparel. Today, the usage of knitted fabrics ranges from hosiery, underwear, sweaters, slacks; suits, and coats, to rugs and other home furnishings.

Hand knitting was an early invention. The earliest known knitted fabric was a pair of thick, hand-knitted wool socks found in an Egyptian tomb, which probably dated back to the fourth century B.C. But the art of knitting seems to have been perfected in Western Europe in the fifteenth century. The word "cnyttan" was first mentioned in English literature in 1492. Hand knitting spread rapidly throughout Europe within a few generations. Primitive needles of bone or wood were first used, producing a coarse mesh. The Spaniards began to use steel needles, which produced a closer mesh and a more evenly knit fabric. In 1589, the Reverend William Lee, an Englishman, invented the first knitting machine, which knit 8 loops to 1 inch (about 3/cm) of width. The machine was seen by the strong guild of wool stocking hand knitters as a threat to their livelihood. In a futile effort to please Queen Elizabeth I and gain her patronage, he worked nine more years to develop a machine that could knit a finer mesh of 20 loops per inch (about 8/cm) for silk stockings. When James I refused Lee a patent and permitted the hand knitters to wreck his machines, he fled to France. There machine knitting was developed among a group of French Huguenots.

Today, knitting is a complex industry which has two main areas, each of which has its subdivisions of specializations. One area produces knitted goods for apparel manufacturers, for sewing centers for consumers, and for others. The other area produces completed apparel such as hosiery, sweaters, and underwear.

KNITTED CONSTRUCTION

Knitted fabrics may be constructed with a single yarn that is formed into interlocking loops by the use of hooked needles. The loops may be either loosely or closely constructed, according to the purpose of the fabric. Crocheting is knitting in its simplest form. A chain of loops is produced from a single thread by means of a hook. The interlocking loops of the knitted construction permit the fabric to stretch in any direction, even if low-grade yarn having little elasticity or yarn that lacks natural elasticity is used.

COMPARISON OF KNITTING WITH WEAVING

Woven fabrics are constructed by the interlacing of two or more sets of yarns, which does not allow the fabric to stretch to any marked degree unless it is specially stretch-woven. If a certain amount of stretching is necessary, woven fabric must be cut on the bias—that is, in a diagonal direction. Even then the fabric can be stretched only in the direction of the diagonal cutting. The advantage of stretchability in knitted fabrics is an important consideration where fit and comfort are concerned—they fit the figure but do not bind it.

Knitted fabrics also give warmth because of the insulative air pockets contained in this type of construction. Yet they are porous and provide "breathing" comfort because body movements cause the loops to expand and contract, thus pushing air through close-fitting garments. However, unless the fabric is heavily napped or foam laminated, it is not windproof.

Knitted fabrics are very absorbent, light in weight, and wrinkle-resistant. It is usually unnecessary to iron them after packing and laundering. However they may shrink considerably more than woven cloth unless special techniques and shrink-proofing processes, such as Pak-nit or Permasized, are used.

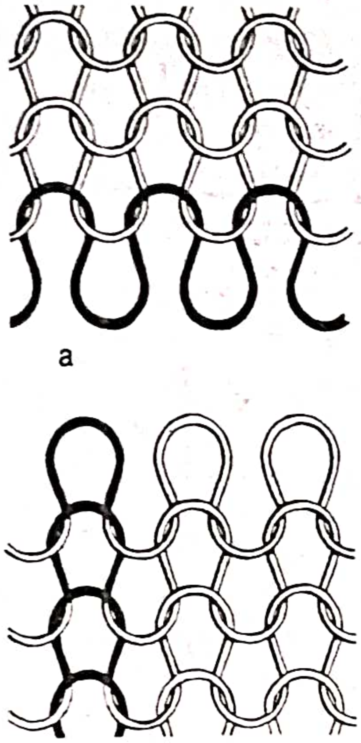
Certain kinds of knitted fabric have one serious disadvantage: if one of the loops breaks, a hole is made, which starts a run. This disadvantage can be eliminated by variation in the stitch, which protects the fabric from raveling if any single stitch is broken. Some knitted fabrics tend to lose their shape and sag. This tendency can be avoided by using a more closely constructed knit, giving the yarn a tighter twist, and using such special techniques as the double knit.

Designs can be changed very rapidly in various types of weft knitting. Therefore, responses to changes in fashion demands can be made much more quickly than is possible with weaving.

Construction of Knitted Fabric

It will be recalled that thread count (the number of threads per square inch, or cm) is used to evaluate the construction of woven fabrics. The construction of knitted fabrics is evaluated by the number of stitches or loops. When the interlocking loops run lengthwise, each row is called a *wale*. A wale corresponds to the direction of the warp in woven fabrics. When the loops run across the fabric, each row is called a *course* (see Figure 5-1). A course corresponds to the filling, or weft. Thus, a knitted fabric having 40 loops or stitches in 1 inch of width, and 50 loops in 1 inch of length, is said to have 40 wales and 50 courses. In metric terms, a knitted fabric having 16/cm loops or stitches across the width and 20/cm loops in the length is said to have 16 wales and 20 courses.

The construction of the knitted fabrics varies with the type, and each type has its own particular appearance and proper-



a

b

Figure 5-1 (*a*) A course in a plain circular-knit fabric. (*b*) A wale.

ties. All other factors of yarn and knit type being equal, the fabric that has more wales in it will be more rigid and stable in width; but the fabric with more courses in it will be more rigid and stable in length. The fabric that has both more wales and more courses per area will also have better recovery from stretching than one with fewer wales and courses per area, whereas, the fabric with less wales and courses per area will be less rigid, stretch more easily, fit to the body contour better, but have poorer recovery ability. Also, the fabric that has more wales will shrink less in the width, while the fabric that has more courses in it will shrink less in the length.

The quality of the needle will affect the quality of the knitted fabric. If the thickness of the hook varies from one needle to the next, the stitches will vary in width. Also, if the needles vary in length, so will the loops. Obviously, these variations will affect the appearance, texture, and performance of the knitted fabric.

Some constructions, such as jersey and rib knitting, are made with a *latch needle*, which has a latch or swinging finger that closes onto the hook of the needle as it pulls the yarn through a loop to form a new loop. Other knits, such as the tricot, milanese, and simplex, are made with a *spring-beard needle* that has a fine, springy hook which slightly resembles a beard. This type of hook must be used with a sinker to hold the fabric down and a presser to close the hook as it forms the loop. However, because of its fineness, the spring-beard needle can be used in the knitting machine in much closer formation to produce more finely constructed fabrics with smaller loops.

There is also a *compound needle* composed of a hook and a sliding closing element. It can be used for knitting at greater speeds than are possible with a latch needle and with less fabric distortion than may occur with the spring-beard needle (see Figure 5-2).

CLASSIFICATION OF KNITTED FABRICS

Knitted fabrics are divided into two general types: (1) those produced by weft knitting, where one continuous yarn forms courses across the fabric; (2) those produced by warp knitting, where a series of yarns forms wales in the lengthwise direction of the fabric.

Weft Knitting

There are three fundamental stitches in weft knitting: (1) plain-knit stitch, (2) purl stitch, (3) rib stitch. Novelty stitches are variations of these three stitches. The hand method of knitting is weft knitting. On a machine, the individual yarn is fed

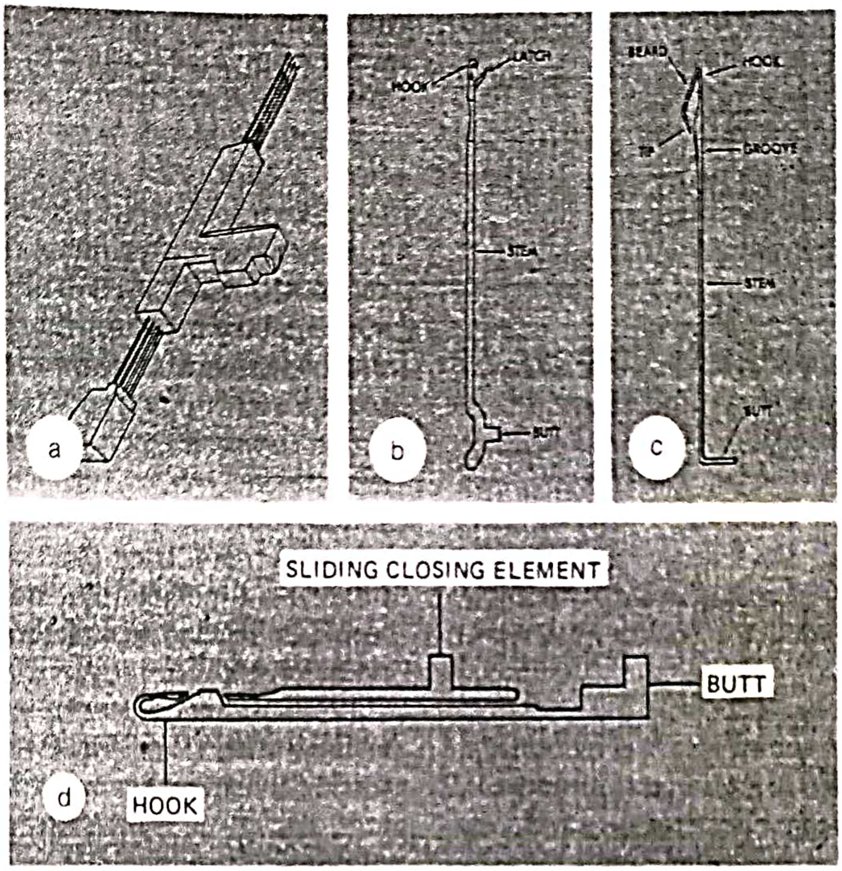


Figure 5-2 (*a*) Working arrangement of a group of needles in its lead. (*b*) Latch needle. (*c*) Spring-beard needle. (*d*) Compound needle. (*Courtesy* CIBA Review)

to one or more needles at a time (see Figure 5-3).

