Textile Processing
A Brief Introduction for Apparel Manufacturers

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This document is intended as an introduction to textile and apparel manufacturing for non – technical personnel. It is not intended, nor should it be used, as a technical document.

Overview

The starting point for any textile or apparel product is the raw fiber. To go from fiber to finished garment, the process is generally as follows:

1. Fibers are most commonly transformed into yarn (exceptions will be discussed below).
2. Yarns are intertwined by either a weaving or a knitting process to form fabrics, or knit directly into garments.
3. Fabrics are cut into garment components; components are sewn into garments.
4. Garments may be embroidered, dyed, "stone washed," or otherwise further processed.

Color may be imparted to a fabric at the fiber, yarn, fabric, and / or assembled garment stage through dyeing and / or printing processes.

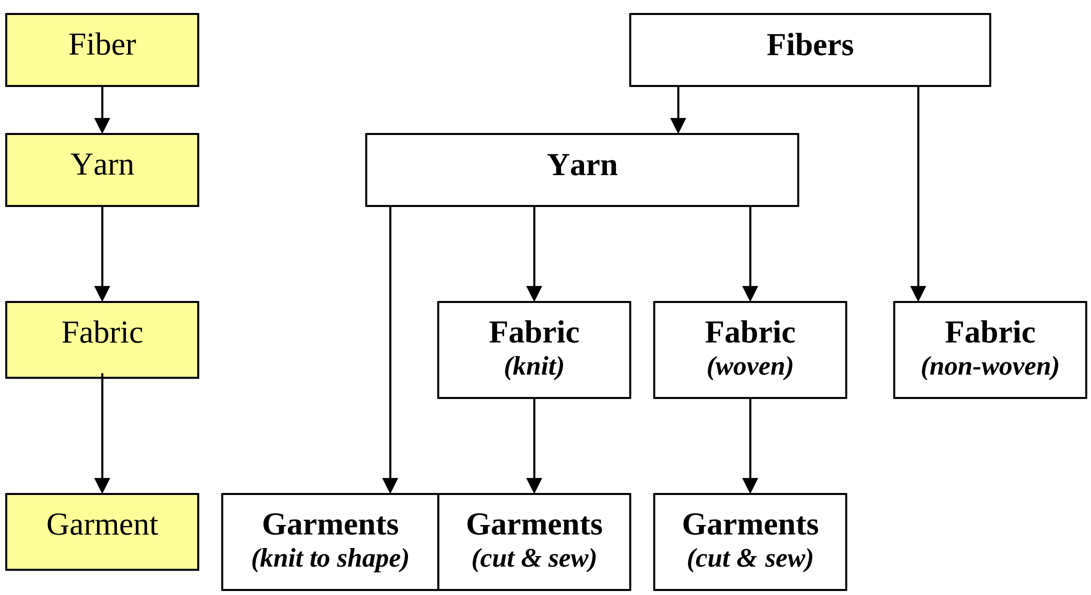


Figure 1. Textile & Apparel Processing

Fibers

Fibers are the raw material for any textile product. They are thin, flexible, hair – like strands of matter that range in length from a few centimeters to hundreds of meters. Short fibers (from a few to many centimeters in length) are called *staple* fibers. Long, continuous fibers are called *filament* fibers.

Fibers are generally classified into two categories:

- *natural*, and
- *man – made.*

Both natural and man – made fibers are further classified into:

- *cellulosic* (plant fibers) and
- *non – cellulosic* (animal, mineral, or synthetic)

fibers, depending upon their source and chemical make up. There are four common types of natural fibers:

- cotton,
- wool,
- silk, and
- flax (linen).

Other less common natural fibers include animal hairs such as vicuna, camel hair, mohair, alpaca, cashmere.

Depending upon their source and chemical make up, natural and man – made fibers are each further classified as:

- *cellulosic* (plant fibers) and
- *non – cellulosic* (animal, mineral, or synthetic).

Man – made fibers are generally produced by extruding a chemical solution through a *spinaret*. The process is similar to that used to make spaghetti noodles, resulting in long, continuous filaments that may be used in filament form or cut into short staple lengths and spun like a natural fiber.

