The *Journal of Cotton Science 21:210–219 (2017)*
http://journal.cotton.org, © The Cotton Foundation 2017

ENGINEERING & GINNING

Textile Industry Needs

Christopher D. Delhom, Vikki B. Martin, and Martin K. Schreiner

ABSTRACT

The immediate customers of cotton gins are the producers; however, the ultimate customers are textile mills and consumers. The ginner has the challenging task to satisfy both producers and the textile industry. Classing and grading systems are intended to assign an economic value to the bales that relates to textile mill demands and the quality of the end product. International textile mills currently are the primary consumers of U.S. cotton lint where it must compete against foreign origins. International textile mills manufacture primarily ring-spun yarns, whereas domestic mills manufacture predominantly rotor spun yarns. Producers and ginners must produce cottons to satisfy all segments of the industry, i.e., domestic and international. Many fiber quality attributes are important to the textile industry including those that are included in HVI-based classing, i.e., strength, length, micronaire, trash, and grade. There are other important fiber quality attributes that are not included in HVI-based classing such as short-fiber content, fiber maturity, stickiness, fiber cohesion, and neps. The general steps of textile processing: opening, cleaning, carding, drawing, spinning, and fabric production have not changed in many years. However, manufacturing systems have become highly automated, and production speeds have dramatically increased. Contamination-free cotton has always been important to the textile industry, but recent changes in harvesting systems in conjunction with higher production speeds and global competition from synthetic fibers and other growths of cotton have increased the industry demand for contamination-free cotton. The ginner plays a vital role in preserving and improving the quality of cotton to meet the demands of the textile industry.

C.D. Delhom*, USDA-ARS Cotton Structure and Quality Research Unit, 1100 Robert E. Lee Blvd., New Orleans, LA 70124; V.B. Martin and M.K. Schreiner, Cotton Incorporated, 6399 Weston Parkway, Cary, NC 27513
*Corresponding author: Chris.Delhom@ars.usda.gov

Although the immediate customer of the gin is the cotton producer, the end user of the ginned lint is the textile mill, retailers, and eventually the consumer. Thus, it is essential for the ginner to satisfy both the producers and the textile industry. Consequently, the ginner needs to be aware of the needs of the textile industry.

The intent of the cotton classing and grading system is to assign an economic value to the bale that documents its properties as it relates to the quality of the end product. Since the last edition of the Cotton Ginners Handbook in 1994, the customers of U.S. cotton have changed radically, shifting from primarily domestic to international mills. International mills have been accustomed primarily to hand-harvested cotton that has been processed at slow ginning rates. The international mills are predominantly producing ring-spun yarns, whereas U.S. mills are dominated by rotor spinning (International Textile Manufacturers Federation, 2014). The overall need for well-ginned, clean, dry cotton remains; however, the specific fiber properties required for both spinning systems differ. Therefore, it is more important than ever that ginners minimize fiber damage while reducing non-lint content to maximize market value.

When the last edition of the Cotton Ginners Handbook was published, more than half the annual cotton production in the U.S. was consumed domestically. Currently, less than a third of the production is consumed domestically and two thirds are sold on international markets where the cotton must compete against foreign origins (USDA-ERS, 2015). U.S. cotton must compete against hand picking and low labor costs while commanding a premium price to enable the U.S. cotton producer to thrive.

Textile manufacturers purchase cotton that has a level of quality that most closely matches the intended end use. All cottons cannot be used for all end products. Generally, lighter weight textile products require higher quality cotton because finer yarns are needed to produce lighter weight textiles. For example, sheeting and shirting yarns are much finer in weight per unit length (higher count) and therefore require cleaner, longer cotton fibers with better length uniformity, fineness, and strength.

Coarser yarns (lower count) such as those used in denim are more tolerant of short-fiber content and non-lint content in the bale, but still require fine and strong fibers.

IMPORTANT FIBER PROPERTIES

For textile processing the following properties are critical; most, but not all, of these are measured with High Volume Instrument® (HVI)-based classing system.

Included in HVI-Based Classing:

Fiber Strength. The strength of cotton fibers (weight normalized force-to-break) is measured by HVI and reported in grams of force per tex. A tex is equal to the weight, in grams, of 1,000 m of fiber. Strength has improved since the last edition of this handbook so that upland cottons typically range from 28 to 32 g/tex to 42 to 46 g/tex for pima cottons.

Fiber Length. Length is expressed as the upper-half mean length (UHML) of a fiber beard. UHML is the mean length by number of the longer one-half of the fibers by weight (ASTM D123). Uniformity index (UI) is a measure of length uniformity. It is the ratio of the mean fiber length to the upper-half mean length. UHML of commercial upland cottons typically ranges from 1.08 to 1.24 inches (27.4-31.5 mm), and pima cottons typically range from 1.36 to 1.43 inches (34.5-36.3 mm). UI of commercial upland cottons typically ranges from 80.0 to 82.5% and pima cottons typically range from 85.0 to 86.5%.

