Quality control and quality assurance in the apparel industry

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16.1 Introduction

Quality control and quality assurance are complex areas of the apparel industry. First off, quality assurance is not quality control, but quality control is an aspect of quality assurance. Quality assurance is the "process of designing, producing, evaluating, and assessing products to determine that they meet the desired quality level for a company's target market" (Kadolph, 2007, p. 6). Quality assurance looks at a product from the first design concept until it is sold to the consumer. Quality control is generally understood as assessing for quality after products have already been manufactured and sorted into acceptable and unacceptable categories. It is costly for companies that do not take a quality assurance method, but only look at quality in terms of quality control. Quality is a multifaceted concept that describes how well a service, process, material, or product possesses desired intangible or physical attributes (Kadolph, 2007).

Several organizations have created standards and specifications to help in assessing consistent quality. Major organizations include the American Association of Textile Chemists and Colorists (AATCC) and the American Society for Testing and Materials (ASTM). These organizations account for the majority of test methods written for the apparel industry. Other organizations include the American Society for Quality (ASQ), American Apparel and Footwear Association (AAFA), Textile Clothing and Technology Corporation (TC^2), American National Standards Institute (ANSI), and the International Organization for Standardization (ISO). These organizations publish industry-wide standards or "commonly agreed on aid for communication and trade; a set of characteristics or procedures that provide a basis for resource and production decisions; a product that meets all specifications and company or product requirements" (Kadolph, 2007, p. 551). These written standards assess fabrics and apparel products usually in terms of characteristics such as pilling, frosting, or color transfer. Individual companies write their own specifications or "a precise statement of a set of requirements to be satisfied by a material, product, system, or service that indicates the procedures for determining whether each of the requirements are satisfied" based on their target market's expectations (Kadolph, 2007, p. 550).

Garment Manufacturing Technology. http://dx.doi.org/10.1016/B978-1-78242-232-7.00016-3

16.2 Quality control in the apparel industry

16.2.1 Preproduction quality control

In preproduction quality control, each component of a garment is tested prior to assembling. Fabric is assessed for major and minor defects as described in Chapter 5. Closures, interlinings, sewing threads, and other design elements are tested for their quality and durability. Fabric with too many defects or closures that do not work properly can be detected prior to construction, which saves time and money in the long run. Fabric, accessories, closures, interlinings, sewing threads, and other design elements are all tested prior to the garment manufacturing in the preproduction quality control phase.

16.2.1.1 Fabric

Fabric quality is of utmost importance to the overall quality of apparel and textile products. Regardless of how well a product is designed or constructed, if the fabric is of poor quality, the product will most likely to fail with the consumer. Most fabric is comprised of fibres that are spun into yarns and then woven or knitted into fabric. Support materials like interlinings usually go from the fibre to the fabric stage. Since fibres are the building blocks of all apparel and textile products, it is important to start with quality fibres regardless if they are natural, manufactured, regenerated, or synthetic. The essential properties of fibre and yarn are beyond the scope of this book. The role of fabric properties in apparel manufacturing has been described in Chapter 3. In addition, various fabric faults and their inspection have been described in Chapter 5. In addition to the inspection parameters described in Chapter 5, fabric can also be assessed in terms of comfort, colorfastness, and durability as described below.

Comfort

Comfort describes “how materials interact with the body and addresses how the body’s functional environment can be expanded” (Kadolph, 2007, p. 187). Comfort is studied by looking at fabric in terms of elongation and elasticity, heat retention and conduction, moisture absorbency, water repellency, waterproofing, hand and skin contact, drape, and air permeability (Nayak et al., 2009). Elongation is the fabric’s ability to stretch without recovery, whereas elasticity is the fabric’s ability to stretch and recover to its original dimension without distortion. Heat retention and conduction of a fabric addresses the way the body reacts to heat. Moisture absorbency is the ability of a fabric to absorb liquid water. Water repellency is a fabric’s ability to repel water or other liquids upon initial wetting. This is usually accomplished with a combination of densely woven material and a water-repellent finish. Water will soak through the fabric with extended time and pressure of water. Waterproofing, on the other hand, is a fabric that will not allow water to penetrate through it no matter how much exposure to water, duration, and pressure used. Water repellent and waterproof fabrics are often seen as uncomfortable due to their stiffness and inability to breathe. Hand and skin contact is the way a fabric feels to the touch. Drape is how well a fabric hangs over a body or object. Fabrics with more drapes bend easily around objects and are often seen as more comfortable because the fabric moves with the body. Fabrics with less drape are stiffer and hang away from the body.

Colorfastness

Colorfastness relates to appearance retention and can be described as "how consumers use textile products and includes factors that may cause colorants to change color or migrate from one material to another" (Kadolph, 2007, p. 266). Colorfastness is studied by exposing the fabric to different conditions including acids and alkalis, crocking, environmental conditions, frosting, heat, light, perspiration, or water. Depending on what condition the material is exposed to, colorfastness is analyzed using one of three different approaches: color change, color transfer, or a combination of both change and transfer.

Various dye classes can be susceptible to acids and alkalis in terms of color loss. Crocking is when color from one surface is transferred to another by rubbing. Frosting is color loss on the surface of the fabric and is evaluated by looking at color loss. Frosting can be looked at in combination with abrasion resistant tests or tested on its own. Some dye classes are sensitive to color change when exposed to heat and different light sources. Tests for perspiration and water can be performed together. Fabric samples are soaked in an artificial perspiration and distilled water and placed into the AATCC perspiration tester with swatches of multifibre test fabric.