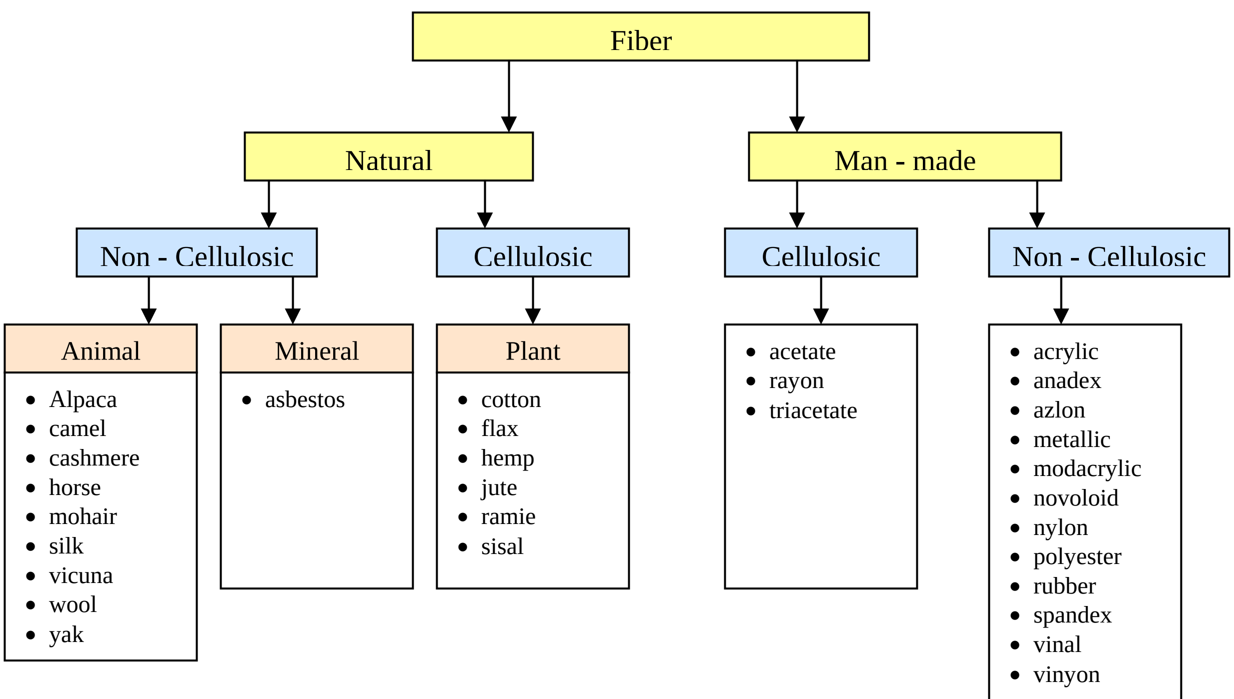


Figure 2. Fiber types

Fiber characteristics

Textile manufacturers engineer fabrics to have certain characteristics, according to the needs of the end – user. Fabric to be used in apparel will be engineered for comfort. Depending upon the intended use of the garment (e.g. children's play clothes, or ladies' evening wear) certain characteristics may be more important, or less important (durability, washability, fabric luster or shine.) This engineering process begins with the careful selection of fibers, according to their characteristics, and continues through the choice of yarn type and size, method of fabric construction, dye selection and dyeing or printing methods, and so on.

Chemical characteristics. Fibers may be categorized as being *hydrophilic* (easily absorbing water), *hydrophobic* (not easily absorbing water), or *oleophilic* (easily absorbing oil, and hence oily stains). Such differences play a key role in how easily a fabric or garment may become soiled, whether it absorbs oily substances that easily stain or mark a fabric and may be difficult to remove. They play a vital role in whether a garment can be laundered (washed with water and detergent) or must be dry cleaned with chemical solvents. Many consumers dislike the latter because of the expense and concerns about the environmental impact of chemicals used in the dry cleaning process.

Most natural fibers are hydrophilic, that is to say they absorb water easily. Polyester is notably oleophilic, meaning it easily absorbs oil, making it less desirable for certain types of apparel or home furnishings uses. These characteristics also make it important for manufacturers to select the proper dyes for coloring a yarn or fabric, as the chemical make – up of the dye must be compatible with the chemical make – up of the fiber (whether the fiber is natural or man – made). *If a garment is to be dyed after assembly (either garment dyed or over – dyed), it is particularly critical that the thread used for sewing the garment be made from a fiber with the same characteristics and dyeability as the fabric. Otherwise, quality problems will occur during the dyeing process, causing unsightly color defects in the finished garment. This is equally important in selecting embroidery threads for any fabrics or garments that will be dyed after being embroidered.*

It is also vitally important to consider fiber content when selecting fibers to be used in swimwear. It can be expected that swimwear will be exposed over prolonged periods of time to salt water, chlorine, and sun. Any one of these in isolation or in combination can be highly degrading to certain fibers (and dyes). Care should be taken to select those fibers (hence fabrics) that can withstand such agents without degradation or loss of quality.

Physical characteristics. Each type of fiber also has its own physical characteristics of strength, luster, softness or rigidity, surface feel, etc. This makes some fibers more suitable to certain types of apparel than others. For example, cultivated silk is known for its smoothness and luster, but many animal hairs (wool, camel, etc.) often have a scratchy feel due to their irregular, scaly surface.

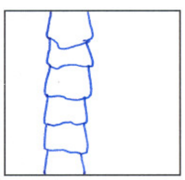


Figure 3. Drawing of wool fibers

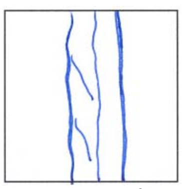


Figure 4. Drawing of a silk fiber

An overview of fiber characteristics follows. Fashion and clothing designers will select and specify a particular type of fabric, including its fiber content, yarn size, method of fabric construction, dye type, and dyeing or printing method according to the characteristics s/he wants in the finished garment.

Designers wanting a finished garment that is cool, comfortable, and easily washed may select a100% cotton, or a blended fabric (two or more fiber types in the same yarn or fabric) containing a high cotton content. Designers wanting superior depth and richness of color, luster, but less concerned with washability, may select silk. Designers wanting ease of care may select nylon or polyester fibers. A table of characteristics of several commonly used fibers follows.

Table 1. Typical characteristics of common textile fibers

Fiber	Strength	Feel / Comfort	Luster
Cotton	Low, especially when wet	Comfortable, especially in heat	Average
Wool	Low, especially when wet	Scratchy, uncomfortable in heat	Low
Silk	High	Smooth, comfortable in heat and cold	High
Polyester	High	Uncomfortable in heat	Varies
Nylon	High	Smooth, uncomfortable in heat	High

Fiber identification

Each specific type of fiber can be easily and clearly identified by various visual, tactile, physical, and chemical tests. It should be noted, however, that sometimes more than one type of fiber may give the same results when tested using a certain method. Therefore, it may be necessary to conduct two or more different tests to determine the exact identification of the fiber.

US law requires that all manufactured apparel sold in the United States carry a permanent label clearly stating the fiber content and care instructions for the garment. Apparel manufacturers should test incoming raw materials for their fiber content, or require that their suppliers provide proof of testing and results.

A word of caution. Companies purchasing yarn or fabric described as, "silk," "China silk," "silky," or "silken" should take care to have the fiber content tested and verified by an accredited third party lab. These terms are often used incorrectly and / or in purposely misleading ways to make buyers believe a particular yarn is silk when it is a different fiber. Similarly, companies buying yarns or fabrics labeled as "linen" should have the fiber content verified by testing at an independent lab as many less expensive fibers may be substituted for linen.

Yarn

Most fibers are too short to be of any use in their original form. They must be formed into yarn to be of real value in textile or apparel manufacturing. In order to form a yarn with sufficient strength and uniformity, the fibers must be straightened and aligned in a parallel orientation. Bundles of fiber must be twisted slightly, elongated, twisted again and elongated more, until the yarns form a thin, tight yarn suitable for weaving or knitting. It is the twist that holds the individual fibers together and gives strength to the yarn. More highly twisted yarns are generally stronger than less highly twisted yarns of the same fiber type and size. However, if the yarn is twisted too much, it becomes less pliable, develops kinks, and becomes difficult to work with in a weaving loom or knitting frame, ultimately causing quality problems in the fabric.

Yarn Manufacturing

Although there may be some technology, terminology, or process differences between yarn manufacturing systems for cotton, wool, linen, spun synthetics (e.g. spun polyester, acetate, etc.) or other fiber types, the general steps and workflow are similar. The general steps are:

1. Cleaning (removing dirt and debris)
2. Blending fibers

3. Aligning fibers and forming loose web or mass of fibers
4. Elongating mass of fibers
5. Spinning, twisting to lock fibers together
6. Plying two or more yarns into one.