Micronaire. Micronaire is an indirect measurement of fiber fineness and maturity. Fiber fineness limits how many fibers can be in the cross-section of a given size yarn, whereas maturity has a direct relationship with fibers tensile properties and performance in dyeing. Upland cotton micronaire typically ranges from 3.9 to 4.9 and pima cottons typically range from 3.7 to 4.2.

Trash and Grade (Leaf and Color). Previously, the classer assigned the grades with the assistance of HVI. In recent years, grades are assigned solely by the HVI instrument, with instrument color grade beginning in 2000 and instrument leaf grade beginning in 2011 (Knowlton, 2014). HVI measures both trash particle count and percent trash area, which is used to determine leaf grade. Color grade is based on measured reflectance (Rd) and yellowness (+b). Trash content has a direct bearing on how well the cotton processes in the mills. Large particles can be removed easily, whereas smaller particles (pepper trash) are difficult to remove and can cause imperfections in the yarn. Some of the trash particles are actually seed coat fragments and/or pieces of bark and grass. Color can serve as an indicator of field weathering or excess moisture content during harvesting and/or seed cotton storage. Color is an important consideration for the mill to be able to produce yarn that is uniform in appearance and performance.

Not Included in HVI-Based Classing:

Short-Fiber Content. Short-fiber content (by weight or by number) is defined in the U.S. as the percentage of fibers shorter than one-half inch (12.7 mm). It has a major effect on how the cotton processes, yarn strength, and evenness. Short fibers are fundamentally unspinnable fibers. A large percentage of short fibers might be removed by the mill depending on the end product. This will result in increased waste at the mill and reduced profitability.

Maturity. Mature cotton is cotton that has a fully developed secondary cell wall. Immature fibers, commonly known as dead fibers, can lead to dyeability issues and increase neps count (entanglements of fiber). Maturity variation in fabrics can lead to appearance defects such as barré (color banding in fabrics) and white specks (small undyed specks in finished fabrics). The ginner has no control over maturity, although immature cotton will be prone to nep formation and fiber breakage during ginning (Anthony et al., 1988).

Neps. Immature cotton fibers tend to be flat and create entanglements known as neps. Long and fine fibers also tend to entangle when submitted to mechanical processing. For this reason, longer cottons are generally handled more gently than shorter cottons. Immature cottons can form neps during all processing stages from harvesting until carding. Most neps are removed during carding and textile mills aim to reduce nep levels by 80 to 90% during the process. Nep levels vary greatly based on growing region, harvesting, and ginning techniques. Nep levels are of particular importance for pima cotton and a goal of fewer than 200 neps per gram in the bale is desired by textile mills.

Stickiness. The form of stickiness that mainly impacts spinning mills is commonly called honeydew. It is an excess of sugar droplets on the lint due to insect activity. In extreme cases, the sugars can build up on processing equipment and slow or even shut down production in a spinning mill. The principal causes of stickiness of entomological origin are due to whitefly or aphid infestations (Hequet and Abidi, 2006). Another cause of stickiness is due to excessive seed-coat fragment contamination due to a buildup of seed meat and oil residue.

Fiber Cohesion. This is the property that controls friction between fibers and affects the manner fibers slide past each other in carding, drawing, and spinning.

MODERN TEXTILE PROCESSING TECHNOLOGY

The U.S. textile industry, as with most of the global textile industry, is highly automated and employs high-speed processing equipment. Automation is intended to speed production while reducing costs and improving quality.

Opening, Cleaning, and Blending. Bales of cotton are unwrapped, unstrapped, and allowed to condition and bloom before processing. The bales are arranged on the floor in what is known as a laydown, which can contain 30 to more than 70 bales. After being selected, the bales are placed on the mill floor in a specific order to ensure a consistent and uniform product throughout and between processing runs. Many modern textile mills utilize software tools, such as EFS® (Engineered Fiber Selection software from Cotton Incorporated), to assist with the bale selection process utilizing HVI data to aid in producing consistent and uniform processing (Cotton Incorporated, 2016). The surface fibers are skimmed off via a top feeder, or plucker, that utilizes revolving fingers and suction to remove a small layer of fiber from the top of each bale in the laydown as it traverses across all of the bales (Fig. 1). The opening process breaks down clumps of compressed fiber into smaller tufts to ease cleaning. The smaller tufts are then transported pneumatically through one or more coarse cleaners that are similar in design and function to cylinder cleaners in the gin plant (Fig. 2). Progressively finer cleaning is performed with a fine opener to further reduce tuft size and remove smaller trash particles (Fig. 3). In plants where blending with synthetic fiber is to be performed, a blender or mixing machine can be included in the sequence to introduce the synthetic fibers to the cotton fibers after cleaning. Another option for blending synthetic fibers with cotton is to card the materials separately and blend the materials together during the drawing process.

Figure 1. Unifloc top feeder for cotton bales in a laydown.