Plain-knit Stitch. The *plain knit* is the basic form of knitting. It can be produced in *flat-knit* or in *tubular* (or *circular*) form. The flat knit is also called *jersey stitch* because the construction is like that of the turtleneck sweaters originally worn by English sailors from the Isle of

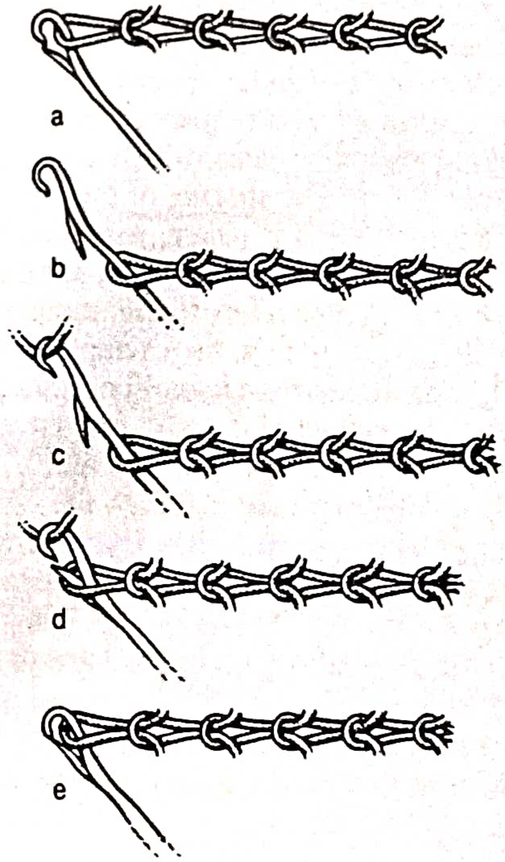


Figure 5-3 Stitch formation with a latch needle on a weft knitting machine; (*a*) the closed needle after drawing off a loop; (*b*) the needle latch opens as the finished loop slips over it onto the needle stem; (*c*) the thread caught and being drawn by the descending needle head; (*d*) the previously finished loop pushes the latch, closing the needle head while the new loop is formed; (*e*) the first loop slips over the needle head onto the newly formed loop. (*Courtesy* CIBA Review)

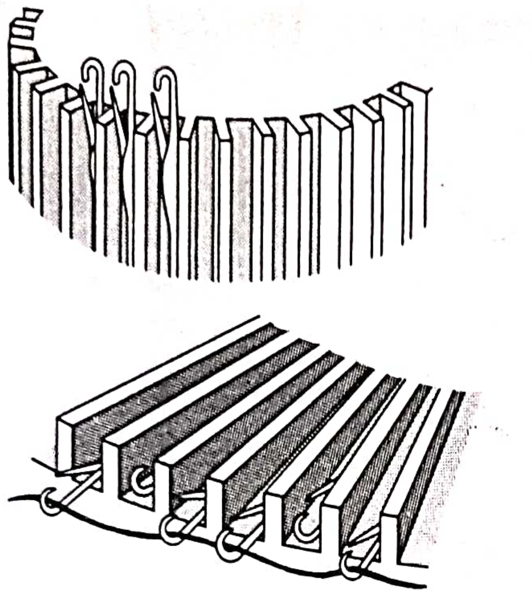


Figure 5-4 (*a*) Section of a circular needle plate showing the arrangement of latch needles. (*b*) Section of a cylinder showing the arrangement of latch needles.

Jersey; it is sometimes called *balbriggan stitch* after the hosiery and underwear fabrics made in Balbriggan, Ireland. Plain flat knits may be shaped or full-fashioned.

The knitting is done with a row of latch or beard needles arranged in a linear position on a needle plate or in a circular position on a cylinder (Figure 5-4). All the needles are evenly spaced side by side and are moved by cams, which act on the needle butts. The spacing of the needles is referred to as the *gauge*, *gage*, or *cut*. As applied to many flat knits and some circular ones, gauge refers to the number of needles in 1½ inches; for example, a 60-gauge machine would have 40 needles per inch. As applied to circular and flat machines that have needles adjustably or slidably mounted, *cut* refers to the number of needles per inch. (In metric terms, "gauge" is expressed as the number of needles/100 mm. Therefore, 126 "gauge," i.e., 126/100 mm, is approximately equivalent to 32 needles/inch.) The count may be determined by a line grating device similar to that used for weaving (see page 77).

The plain knit is made by needles intermeshing loops drawn to one side of the fabric. These loops form distinctive vertical herringbonelike ribs or wales on the right side (or technical face) of the fabric. On the reverse side (or technical back), the courses can readily seen as interlocking rows of opposed half circles. This construction gives the face of the fabric relatively smooth surface in relation to the back.

Although there is a technical face and a technical back to the plain knit (jersey stitch), either side may be used as the face —unless a finish or print is given which produces a specific right side. When the technical back is used as the face, the fabric may be called *reverse jersey*.

Jersey fabrics have a tendency to curl at the edges. The sides will curl toward the technical back, while the top and bottom will curl toward the technical face. Although this characteristic can be reduced by techniques of fabric construction and certain finishes, it can not be completely eliminated.

If a yarn is broken in a plain jersey knit, a run will form vertically as the broken loop drops the loops above and below it. This is most pronounced when filament yarns are used; however, textured filament yarns provide some resistance to runs, and staple fiber yarns have a greater tendency to resist runs because of the rougher texture and cohesiveness of the fibers (see Figure 5-5).

The plain knit produces a relatively lightweight fabric compared with the thicker fabrics produced by other stitches. Single or plied yarns may be employed. It has a high rate of production (up to 5 times faster than weaving), is inexpensive, and lends itself readily to variation in design by pattern devices. These variations include stripes, multicolored patterns, textured surfaces produced by raised designs, and pile effects.

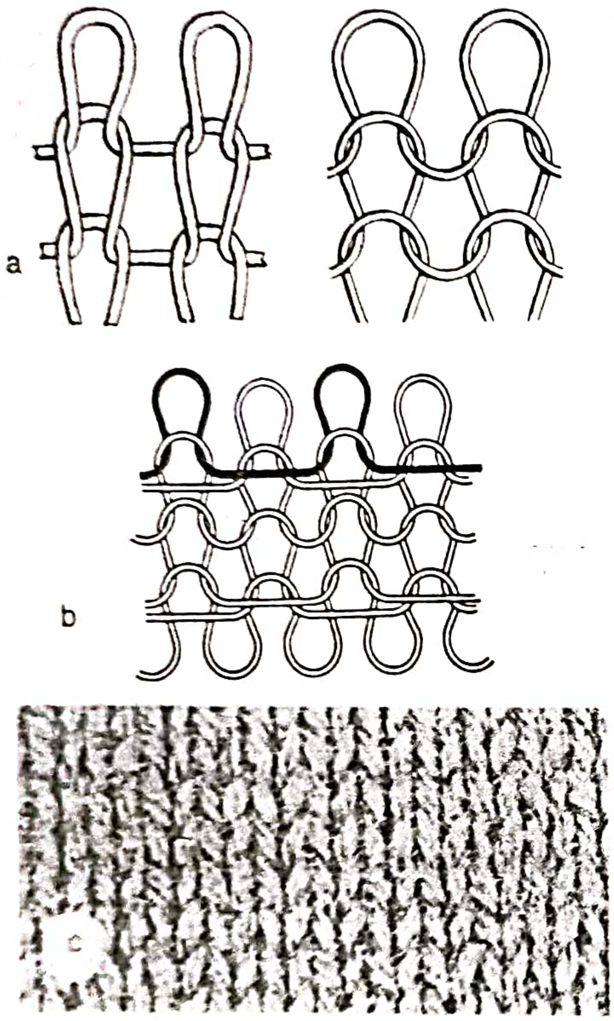


Figure 5-5 (*a*) Plain knit, showing right (face) side at left and reverse (back) side at right. (*b*) Run-resistant circular knit. (*c*) Section of a garment knitted in the jersey stitch. (*Courtesy* CIBA Review)

Horizontal stripes can be knitted in plain jersey by using yarns of different colors and/or different types of yarn on different feeds or by setting certain feeds to produce a looser stitch. Vertical stripes can be obtained by removing specific needles from the machine's operation, thereby producing an open space between the wales made by the needles knitting on both sides of the eliminated needles.

Multicolored designs, called *intarsia* patterns, can be knitted into a jersey fabric through the use of highly specialized flat-bed machines—except for the production of argyle hose which are made on a specialized circular machine. Intarsia designs are solid color area patterns formed by feeding specific numbers of different colored yarns to their respective groups of needles in the same course. Each colored yarn is fed to the appropriate group of needles by its own yarn carrier which operates over a controlled predetermined distance in order to obtain the desired design (see Figure 5-6). There are several techniques of interlinking the different colors with each other along the design

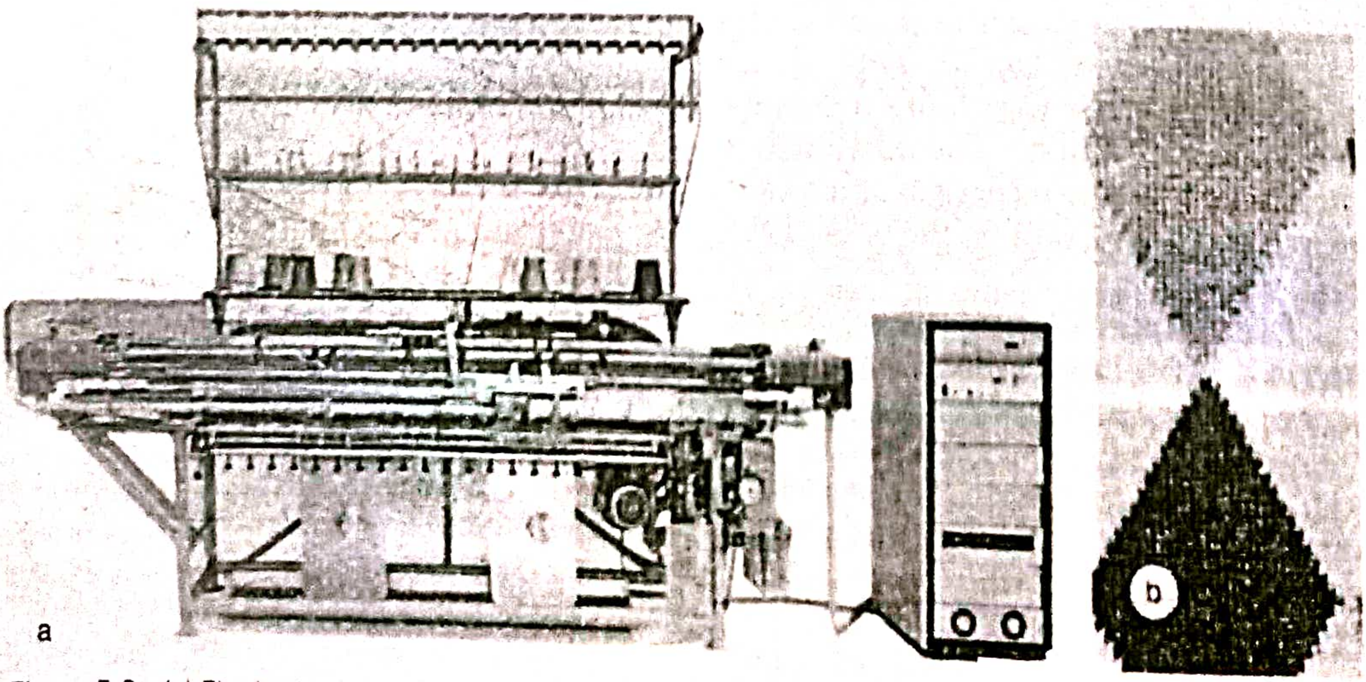


Figure 5-6 (*a*) Flat-bed knitting machine with electronically controlled intarsia device at right. Note the two fabrics with intarsia patterns emerging below the bed. (*b*) Close-up of intarsia knit.

course, such as by causing the yarns to overlap by one or two wales to form plaited stitches. Intarsia patterns, which are of solid colors on both sides of the fabric, should not be confused with Jacquard designs, which have a bird's-eye appearance on the back (see pages 117–118). Mock intarsia designs are made with miss knit stitches which result in floating yarns on the back of the fabric, making it heavier, less elastic, and subject to snagging.