Step 1. Cleaning. All natural fibers must be cleaned and separated before processing. Seeds (e.g. cotton) must be removed, dirt and other foreign matter must be removed (plant and animal fibers). Processing fibers without properly or thoroughly cleaning them causes very poor quality yarn not suitable for apparel. Bales of raw fiber are opened and fed into machines that separate dirt and debris from fiber.

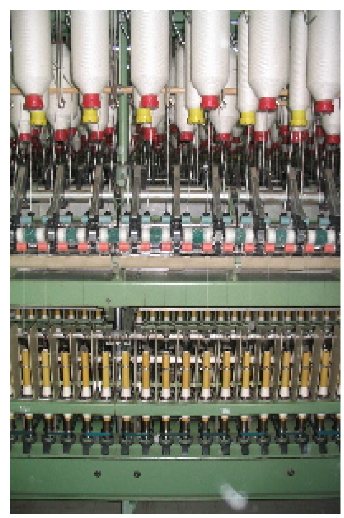
Step 2. Blending. In order to achieve a better combination of desirable characteristics in a yarn or fabric, manufacturers often blend two or more fiber types (or lengths) together into the one yarn. This is generally done at the fiber stage. Fibers are usually fed into a large (2,000 kg or larger) blending machine that mixes the fibers for an even distribution of each fiber type and / or length.

Step 3. Alignment. Before fibers can be formed into a yarn, they must be aligned in parallel (or nearly parallel) orientation. Shorter fibers give significantly less strength to a finished yarn, so manufacturers maximize the length of each fiber by straightening it and laying it parallel to other fibers before beginning the yarn formation. Once aligned, the loose fibers form a wide, thick, fluffy mat with little or no strength. These mats of fiber are then pulled gently into a loose, rope – like cylinder a couple of centimeters in diameter, (about the diameter of a medium carrot) called a *sliver*.

Above: slivers feeding into roving frame

Step 4. Elongating. In order to give yarn strength, the slver must be further elongated and some twist must be imparted to hold the individual fibers together more tightly. The sliver is pulled (*drawn*) and twisted down to a *roving*, the size of an ordinary pencil.

Step 5. Spinning. The roving is drawn again, twisted tightly, forming a continuous thread – like yarn with substantially more strength than the roving. Different methods may be used for spinning, but *ring – spinning* and *open – end spinning* are the most common. After spinning, yarn is wound onto a thick cardboard or plastic *cone*, or onto a *bobbin*, depending upon how it will be used.



Right: Ring spinning frame producing cotton yarn

Left: cone of yarn

Step 6. Plying. For greater strength, thickness, and at times certain other design characteristics, two or more yarns may be twisted together. Each individual yarn is then referred to as a "*ply*." The number of plys is often noted in describing the yarn (e.g. a singles yarn denotes it has not been plyed; a two-ply yarn indicates two yarns have been twisted together into one,)

Yarn numbering systems

Different yarn numbering systems are used for cotton, linen, wool, and silk or synthetic yarns. Traditionally yarns have been bought and sold by weight rather than length. To further complicate matters, each yarn manufacturing system (cotton system, wool system, etc.) had its own unique measuring / numbering system to describe the weight (hence size) of the yarn produced. The various systems can be categorized as either *direct* yarn numbering systems, or *indirect* systems.

Direct systems. Direct yarn numbering systems quantify the weight per a standard length of yarn. As the weight of the yarn increases, so does the numerical value assigned. Silk and most synthetic yarns are measured using the direct system. One unit of measure is called *denier*. The weight of a yarn using this system is expressed as the number of grams (weight) per 9000 meters (length). The higher the denier of a yarn, the greater its weight (per given length of yarn), therefore the higher the denier, the heavier and often thicker the yarn.

Indirect systems. With indirect yarn numbering systems, the weight / length relationship is reversed. The larger the number assigned to a given yarn, the lighter (and generally thinner or finer) the yarn. While there are several different indirect systems, each based on one or another of the different yarn manufacturing systems (e.g. cotton, wool,…) the most commonly used today is the measurement system from the cotton system. Because cotton, wool, and linen yarns typically are plied (two or more individual yarns are twisted together to form a stronger, thicker yarn), the yarn numbering system derived from these manufacturing systems indicates the number of plys.

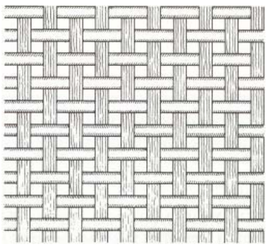
The cotton system, used for cotton yarns and cotton blend (e.g. cotton / polyester) yarns utilizes a two – part number, with the two numbers separated by a slash (/). The number preceding the slash indicates the length (in 840 yard lengths for the cotton system) per pound of yarn. The greater the length of yarn needed to weigh 1 pound, the lighter / finer the yarn. The number following the slash indicates the number of plys (individual yarns) used to make the final yarn. A 20/1 yarn is a single ply yarn. A 20/2 yarn is a two – ply yarn. As the yarn count increases, the weight (and generally the fineness) of the yarn decreases, hence the term “indirect numbering system.”

Yarn system	Weight per length	Number
Direct	increases	increases
Indirect	increases	decreases

Fabric

There are three types of fabrics. Each is distinct, with different physical characteristics resulting from the particular method used to produce the fabric. The three types are: *non – wovens, wovens*, and *knits*.

Non – woven fabrics. These are the simplest of the three. Loose fibers are made directly into fabrics without passing through the yarn stage. Loose fibers are matted together and either rubbed, pressed, punched with barbed needles, melted, or fused together (sometimes in a quilting pattern) in order to lock loose fibers together. Non – woven fabrics are usually inexpensive but have very little strength and are therefore not generally suitable for garments. (Felted fabrics may be used for certain outer garments but still generally suffer from lack of strength.) Certain non – woven fabrics may be used as *interfacing* inside garments (between the shell fabric and the lining), to give stiffness or “*body*” to the finished garment.



Woven fabrics. Woven fabrics are the most commonly used for apparel, though knit fabrics have become increasingly popular because of the comfort from their inherent stretch. Woven fabrics are produced by intertwining two yarns in a perpendicular orientation. The yarns (*ends*) that run the length of the fabric are called "*warp"* yarns, and may be thicker and usually must be stronger than the crosswise yarns. The latter are called "*weft*" or "*filling*" yarns.