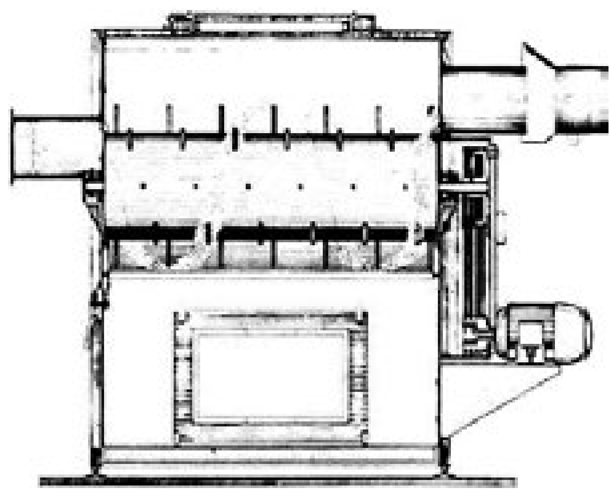

Figure 2. Axi-Flo-type cotton opener and cleaner (courtesy of Marzoli, Inc.).

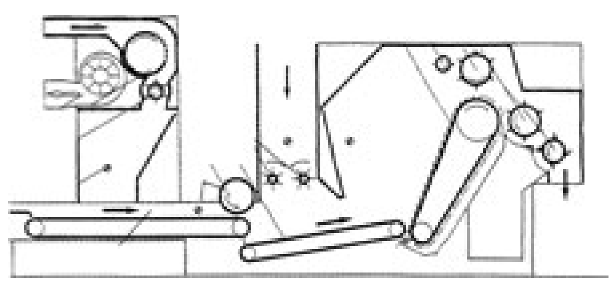

Figure 3. GBRA fine opener (courtesy of Truetzschler GmbH).

Carding. After opening and cleaning, the fiber is transported to the carding machine or card (Fig. 4). A single opening line can feed 20 or more cards. The primary function of the card is to clean and give a preferred orientation to the fibers in preparation for further processing into yarn. Fibers begin to be made parallel, and fine cleaning of trash, seed coat, and neps is performed by the sawtooth wire wrapped around the main cylinder and the fillet wire on the revolving flats moving against the main cylinder. The fibers are doffed from the main cylinder by a doffer cylinder to form a web. The web is then condensed to a rope-like strand called sliver. The sliver is collected in cans and moved to further processing and blending steps.

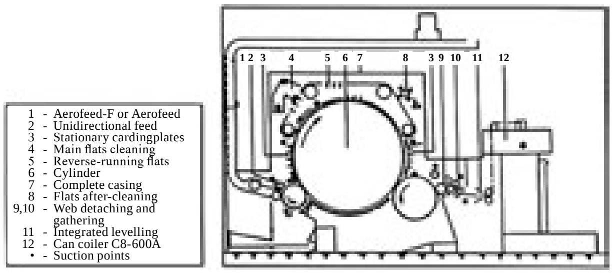

Figure 4. Schematic of a high production card (courtesy of Rieter Machine Works, Ltd.).

Drawing. Drawing is a process of further parallelizing the fibers and evening out variations through blending (Fig. 5). Typically six to eight slivers are drawn together and drafted into a single sliver. The drawing process blends the multiple slivers through drafting between several pairs of rollers, with each pair of rollers moving progressively faster than the preceding pair. The drafting action reduces the weight per unit length of the sliver, thus necessitating the use of multiple slivers. Drawn sliver is collected in a can for further processing. Generally one or more successive stages of drawing are used, depending on the spinning system and desired yarn characteristics. For open-end (also called rotor) spinning, drawing could be omitted entirely or performed as part of the carding process on some modern equipment. Open-end spinning and air-jet spinning is performed using drawn sliver as the feedstock. The drafting process in drawing, roving, and ring spinning is particularly sensitive to sticky cotton, as the fibers will stick to the rollers and cause processing stoppages. Such a failure requires manual cleaning of each roller on the machine. Figure 6 illustrates how honeydew from sticky cotton can build up on surfaces and begin to pull fiber out of the mass being processed.

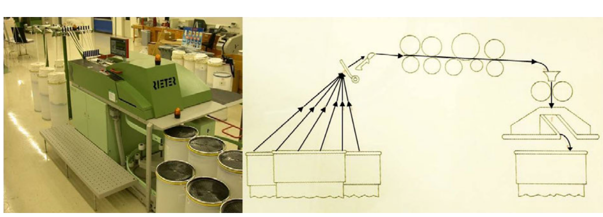
Figure 5. Rieter draw frame and drawing schematic.


Figure 6. Sticky cotton residue buildup on machine surfaces.

Combing. Fine count yarns (extremely fine yarns) are made from combed cotton, which allows for the production of fine fabrics. Combing cotton is done using a comber machine that combs the cotton fiber to remove short fibers and some hard-to-remove residual foreign material such as seed coat fragments and neps (Fig. 7). The combing process is time consuming and expensive as it requires multiple additional steps and typically removes 10 to 15% of the material. Material removed during combing is known as noil.