Durability

Durability evaluates "how various materials used in a product perform when subjected to different conditions" (Kadolph, 2007, p. 152). Durability of a fabric is tested until it fails, and both warp and weft yarns are tested. There are many ways to assess fabric durability, including strength (tensile, tear, and bursting), abrasion, pilling, snagging, and dimensional stability (Nayak and Padhye, 2014). Tensile, tearing, and bursting strength looks at the amount of force used in order for the fabric to rupture. Tensile strength, also known as breaking force, tests for durability when a fabric is placed under tension. The yarns in a fabric (warp or weft), are put under force and stretched (elongation) until they can no longer stretch and then rupture or break. Tearing strength is the force needed to continue a tear that has already been created in a fabric, which is essential for loose-fitting garments. Bursting strength looks at both the warp and weft yarns simultaneously as a diaphragm is inflated under the fabric or a large ball is forced through the fabric.

Abrasion is a progressive loss of fabric caused by rubbing against another surface. It has also been reported to occur through molecular adhesion between surfaces which may remove material. The hard abradant may also plough into the softer fibre surface. The breakage of fibres has been reported to be the most important mechanism causing abrasion damage in fabrics. Abrasion can be of three types: flat or plane, edge, and flex. In flat abrasion, a flat part of the material is abraded, edge abrasion occurs at collars and folds, and flex abrasion rubbing is accompanied by flexing and bending. Abrasion is a series of repeated applications of stress. The selection of suitable yarn and fabric structure can therefore provide high abrasion resistance. Abrasion resistance is the ability of fabric to withstand destruction when a fabric rubs against a surface or other textiles, as when wearing layers or during the cleaning process. Pile retention is a fabric's ability to retain its pile during abrasion. Pile fabrics such as terrycloth and corduroy are susceptible to losing their three-dimensional form when rubbed against another surface as part of the fabric is raised and more exposed to abrasion.

Pilling resistance is the ability for a fabric to withstand forming pills. Pilling is a common problem with apparel products prepared from synthetic fibres. Pills are tiny balls of entangled fibres that stay on the fabric surface. Both woven and knitted fabrics are prone to pilling. The propensity may be related to the type of fibre used in the fabric, the type and structure of the yarn, and the fabric construction. Generally, pills are formed in areas which are especially abraded or rubbed during wear and can be accentuated by laundering and dry-cleaning. The rubbing action causes loose fibres to develop into small spherical bundles anchored to the fabric by few unbroken fibres.

Snagging occurs when yarns are pulled from the surface of the fabric. This is usually a problem with fabrics with longer floats like in satin fabrics or in larger knits, knits with multiple colors, or open-work and lacey knits. Only the appearance of a garment is changed by snagging and its other properties are not affected. Snagging is observed particularly in filament-type fabrics and in extreme cases, a single blemish may render an article unserviceable even though unsightly ladders do not necessarily ensue. Soft twisted yarn and loose fabric structure are prone to snagging which may rupture the yarn and ruin the fabric. Woven fabrics with long floats and fabrics made from bulked continuous filament yarns are susceptible to snagging. Frosting is often a side issue when testing for abrasion resistance. Frosting is the white or discolored areas on a fabric before a hole usually appears. With frosting, the dye of yarns is rubbed off, exposing the insides of a yarn in yarn or fabric/piece-dyed fabrics.

16.2.1.2 Inspection of other accessories

Apparel accessories are inspected in the same manner as other textile and apparel products. Accessories are checked during preproduction, production, and post-production with a final inspection. Various fashion accessories include closures, interlinings, sewing threads, elastic waistband, and other design elements. These accessories should be able to withstand the care and maintenance procedures devised for the clothing (Nayak and Padhye, 2014). The selection criteria for various accessories are described in Chapter 6. A brief inspection procedure for the accessories is described in the following section.

Closures

Closure strength and durability is extremely important to garment construction and consumer satisfaction. Closures for apparel and textiles products include zippers, buttons, hooks, snap fasteners, drawstrings, hook-and-loop fasteners, and others. Zippers are tested for cross-wise strength of the zipper chain, the holding strength of zipper stop to prevent the slide from coming off, and the gripping strength of the zipper around the teeth. Zippers are also assessed in terms of teeth strength to prevent pulling apart while zipped, prevention of twisting or rippling of the zipper tape, and the zipper's resistance to crushing or breaking. Zippers should be inspected for correct dimensions (i.e., tape width and overall length) and other manufacturing defects (color uniformity of tape, securely locking by slider, smooth slider movement, securely attached top and bottom stops, proper attachment of pull tab with the slider, etc.).

Zippers often fail in the garment as a result of human error during their use, due to: (1) improper attachment during sewing, (2) wrong combination of zipper and garment type, (3) inappropriate garment design, and (4) wrong use by the customer. Zippers may show various problems such as ratcheting, shear, crushed slider, puckering at the attachment, humped and popped zipper, after they are attached to the clothing. Ratcheting (forcibly pulling the slider down the chain by holding the two zipper halves) and shear (relative shifting of one half with respect to the other, with the slider mounted) are the major use related errors, which can permanently damage the zipper. Zippers should be inspected in accordance with the ASTM standards (D 2061, D 2062, D 2057, D 2059, etc.). Buttons are tested for their ability to stay in their buttonhole and impact resistance against creaking, chipping, or breaking during sudden external force. Hook-and-eye or snap fasteners are tested for the amount of force needed to separate the hook and eye or snaps from each other or to tear from the fabric. Hook-and-loop fasteners (also known by the trademark name Velcro) are tested similarly to snap fasteners and measured for the amount of force needed to peel the fasteners apart. Hook-and-loop fasteners are also assessed for the amount of force needed to shift each side of the strip while connected, known as shear strength.

Interlinings

Interlinings, also called interfacing, are generally nonwoven fabrics that add more structure and body to garment components like collars, button plackets, waistbands, and cuffs. Interlinings may be fusible or sew-on. Interlining durability is important for garment construction. Fusible interfacing can become unglued from fabric and shift, creating rippling, puckering, and unevenness. Hence, the fusible interfacing should be tested for their performance for defects such as cracking, bubbling, and delamination during their regular use. Fusible interfacings are susceptible to the adhesive bleeding through causing darker spots on the surface called strike-through. Fusible interlinings are assessed for their ability to stay bonded to the fashion fabric and not shift during wear and cleaning. They are also tested for compatibility and shrinkage. Compatibility indicates good drapability, bulk, and support of the fabric at the attachment point. Shrinkage can cause puckering of the attached point and bubbled appearance. The three parameters such as temperature, pressure, and time should be appropriately selected to avoid improper interlining attachment.