Figure 5. Common woven fabric structure

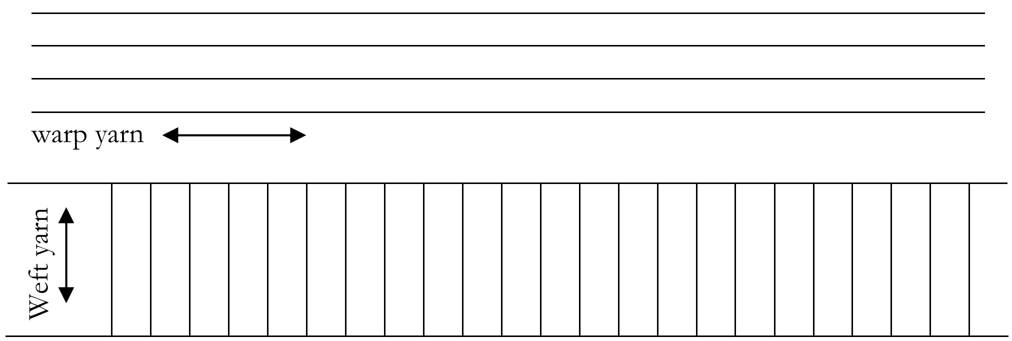


Figure 6. Warp and weft directions

Woven fabrics are described by the type or pattern of weave (e.g. plain weave, twill, satin,…) and by the thread count. Thread count is denoted by the number of warp and weft yarns per cm or inch (depending upon the country where the fabric is manufactured). It is stated as warp ends X weft ends, for example, 31 x 17 (31 warp ends per cm and 17 weft ends per cm, a common thread count for 100% cotton fabric.) In some countries, such as the United States, inches may be used instead of cm. In the example above, in the US version of the thread count (based in inches) would be would be 78 x 44 (both numbers multiplied by 2.54). One also frequently runs across goods described as 80 thread count goods this might be a 50 x 30 or a 40 x 40 or any other combination where the sum of warp + fill = 80. *Plain* and *basket* weaves have a balanced appearance, with warp and weft yarns clearly running at right angles to each other. *Twill* weaves, though still formed with warp and weft yarns running at right angles, have a distinctive diagonal appearance. *Satin* weaves have a smooth, shiny surface. Entire books have been written on the different weaving patterns.

Knit fabrics. Of the three types of fabrics, knit fabrics have the most stretch, owing to the way in which yarns are intertwined in loops to form the fabric. Knit fabrics are constructed on a *knitting* machine. They may be formed either by intertwining the yarn back and forth across the width of the fabric (*weft knits*), or intertwining it parallel to the length of the fabric (*warp knits*). Hand knitting is a good example of artisanal scale weft knitting. Depending upon the type of machine and fabric, yarn may be fed into the knitting machine directly from a individual cones of yarn placed on a creel, or may be first wound from a creel onto a warp beam and then fed into the knitting machine.

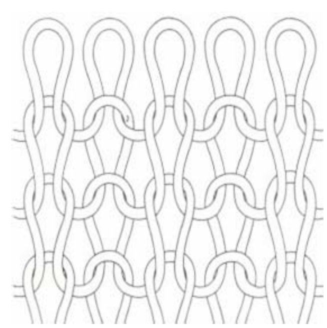


Figure 7. Typical knit fabric construction

In the case of either weft or warp knits, these fabrics have less dimensional stability than woven fabrics, meaning they lose their shape more easily and may curl, become distorted, or stretch out. In recent years stretch fibers have been widely used in knit fabrics to provide "*memory*" so that when a knit fabric is stretched, it will bounce back to its original shape. This characteristic has been highly prized by consumers.

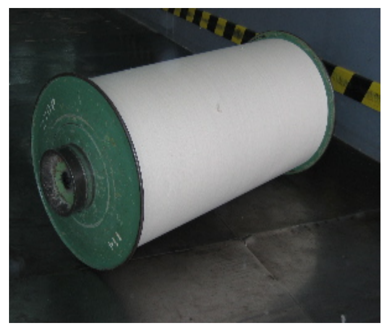
Yarn Preparation

Fabric manufacturing requires preparation of the yarn before the yarn can be interlaced (woven) or looped together (knit) to form the fabric. Yarn preparation involves several steps that vary depending upon whether the yarn will be used to weave or to knit a fabric.

Because of the tension placed on warp yarn, and the abrasion it faces during the weaving process, warp yarn must be sized and / or lubricated for added strength, and so yarns will easily slip past one another during the weaving process without catching and breaking. Generally starch is applied to the yarn, as well as some sort of slippery lubricating agent. This lubricant / starch is called "*sizing*." Depending upon the type of fiber and yarn these may be added at various points during the yarn forming process. Sizing is not added to yarn used for knit fabrics.

Cones of yarn are placed into a large frame called a *creel*. Each creel holds hundreds of individual cones, with guide wires to position each piece of yarn toward a device that winds yarn onto a large *beam*. A warp beam resembles a giant spool of thread, but with hundreds of individual yarns (ends) wound next to each other around the beam rather than one yarn wound around the spool. Each individual yarn is called an *end*. Normally there are between 19 and 70 ends per cm.

Below: yarn creel



Above left: preparing to wind warp beam
Above right: full warp beam ready to be put onto a loom

Woven fabric manufacturing

Step 1. Loom preparation. The process of *setting up* the loom (threading each individual warp ends into the proper position on the loom) is a lengthy, painstaking process but is critical to the quality of the woven fabric. Any mistakes made during the set – up will run the entire length of the fabric. It cannot be corrected without rethreading part or all of the loom.

Step 2. Weaving. Depending upon the exact pattern in which the warp and weft yarns are interwoven, the resulting fabric may have one appearance (pattern), or another. In order to hold the yarns together into a fabric, and to create the specific pattern desired, selected warp yarns are raised and separated from other warp yarns. The weft yarn is placed between this "*shed*" or triangular separation of warp yarns. Before the yarn is brought back across the warp yarns a second time, the warp yarns are lowered, and different warp yarns are raised. The weft yarn is brought back between the new shed, and beaten into place. This process is repeated hundreds of time a minute to form the fabric.