Figure 7. Reiter rectilinear comber.

Roving. Ring-spun yarn is produced from roving. Roving is prepared by further drafting drawn sliver to reduce the weight of the material being fed to the spinning frame. The process of drafting individual slivers down to a finer state is known as roving and is performed on a roving frame, also known as a speed frame (Fig. 8). Packages of roving are suitable for ring spinning.

Figure 8. Roving frame. Sliver has entered from behind and is drawn into roving at the top and wound onto bobbins at the base of the machine.

Spinning. *Ring Spinning*. There are three major systems of spinning in use: ring spinning, open-end spinning, and air-jet spinning. Ring spinning is the oldest and slowest industrial spinning method. However, it is capable of producing the finest and highest quality yarns. In ring spinning, the roving is further drawn out and the fibers are twisted by a small wire device called a traveler that is located on a ring around the spinning bobbin on which the yarn is collected. Figure 9 shows a typical ring spinning frame and a close up of the "draft zone" where roving is drawn into yarn and then wound onto a bobbin. Spindle speed, the speed of the traveler around the ring, is typically in the range of 15,000 to 25,000 rpm and yarn production speed typically varies between 15 and 25 yd/min (13.7-22.9 m/min). Ring spinning is sensitive to fiber length, short-fiber content, micronaire (specifically fineness), and foreign matter content (Ramey et al., 1977). After yarn is produced on a ring spinning bobbin, the individual bobbins must be spliced together and wound onto larger packages for sale or further processing into fabric. To increase production speeds, ring diameters have become smaller to allow higher spindle speeds, this, in turn, reduces the amount of yarn that can be placed onto one bobbin. A typical bobbin can hold approximately 0.1 lb (0.05 kg) of yarn. The need for roving production and winding of bobbins onto larger packages as well as the slow yarn production speeds makes ring spinning the most expensive type of spinning. Currently, the Asian textile industry is dominated by ring spinning and the newer compact ring spinning.

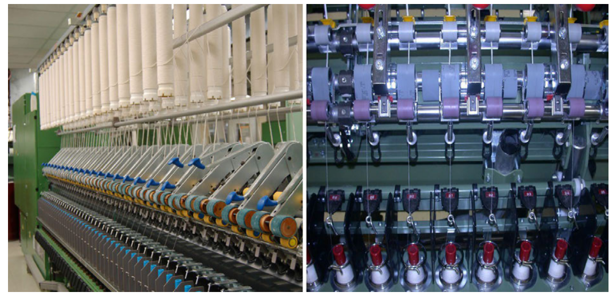

Figure 9. Typical ring spinning frame (left) and close-up of drawing zone and yarn winding onto a bobbin (right).

Open-End (Rotor) Spinning. The second major spinning method is open-end spinning, also known as rotor spinning. In rotor spinning, yarn is produced from a sliver. A sliver is fed into a rotating opening roll, which individualizes the fibers and transports the fibers into the rotor that is operating at speeds up to 180,000 rpm (Fig. 10). Centrifugal force causes the fibers to separate and align in the groove of the rotor. The fibers are assembled into a yarn and continuously pulled out from the back of the rotor chamber and wound onto a package. Figure 11 shows an open-end spinning machine in which the sliver is drawn from a sliver can located below the frame, and the spun yarn package is wound above the spinning position where a robotic piecing unit can reattach broken yarn ends. Open-end spinning is capable of producing yarn at speeds up to 300 yd/min (275 m/min). The final package can be quite large (several pounds) in size and is ready for sale or further conversion into fabric. Rotor spinning is sensitive to micronaire, with coarse fiber limiting the yarn count produced (Louis, 1983). Typical rotor spun yarn is weaker and has a harsher feel than ring-spun yarn. Rotor spinning is limited to medium to coarse yarn counts (typically less than Ne 30), but is more economical to produce due to reduced processing steps, highly automated equipment, and high rate of yarn production. The domestic U.S. textile industry is dominated by open-end spinning.

Air-Jet Spinning. Air-jet spinning is the third major type of cotton yarn production system. As the name implies, the process is based on a system of air jets to manipulate the fiber from sliver into yarn (Fig. 12). The biggest advantage of air-jet spinning is production speed. In the early 1990s, production speeds were in excess of 300 yd/min (275 m/min); newer advances now allow production speeds approaching 500 yd/min (460 m/min). Air-jet yarn is typically weaker than ring-spun yarn but it has good abrasion resistance and low hairiness. Although air-jet yarn can have a harsher feel than ring yarn it is typically softer than rotor yarn. Air-jet spinning is extremely sensitive to fiber length distribution and cleanliness. It typically needs combed cotton for 100% cotton yarn production. Most air-jet yarn production containing cotton is made of cotton/ synthetic blends (Artzt et al., 1992). Air-jet spinning can produce finer yarns than rotor spinning, but not as fine as ring spinning.