Sewing threads

Sewing thread is the yarn used to combine two or more fabric pieces together in garments, accessories, and other textile products. Thread may be comprised of the same construction and fibre content as the garment, but is often different. Thread encompasses the majority of the stress and strain from movement and needs to be strong and durable. It must resist breaking and be compatible with the rest of the garment in terms of color, care instructions, and construction. Major quality checks for sewing threads include construction (diameter and fineness), strength and elongation, shrinkage, twist, twist balance, and color. The other parameters include sewability (Nayak et al., 2010), imperfections, finish, package density, and winding. Sewability is tested by sewing the thread in the intended fabric at the highest machine speed. The sewn fabric should consist uniform and consistent stitches, which indicates good sewability. Sewing thread should be free from imperfections such as knots, slubs, thick and thin places.

Elastic waistband

Elastic waistbands are tested for fit (as per size) and durability (loss of elasticity). The fit is measured by the force needed to stretch the waistband about 2″ more than the hip size (as per the size label) and bringing back to the waist size. The force can be measured by a tensile testing machine, which simulates the condition that exists while putting the garment. The durability can be measured by stretching the waistband by 50% and measuring the force needed to stretch it. Then the waistband is laundered 3 times as per a specific standard and again the force is measured to stretch it by 50%. The loss of force in the two cases should be less than 10% for the waistband to be acceptable. If it exceeds 10%, the elastic waistband will be loose due to the loss of elasticity. Alternatively, the durability can be measured by accelerated aging method. The elastic waistband, with marks 10″ apart is subjected to high temperature (150 °C) for 2 h, followed by cooling to room temperature. The waistband is stretched by 50% and kept stretched for 24 h by a tensile testing machine. Then it is relaxed for 10 min and the distance between the 10″ marks is measured and the percentage change in the size is calculated. A growth of 8% or higher is not acceptable, whereas any shrinkage is not acceptable as it will cause tighter fit.

Other design elements

Other design elements include beads, sequins, braids, and fringes. They are tested for quality in similar ways as closures. Beads are similar to buttons and are tested for their impact resistance against creaking, chipping, or breaking during sudden external force. Sequins are assessed for their strength and resistance to breaking or tearing. Braids and fringes are checked for their quality in terms of durability from fraying, unraveling, tearing, and ripping.

16.2.2 Quality control during production

Each step in the production process is vital to the overall quality of apparel products. The production of apparel products includes cutting, assembling, pressing and other finishing procedures, and final inspection. Pattern pieces need to be cut with precision and on grain. Cut pattern pieces should be assembled with accuracy and care. Assembled garments are finished and pressed. Poor attention to detail, or carelessness when sewing, could have the domino effect on other components or future assembling. For example, skewed fabric pieces will not fit together easily and sewing is difficult. Poorly sewn garments have popped stitches and loose seams. Poorly pressed garments will not lie on the body correctly and could have permanent wrinkles. The following section describes the quality control of apparels during various production processes.

16.2.2.1 Spreading and cutting defects

Proper care should be taken to avoid any mistakes during spreading, otherwise, it will result in improperly cut components. The major parameters such as ply alignment, ply tension, bowing, and splicing should be done with a great care. Not enough plies to cover the quantity of garment components required should also be taken care. Misaligned plies will result in garment parts getting cut with bits missing in some plies at the edge of the spread. Narrow fabric causes garment parts at the edge of the lay getting cut with bits missing. Incorrect tension of plies, i.e., fabric spread too tight or too loose, will result in parts not fitting in sewing, and finished garments not meeting size tolerances. Not all plies facing in correct direction (whether "one way" as with nap, or "either way" as with some check designs), may create in pattern misalignment or mismatch. This happens when the fabric is not spread face down, face up, or face to face as required.

Garment parts not fully included owing to splicing errors, should be dealt carefully. Spread distorted by the attraction or repulsion of plies caused by excessive static electricity, can result in mismatching checks or stripes. The patterns should be aligned with respect to the fabric grain, or else may not fit or drape properly. Insufficient knife clearance space; mismatching of checks and stripes; missing notches and drill marks; poor line definitions; mixing of wrong-sized components; and too wide markers; are some of the mistakes that should be avoided during spreading.

Cutting is an important phase of the production process. Yards of fabric are laid flat in multiple layers and the marker arranged on top. Precision is needed to cut accurate pieces that will fit together during the assembly process. Cutting defects include frayed edges; fuzzy, ragged, or serrated edges; ply-to-ply fusion; single-edge fusion; pattern imprecision; inappropriate notches; and inappropriate drilling (Mehta, 1992). Frayed edges, fuzzy or serrated edges, scorched or fused edges, are caused by a faulty knife, not sharp enough knife, or knife working at too high a speed. Garment parts are damaged by careless use of knife, perhaps overrunning cutting previous piece. Failure to follow the marker lines results in distorted garment patterns. Top and bottom plies can be of different sizes if the straight knife is allowed to lean, or if a round knife is used on too high spreads. Marker incorrectly positioned on top of the spread can lead to garment parts having bits missing at the edge of a lay. If too tight or too loose, then garment parts are distorted. Notches, which are misplaced, too deep, too shallow, angled, omitted, or wrong type to suit fabric are notch faults. Drill marks, which are misplaced, wrong drill to suit fabric, omitted, not perpendicular through the spread are drilling faults.