Traditional *fly shuttle* looms can produce only simple weaves (though 8 - shaft looms can produce much more complex patterns or weaves than 4 - or even 6 – shaft looms). A fly shuttle loom is one in which a wooden object (the shuttle) traverses (or "flies" across the warp yarns) to place the weft yarn. Other more modern looms include *rapier* looms in which a rapier, or metal band carries the yarn across, then cuts the yarn and retracts leaving the yarn in place, air jet or water jet looms, in which a burst or jet of air or water carries the weft yarn across the warp yarns. *Jacquard* looms are the most complex, using individual *heddles* to raise and lower each individual warp yarn, rather than the broad shafts used on other types of looms. Being able to independently raise and lower each warp yarn allows infinite flexibility in design, enabling weavers to create fabrics with very complex patterns. Jacquard fabrics, however, are also generally expensive relative to other types of fabrics. They are most often used for upholstery fabrics. In apparel, they may be used for coats or jackets.

Above: "weaving room" full of fly shuttle looms

Because of the perpendicular orientation of the warp and weft yarns, woven fabrics have good dimensional stability (unless very loosely woven) meaning they will not curl or twist in the way knit fabrics tend. However, they have no inherent stretch, unless made using yarns of stretch fiber such as lycra.

Knit fabric manufacturing

Just as there are different types of knit fabrics (warp and weft knits), there are several different designs of knitting machines. The type of machine used for a particular product is generally determined by the type of good to be produced. For example circular knitting machines are used for producing socks, hosiery, some intimate apparel, and the body of a t-shirt, in short, products that are tube-like in their finished form. Flat knitting machines (like *rachel* or *racheltronic*) are generally used for fabrics that are to be cut and sewn, and for laces.

In knitting, yarn may be fed into the knitting machine directly from cones racked in a creel, or yarn may be first wound onto a warp beam (as in weaving). For yarn fed directly from the cones into the knitting machine, the shape of a creel is particular to the kind of cloth, the type of yarn, and the tensions needed to produce the goods. Spandex or other specialty yarns are typically wound onto beams before being fed into the knitting machine.

Fabric processing

Desizing and bleaching. Fabric, when it comes off the loom or the knitting machine before it undergoes any additional processing, is called *greige* fabric (pronounced "gray," like the color). Typically this fabric is a natural off-white color (as in the case of cotton, silk, or many wool fabrics), or bright white (as is the case in many synthetic fabrics). To be suitable for use in apparel manufacturing, greige fabric needs additional treatment.

Generally the next steps for greige fabric are *desizing* and bleaching. These prepare the fabrics for dyeing, printing, and / or finishing. (Because yarns used for knitting are not sized prior to use, no desizing step is necessary for knit fabrics. Desizing is simply the washing off of the starches or lubricants. This is typically by processing the fabric through a trough of enzyme solution, followed by vigorous washing in hot water. Starch and most other sizings dissolve poorly in plain water; the enzyme helps degrade the starch.

The fabric (both woven and knitted) is then typically bleached. This is commonly done by processing the fabric through a series of one to three troughs containing various chemicals, including a strong oxidizing agent (usually hydrogen peroxide). Chemicals used in bleaching need to be stored carefully. Both hydrogen peroxide and caustic (sodium hydroxide, a commonly used bleaching chemical) are very dangerous if mishandled. The particular types of processing equipment used will depend on the type of cloth to be processed (woven, knit), and whether the fabric is to be printed.

Dyeing and / or printing

Dyeing and printing are the steps that impart color to a fabric, making finished products such as garments much more attractive. Dyeing and printing is highly complex, requiring years of study and / or experience. Only the highlights will be summarized here.

Dyes and application methods vary greatly. *Colorfastness* is the degree to which a fabric will retain its color when subjected to adverse conditions such as sunlight, detergent, bleach, or other agents. Different types of dyes, and different methods of application produce substantially different levels of clarity and colorfastness. For optimal quality of the fabrics and final products, dye types and application methods must be carefully selected according to the fiber type, fabric type, and expected end use.

Color can be imparted at any one of several stages in textile and garment production, from the fiber to the sewn garment. As with the types of dye and the application method used, the point at which the color is introduced affects the clarity and fastness of the color.

Table 2. Stages at which color can be applied to a textile product.

Stage	Step
Fiber	The chemical solution used to make synthetic fibers may be dyed before being extruded into fibers.
Yarn	Yarn may be dyed to allow weavers or knitters to build colored patterns into the fabric itself, as in the case of woven stripes or plaids, *ikat* patterns, or knitted stripes or plaids.
Fabric	Fabric can be dyed a single color, or it can be printed with a colorful pattern using one or more of several different printing techniques.
Garment	Fully assembled garments can be dyed, though this is seldom done.

Fiber Each point at which color is imparted has its own advantage. Solution – dyed fiber generally enjoys very high colorfastness. Fiber dyeing is really only suitable for man – made fibers that can be dyed in solution form (before the actual fiber is formed) however, as attempts to dye loose fibers easily tangles and mats fibers into an unusable mess.

Yarn. Yarn can be dyed after spinning. Dyed yarn can be used to create woven stripes or plaid designs in fabric. However, dyeing at the yarn stage is relatively difficult, often resulting in uneven color application. At this stage, yarn can be dyed either in *skein* form (large bundles of loosely wrapped yarn) or wound on tubes or cones. The former allows yarn to move more freely in the dye bath or dye solution, helping ensure greater uniformity of dye penetration and therefore better color uniformity. It may also result, however, in tangled yarn. For dyeing on cones, yarns must be wound on special perforated tubes or cones that allow the dye solution to be force through the layers of yarn from the interior as well as the exterior. Dyeing cones of yarn requires high – pressure equipment that can force dye through hundreds of layers of yarn wrapped tightly around the cone, but this method generally produces fewer tangling problems.

Whether dyed in skein or cone form, each batch of yarn dyed together is referred to a *dyelot*. While color should be uniform within a single dyelot, there is often a discernable difference in color between dyelots. For quality control is it vital to segregate dyelots so only one is used in a single garment, helping ensure that within the garment, yarn (hence fabric) color will be uniform.

Fabric. Dyeing and / or printing fabric allows the greatest design flexibility but varying levels of colorfastness, depending upon the dyes and methods used. It also requires that substantial quantities of fabric be dyed or printed the same color or pattern to be cost effective. As with yarn dyeing, each batch of fabric dyed becomes an individual dyelot. With fabric, individual dyelots should also be segregated at the apparel manufacturing stage to help avoid color – related problems in the finished garment.

Modern technology and computers are allowing designers to print only select areas of a fabric, depending upon the shape of the garment to be made from the fabric, effectively eliminating a split in the printed pattern where fabric is seamed. To date, however, this remains more a laboratory experiment than a commercially viable printing method. (For greater detail on fabric dyeing and printing, see *Fabric dyeing and printing* section below.)