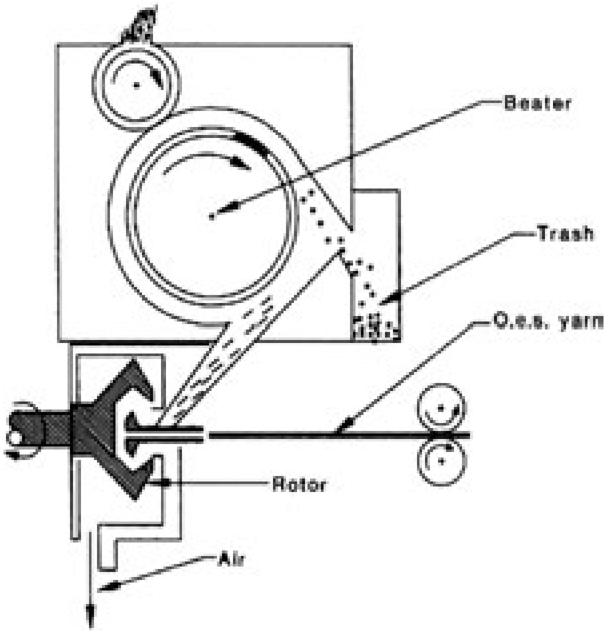

Figure 10. Schematic diagram of the principle of open-end spinning.

Figure 11. View of an open-end spinning machine with piecing robot.

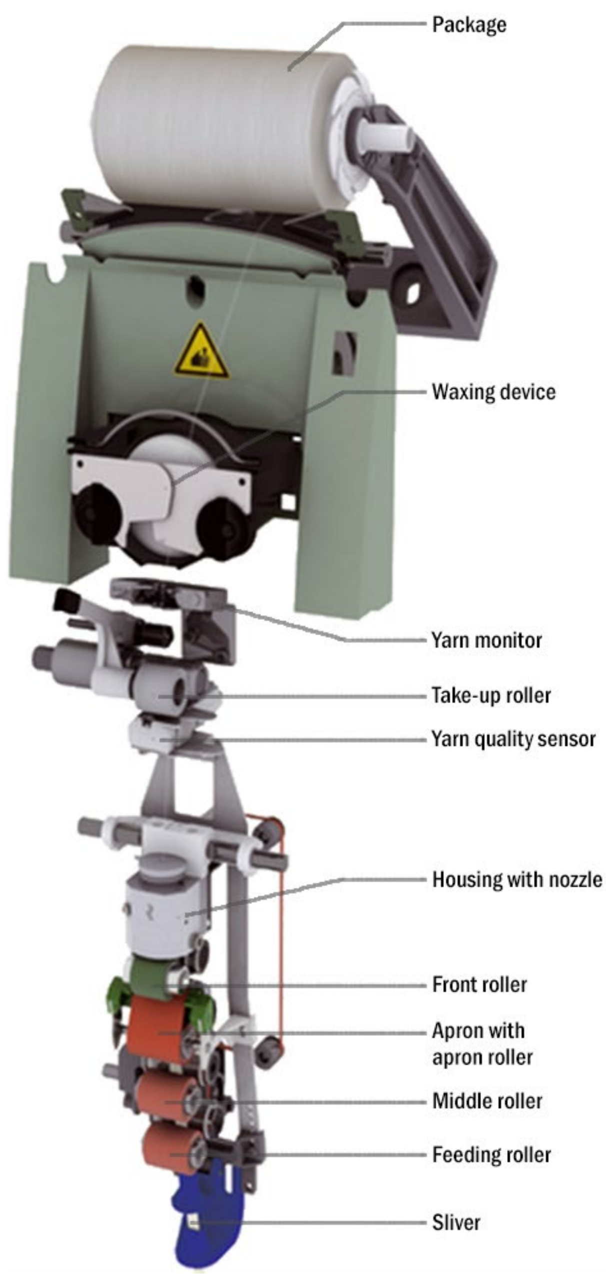

Figure 12. A typical air-jet spinning process on the Rieter J10 (courtesy of Rieter Machine Works, Ltd.).

Fabric Production. For apparel use, there are two major types of fabric production: weaving and knitting. The third type of fabric production is known as nonwovens, which typically are not used for apparel but are increasing in market share.