16.2.2.2 Defects in assembling

After the pattern pieces have been cut, they are assembled. Many issues and defects can arise during the sewing process. Defects in assembling include defects with both stitches and seams. Possible stitching defects include needle damage, feed damage, skipped stitches, broken stitches, wrong or uneven stitch density, balloon stitches, broken threads, clogged stitches, hangnail, and improperly formed stitches. Possible seam defects include seam grin, seam pucker, incorrect or uneven width, irregular or incorrect shape, insecure back-stitching, twisted seam, mismatched seam, extra material caught in seam, reversed garment part, wrong seam type used, slipping seam, and wrong thread used (Mehta, 1992).

Various types of stitch and seam defects are discussed below:

Needle damage causes the fabric to be damaged by the wrong type or size of the needle during sewing. Feed damage is caused by inappropriate feed system, excessive pressure by foot, higher machine speed, damaged throat plate, and misalignment of feed and foot. Skipped stitches are caused when the sewing thread partially skips and stitching is not performed completely. Broken stitches are caused by the selection of wrong stitch type, too tight thread tension, excessive pressure and machine speed. Uneven stitch density arises when stitching is not performed straight and the machine is not controlled properly. Balloon stitches occur when large or small thread loop projects from the surface of the fabric (face or back) at the knotting point of the thread. Threads can break during sewing due to wrong thread size, needle heat, excessive tension, improper combination of thread and needle, etc. Clogged stitches are caused due to resistive force applied to the garment components during sewing such that there is less feed than the normal. Hangnail arises when several parts of the sewing thread are cut during sewing. Improperly formed stitches can be caused by wrong tension, lack of sewing machine maintenance, and improper machine timings.

Seam grin is the defect when stitch opens due to insufficient sewing thread tension. Seam pucker is the distorted appearance of the sewn garment near the stitches and there are various causes for this. Uneven seam width and incorrect shape (runoffs) are caused by wrongly set guide or improper material handling by the operator. Insecure backstitching arises as subsequent rows of stitch do not cover the first row. Twisted seam is caused by improper fabric alignment, mismatching of notches, and when one fabric ply creeps over the other. Mismatched seam is the problem where transverse seams do not match. Many foreign materials can be caught in the seam; the fabric components may be not positioned in correct side facing up/down, leading to poor appearance. Slipping seam is caused by the slippage of the upper and lower fabric with respect to each other.

In addition to the above faults, there may be other faults related to stitch and seam, such as the wrong type of seam or stitch selection, wrong shade of sewing thread selected, oil marks or stains in the fabric during sewing, blind stitching, which can arise during the production process. Some of the major sewing room problems and possible remedies are discussed in Chapter 12. Furthermore, there are several faults that can arise during the assembling, which are not related to the stitches and seams, some of these faults are discussed below:

Finished garment may not be in proper size due to incorrect patterns, inaccurate marking or cutting, shrinkage or stretch, etc. The garment components may not be symmetrical or wrong size; there may be shade variation due to mixing of batches; wrongly positioned or misaligned components due to incorrect marking or sewing not in the right direction. The accessories such as buttons, zippers are damaged during their attachment or attached inappropriately. Interlinings are positioned incorrectly, twisted, cockling, too tight, or too full; linings may be too tight, twisted, incorrectly pleated, projecting beyond the bottom of the garment, which can lead to fault in the final garment.

16.2.2.3 Defects during pressing and finishing

After garments are constructed, final preparations are completed. These final preparations include pressing garments to help set seams and finish garment shaping. Defects during pressing and finishing include burned garments, water spots, change in original color, flattened surface or nap, creases not correctly formed, fabric of finished garment not smooth, edges stretched or rippled, pockets not smooth, garment not correctly shaped, and shrinkage from moisture and heat (Mehta, 1992). Finishes might also be added during this phase of apparel production. Finishes can be temporary or permanent. Temporary finishes need to be reapplied and include starching and some waterproofing finishes. Permanent finishes change the chemical composition of the fibre, which cannot be changed back to its original form. An example of a permanent finish is mercerization on cotton. During the cleaning process, the effectiveness of finishes can be compromised and diminished.

16.2.3 Final inspection

After materials have been tested for quality and the products have been manufactured, products are tested for their performance requirements, overall appearance, and sizing and fit. Proper sizing and fit can be measured as per the size of the garment or they can be tested by putting the garments in manikins or even live models. They are also checked visually for any faults during the production process. Hence, the quality of stitching, joining of garment components and accessories are inspected. Although each component of a garment is tested individually, in preproduction quality control, products are tested for a final time to assess the compatibility of materials used together and any noticeable fault. Garments are inspected for off-grain fabric, poor or uneven stitching, mismatched plaids or stripes along seams, puckered or extra material caught in seams, and uneven seams along hems, among many other problems that can occur in the apparel industry.

During inspection, some parts of a product are more important than others in terms of allowable defects. Each company defines its own product zones and includes these in their specifications as there is no industry standard. The highest priority zone (could be identified as Zone 1, Zone A, or Zone I) is usually identified as the area that will most likely been seen during a face-to-face conversation, whereas the inside of a garment is not as critical in terms of acceptable defects. Companies will also define what they deem as critical, major, and minor defects. A critical defect results in a flaw that produces an unsafe or hazardous situation like a hole in a latex glove that would compromise the safety of the wearer. A major defect is a flaw that often contributes to product failure or lack of usability for a product. Examples of a major defect could be a broken zipper, broken stitches, or tears in the fabric. A minor defect is a flaw that does not reduce the usability of a product, but still deviates from standards and specifications. Examples of minor defects could be an unclipped thread, untrimmed seam allowance, or slubbed yarns in the fabric.