The *tuck stitch* is a variation of the plain knit used to create special effects of raised designs which generally impart a lofty appearance and a soft hand. The tuck stitch is made when a needle receives a new yarn while still holding its former loop, thus forming two loops in the one needle hook. This may be repeated several times, but eventually the yarns must be cast off the needle and knitted. Tuck stitches appear on the back of the fabric as an inverted V, providing an elongated wale which may be across two or more courses, depending upon the number of tucked stitches.

The *miss*, or *float*, *stitch* is another variation, which is created when one or more needles are deactivated and therefore do not move to knit the yarn. As no loop is formed, the yarn forms a float on the back of the fabric. The miss stitch is used in knitted colored designs as a means of passing colored yarn on the back of the material.

Pile surface variations are created by napped, terry, and velour effects described on pages 118–122.

As the fabric will stretch more in the width than in the length, the plain-knit stitch is widely used for underwear, gloves, hosiery, and sweaters. Most jersey sweaters are knitted with two-ply yarns, providing greater strength and shape retention.

Purl Stitch. This construction is also referred to as the *links-and-links stitch* (after the German word "links," or *on the left*). It is made on flat-bed and circular machines by needles using hooks on both ends to alternately draw loops to the front of the fabric in one course and to the back in the next course (see Figure 5-7). It is a slower and more costly technique. The

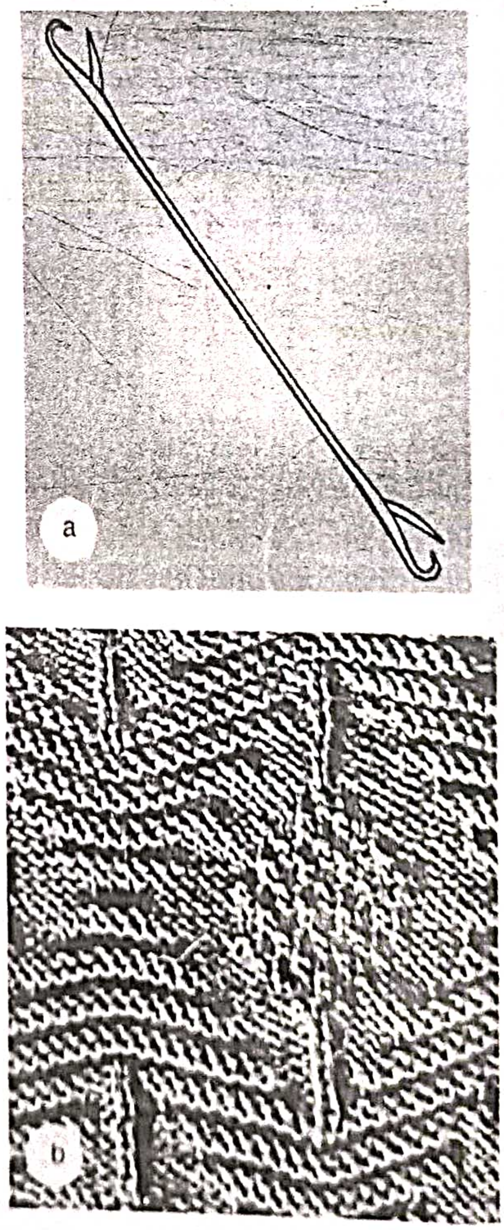


Figure 5-7 (a) Links-links double-latch needle with complete head and latch at each end (b) Fabric made on a links-links flat knitting machine (Courtesy CIBA Review) fabric looks the same on both sides and resembles the back of the plain knit. Like the plain knit, the purl knit will run up and down if a loop is broken. But a purl knit fabric will not curl at the edges.

The use of double-hook needles enables ready changeover during fabric construction to include flat and rib stitches, which makes it possible to duplicate virtually any hand-knitted structure. It lends itself to the heavy, jumbo stitch that produces the familiar bulky effect. Because the purl stitch has crosswise stretch and excellent lengthwise stretch, it is widely used in infants' and children's wear.

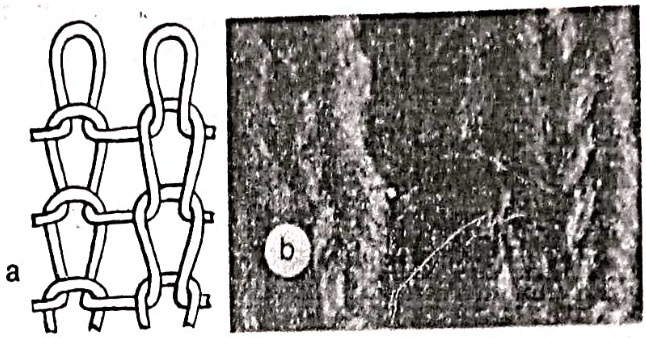


Figure 5-8 (*a*) Diagram of the rib stitch. (*b*) Fabric sample of 2 × 2 rib stitch.

Rib Stitch. Rib-knit fabrics have alternating lengthwise rows of plain and purl stitches constructed so that the face and back of the fabric appear alike. This may be produced either on a flat rib machine or a circular rib machine. In the flat rib machine, one set of needles is placed opposite the other set of needles in an inverted V position of 45 degrees to the horizontal; in the circular rib machine, one set of needles is placed vertically in a cylinder and the other set of needles is placed horizontally on a dial. In both machines, one set of needles pulls the loops to the front and the other set pulls the loops to the back of the fabric. Each set of needles alternately draws loops in its own direction, depending upon the width of the rib desired. For example, rib stitches can be 1 × 1, 2 × 2, 2 × 1, 3 × 1, and so on. A combination of 1 × 1 and 2 × 2 is called an *accordion rib*. Rib construction is costlier because of the greater amount of yarn needed and the slower rate of production (see Figure 5-8).

The rib construction will not curl at the edges. If a yarn breaks, it will cause a run downward only. The rib stitch has excellent widthwise elasticity, particularly in the 2 × 2 rib structure. This characteristic has resulted in its extensive use in apparel where snugness of fit is essential, such as wristbands of sleeves and waistbands of garments. It is also widely used for underwear and socks for men and children.

Horizontal stripes can be knitted in plain rib fabrics in the same manner as in jersey. Vertical stripes can be achieved by removing selected needles, also as in jersey, but the effect can produce more interesting textural variations. An extension of the vertical stripe is the variation of producing pleats. Other variations of the rib stitch include the full-cardigan stitch, the half-cardigan stitch, the interlock stitch, the cable stitch, and the double-knit stitch.

The *full-cardigan stitch* is a bulky rib knit and is produced by one set of needles knitting and the other set of needles tucking on the first course. They reverse on the next course, with the plain needles tucking and the rib needles knitting. The fabric has the same appearance on both sides, looking like slightly stretched jersey fabric (see Figure 5-9).

The *half-cardigan stitch* is a variation of the full-cardigan stitch. It is produced by one set of needles alternately tucking and knitting on alternate courses. The

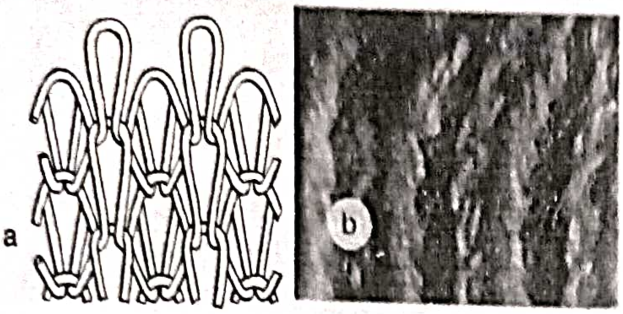


Figure 5-9 (*a*) Diagram of the full-cardigan stitch. (*b*) Fabric sample of full-cardigan stitch.

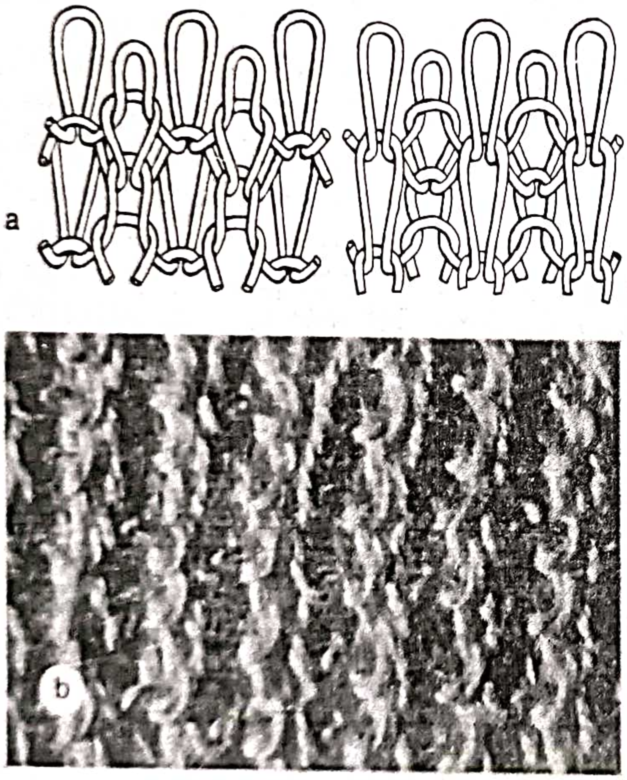


Figure 5-10 (*a*) Diagram of the half-cardigan stitch showing face side at left, reverse side at right. (*b*) Fabric sample of half-cardigan stitch.

construction on the back of the fabric is the reverse of the face (Figure 5-10). A variation of this stitch is the *rack stitch*, which has a herringbone pattern on the face.

The *interlock stitch* is also a variation of the rib stitch, resembling two separate 1 × 1 rib fabrics interknitted. To accomplish this, production is slow. Fabric edges will not curl, and a broken interlock stitch will cause a downward run only. The fabric is relatively firm and smooth. It has the same appearance on both sides, and pattern variations are limited. Horizontal and vertical stripes can be knitted by using yarns of different colors and/or different types of yarn for textural effects.

The limited widthwise but excellent lengthwise extensibility of this stitch has been used to advantage for knit shirts and other sportswear. The fabrics made with the interlock stitch are extremely soft, firm, and absorbent (see Figure 5-11*a*).

The *cable stitch* is formed by small groups of plain wales plaited with one another in ropelike fashion. One familiar form is made of two groups of three wales each, thus utilizing six needles. At regular intervals during the construction, the groups interchange their knitting actions, producing the twisted cable effect. The interesting appearance and textural effect has made this construction popular for outerwear, particularly sweaters (Figure 5-11*b*).

The *double-knit stitch* is made on the rib or interlock machine. Two sets of needles knit a close stitch of 16 cut or finer, producing a design effect. Simple double knits are almost identical on both sides, which look much like a regular rib knit with close, distinct stitches. They are usually thicker and heavier than jersey, and this may have given rise to the name double knit (however, some double knits are relatively lightweight compared to some jersey which could be heavy and bulky). There are several forms of double-knit construction. One type, called *double jersey*, looks like a fine-ribbed fabric on the face and a fine jersey on the reverse. The cloth is quite compact, yet a bit spongy.