Woven Fabric. Woven fabric is produced using two separate sets of yarns, the warp and the weft, and weaving them together on a loom. The warp yarns are prepared to be mounted on a loom by first going through warping and slashing. Yarn packages are loaded onto a creel and wound onto a beam on a machine called a warper; each yarn package will become a single yarn in the warp of a fabric. Several hundred yarn packages can be wound onto each beam depending on the width of the beam and the loom on which the fabric will be produced. The weaving process can be quite abrasive, so the yarns on the warp beams are coated in a material called warp size. This protective coating is typically made from starch or polyvinyl alcohol. Size is applied to yarns on a machine called a slasher. Multiple warp beams are loaded onto a slasher and the individual yarns are pulled from the warp beams through a bath containing the water-based solution of size. The yarns are passed through a padder to squeeze excess liquid off the yarn and then dried using an oven or large steam cans. The amount of size add-on can vary but is typically approximately 5% of the weight of the yarn. The dried yarns are collected on a single loom beam that is ready to be mounted behind a loom. The warp yarns are drawn through the loom and a second set of yarns, known as the weft or fill, is inserted one yarn at a time to create fabric (Fig. 13). Traditionally shuttle looms were the backbone of the textile industry, in which a shuttle moved back and forth across the warp yarns to insert the weft yarn. Currently the weaving industry is dominated by flexible rapier and air-jet looms. Modern looms are capable of producing fabric at much higher speeds than traditional shuttle looms. Flexible rapier looms can run at more than twice the speed of the highest speed shuttle looms, inserting filling yarn at more than 2,000 yd/min (1800 m/min). Air-jet looms use air rather than moving shuttles or rapiers to insert the filling yarn and can insert yarn at more than 3,000 yd/min (2740 m/min). These high production speeds demand uniformly strong yarn as any weak spot in a yarn package will cause a yarn break, leading to lost production and defects.

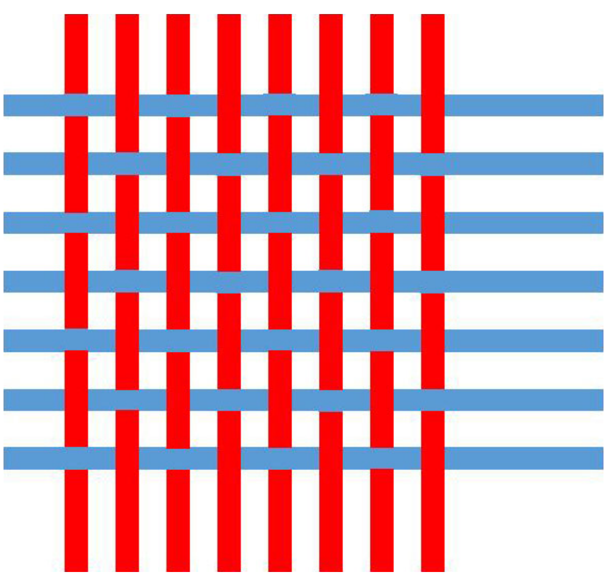

Figure 13. Simple plain weave fabric schematic.

Knit Fabrics. Knit fabrics are typically made from a single set of yarns that are interlocked with a series of loops (Fig. 14). Yarns destined for knitting do not require the warping and slashing preparation that weaving does. Yarns for knitting are typically coated with a light coating of wax that is applied either during winding, for ring spinning, or as the yarn is wound onto the package for rotor spinning. Modern knitting machines can consume yarn at speeds of more than 100 yd/min (90 m/min) per package of yarn fed into the knitting machine.

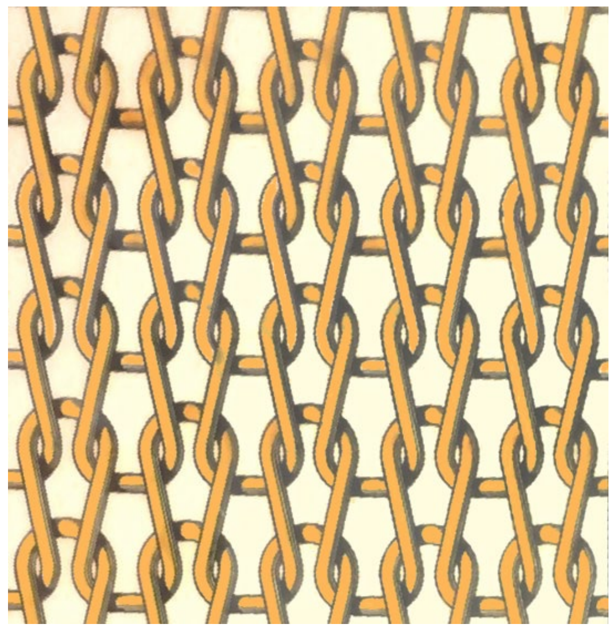

Figure 14. Simple weft knit fabric schematic.

Nonwoven Fabric. The nonwoven fabric industry is dominated by synthetic fibers. There are numerous methods and combinations for non-woven fabric production. Bleached cotton is the cotton of choice due to processing and cleaning limitations of existing nonwoven lines. Cotton fiber was limited to those nonwoven methods that originated with some form of carding of the fiber. However, advancements in machine technology (cotton-friendly air-lay webs) and the introduction of mechanically cleaned, virgin cotton are opening up new opportunities with improved, cost-effective options for cotton-containing end products. In general, when cotton is used in nonwoven fabrics, the fiber is often blended with synthetic fibers. Then, then the carded web is bound together, either through fiber entanglements created with barbed needles (needle-punched fabric) or high-pressure water jets (hydroentangled fabrics).The web can be thermally bonded using heat to melt low-melt synthetic fibers in the blend to bind the cotton fiber (Luitel et al., 2015).