16.2.3.1 Material interactions

Products are tested for their material interactions or "the way in which materials that are combined in a product act and react when their performance is influenced by the presence of another material" (Kadolph, 2007, p. 384). Even simple textile products, like tablecloths, are comprised of at least two materials: fabric and thread. The way those materials interact with each other is important to the manufacturer and the consumer. Threads can shrink, causing the hem of the tablecloth to scallop. Product performance may increase, stay the same, or decrease based on the material interactions. Material interactions include fabric combinations, thread, closures, and trims. Many of the 1 garments include closures like buttons and zippers.

In many apparel products, more than one fabric is used in the construction of a garment. Collars, cuffs, and button plackets incorporate fusible interfacing for stability; vinyl for chair cushions might have attached foam for comfort; and outdoor gear might have a laminate covering for waterproofing. These fabrics or materials might be successful on their own, but when combined with each other they should be compatible and should not, cause buckling or rippling of the component.

16.2.3.2 Process–material interactions

Process–material interactions are "the effect of a production process on the performance of a material and its effects on the performance of the finished product" (Kadolph, 2007, p. 545). The processes include sewing, fusing, and finishing processes. Many issues can arise when combining both fabric and thread in a garment. Both fabric and thread need to be compatible for optimal process performance; the conditions of the workroom could also be out of balance, and the equipment could not be in ideal working condition or not suited for the material. Many issues can arise when sewing garment pieces including buckling (a tuck in the seam when two fabrics of different lengths are sewn together), yarn distortion, seam grin (individual stitches can be seen in the seam), and seam slippage (incorrect thread and seam type are used for the fabric and yarns start to pull from the seam), among other issues. Issues of fusing occur when inappropriate fusible interfacing, in terms of thickness or permanence of adhesive, is used or is not fused properly. Improperly fused interfacing can cause ridging in components or the adhesive can bleed through to the face of a product, causing unsightly spots. These issues cannot generally be repaired on the consumer side.

16.2.3.3 User–production interactions

User–production interactions are "an examination of the ways in which product and user interact and influence consumer satisfaction with the product" (Kadolph, 2007, p. 555). Products that are finished are used to test these interactions. This includes the design of the product, function, appearance, size or dimension, fit, construction, and packaging. Whole products are inspected for their overall design and whether or not they meet the specified criteria set forth by the company. Seams are checked for overall smoothness, and design motifs, like stripes and plaids, are checked for matching along seams. Products are tested for their function, to see if they are performing the way they are intended to perform. Consumers can participate in wear studies at this point to assess products for their mobility and dexterity. The appearance of a product is assessed visually at what would be considered a conversational distance. The outside and the inside of a garment are examined for conformance to company standards and specifications.

Sizing is not standardized in the apparel industry, but is one of the main concerns for consumers and the manufacturers. Several products that are stated to be the same size are compared in each area of the important dimensions (chest, waist, sleeve length, etc.) for conformance to a company's stated size requirements. Fit is related to size, but the same garment can fit differently on different body types. Live models or mannequins are used to see how the same garment fits on different shapes.

Products are evaluated for their construction during the manufacturing process. Seams are viewed for their integrity and appropriateness for the garment. Packaging is one of the last criteria to be checked. Garments are checked for their adherence to number of items per box, that hang tags are correct and attached in the correct spot, and fibre and care labels are correct and affixed in the correct spot.

16.2.3.4 General requirements for final inspection

The following points should be taken care for the final inspection.

- Work area must be well lighted and the measuring table should be large enough to hold the entire garment spread out flat and buttoned.
- Use a soft fibreglass ruler or a metal ruler that has been calibrated against a rigid steel ruler.
- Cuts should be stored in the auditing storage area to facilitate the access of the boxes for the auditor.
- Sample boxes must be randomly obtained. Cuts that are only partially boxed are not ready for the final statistical audit and should not be audited until all boxes are complete. Samples must be randomly obtained from finished sealed boxes.
- Final Statistical Audits are done following a 4.0 AQL (Acceptable quality level).
- Auditors should establish a routine for inspecting garments in order to eliminate the possibility of overlooking an operation.
- The auditor must be aware of the specifications of the garment.
- Round measurements are made to the nearest 1/8th unless specifications require that it is taken to the 1/16th.
- All operations must be checked in the final audit. Also, tacks, shading, long threads, raw edges, skip stitches, and other defects must be checked.
- Garments with major defects are to be marked by colored tape and set aside for repair.
- Detailed records should be recorded and major defects must be properly recorded with their code.
- Cuts that have not passed a final audit or that have only been partially audited should not be loaded on the truck.
- After inspection, the remainder of the garments in the box must be counted and checked for size. The label on the exterior of the box must reflect what is inside the box.

- Garments that have passed the inspection must be returned to the box in the same manner that they were in when they were taken out. All repairs should be set aside and marked.
- Detailed records of any defects must be recorded.

As an example, general final inspection procedure for a pant and a shirt is discussed below.

Pant inspection procedure

- Lay garment face up and visually check the front for shading, fabric defects, and soil.
- Measure the waist with a metal or fibreglass ruler. Check that the measurement of the waist is the same as the size on the label.
- Check that pockets are functional and have no shaded pieces, missing tacks, and are overall correct.
- Check the placement of the button and that it lines up with the hole. Button and unbutton the garment to ensure that there are no problems with function.
- Check the zipper making sure it is properly placed, the right length and that it is functional (must zip and unzip smoothly).
- Check that the crotch has the correct tacks and no "dog ears". A slight pull should be administered to the crotch area to ensure that all the seams are secure.
- Measure the inseam and verify that it is the same as the size label. Also, measure the inseam to ensure that both legs are the same length.
- Flip garment over and visually inspect the back for shading, fabric defects, and soil.
- Check that the back pockets are properly aligned, have tacks, and are not too open (exposing the inside of the pocket).
- Compare the sobar in the back pocket to the paper ticket and the woven size label to be sure that the garment is correctly labeled.
- Check belt loops for correct size, attachment, and alignment.
- Ensure that the label is properly placed and aligned correctly.
- Turn the pants inside out and inspect all seams and operations.
- Then turn the garment outside in and rebutton, zip, and fold the garment.

