BOND STRENGTH, DIMESIONAL STABILITY, AND APPEARANCE OF FUSED FABRICS AFTER PROFESSIONAL CLEANING

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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BY

JANACE E. BUBONIA-CLARKE, B.S., M.A.

DENTON, TEXAS

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TEXAS WOMAN'S UNIVERSITY
DENTON, TEXAS

April 13, 1998
Date

To the Associate Vice President for Research and Dean of the Graduate School:

I am submitting herewith a dissertation written by Janace E. Bubonia-Clarke entitled "Bond strength, dimensional stability, and appearance of fused fabrics after professional cleaning." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Fashion and Textiles.

Charles Riggs, Ph.D., Major Professor

We have read this dissertation
And recommend its acceptance:

Accepted

Associate Vice President for Research
and Dean of the Graduate School.

ACKNOWLEDGMENTS

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BOND STRENGTH, DIMENSIONAL STABILITY, AND APPEARANCE OF FUSED FABRICS AFTER PROFESSIONAL CLEANING

Janace E. Bubonia-Clarke. Texas Woman's University. Denton, Texas. May 1998. Ph.D. Fashion and Textiles. Dr. Charles Riggs, Major Professor.

The purpose of the study was to determine whether twill-weave lyocell, twill-weave wool, and plain-weave mohair/wool blend fabrics, fused to appropriate nonwoven interlinings, would be compatible with wetcleaning technologies when tested for bond strength and dimensional stability, and evaluated for appearance. Data collected consisted of bond strength scores before cleaning, bond strength scores after five drycleanings, bond strength scores after five wetcleanings, dimensional stability of unfused shell fabrics after five drycleanings, dimensional stability of unfused shell fabrics after five wetcleanings, dimensional stability of fused shell fabrics after five drycleanings, dimensional stability of fused shell fabrics after five wetcleanings, appearance of fused shell fabrics after five drycleanings, and appearance of fused shell fabrics after five wetcleanings. Bond strength and dimensional stability data were examined with BMDP statistical programs. Appearance was evaluated through descriptive statistics. Significant differences were found for bond strength of lyocell, wool, and mohair/wool fused fabrics after drycleaning and after wetcleaning processes based on ASTM D test method 2724. Significant differences were found for dimensional stability of lyocell, wool, and mohair fused fabrics

after drycleaning and after wetcleaning based on ASTM test method D 2724. No changes in appearance were found for lyocell, wool, and mohair fused fabric after drycleaning and after wetcleaning processes based on AATCC test method 124. In conclusion, the lyocell unfused and lyocell fused fabric/interlining combinations were not acceptable for wetclean care methods when evaluated for bond strength, dimensional stability, and appearance. The unfused wool and wool fused fabric/interlining combinations were acceptable for wetclean care methods when evaluated for bond strength, dimensional stability, and appearance. The unfused mohair/wool and one of the mohair/wool fused fabric/interlining combinations were acceptable for wetclean care methods when tested for bond strength, dimensional stability, and appearance.

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CHAPTER I

INTRODUCTION

Due to environmental concerns of the Environmental Protection Agency (EPA) in regard to the use of perchloroethylene (perc) for drycleaning purposes, new wetcleaning technologies are being tested along with new systems for treating waste water and controlling the release of perc into the environment. According to Jehassi (1996), the " . . . EPA forged a voluntary partnership with the [drycleaning] industry to reduce exposure to dry cleaning solvents through safer work practices and alternative technologies" (p. 19). Researchers are investigating wetcleaning technologies, a method of controlled application of detergents and water, and alternative solvent-based cleaning such as carbon dioxide and ultrasonic technologies instead of petroleum or perc solvents (Jehassi, 1996).

Perc, also known as tetrachloroethylene ($Cl_2 C{=}CCl_2$), is a noncombustible, colorless, heavy toxic liquid (The International Technical Information Institute, 1975). As greater evidence concerning the negative health effects of exposure to the toxic chemical perc and strict regulation for handling and use increases, the apparel and textile industry is forced to seek alternative methods of cleaning.

Of the 36,000 dry cleaners in the United States ("Wet vs. Dry", 1993), perc is used by 90%, whereas the other 10% use petroleum-based solvents (EPA-Air and Radiation Division, 1996). These petroleum solvents are class III flammable products and have a lower