Dyeing and Finishing. Dyeing and finishing is used to give fabric its color(s) as well as to impart some functional characteristics. Finishing treatments can include chemical treatments such as permanent press, moisture control, or flame resistance, as well as mechanical treatments such as sanding or tumbling with stones (for softer feel or "hand"). The dyeing and finishing operations are often carried out in plants separate from spinning, weaving, and/or knitting.

Before dyeing or finishing occurs, the fabric is known as greige fabric, meaning it is unbleached and undyed. Some woven fabrics can be singed, using gas burners to singe off short fibers protruding from the yarns, which makes the fabrics feel smoother. Greige fabrics are scoured, which is a wet process using a variety of caustic chemicals. Scouring removes the wax and size from fabric formation as well as enables the cotton fiber to absorb water more readily and accept further wet processing. Bleaching follows scouring and is used to remove pigments and aid in further removing whatever trash particles that remain in the fabric. Figure 15 shows a view of a typical scouring and bleaching range.

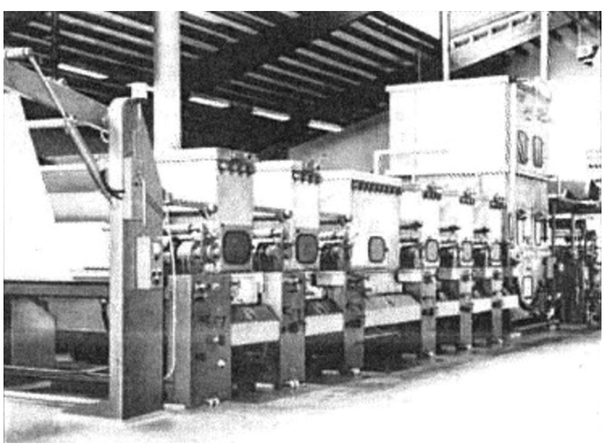

Figure 15. View of a typical (open-width) scouring and bleaching range. Process flow is from left to right.

Dyeing follows bleaching, although there are some instances in which a process called mercerization can be performed prior to dyeing. Mercerization uses a much higher concentration of caustic chemicals than scouring and causes fibers to swell. Mercerization improves dyeability (including the dyeability of immature fibers that can lead to whitespecks), it evens out color, and can impart a sheen to the finished goods (Lewis and Lei, 1989). Mercerization is expensive and is not always economical to use. Dyeing can be done in either a continuous or a batch process, and there are many methods and chemicals that can be employed. Traditional dyeing requires large amounts of water and energy. However, advances are being made to reduce the water and energy requirements for textile finishing. Immature fibers, which can be related to poor control of micronaire in bale laydowns and seed coat fragments, can lead to visible defects in the dyed fabric, which will result in a significant discount of the fabric.

After dyeing, further finishing of the fabric might be required. Permanent press or wrinkle resistance are common names for finishes that minimize wrinkling. These finishes treat the fabric with a resin solution that is heat-cured to create chemical cross linking within the cotton to ensure the fabric maintains a smooth appearance. Finishing options must be determined carefully after considering intended end use of the fabric. Many finishes can reduce the strength and/or abrasion resistance of the fabric.

Handling and processing fabric through dyeing and finishing will enable some shorter fibers to continue to work to the surface of the yarn and fabric. These short fibers can give the fabric a hairy appearance that might not be desirable. As a final step, the fabric can be sheared to smooth the surface.

CONTAMINATION-FREE COTTON

Textile mills do not want any contaminants in cotton bales as they have the potential to end up in the finished textile products (Fig. 16). U.S. cotton has the international reputation of being amongst the cleanest and most contamination free cotton available. The technology to detect contamination in the spinning mill is improving rapidly. Detecting contaminants is the necessary step before removing them, thus preventing contaminants from reaching the textile products. Prevention is paramount to avoid contaminants reaching the mill. Contamination is different than the plant material that is measured via classing. Contamination can be any non-cotton component ranging from bird feathers, twines, and fabrics to plastics, oils, and in rare cases metal parts and tools from the gin. Oil-type contaminants can lead to issues in dyeing and finishing of textile products. Foreign materials such as plastics and rags are difficult for the mill to eliminate as they tend to fray or behave like fiber. These loose foreign fibers are then impossible to remove. Foreign materials will either cause stoppages in spinning, or worse, become part of the yarn and lead to defects in the finished textile products. One recent study found between 4 and 8 grams of plastic per bale in a shipment that was suspected of having contamination (van der Sluijs and Freijah, 2016). One industry guide states that contamination complaints will be minimal if contamination is less than 1 gram per ton of ginned lint (Furter, 2006).