Shirt inspection procedure

- Visually inspect the front of the garment for any defect.
- Check that the two sides of the shirt are the same length and evenly meet at the bottom.
- Check that all buttons line up with their button holes and are properly placed. (Also, make sure that the number of buttons is correct and that all of them are securely attached to the garment.)
- Buttons should be checked for function (button and unbutton to ensure that no button holes are too small).
- When checking short-sleeve garments, both arm holes must be checked for size.
- Pockets must be checked for shading, tacks, and placement. Crooked or uneven pockets are unacceptable. Pockets of a patterned fabric must line up according to the print. (A pocket set even slightly off can be very apparent when using a patterned fabric.)
- Garments must be turned inside out and all seams must be checked.
- Three garments of every size must be measured. (Bust, sweep, collar, yoke, cuff, arm hole, natural shoulder, and pockets must all be measured and compared to the specifications of the garment.

Lot failure

If a lot fails, then a 100% inspection must be done. First, 20% must be inspected and those results should be combined with the failure results. If the lot still fails, then continue to inspect 100%.

16.2.4 Developing a sampling plan

Although quality has been incorporated into each product up to this point, products are selected for audits and sorted into acceptable or unacceptable categories prior to shipment to their final destination. There are many types of samples including random, representative, convenience, stratified, constant percentage, and systematic samples. A random sample is where every item has an equal chance of being selected. A representative sample includes a planned variation of items in a ratio that is appropriate. A convenience sample is made up of items that are easier to inspect over others and not random. A stratified sample is selecting a sample when a large lot of similar items exist. A constant percentage sample is sampling with a known constant percentage regardless of lot size to determine the sampling size. A systematic sample consists of items from equal intervals of time or the same location (Kadolph, 2007).

Types of sampling plans include lot-by-lot sampling, lot-by-lot sampling by attribute, skip-lot sampling, continuous production sampling, and arbitrary sampling.

16.2.4.1 Lot-by-lot sampling

A lot-by-lot sampling is the case where samples are taken from each production lot. A lot-by-lot sample by attribute is similar to a lot-by-lot sampling plan, but items are inspected according to their attributes. A single sampling plan occurs when the total size of the sample used, and the total number of sample products inspected, is equal. A double or multiple sampling plan extends the sampling to more products when the first sampling plan barely meet the acceptance levels (Kadolph, 2007).

16.2.4.2 Skip-lot sampling

A skip-lot sampling is where some production lots may not be represented. The number of items sampled is decreased. Skip-lot sampling is used in the apparel industry for factories that produce basic goods or consistently high-quality goods (Kadolph, 2007).

16.2.4.3 Continuous production sampling

A continuous production sample is for products that are staple items and stay consistent for extended periods of time. This practice is common for basic apparel items like pantyhose, where the production line does not stop for long periods of time (Kadolph, 2007).

16.2.4.4 Arbitrary sampling

If a company does not employ a 100% inspection plan, arbitrary sampling is used. With arbitrary sampling, companies determine a set percentage to sample and do not inspect the whole production lot. The most common percentage amount used in arbitrary sampling is 10%. Arbitrary sampling is not always the most sound sampling plan in the apparel industry as sometimes 10% inspection is too small a sample size or too large a sample size based on the production lot (Mehta, 1992). Statistical sampling represents a better sampling plan in the apparel and textile industries.

16.2.4.5 Statistical sampling

Statistical sampling indicates “selecting a sample of units from a lot or shipment of material or product, inspecting the sample for defects, and making a decision as to whether the lot is acceptable or not based on the quantity of the sample” (Mehta, 1992, p. 56). Conducting statistical sampling is often the best choice of sampling plan in the apparel industry by representing the whole of the production lot relatively well.

Associated with statistical sampling of apparels, acceptance quality level (AQL) is the “minimal standard for a satisfactory process or product average” (Kadolph, 2007, p. 434). The detailed information on AQL can be found in the Military Standard 105 (MIL-STD-105). This standard is widely used for acceptance sampling around the world and the corresponding international standard is ISO 2859. Since 100% inspection is not conducted, AQL inevitably allows some defective products through the inspection process, but calculates the maximum number of defective products in a lot before the production lot is rejected. AQL depends on percentage defective or defects per 100 units. Percentage defective is used in the apparel industry for simply made products, components, and materials. It is calculated by taking the number of defective products, multiplying by 100 and dividing by the number of units inspected. Defects per 100 units is a more exact way to find acceptable production lots. Defects per 100 units is calculated by taking the total number of defects, multiplying by 100 and dividing by the number of units inspected (Kadolph, 2007).

Three groups of sampling plans are mentioned in MIL-STD-105 such as single, double, and multiple sampling plans. This chapter will deal with single sampling plan and double sampling plan only as they are generally used for apparel inspection rather than the multiple sampling plan. Although there are three tables in MIL-STD-105 standard, only two tables will be discussed for the sake of simplicity for apparel inspection. The table used to find the code letter for a lot size, is not discussed here. However, the corresponding lot sizes are mentioned in these two tables, Tables 16.1 and 16.2, which describe the single sampling plan and double sampling plan, respectively, for general inspection levels. These tables also indicate the number of samples to be inspected and the number for acceptance or rejection of a lot. Generally, for clothing items 1.5%, 2.5%, 4.0%, 6.5%, and 10% AQL values are used depending on the type and price of the clothing. The following examples will explain the method of using the AQL table.