Garment. Last, fully - constructed garments can be garment - dyed, allowing retailers to wait until the last point in the manufacturing chain to make decisions on the number of garments to produce in each color, thereby reducing the risk of unsold inventory from bad color decisions. With garment dyeing, however, more highly specialized equipment is required, the entire garment must be dyed the same color, threads must accept dye in the same way as base fabric or off quality results, and it may be more difficult or impossible to do certain additional types of fabric processing normally done after dyeing or printing many apparel fabrics.

Fabric dyeing and printing

Because of its complexity, fabric dyeing and printing will be described in greater detail here than other stages at which color may be imparted.

Dyeing. Dyeing is the process of giving color to a fabric, one color at a time. With dyeing, the entire length of fabric is exposed to the dye solution (called, in industry, dye *liquor*). In dyeing, the entire fabric is placed in the dye solution, causing most or all the fabric to take a single color. (By contrast, in printing, color is placed onto one side of the fabric in selected patterns.) Certain dyeing techniques (such as *resist dyeing* in which parts of a fabric are tied or waxed to prevent the dye solution from penetrating the cloth) may prevent dye from fully reaching selected parts of the fabric, however these methods are generally more suitable to artisanal operations than industrial application, and they do not fully prevent dye uptake. The "crackled" look of batik fabrics results from some dye penetrating where there are cracks in the wax used to resist dye or prevent it from reaching the fabric.

Industrially, fabrics may be dyed in *batch form* or in a *continuous process*. In the former, certain lengths of fabric will be dyed at one time, generally in a large machine similar to a clothes washing machine. More common at the industrial scale, however, is continuous processing, whereby lengths of fabric are stitched together temporarily so one continuous length of fabric runs through sequential processing equipment, including a series of troughs containing the dye liquor, allowing greater processing efficiency.

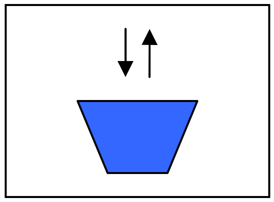


Figure 8. Batch processing

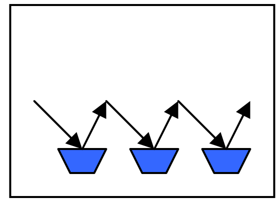


Figure 9. Continuous processing

Printing. While dyeing a fabric increases its visual appeal to consumers, many consumers appreciate fabrics with multicolor patterns, such as flowers, figures, symbols, or abstract designs. Printing is the least expensive method for producing such designs. Printing can be done at either the fabric stage, or with limits, at the garment stage. The most common example of the latter is screen – printed t – shirts in which a design is printed onto a finished t – shirt.

In fabric form, cloth can be printed in continuous process using rollers with the selected pattern, it can be screen printed, or it can be printed using thermal transfer techniques. Each will be described below:

Roller printing. This is a continuous process in which fabric runs over a flat bed or a large cylinder. While fabric is passing over the bed or cylinder, a series of one to several rollers pass over the *face*, or "*right*" side of the fabric. One of two types of rollers will be used: *engraved rollers*, or *screen rollers*. In the former, the metal surface of the roller is engraved with a selected pattern. Dye *pigment* (concentrate) is applied to the roller, sticking in the engraved areas and transferring the dye to the fabric in the same pattern. In the latter, a fine screen covers the roller. Selected portions of the screen are solid while others are porous. The porous areas allow dye to be forced through in a selected pattern, replicating that pattern in color on the fabric (called *substrate* at this stage). Because only one color can be applied by each roller, most patterns require several rollers. Designers are limited by the number of rollers that can be used in a given machine. Those machines that pass substrate over a drum or large cylinder are more limited (usually to no more than six rollers, often fewer) than those machines that pass fabric over a horizontal bed.

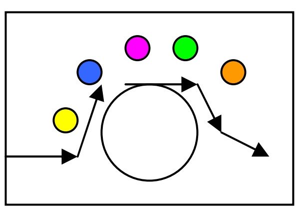


Figure 10. Rollers over drum

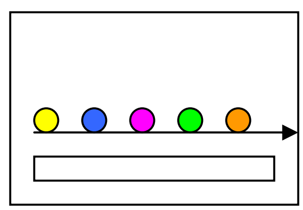


Figure 11. Rollers over flat bed

Great care must be taken when patterns are designed, to make sure the pattern repeat conforms to the surface of the rollers used. If the pattern repeat is greater than the circumference of the rollers, a portion of the pattern will be cut off, causing a rupture in the printed pattern. If the pattern repeat is shorter than the circumference of the roller, there will be a gap in the pattern once printed. In addition, rollers must be placed on the printing machine with great precision. Each roller must be carefully synchronized as it lays down the dye to form the final pattern. Because the final pattern is created by overlaying one color at a time, even a minute error in the placement of any roller will result in one color in the pattern shifting, causing the fabric to be defective and generally unusable.

In a similar fashion, *wax prints* are created by using rollers to apply wax to the fabric substrate in a selected pattern. Fabric is then dyed. The wax *resists* the dye, or prevents the dye from penetrating the fabric, leaving those parts of the fabric covered with wax to be the color of the substrate. The wax is then removed using a solution of hot water and solvent, showing the pattern. Wax printing is simply an industrial application of the hand resist - dyeing method known as *batik*. Wax printing is still being done by some companies in West Africa, but more commonly the appearance of wax printing is now being printed to save the costly waxing process. With true wax printing, each length of fabric, though similar in pattern, is truly unique (as the wax cracks during the dyeing process, it imparts a unique pattern of its own). When this pattern is replicated without using the wax resist technique, the subtle uniqueness is lost, with each pattern repeat being identical.

After dyeing and / or printing, fabrics are *cured*, or heated in a large oven to dry and set the dyes. For this process, fabrics are stretched onto a moving frame called a *tenter* frame. Fabric may either be clipped onto the frame at the edges of the fabric, or may be held into place by placing the fabric over a line of short upright pins. Looking closely at the edge, or selvage of a fabric, you can sometimes see two rows of tiny holes. These are tenter frame pin marks. In rare cases they may cause problems in the fabric. If fabric is not straight (with warp and weft yarns perpendicular to each other) when placed on the tenter frame, it will become permanently skewed and garments made from the fabric will not hang properly, causing serious quality problems. A good example is the twisting of a pant leg.