Double-knit fabrics lay flat and do not run. However, stitches may catch or snag. This is particularly true when the coarser stitches and textured yarns are

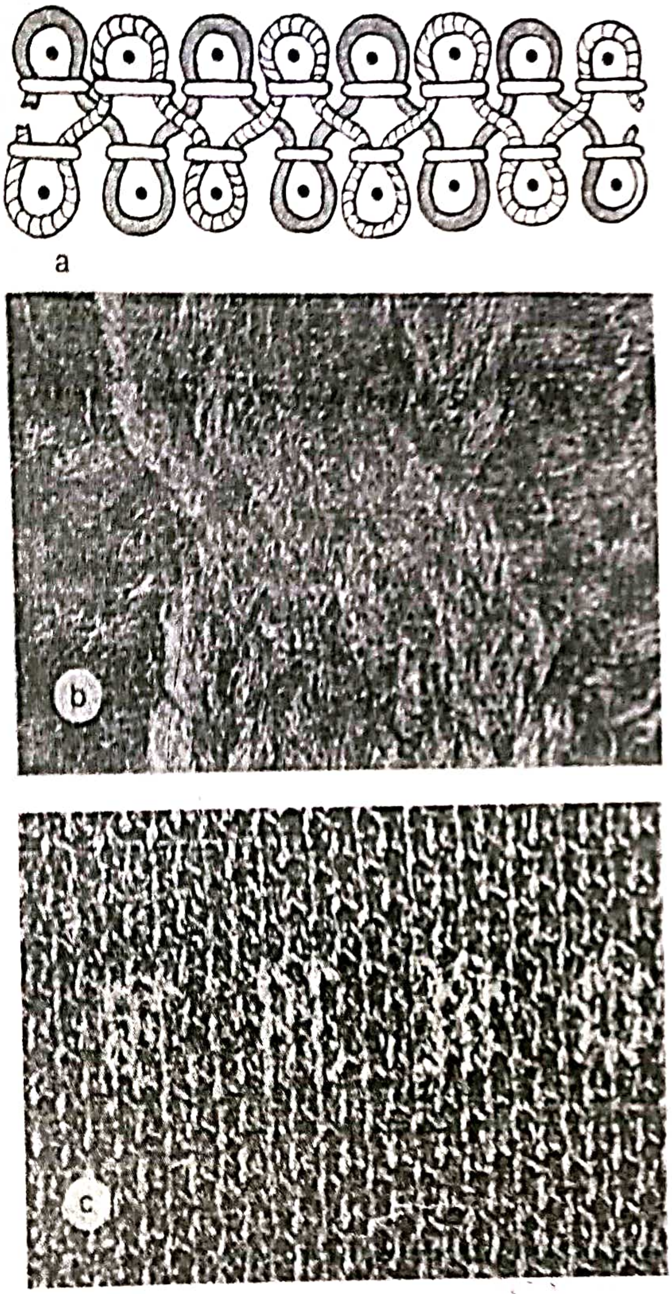


Figure 5-11 (*a*) Needle set-out for interlock knitting. (*b*) Sample of cable stitch. (*c*) Sample of double-knit stitch.

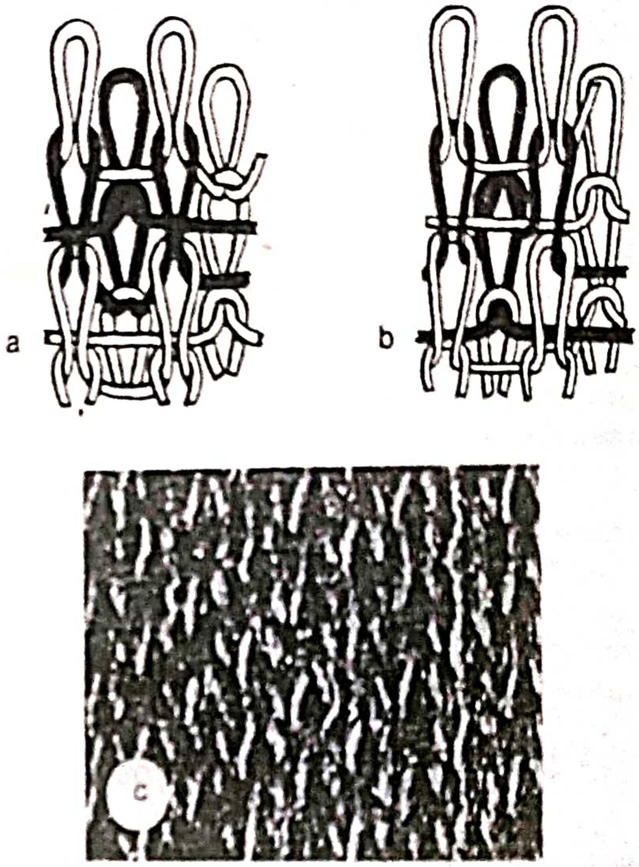


Figure 5-12 (*a*) Swiss double piqué stitch. (*b*) French double piqué stitch. (*c*) Fabric sample of French double piqué stitch.

used. Finer knits, such as 24 cut or more, and smoother yarns will reduce the tendency to snag.

Double knits have very desirable properties and characteristics customarily found in woven fabric as well as those found in knitted goods. Double-knit fabrics have firmness, body, and dimensional stability. They therefore do not sag or get baggy. They have hand and drape similar to that of woven cloth. Yet, the double knits are naturally shape retentive, wrinkle-resistant, and quite durable (see Figure 5-11*c*).

These characteristics have made double-knit fabrics very popular. They lend themselves to such apparel as sportswear and women's suits and dresses, and they are promoted for men's suits and slacks.

Another type of double knit is *double piqué*. The surface of this fabric can vary to look like diamond or honeycomb piqué, or the reverse side of wale piqué. Double piqué is produced on circular machines. The Swiss double piqué is made with a smaller, finer loop than the French double piqué (see Figure 5-12).

Warp Knitting

Warp knitting differs from weft knitting, basically, in that each needle loops its own thread. The needles produce parallel

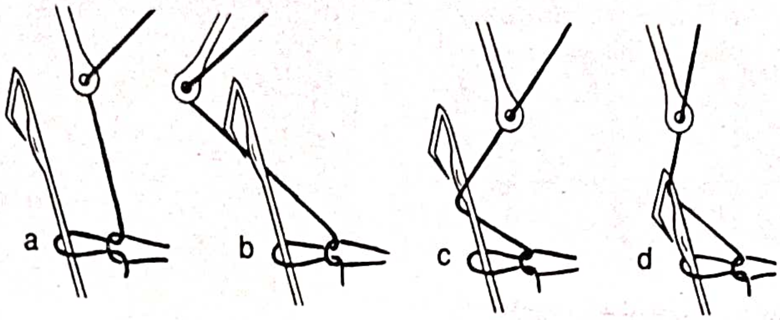


Figure 5-13 Stitch formation with a spring-beard needle on warp knitting machine: (*a*) the needle returns after drawing off a loop; (*b*) the thread guide lays the thread over the needle stop; (*c*) the needle draws the thread to hook it; (*d*) the thread is pulled through the first loop to form another one. (*Courtesy* CIBA Review)

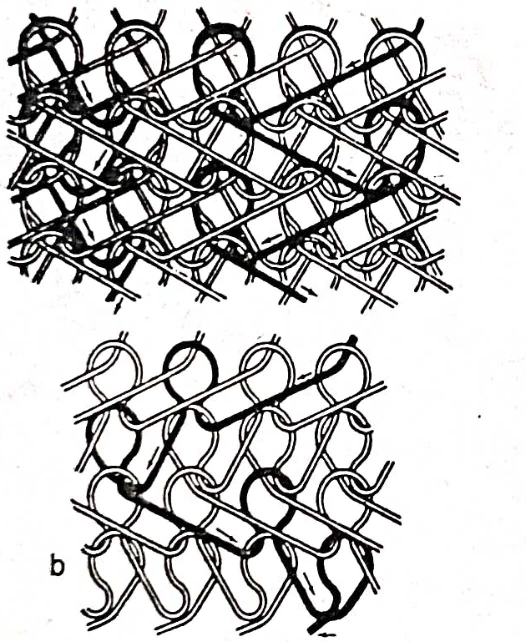


Figure 5-14 (*a*) Double-warp (two-bar) tricot. (*b*) Single-warp (one-bar) tricot.

rows of loops simultaneously that are interlocked in a zigzag pattern (Figures 5-13 and 5-14). The stitches on the face of the fabric appear vertically, but at a slight angle; and the stitches on the back appear horizontally as floats at a slight angle. These floats called *laps*, or *underlaps*, are a distinguishing identification of warp knits.

Warp knitting may be flat or tubular and can be produced in many varieties of patterns. It can yield cloth with a dimensional stability almost equal to that of woven fabric. Yet, a modern 28-gauge machine (74 needles/100 mm) can produce a cloth 168 inches (428 cm) wide at a rate of 1,000 courses per minute—that is, 4,700,000 stitches per minute, or more than 40 square feet (2.7 m²) of fabric per minute. This speed coupled with the use of yarns of manmade fibers has resulted in a great production of warp-knitted fabrics that enjoy popularity.

Consumers like warp knits because of their smoothness, possible sheerness, wrinkle and shrink resistance, strength, and abrasion resistance. Warp-knit fabrics, as compared with weft knits, also have certain other advantages. Warp knits will not ravel or run and are less susceptible to snagging. Quality is usually better; stitch definition, texture, and fabric cover are generally better than in weft knits. Warp knits have superior dimensional stability.

Products ranging from hairnets to rugs may be produced by warp knitting, depending upon the machine and technique employed. The seven types of warp knitting are tricot, milanese, simplex, raschel, ketten raschel, crochet, and weft-insertion warp.

Tricot Knit. The word "tricot" comes from the French word "tricoter," which means *to knit*. The tricot production began between 1775 to 1780 with the invention of the ***warp loom*** by an Englishman named Crane. The machine has one or more warp beams mounted above it. Each set of yarns from a warp beam is fed to a row of needles arranged across the width of the machine and is controlled by yarn guides set in a guide bar that is also laid across the machine. Since one guide bar is used for each set of warp yarns, the number of warp beams determines the number of guide bars employed. Consequently, the terms of one-bar tricot, two-bar tricot, etc., indicate the number of guide bars used to produce the fabric (see Figure 5-15). The greater the number of bars, the greater the design flexibility. The movement of the guide bars is controlled by chains with links of various heights. As the guide bar is raised and moved sidewise, it lays the warp yarns in their respective needle hooks to form a course of loops simultaneously when the needles are drawn down through the loops of the preceding course.

The gauge in tricot knit is expressed in terms of the number of knitting elements per bar inch (in metric terms, number of needles/100 mm). They range from the coarsest of 14 (55 needles/100 mm) to the finest of 44 (173 needles/100 mm), with the most popular being 28 gauge (75 needles/100 mm). The higher the gauge, the lighter the fabric and the greater its strength per ounce (or mass).