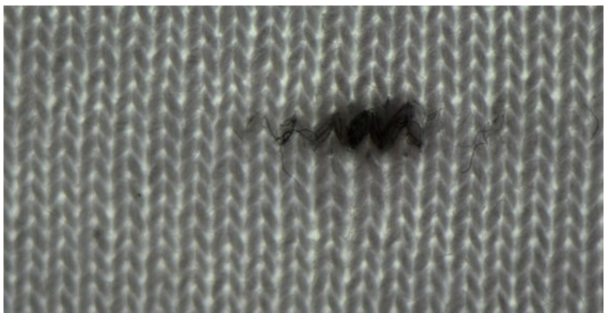

Figure 16. Typical contamination in knit fabric.

Plastic encased modules, twine from conventional module covers, cleaning rags, and equipment leaking oil or hydraulic fluid can all potentially lead to contamination of the ginned lint. Twine or plastic wrapped around the module feeder or other cylinders in the gin can take contamination from one module and spread it across countless bales before it is detected and removed. The producer must take care to prevent contaminants from entering the seed cotton during harvest, and the ginner must take care to prevent contamination of the bales at the gin.

IMPACT OF GINNING

The effect of excessive heat, over-drying, and overly aggressive cleaning of cotton in the gin has an important impact on the textile mill processing as well as the overall economic value of the bale to the producer and ginner. Over-drying the cotton in the gin will lead to increased fiber breakage, which in turn lowers the overall length of the fiber and increases short-fiber content. The impact of this fiber length change is found not only in classing of the bale, but is felt throughout spinning, fabric formation, and finishing.

Excessive moisture content of cotton can cause chokages in the gin and reduce grades. Lower grade cotton, due to moisture content, can be difficult to process. High moisture cotton is difficult for the textile mill to clean and the fibers will not doff and draft properly due to fiber being more likely to stick to processing rolls. And as the majority of U.S. cotton is exported , high moisture content in bales can lead to fiber quality deterioration during lengthy transport and typically hot storage conditions in Asia.

SUMMARY

The customers for U.S. cottons are located throughout the world. The U.S. cotton industry must compete with every other cotton-producing country while commanding a premium price for a premium product. The raw material produced by the U.S. cotton ginner is recognized as the cleanest and most consistent cotton that enables textile mills to run as efficiently as possible. Generally, textile mills need strong, fine, mature, long, uniform cotton that is free of seed coat fragments, trash, and contamination. Proper harvesting and ginning techniques are needed to preserve the properties of the lint to enable mills to produce world-class quality textile products.

DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA, an equal opportunity employer.

REFERENCES

Anthony, W.S., W.R. Meredith, and J.R. Williford. 1988. Neps in ginned lint: The effects of varieties, harvesting and ginning practices. Text. Res. J. 58(11):633–640.

Artzt, P., G. Steinbach, and C. Stix. 1992. Influence of fiber fineness and fiber length on processing performance and quality in the air jet spinning of polyester/cotton yarns. Int. Textile Bull. Yarn Forming 92(2):5–14.

Cotton Incorporated. 2016. Cotton fiber management [Online]. Available online at http://www.cottoninc.com/fiber/quality/Fiber-Management/ (verified 4 October 2017).

Furter, R. 2006. Uster Quantum 2 Application Report: Experience with foreign matter removal systems for cotton. Uster Tech., Uster, Switzerland.

Hequet, E.F., and N. Abidi. 2006. Sticky Cotton: Measurements and Fiber Processing. Texas Tech Univ. Press, Lubbock, TX.

International Textile Manufacturers Federation. 2014. International Cotton Industry Statistics (Vol. 57). International Textile Manufacturers Federation, Zurich, Switzerland.

Knowlton, J.L. 2014. Progress Report on Leaf Grade by Instrument. Intl. Textile Manufacturers Federation, Zurich, Switzerland.

Lewis, D.M., and X. Lei. 1989. Improved cellulose dyeability by chemical modification of the fiber. Textile Chemist Colorist. 21(10):23–29.

Louis, G.L. 1983. Some factors affecting open-end-spun cotton yarns. Textile Res. J. 51(10):674–678.

Luitel, K.P., D. Hudson, and D. Ethridge. 2015. Evaluating cotton utilization in nonwoven textiles. J. Cotton Sci. 19:298–306.

Ramey, H.H., R. Lawson, and S. Worley. 1977. Relationship of cotton fiber properties to yarn tenacity. Textile Res. J. 47(10):685–691.

United States Department of Agriculture-Economic Research Service [USDA-ERS]. 2015. Cotton and Wool Yearbook. USDA Economic Research Service, Washington, D.C..

van der Sluijs, M.H., and M. Freijah. 2016. A preliminary investigation into the removal of plastic wrap during ginning and textile processing. p. 885 *In* Proc. Beltwide Cotton Conf., New Orleans, LA. 5-7 Jan. 2016. Natl. Cotton Counc. Am., Memphis, TN.