Screen printing. Though more commonly used for printing garments such as t – shirts, screen printing can also be used for fabrics. The method is basically the same whether used in an industrial or artisanal application. Patterns are transferred onto large, flat screens, with selected parts of the screen left porous and other parts blocked, according to the pattern and color. Each screen is placed over the flat fabric, and dye paste is forced through the porous areas of the screen, onto the fabric substrate. Like roller printing, each color in a pattern must be applied with one screen. Screens are placed sequentially over a fabric, to allow addition on each additional color. As in roller printing, great care must be taken to properly align the sequential screens over the fabric so all colors in the final pattern will be properly aligned as well.

Thermal transfer (heat transfer) printing. Thermal transfer, or heat transfer as it is sometimes called, is the technologically simplest method of printing, but generally gives the poorest colorfastness. In this process, patterns are printed onto heat sensitive paper. The paper is placed against the fabric (or garments, as in the case of t – shirts), heat and pressure are applied, and the pattern transfers from the paper onto the fabric or garment. Heat transfer has been used extensively to print synthetic knits whose stretch makes it difficult to process on standard printing equipment.

Garment dyeing

While garments are generally made from dyed and / or printed fabrics or yarn, occasionally garments will be made from undyed / unprinted fabric, and dyed in garment form. More rarely, garments may be "overdyed" once assembled. In the former, color is applied to the garment only at the garment stage. In the latter case, the garment has been assembled from dyed yarn or dyed or printed fabric, but then is dyed again (with a weaker dye solution) at the garment stage to give a particular design look.

Fabric finishing

Mechanical and chemical treatments or *finishes* may be added to fabrics to enhance appearance and / or performance of the finished apparel product. Common treatments or finishes include physical treatments such as *calendaring*, *napping*, *brushing*, *sanding*, and chemical treatments such as *permanent press*, *water repellant*, and / or *flame retardant* finishes. Flame retardant finishes are required for certain types of clothing sold in the United States, such as children's sleepwear. Examples of specialty finishes and their uses are listed in the table below.

Table 3. Textile finishes

Finish	Temporary / permanent	Purpose	Example of use
Physical finishes			
Calendaring	temporary	give shine	girls' party dresses
Napping	semipermanent	give softness, and "direction" to fabric	flannel shirts
Brushing	semipermanent	give softness, and "direction" to fabric	flannel shirts
Sanding	permanent	give distressed or worn appearance	faded jeans
Chemical finishes			
Permanent press	semipermanent; wears off with repeated washing	prevent wrinkling, reduce need for ironing after laundry	men's tailored (business) shirts
Water repellant	semipermanent; wears off with repeated washing	cause water to run off fabric surface	raincoats
Flame retardant	semipermanent; wears off with repeated washing	reduce speed at which fabric or garment will burn when exposed to an open flame such as a lighted match or burning cigarette	children's sleepwear

Physical finishes. Physical finishes are applied to give specific characteristics to the fabrics that are sought by consumers. *Calendaring* involves running fabric between heavy metal drums that turn at varying speeds. Heat and pressure are used to produce a smoothness and sheen on the surface of the fabric similar to that sometimes caused by ironing a piece of dark – colored cloth. One drum may be engraved, thus imparting a pattern to the sheen, creating a subtle watermark – type effect on the surface of the fabric. The effect created by calendaring disappears with repeated laundering or dry cleaning.

Brushing, *napping*, and *sanding* are designed to give a softer appearance and much softer feel to the surface of a plain fabric, by using wire brushes to scrape the surface of the fabric, raise fibers from the surface of the exposed yarns, and thereby creating a more matte appearance and softer feel to the fabric surface. If done too harshly, these treatments abrade the fabric weakening it and even wearing holes in the fabric. They nonetheless remain popular, particularly in such wearing apparel as men's flannel shirts.

Chemical finishes. With the development of higher performance yarns, and the popularity of distressed looks in fashion apparel, and consumer concern about processing chemicals such as formaldehyde, chemical finishes are somewhat less popular today than in recent years. The most common for wearing apparel are permanent press or no – wrinkle finished, water repellant finishes, and flame retardant finishes. Each serves a separate and distinct purpose for the consumer.

Permanent press finishes are most commonly used for fabrics destined for men's dress shirts. These finishes help prevent wrinkling of cotton or cotton / polyester fabrics when laundered, thereby improving the appearance during wear, and reducing the ironing required after home laundry. Permanent press finishes have been popular with businessmen and their wives.

Water repellant finishes. These chemical treatments help prevent hydrophilic fabrics such as cotton or cotton blends repel water that touches the surface of the fabric. Such finishes are widely used for fabrics intended for raincoats and some other outerwear. Although they do not prevent water from soaking into the fabric in heavy rains or under prolonged exposure, they do help substantially. Similar finishes may be applied to help prevent soiling when fabric is exposed to dirt.

Flame retardant finishes. These finished are mandated by law for certain types of wearing apparel. Most notable, are the requirements for children's sleepwear. Anyone considering manufacturing children's sleepwear should take care to research the current legal requirements for flame retardant finishing.

Garment manufacturing

Garments can be constructed or assembled by either of two methods:

1. *cut and sew*
2. *knit – to – shape.*

The difference is whether the individual parts, or components, of a garment are cut to the necessary shape from flat fabric, or are produced directly in the shape needed.

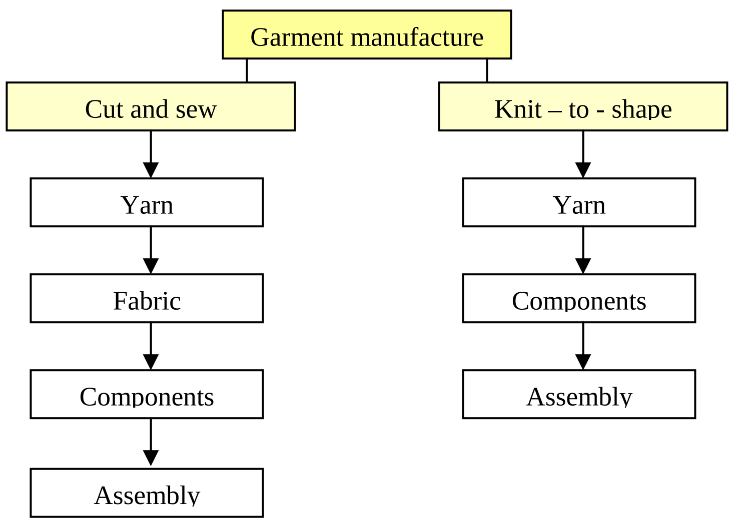


Figure 12. Cut – and – sew vs. Knit – to – shape construction

Cut and sew

Pattern making. Cut and sew is the more common. Either woven or knit fabrics may be used. Unlike artisanal methods (including exclusive *haute couture* and custom clothing) in which each individual garment is made one at a time, industrial methods are designed to manufacture many identical units at the same time. In large factories thousands of identical units may be made in a single day. Unlike artisanal methods, under which one worker completes most or all steps of one garment, industrial methods employ a division of labor whereby one worker may perform only one step in the preparation and assembly process, pass the component/s on to the next worker, who will complete the next step in assembly. Such methods are employed to allow individual workers to specialize in and perfect selected garment assembly steps, and to allow greater efficiency in overall manufacturing.