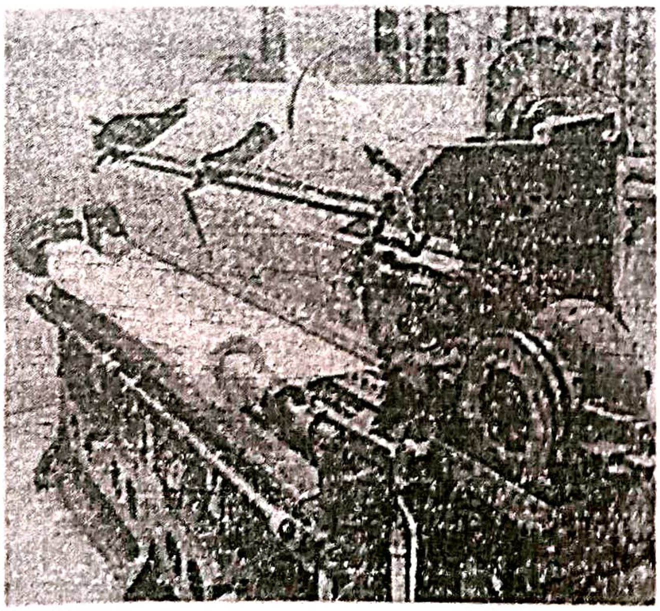


Figure 5-15 Tricot fabric being made on a high-speed, two-bar warp knitting machine. *(Courtesy Allied Chemical Corp.)*

In order to achieve the high gauge and very high speeds of the tricot machine, exceptionally uniform yarns of high quality are required. Therefore, filament yarns and textured filament yarns are usually used in order to obtain the high degree of uniformity in stitch definition, appearance, and weight.

Tricot fabrics have many good attributes. They are porous and permit passage of water vapor and air for body comfort. They also offer bulk without undue weight. Tricot fabrics are soft, wrinkle-resistant, and have good drapability. They have controllable elasticity, and they do not run or fray. Tricot construction contributes to good abrasion resistance and high bursting and tearing strength. Other factors that contribute to the fabric's strength are the fiber and yarn structure.

Tricot knits are used for a wide variety of fabric weights and designs. Typical uses of tricot fabrics are lingerie, loungewear, sleepwear, blouses, shirts, dresses, slacks, uniforms for nurses and waitresses, bonded fabric material, outerwear, and automobile upholstery. These fabrics may be identified by type.

Plain tricot, or *tricot jersey*, is the basic fabric using two-bar construction. It is used for the widest range of applications.

Satin tricot is a variation of the plain tricot and is made with long underlaps of up to 6 wales wide, which provides an extremely smooth hand. The fabric does not curl and has excellent stability in the width.

Mesh and *fancy open effect tricot* also refers to a range of fabrics. The mesh or open effects are produced either by eliminating needles and yarns at certain points or by threading certain guides with two or three yarns. The fabrics are generally of fine gauge and are light- to medium-weight.

Clipped dot tricot is a variation of the two-bar tricot jersey that has a third bar knitting a different kind of yarn at intervals on the face and floating the yarn on the back between the dots. The floats are then clipped off. Subsequent cross dyeing (see page 215) results in a dot pattern of one color on a background of another color.

Outerwear tricot is not really a specific fabric; the term represents a wide variety of fabrics constructed for specific purposes. They are frequently made with textured yarns of three- and four-bar constructions. They often have interesting color and surface effects. Sometimes the fabrics are made with *inlay* yarns, which are additional yarns from a separate warp beam caught into the knit stitches to add texture, design, and stability.

Upholstery tricot is often a two-bar jersey made of relatively heavy filament yarn and rather tightly knitted. There are many variations, including three- and four-bar constructions with interesting surface and color effects.

Napped, or *brushed*, tricot is a plain tricot that has been given a napped finish (see page 176).

Raschel Knit. The raschel knit ranks in importance of production with tricot, but it surpasses it in variety of products, which range from veilings and laces to powernets for foundation garments to such pile fabrics as carpets. The raschel knit is made with latched needles rather than the bearded type used for tricot, milanese, and simplex. The raschel fabrics can usually be distinguished from tricot fabrics in that raschel constructions are made with heavy yarns and usually have an intricate, lacelike pattern, whereas tricot constructions are made with fine yarns and are either flat or have a simple geometric pattern.

The gauge of raschel knits is measured in terms of the number of needles per 2 inches (in metric terms, number of needles/100 mm). The finest gauges used for elastic cloths are 48 and 56 (95 and 110 needles/100 mm respectively) compared to 18 gauge (35 needles/100 mm) used for such products as outerwear and bedspreads. Raschel fabrics are knitted on machines having two to forty-eight guide bars, which accounts for the wide variety of fabrics. Programming the large number of guide bars can be very complex and expensive. For example, the chains of pattern wheel links for an intricate raschel lace may be as long as 30 feet (about 9 m) and could take as much as two weeks to prepare for fabric production. The great majority of these materials are made on a *pillar and run-in*, or *inlay*, *principle* that uses one bar of needles knitting vertical rows of loops, or pillars, with each row connected by a horizontal inlay thread. The variety of patterns can be further increased on the Raschel machine by utilizing the inlay principle to produce *pointelle* effects, that is, regularly spaced open-work or small pointed areas, which may have a raised surface.

Raschel machines are extremely versatile. They can knit every type of yarn made of *any* kind of fiber, including metallic and glass, and in *any* form, whether staple or filament, standard or novelty. This versatility naturally extends the possible characteristics and properties of the fabrics produced.

Ketten Raschel Knit. This knit is also called the *chain raschel*. It is a variation of the tricot knit that produces a coarse gauge of 14 to 20 needles per inch (55–80 needles/100 mm) on widths of 90 to 120 inches (230–305 cm). The machine can be equipped to produce raised pattern effects in one or more colors by a *shell-stitch construction*. Since the ketten raschel knit is produced with bearded needles, the fabric is finer, has a better hand, superior elasticity, and cover.

Crochet. This basic stitch is used in hand-crochet work employing a pillar chain. Using either latch or beard needles, this construction is used in a wide variety of fabrics ranging from nets and laces to bedspreads and carpets.

Milanese Knit. The milanese stitch, though accomplished by a different technique, produces a fabric very similar in appearance to tricot. It can be identified by the fine rib on the face and a diagonal pattern on the back (see Figure 5-16). Milanese is knitted on the flat bed machine with spring-beard needles and on the circular machine with latch needles. It is usually knitted from filament yarn into fine lightweight fabrics.

Milanese fabrics are superior to tricot in smoothness, elasticity, regularity of structure, and split and tear resistance. Despite the apparent advantages of milanese fabrics, production is limited due to the costly low production rates of milanese machines and their limitations in scope of patterns.

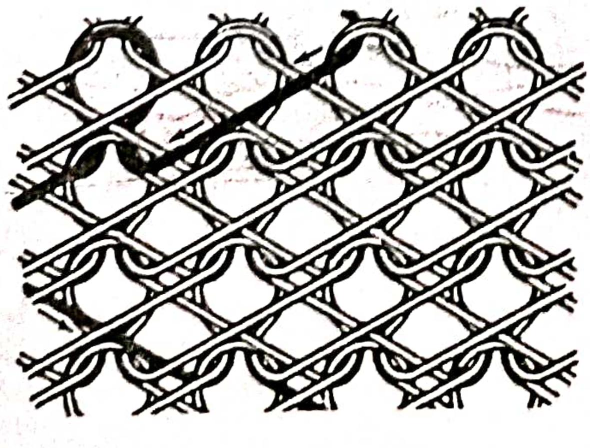


Figure 5-16 Diagram of the milanese stitch.

Simplex Knit. Simplex fabrics are produced with spring-beard needles on a machine that is essentially two tricot machines arranged back to back. The fabrics are of fine gauge knits generally ranging from 28 to 34 (74–89 needles/100 mm) and in widths of 84 to 112 inches (215–285 cm). The stitches appear on both sides of the cloth which looks like a double-faced tricot.

Simplex fabrics are made of fine yarn but are, nevertheless, relatively dense and thick. Sometimes the cloth is lightly napped to obtain a soft, suedelike finish. Simplex fabrics are a relatively small part of warp knit production. They are used for such purposes as gloves, handbags, sportswear, and slipcovers. Eyelet and other openwork may also be produced on the simplex machine.

Jacquard Knitting

Both weft and warp knitting can incorporate the Jacquard mechanism to produce multicolored designs. The Jacquard punched-card technique used in weaving can also be adapted to knitting. Cards control the selection or inhibition of the needles to produce the pattern.

Another technique for controlling the individual needles to produce the various types of knits and designs utilizes electronic or electromagnetic devices. A third means is the use of a strip of film encoded in a boxed fashion. The film is divided into successive opaque and transparent squares that act similarly to the holes in the Jacquard card or paper tape. A lens directs light through the moving film to phototransistors to select the particular needle for each stitch (see Figures 5-17 to 5-20).

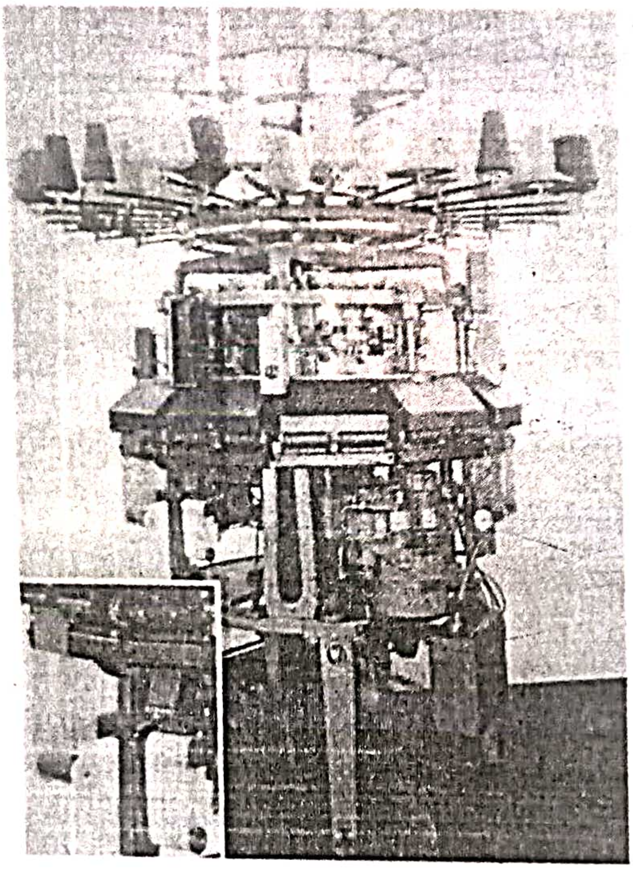


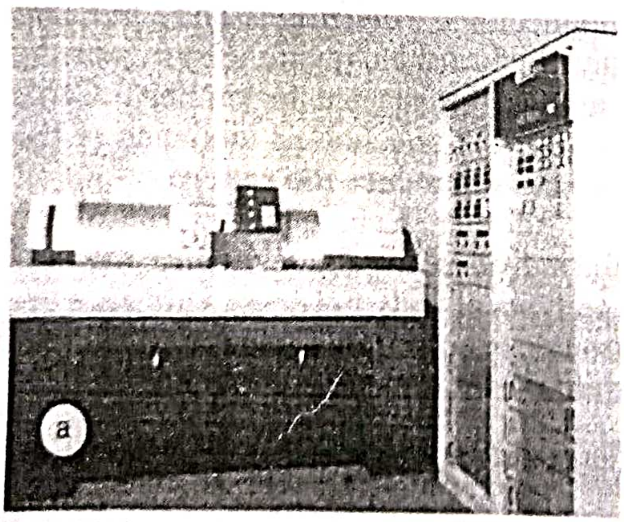
Figure 5-17 The circular Jacquard knitting machine employs spools of yarns of various colors to obtain the design governed by the action of the code-punched tapes (see insert) shown connected around the middle of the machine. *(Courtesy Wildman Jacquard Co.)*

Jacquard knits are made on flat-bed and circular machines, and the fabric may be flat or ribbed. The fabrics are multicolored; each color requires consecutively its own respective feed on each course of the design. The back of the fabric can be varied, as with a novel effect, striped, piqué (birds-eye), blister, or solid back.