Table 16.1 Master table for normal inspection (single sampling)

Lot size	Inspect (sample size)	← AQL (normal inspection) →				
		1.5	**2.5**	**4.0**	**6.5**	**10**
		Accept/Reject	**Accept/Reject**	**Accept/Reject**	**Accept/Reject**	**Accept/Reject**
2–8	2	↓	↓	↓	0/1	↓
9–15	3	↓	↓	0/1	↑	↓
16–25	5	↓	0/1	↑	↓	1/2
26–50	8	0/1	↑	↓	1/2	2/3
51–90	13	↑	↓	1/2	2/3	3/4
91–150	20	↓	1/2	2/3	3/4	5/6
151–280	32	1/2	2/3	3/4	5/6	7/8
281–500	50	2/3	3/4	5/6	7/8	10/11
501–1200	80	3/4	5/6	7/8	10/11	14/15
1201–3200	125	5/6	7/8	10/11	14/15	21/22
3201–10,000	200	7/8	10/11	14/15	21/22	↑
10,001–35,000	315	10/11	14/15	21/22	↑	↑
35,001–150,000	500	14/15	21/22	↑	↑	↑
150,001–500,000	800	21/22	↑	↑	↑	↑
500,001 and Over	1250	↑	↑	↑	↑	↑

↓ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100% inspection. ↑ = Use first sampling plan above arrow. Accept/Reject indicates the numbers for acceptance/rejection, respectively. This table is a part of the Military Standard MIL-STD-105 for garment inspection only. The full table can be viewed in the original standard.
Source: MIL-STD-105E/ BS 6001/ DIN 40080/ ISO 2859.

Table 16.2 **Master table for normal inspection (double sampling)**

Lot size	Sample	Sample size	Cumulative sample size	← AQL (normal inspection) →				
				1.5	2.5	4.0	6.5	10
				Accept/ Reject	Accept/ Reject	Accept/ Reject	Accept/ Reject	Accept/ Reject
2–8				↓	↓	↓	•	↓
9–15	First	2	2	↓	↓	•	↑	↓
	Second	2	4					
16–25	First	3	3	↓	•	↑	↓	0/2
	Second	3	6					1/2
26–50	First	5	5	•	↑	↓	0/2	0/3
	Second	5	10				1/2	3/4
51–90	First	8	8	↑	↓	0/2	0/3	1/4
	Second	8	16			1/2	3/4	4/5
91–150	First	13	13	↓	0/2	0/3	1/4	2/5
	Second	13	26		1/2	3/4	4/5	6/7
151–280	First	20	20	0/2	0/3	1/4	2/5	3/7
	Second	20	40	1/2	3/4	4/5	6/7	8/9
281–500	First	32	32	0/3	1/4	2/5	3/7	5/9
	Second	32	64	3/4	4/5	6/7	8/9	12/13

501−1200	First	50	50	1/4	2/5	3/7	5/9	7/11
	Second	50	100	4/5	6/7	8/9	12/13	18/19
1201−3200	First	80	80	2/5	3/7	5/9	7/11	11/16
	Second	80	160	6/7	8/9	12/13	18/19	26/27
3201−10,000	First	125	125	3/7	5/9	7/11	11/16	↑
	Second	125	250	8/9	12/13	18/19	26/27	
10,001−35,000	First	200	200	5/9	7/11	11/16	↑	↑
	Second	200	400	12/13	18/19	26/27		
35,001−150,000	First	315	315	7/11	11/16	↑	↑	↑
	Second	315	630	18/19	26/27			
150,001−500,000	First	500	500	11/16	↑	↑	↑	↑
	Second	500	1000	26/27				
500,001 and Over	First	800	800	↑	↑	↑	↑	↑
	Second	800	1600					

↓ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100% inspection. ↑ = Use first sampling plan above arrow. Accept/Reject indicates the numbers for acceptance/rejection, respectively. • = use corresponding single sampling plan (or alternatively, use double sampling plan below where available). This table is a part of the Military Standard MIL-STD-105 for garment inspection only. The full table can be viewed in the original standard.

Source: MIL-STD-105E/ BS 6001/ DIN 40080/ ISO 2859.

Example 1: In a single sampling if we need to inspect a lot size of 1500 garments, with an AQL of 6.5%, the following steps should be followed:

1. The number of samples to be inspected for a lot size of 1500 = 125 (Table 16.1)
2. The corresponding values at 6.5% AQL for Accept/Reject are 14/15. This indicates, if the number of defective garments is 14 or less, out of the 125 garments inspected, the whole lot (1500) should be accepted. If the number of defective garments is 15 or more out of the 125 garments inspected, the whole lot (1500) should be rejected.

Example 2: In a double sampling if we need to inspect a lot size of 1500 garments, with an AQL of 6.5%, the following steps should be followed:

1. The number of samples to be inspected for a lot size of 1500 = 80 (Table 16.2)
2. The corresponding values at 6.5% AQL for Accept/Reject are 7/11. This indicates, if the number of defective garments is seven or less out of the 80 garments inspected, the whole lot (1500) should be accepted. If the number of defective garments is 8, 9, or 10, take another sample of 80 garments for second inspection (which makes a total of 160 garments for inspection). The Accept/Reject values now for the second inspection are 18/19 (cumulative). This indicates, the total (cumulative) defective garments out of the 160 inspected should be 18 or less defective. If it is 19 or more, the lot is rejected.

16.2.5 Post-production quality evaluation

Post-production quality evaluation in the apparel industry includes wear testing for realistic reactions to everyday scenarios and testing with a simulation study when a consumer's reliability is in question. In wear testing, which is sometimes called product testing, companies provide a small group of consumers with products. Consumers are contracted to wear garments under certain stated guidelines and requirements in order to determine whether they meet the company's intended performance criteria. Consumers report back to the company and identify issues with the product before an entire production lot of garments are produced. Testing with a simulation study is similar to wear testing, but a consumer's safety might be in question. Companies would test items like helmets with a simulation prior to producing an entire production lot, or would test the effectiveness of nonskid shoes on wet surfaces. Appearance retention and care are other aspects of post-production quality evaluation.