They also allow for greater uniformity between garments, which is demanded by most commercial buyers.

Paper patterns are drawn in the shape and size of each component (e.g. sleeves, collars, pant legs, waistbands,...) of the garment. They are then arranged on a paper *marker* to determine the most efficient arrangement of the components on the fabric, so as to maximize use of the fabric and minimize waste.

Cutting. Fifty to one – hundred meter (or yard) rolls of fabric are unrolled onto large cutting tables using "*spreaders*" or devices that unroll and layer the fabric uniformly. Cutting many layers (as many as twenty-five or fifty) layers of cloth at one time reduces labor significantly, but layers must be smooth and even to prevent distortion in the component shapes that would result in defective garments. The marker is placed on the top layer of fabric, indicating the shapes into which the fabric should be cut. A worker using a hand - operated saw cuts the fabric into the individual garment components. In large scale industrial cut and sew operations, laser cutting or dye cutting may be employed for greater efficiency and accuracy. Each component stack is tied into a bundle and passed to the sewers. Cutting multiple layers of cloth at once is key to cost efficiency and quality assurance.

Assembly. Individual components are then sewn together, or "*assembled*" to form the garment. One worker performs on step, passes the bundle of components to the next worker, who performs the next step, and so on until the garment assembly is completed.

Knit – to - shape

Knit – to – shape garments are made by knitting the individual components of a garment according to their finished shape. Individual components are then stitched together (assembled) with little additional cutting or trimming. Higher quality sweaters are knit – to – shape. They may also be referred to as "*full – fashioned*." In knit – to – shape apparel manufacturing there is no need to spread and cut layers of fabric.

Product specifications

One of the most important steps in garment manufacturing is to develop clear and detailed product specifications. A product specification is a document that details every aspect of the materials and findings used to produce a given product, the methods of construction used (type and size of seams, type and size of stitching, type of finishing), design and size of the product, labeling, care instructions, etc. The product specification should be so detailed and accurate that someone with no prior knowledge of the product should be able to take the specification sheet and manufacture the garment as intended. The product specification sheet not aids the production managers and supervisors to make every unit of a given product identical It also allows them to make sure each unit conforms to the buyer's expectations. The buyer will compare the products shipped to the product specification sheet, and will reject any units that do not conform. In most cases, if a buyer finds just one or a few unites that do not conform, s/he will reject the entire shipment, and it will be returned at the manufacturer's expense. The time necessary to carefully develop a detailed product specification sheet for each product is time well spent, as carefully written and carefully followed product specification sheets will greatly reduce the number of costly errors or mistakes in manufacturing that can quickly ruin a company's export business.

Further processing.

Fully constructed garments may be "*further processed*," by dyeing, chemical treatment, embroidery, or other mechanical or chemical treatments. The ultimate goal at each step is to produce an end – product that meets the needs of the target consumer.

Chemical treatments. With the popularity of the faded or distressed look in garments, particularly denim garments such as jeans, many garments are being further processed with enzyme, acid, or other chemical treatments. These treatments fade the color as if the garments had been laundered repeatedly over a long period of time. Although such treatments weaken the fabric (hence garments) somewhat (sometime substantially), fashion trends have made the processes popular. For some garments such as rainwear, water repellant finishes may be applied or reapplied to assembled garments. In the case of high performance rainwear, and some types of activewear for which water repellency is important, sealants may be applied to seams after garments are assembled.

Physical treatments. Similar distressed looks, and a softer feel can also be achieved at the garment stage using "stone washing" or "sand washing" methods.

Embroidery. Embroidery is commonly used on apparel for decorating or embellishing the garment. For greatest quality and efficiency, many garment manufacturers invest in highly computerized embroidery equipment that replicates a design over and over again with precision and speed at low cost.

Quality assurance / quality control

Quality assurance and quality control have attracted much attention in recent years. While formerly only quality control was emphasized, that is inspecting products and rejecting those that did not meet quality standards, in the past thirty years or so, emphasis has shifted to preventing defects (or *assuring* quality) rather than simply *controlling* for quality after defects may have been introduced. Emphasis was also placed on taking steps throughout the manufacturing process to assure high quality, rather than waiting until the end after which many resources (raw materials, labor, energy) have been expended.

Quality assurance. QA, as it is often called, incorporates engineering quality into the garment from the earliest stages: selecting the proper raw materials, selecting the best construction techniques, calibrating and maintaining equipment properly so that stitching, pressing, and finishing is correct, and so forth. QA begins with the product design and specification, carries through raw materials sourcing and receipt, and ends only after finished garments have been shipped, and follow – up correspondence has been completed.

Because the quality of raw materials and findings is critical to the quality of the finished garment, apparel manufacturers should carefully select raw yarns, fabrics, threads, buttons, zippers, and other findings from reliable suppliers, should require that suppliers conduct or guarantee certain specific levels of colorfastness, strength, shrinkage, and should conduct some testing of raw materials and findings themselves. Any that do not meet agreed upon standards should be returned immediately to the supplier for replacement or refund.

Common quality testing in the apparel industry includes:

- Fabric strength
- Colorfastness
- Shrinkage

- Wrinkling
- Seam strength
- Flammability

For companies not able to do their own testing, outside labs are available for third – party testing, for a fee. Such labs are expensive, but provide a good alternative to equipping and staffing an in – house lab. Additionally, apparel manufacturers should invest in high quality equipment and in recruiting and retaining well – trained mechanics skilled in setting up, maintaining, and repairing the specific types of equipment used in the manufacturing plant.

Quality control. Long used in the apparel industry, quality control helps make sure that any *defective*, *off – quality*, or *second quality* merchandise does not get shipped to the customer. This is generally accomplished by inspecting components and finished garments at key points in the assembly process and correcting or rejecting those that do not meet the established quality standards.

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