Pile Knitting

The production of *pile knits* has steadily grown in variety, importance, and volume. They are constructed as fleece, high pile, terry, and velour knits. Depending upon the type of construction, they are used for fur fabrics, rugs, and fashion apparel fabrics.

Fleece Knit. Technically, fleece fabrics are not truly of a pile construction. Fleece fabrics are knitted so that, when finished, they will have a short to medium nap that has a soft, pleasant hand, will provide warmth and body, as well as moisture wicking and absorption, if desired.



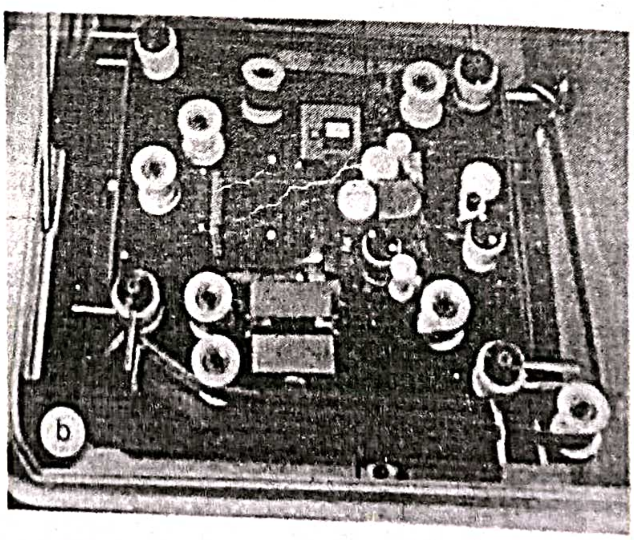
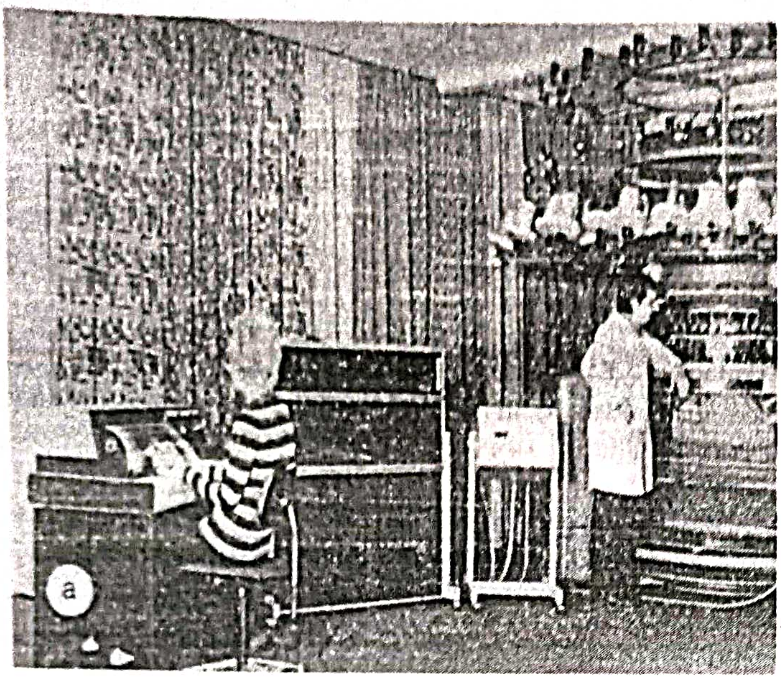


Figure 5-18 *(a)* This Morat Patronik 500 unit reads freehand designs, fabrics, photographs, or pattern grids in any combination of up to seven colors or shades. The pattern information is stored on magnetic tapes which activate the needles of the circular knitting machine. *(b)* This Morat unit controls the selection of needles for Jacquard knitting by a light directed through moving film that has the design translated into opaque and transparent squares. The light passing through the transparent squares contacts phototransistors which activate the particular needle selection. This device permits the use of up to seven colors in one design. *(Courtesy Sulzer Bros., Inc.)*



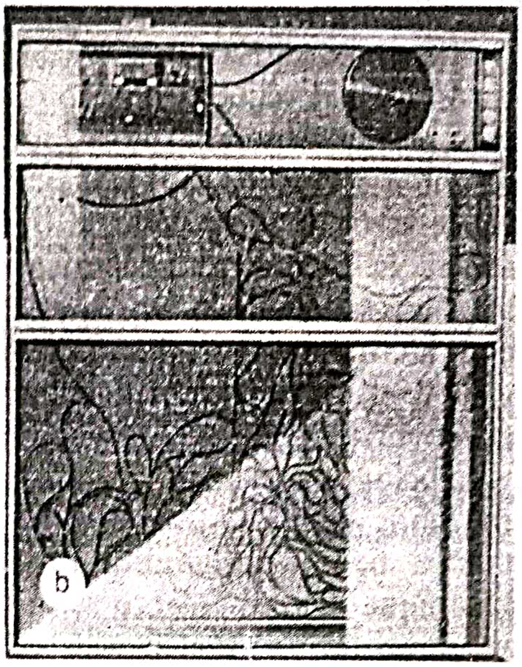
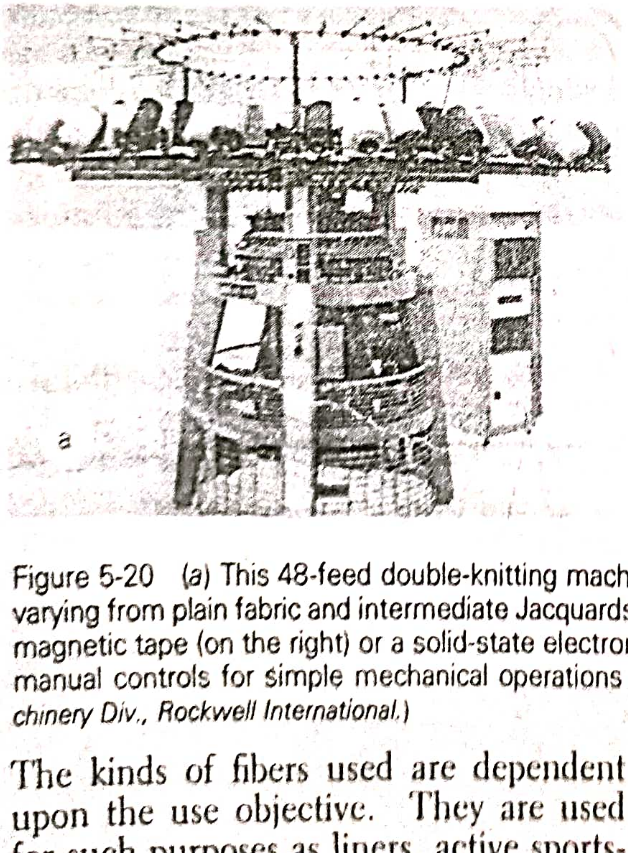


Figure 5-19 (*a*) Circular Jacquard knitting can be accomplished by this Morat Patronik 200 system which, left to right, uses a semiautomatic scanner that records a rough pattern sketch of up to six colors (done in colors, black-and-white, or representative symbols) and translates that pattern onto paper tape, a paper tape reader, and a compact computer which transmits the design to the needle-controlling mechanism in this knitting machine. (*b*) Close-up of the punch tape reader of the Morat Patronik 200 semiautomatic pattern scanning and knitting system. (*Courtesy Sulzer Bros., Inc.*)



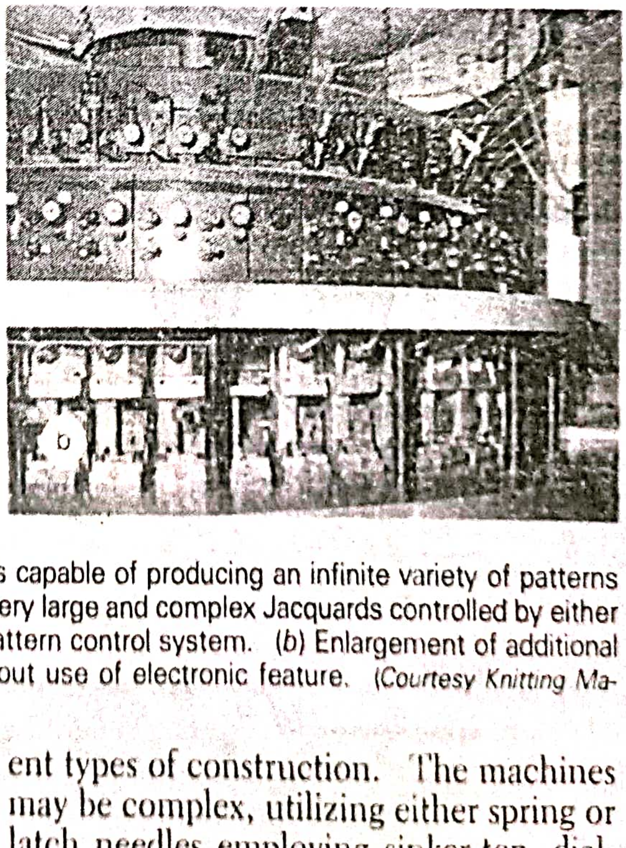


Figure 5-20 (*a*) This 48-feed double-knitting machine is capable of producing an infinite variety of patterns varying from plain fabric and intermediate Jacquards to very large and complex Jacquards controlled by either magnetic tape (on the right) or a solid-state electronic pattern control system. (*b*) Enlargement of additional manual controls for simple mechanical operations without use of electronic feature. (*Courtesy Knitting Machinery Div., Rockwell International.*)

The kinds of fibers used are dependent upon the use objective. They are used for such purposes as liners, active sportswear, outerwear, and plush toys.

Fleece knits can be made on circular-knit machines in any one of three different types of construction. The machines may be complex, utilizing either spring or latch needles employing sinker-top, dial, cylinder, or dial/cylinder mechanisms. With this equipment, various effects can be produced.

One type of fleece knit construction is the three-yarn system, where three yarns are fed sequentially from separate yarn positions around the cylinder of the machine. The first yarn is the backing or fleece yarn. The second and third yarns are the tie-in and ground yarns which are fed successively in a *plaiting* relationship and knitted so that the fleece yarn is caught at predetermined intervals between them. This results in the fleece yarn being floated on the technical back of the fabric and held in place by the wales of plaited tie-in and ground yarns. The technique hides the fleece yarn from the technical face so that it will be exposed only on the back (see Figure 5-21). The fleece yarn, which may be coarse spun and low twist, can thus subsequently be readily napped and given other surface finishes.