16.2.5.1 Appearance retention

Appearance retention is "the degree to which a textile product retains its original appearance during storage, use, and care" (Kadolph, 2007, p. 526). Aspects of appearance retention include wrinkle recovery, storage, and resistance to insects, fungus and bacteria, aging, and dye transfer (Nayak and Padhye, 2014). Wrinkle recovery is a fabric's ability to recover from creases and fabric deformations created during storage and is different from durable press during care of a garment. In addition to wrinkle recovery during storage, products can be susceptible to insects, fungi, bacteria, aging, and dye transfer, which should also be taken care to retain the appearance.

16.2.5.2 Care

Care is "the procedure(s) recommended for returning a soiled item to its clean and as near to new condition as possible" (Kadolph, 2007, p. 529). Care is looked at in terms of home care and dry cleaning. Home care is assessed in terms of colorfastness, dimensional change, appearance retention during cleaning, and durability of finishes. Colorfastness is assessed by looking at both color loss and color transfer. Color loss occurs when dye molecules detach from the fabric; these might attach to another surface, which is called color transfer. Dimensional change is when a product shrinks or grows due to the laundering process. Products can shrink (or grow) in the lengthwise direction, in the cross-wise direction, or in both directions. Appearance retention during cleaning looks at how a product retains its original appearance during the cleaning process. Products abrade against each other or transfer dye between garments. The care labels in a garment describe the appropriate methods of washing or dry-cleaning and ironing to take care of it. The details of care labellings is described in Chapter 17.

16.3 Future trends

What an exciting time for the textile industry with new technologies always on the forefront of the marketplace. Current and future trends in quality control and quality assurance in the apparel industry include, but are not limited to, green or environmentally friendly textile testing, sustainability, and analyzing new horizons in nanotechnology textiles. The "green" movement, or practicing environmentally friendly methods, is not a new trend, but has gained momentum in the last several years. The apparel industry is one of the biggest culprits and promoters of this movement. The entire manufacturing systems from fibre to garment, in apparel production is not environmental friendly.

Traditionally in the textile and apparel industry, fabric inspection has been done by trained inspectors. With any process that is conducted primarily by humans, error is inevitable. Physically inspecting fabric can become tedious and is repetitive in nature, which causes eye fatigue. Textile companies are now installing machines that inspect fabric prior to shipment. With automated fabric inspection, 100% of the fabric is inspected. Although the initial cost is much greater than using skilled fabric inspectors, the cost is reduced as more fabric defects are identified prior to shipment and manufacturing. Widths of fabric are run through automated fabric-inspections machines that use light and cameras to look for fabric defects including slubbed yarns, color discrepancies, holes, etc. Complex algorithms are used to identify the number of defects in the fabric (Chan et al., 1998; Banumathi and Nasire, 2012).

Merriam-Webster (an on-line dictionary) defines sustainability as "able to be used without being completely used up or destroyed." Cotton Incorporation stated that the industry is replacing practices in order for denim jeans to be more environmentally friendly. These practices include replacing sodium hypochlorite with enzymes for bleaching, using laser etching to replace harsh chemicals for sanding and spraying, dry ice blasting in place of sand blasting, eliminating washing and abrading, digital printing on denim to create different effects, and energy audits in textile mills (Musante, 2013a).

Smart textiles or "e-textiles" incorporate electronics, lights, circuits, and other nontraditional components into fabrics and garments. For example, designers incorporate fibre-optic lights that make their clothing glow. New standards and specifications will have to be written to account for these new e-textiles. One major concern for these futuristic fibres is durability, specifically related to care. Another concern is whether the e-textile will detract from the overall appearance or hand of the garment (Musante, 2013b).

Safety "addresses the physical risks to which the user of a textile product is exposed" (Kadolph, 2007, p. 215). A major safety issue is flammability, which is mandatory to address for children's sleepwear, mattresses, and other products that might come into contact with a heat source like firefighter uniforms. Voluntary procedures include thermal protection, chemical resistance, and impact resistance. Chemical resistance would be important for people working in a factory, laboratory, or medical environment. Impact resistance would be used for safety gear such as helmets and knee or elbow pads. Health is the "interaction of physical, mental, emotional, and social aspects of an individual" (Kadolph, 2007, p. 223). Health issues include allergens and irritants, ultraviolet protection, and biological resistance. Ultraviolet protection is a new and emerging area of apparel where finishes are added to garments and provide a barrier from the sun's harmful rays similar to the effects of wearing sunscreen.

16.4 Conclusions

Quality assurance and quality control are the important, unique, and complex area of the textile, apparel, and accessories industries. Quality assurance is not quality control, but quality control is an aspect of quality assurance. Quality needs to be incorporated into every aspect of a product from the original design concept to the marketing and selling of a product. Many organizations, such as AATCC and ASTM, focus on setting standards for the industry. Individual companies look at those standards and set their own specifications based on their target market.

Quality is assessed in the apparel industry during preproduction, production, and post-production operations. In the preproduction phase, fabric, accessories, closures, interlinings, sewing threads, and other design elements are tested prior to the construction of garments. The production of apparel products includes cutting, assembling, pressing and other finishing procedures, and final inspection. At each step of the production phase, garments are assessed for quality. Companies develop various sampling plans to inspect products during the final inspection. Post-production quality evaluation includes wear testing and testing with a simulation.

Quality assurance and quality control are evolving in apparel industry with technological advances, similar to most other industries in the world. Fabric inspection is now an automated process, and can find defects in fabrics quicker, more accurately, and save money in the long run. Current and future trends in quality assurance and quality control in the apparel industry include, but are not limited to, green or environmentally friendly textile testing, sustainability, and analyzing new nanotechnology applications in textiles. Incorporating quality assurance into an apparel company program can improve product quality and aid in increasing customer satisfaction.

16.5 Sources of further information and advice

For further information on the topic of quality assurance and quality control in the apparel industry, consult the following materials:

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American Association of Textile Chemists and Colorists 2014. Available from: http://www.aatcc.org/ (14.07.14).

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