Another type of fleece knit is the two-yarn system. One yarn, which provides the ground or body is knitted in either a single or double jersey construction. The second yarn, which may be coarser and heavier to accommodate subsequent napping, is the floating or inlay yarn that is tucked at predetermined intervals on selected needles. This is the most productive method of making fleece knits, but there is a disadvantage of "grin-through" to the technical face unless it is camouflaged by knitting design effects, such as a double lay-in (see Figure 5-22).

The third type of fleece construction is the one-yarn system. A single or plied yarn is knitted according to a predeter-

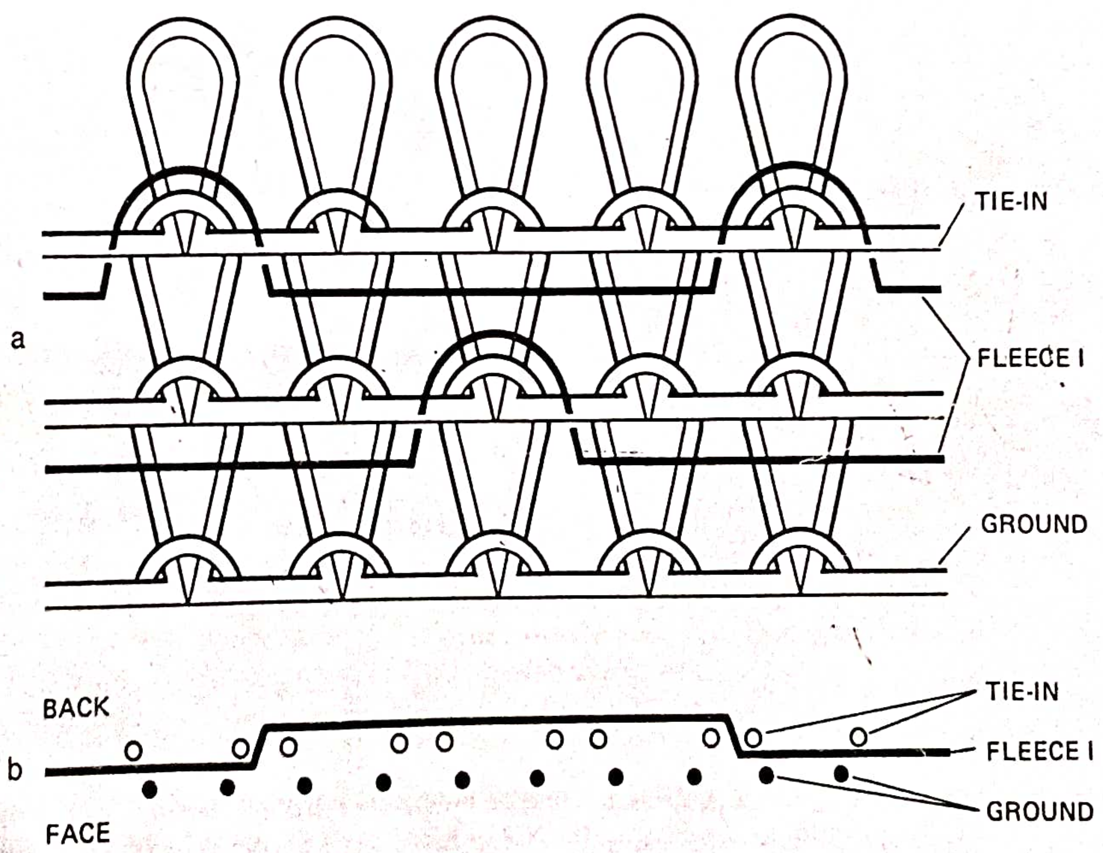


Figure 5-21 Schematic of three-yarn fleece construction showing (*a*) the fleece yarn floated and held in place between the ground and tie-in loops and (*b*) a sideview of the knitted fleece fabric. (*Courtesy* Knitting Times, *official publication of the National Knitwear & Sportswear Association.*)

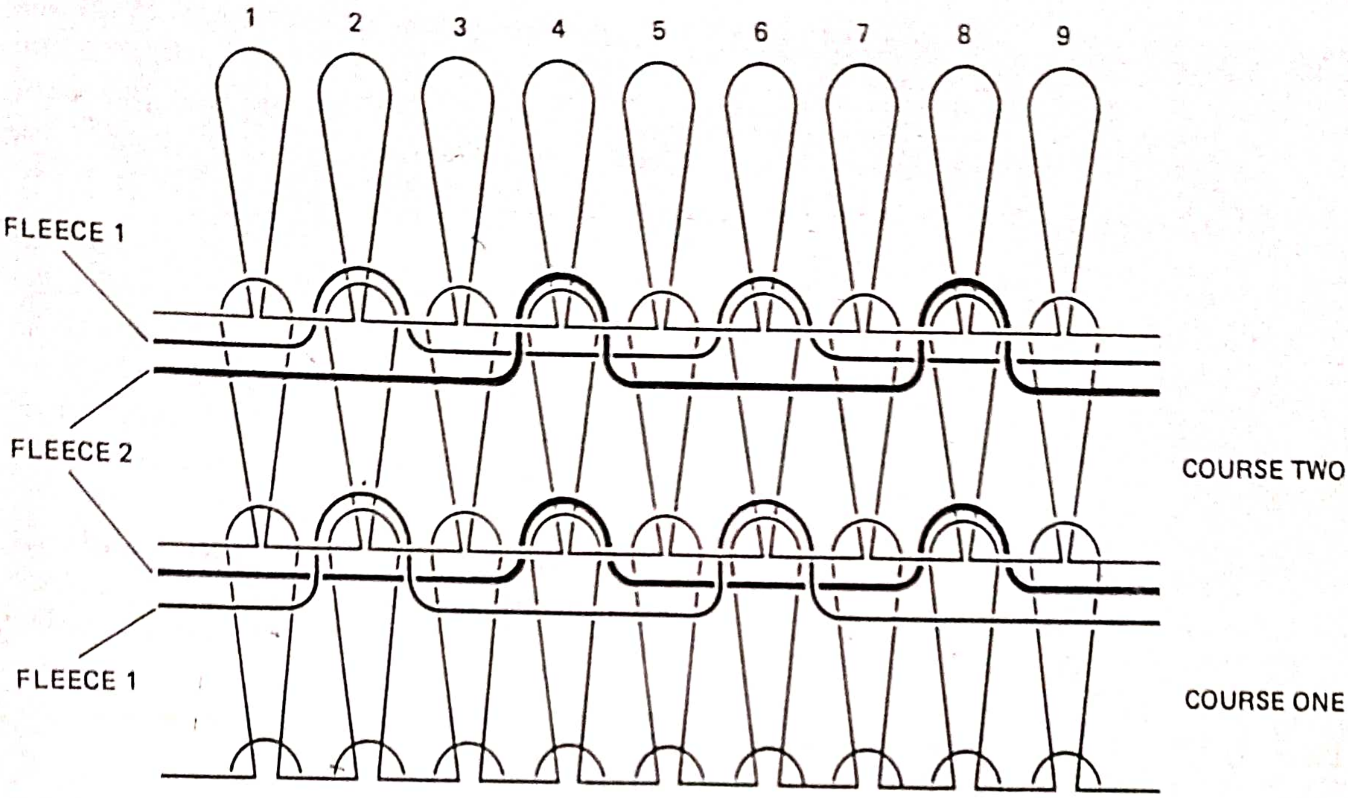


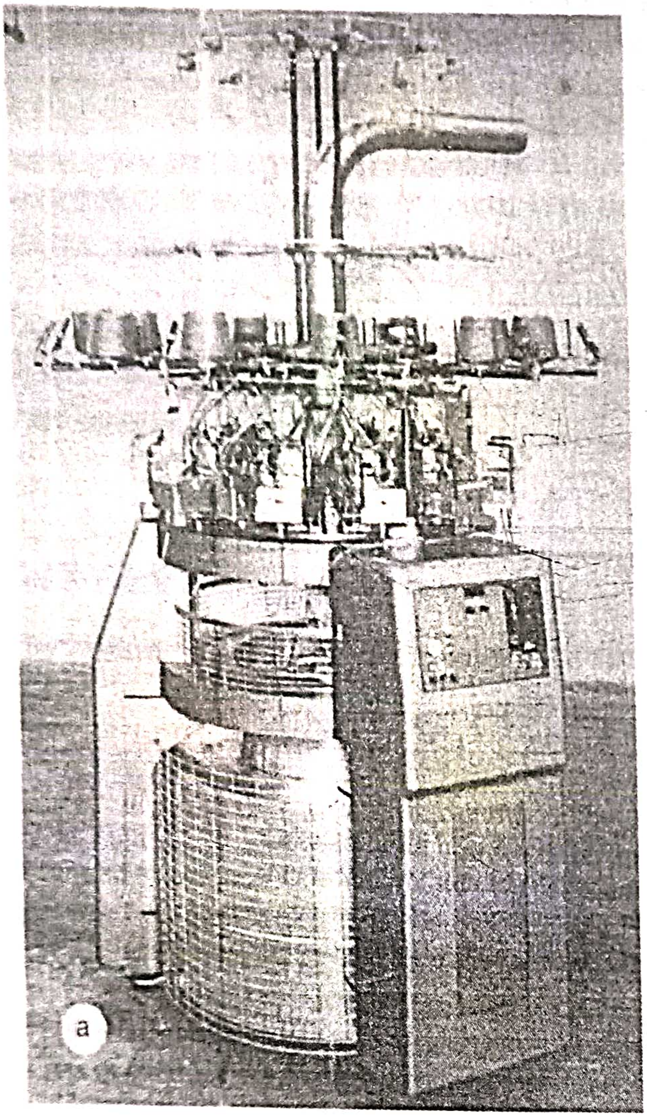
Figure 5-22 Schematic of two-yarn double lay-in fleece effect showing individual lay-in fleece yarns 1 and 2 introduced in Courses One and Two. In Course One, lay-in yarn 1 is caught in needles 2, 6, 10, etc.; lay-in yarn 2 in needles 4, 8, 12, etc. In Course Two, opposite selection to that in Course One insures a balanced fabric. (*Courtesy* Knitting Times, *official publication of the National Knitwear & Sportswear Association.*)

mined pattern of knit and tuck combinations that would provide floats which are to be subsequently napped. Since the yarn must be strong enough and fine enough for knitting purposes, the use of coarse, low twist yarns are precluded. The use of only fine yarns as well as the resulting additional napping and other finishing costs makes this type of fleece more expensive.

High Pile Knit. Both weft and warp knitting machines are used to produce imitation fur fabrics and rugs utilizing acrylic, modacrylic, polypropylene, or nylon as determined to be appropriate for the end product. The fabrics are similar in appearance to their original counterparts but are more flexible and have better drape. These fabrics are lightweight and easy to care for. They usually can be laundered and cold tumble-dried, unless the garment construction requires dry cleaning. When the pile is crushed or distorted due to washing, packing, or storing, it should be combed or brushed with a soft or medium bristle brush.

The techniques for knitting high pile fabrics are quite complex. The slower and more common method uses a plain knit with heavy yarn for the background and a carded sliver for the pile. As the needles pull the ground yarn to form loops, they catch and draw the sliver through, causing the fibers to get locked into place as the stitch is tightened. Production runs from 5 to 11 yards (4.5–10 m) per hour.

A faster method uses circular-knitting units operating on a cutloop and ground-yarn principle (Figure 5-23). Another technique is the cut-pile and ground-yarn



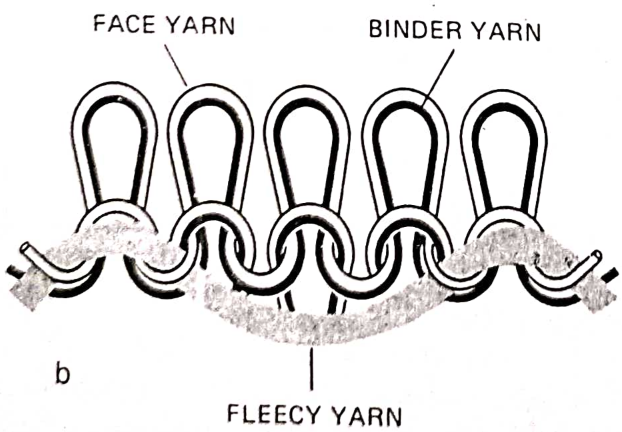


Figure 5-23 (*a*) The needles of this circular-pile knitting machine form loops from the ground yarns as they come off the spools and draw the carded slivers through these loops, causing the fibers to get locked into the stitches and forming the pile effect. (*Courtesy Wildman, Jacquard Co.*) (*b*) Structure of pile knit showing sliver yarn before raising. (*Courtesy Shirley Institute, Manchester, England.*)

method on a Raschel machine. High pile fabrics can also be made on double-knit equipment to knit plain and Jacquard fleece with the aid of special devices including an inlay yarn carrier (Figure 5-24).

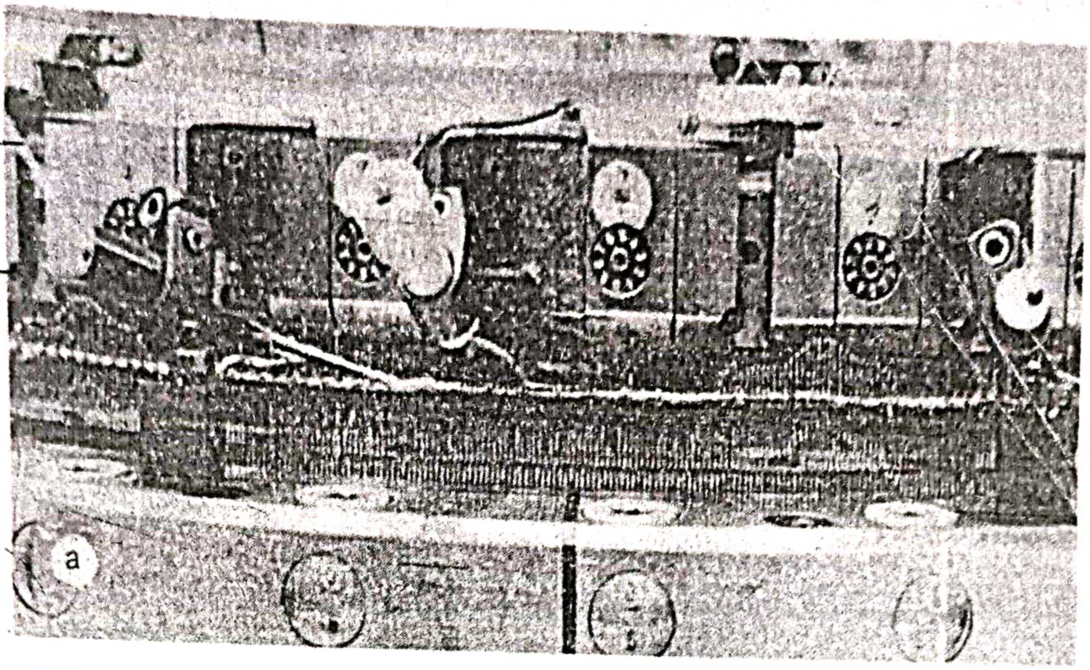
Terry Knit. Knitted terry fabrics are made of a variation of the jersey knit construction where two yarns are fed simultaneously into the same needles. The fabric is knitted by a plaiting technique which causes one yarn always to appear on the face and the other always on the back of the cloth. As the fabric is knitted, the face yarn is pulled out by small devices to form the loop pile, leaving the other yarn to serve as the ground (see Figure 5-25). Knitted terry is produced in weights ranging in suitability for robes and beachwear to fashion apparel.

Terry knits tend to be more flexible, softer, and more absorbent than woven terry cloth. However, they are not as sturdy or durable. They do not hold their shape as well and they tend to snag, causing the loop yarn to pull and trail. Should such a pull occur, it should not be cut because it would cause a run. Rather, it should be drawn through to the back of the material.

Velour Knit. Knitted velour fabrics are constructed in the same manner as knitted terry. After the material is knitted, the loop pile is sheared (see page 177) at a uniform height and then brushed. This produces a soft, suedelike surface that is somewhat like that of velvet. However, knitted velour is softer and has better drapability. It is used for such fashion apparel as men's shirts and women's dresses.

IDENTIFICATION OF KNITTED FABRIC DEFECTS

Imperfections sometimes occur in the course of knitting fabrics. They may be



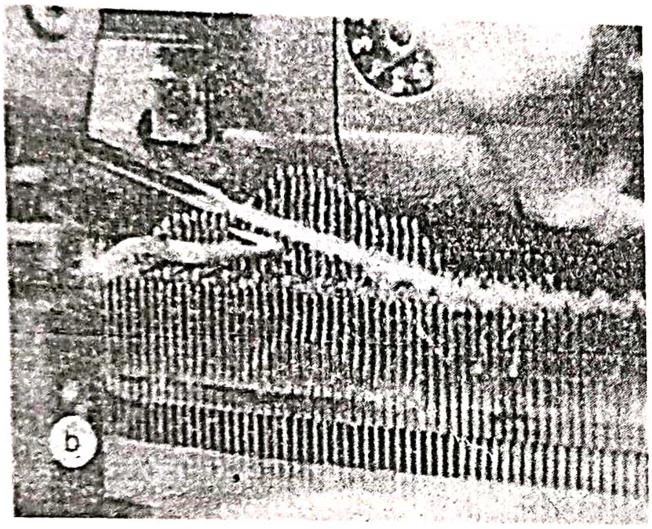


Figure 5-24 (*a*) Fleece yarn being fed in a double-knit machine to produce a pile fabric. (*b*) Close-up of fleece yarn passing from an inlay yarn carrier to the dial needles. *(Ccurtesy Sulzer Bros. Inc.)*

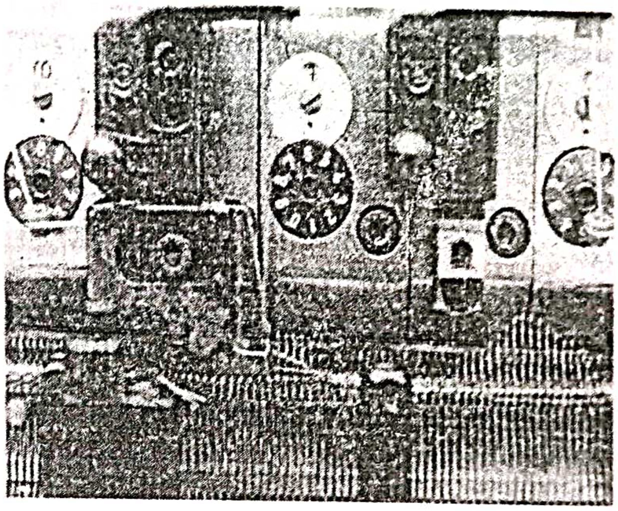


Figure 5-25 Terry fabric for apparel being knit on a double-knit machine with the aid of a special attachment providing a two-feed sequence with the loop produced on the cylinder needles. *(Courtesy Sulzer Bros., Inc.)*

the result of faulty yarn, knitting machine malfunction, or improper finishing. The various kinds of yarn defects have been discussed in the previous chapters on yarn formation and weaving. The defects in knitting construction can be considered in terms of appearance and nature.

Bands and Streaks

There are several kinds of bands and streaks that may occur in knitting. A *barré* effect, which has the appearance of a stripe with shaded edges, could be horizontal in weft knits and vertical in warp knits. It could be caused by lack of uniformity in yarn size, color, or luster; too much tension on the yarns during knitting one section of the fabric; uneven shrinkage or other finishing defect.

A line or a design may curve across the fabric. This *bowing* would be a distortion caused by faulty take-up mechanism on the knitting machine. A straight horizontal streak, or *stop mark*, in the fabric would be due to the difference in tension in the yarns caused by the machine being stopped and then restarted. A *skewing* effect would be seen as a line or design running at a slight angle across the cloth.

Vertical lines, or *needle lines*, may be due to a wale that is either looser or tighter than the adjacent ones. This may be caused by needle movement due to a tight fit in its slot or a defective sinker.

Stitch Defects

If the fabric is *boardy* (a stiff or harsh hand), it may be due to the stitches having been knit too tightly. If the fabric is *cockled*, or puckered, it may be due to uneven stitches or uneven yarn size.

A *dropped stitch* is an unknitted stitch caused either by the yarn carrier not having been set properly or the stitch having been knitted too loosely. A *run*, or *ladder*, would indicate a row of dropped stitches in the wale. A large hole, which may be referred to as a *press off*, would be the result of a broken yarn at a specific needle feed so that knitting could not occur.

A *tucking* (or *bird's-eye*) defect would be the result of an unintentional tucking due to either a bent latch on a needle or a needle that had not been raised high enough to allow the previous loop to have been cast off. An unwanted *float* would be caused by a miss stitch due to the failure of one or more needles to have been raised to catch the yarn.

REVIEW QUESTIONS

1. How does the construction of knitted fabrics differ from that of woven fabrics?
2. What is the chief advantage gained by the knitted construction?
3. Why is a knitted fabric a relatively warm fabric?
4. (a) What is a disadvantage of the knitted construction? (b) How can it be eliminated?
5. How would you evaluate the construction of knitted fabrics?
6. What are the characteristics of the basic types of weft knits?
7. Distinguish between a miss and a tuck stitch.
8. Identify the several types of rib knits and their characteristics.
9. What are the advantages of the double-knit construction?
10. What are the characteristics of the basic types of warp knits?
11. Describe the characteristics of each of the tricot variations.
12. Distinguish between intarsia and Jacquard knitting construction.
13. How is pile knitting accomplished?
14. How are fabrics simulated to look like fur?
15. What are the common defects in knitted fabrics and how can they be identified?

SUGGESTED ACTIVITY

Identify five different kinds of knitting construction found in your household that are used for apparel or home furnishings. Describe their construction and appearance that led to each identification.