toxicity level than perc. Although perc has no flash point, "Vapor may decompose at high temperature[s] such as [an] open flame, [or] red-heated materials, with evolution of poisonous gases such as chlorine, carbon monoxide, [and] phosgene" (The International Technical Information Institute, 1975, p. 507). In concurrence to recent studies performed by the EPA and the National Institute for Occupational Safety and Health, perc is a suspected carcinogen and can cause damage to the central nervous and reproductive systems (EPA-Air and Radiation Division, 1996). According to the Pollution Prevention Education and Research Center at UCLA (1996), "Symptoms resulting from exposure to perc include headaches, dizziness, irritation of the skin, eyes, and respiratory tract, diminished cognitive ability, and damage to the liver and kidney" (p. 2). Further outlined by The International Technical Information Institute (1975), toxicity symptoms from perc include, " . . . conjunctivitis, inflammation of the skin, headache, dizziness, failure of strength, defective control of muscles, irritability, tremor and convulsions, paralysis and coma, irritation of respiratory tract, cardiac irregularity, nausea, vomiting, diarrhea, and bloody excrement" (p. 507). Perc has been designated by the U.S. federal government as a hazardous air pollutant under the Federal Clean Air Act (United States Environmental Protection Agency, 1994). In September, 1993, the EPA finalized the National Emission Standards for Hazardous Air Pollutants (NESHAP) which required dry cleaners to follow strict emissions control guidelines including the use of add-on refrigeration and vapor absorbers and the elimination of all open containers of perc. However, the new perc air standard rules did not require existing dry cleaners to comply until 1996 (Meijer, 1995).

According to Meijer (1995), "The current federal permissible air exposure level (PEL) standard for drycleaners using perc is 100 parts per million (ppm) and a maximum allowable concentration of 300 ppm ... some states are retaining the 1989 standard of 25 ppm, as originally proposed by OSHA" (p. 21). Inhalation is the primary route of exposure to perc. Exposure to perc at levels of 100 ppm for 7 hours or 200 ppm for 1 hour is found to cause mild irritation to the eyes, nose, and throat and flushing of the face and neck, as well as, headaches, slurred speech, and drowsiness. In addition, inhalation of perc at levels of 200 ppm can cause dizziness and lightheadedness. Inhalation of perc at 600 ppm for a period of 10 minutes will cause numbness around the mouth, dizziness and incoordination. Mild narcosis can occur within 5 minutes of exposure to perc at levels of 2,000 ppm, and 5,000 ppm is found to be intolerable, causing vertigo, nausea, and mental confusion (Vulcan Chemicals, 1988). "Unconsciousness or death can occur at extremely high concentrations or prolonged exposures above 500 ppm" (Vulcan Chemicals, 1988, p. UN 1897).

Improved technology of drycleaning equipment and better operation and maintenance procedures are reducing perc consumption. Perc consumption over the past 5 years is down 40% (Seitz, 1996). Seitz (1996) stated, " As older equipment e.g., transfer units and dry-to-dry units are replaced with third and forth generation equipment, solvent consumption will continue to decline even more" (p. 72). The reduction in consumption of perc is important to reduce exposure to workers in drycleaning establishments and also people in restaurants and apartment and housing structures that are closely located to these cleaning establishments (Seitz, 1996).

As the apparent phase-out of perc and petroleum solvent progresses, the apparel industry must be able to adapt products with the necessary changes for other alternative cleaning technologies. Within manufactured apparel, the component of a garment most frequently affected by cleaning methods is fused interlining. Therefore, interlining producers need to be aware of the problems that could occur with currently used fusible interlining products when cleaned through the use of wetcleaning technologies, and determine how currently used fusible interlining products can be improved for successful use with wetcleaning technologies. The motivation for this study was to determine whether currently used nonwoven fusible interlining products could be used in garments cleaned by new wetcleaning technologies without adverse effects. Through this research, study results determined whether interlining producers need to develop new technologies for fusible interlinings in order for fused fabric to maintain bond strength, shape, and appearance when cleaned through the use of new wetcleaning technologies.

Purpose of the Study

The purpose of the study was to determine whether twill-weave lyocell (the generic form of Tencel®, a registered trade mark of Courtaulds Fibers Inc.), twill-weave wool, and plain-weave mohair/wool fabrics, fused to appropriate nonwoven fusible apparel interlinings, would be compatible with wetcleaning technologies when tested for bond strength and dimensional stability, and evaluated for appearance. Appearance testing was visually evaluated for puckering, cracking, blistering, and pilling.

Hypotheses

Hypotheses for the study were the following:

H1: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H2: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H3: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H4: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H5: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H6: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H7a: For unfused lyocell fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H7b: For unfused lyocell fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H8a: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H8b: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H9a: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H9b: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H10a: For unfused wool fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H10b: For unfused wool fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H11a: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H11b: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H12a: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H12b: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H13a: For unfused mohair/wool blend fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H13b: For unfused mohair/wool blend fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H14a: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H14b: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H15a: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

H15b: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Questions

Research questions for the study were the following:

R1: Will there be differences in appearance of lyocell fabric fused with nonwoven fusible interlining 5025, when evaluated for puckering, cracking, blistering, and pilling,

between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

R2: Will there be differences in appearance of lyocell fabric fused with nonwoven fusible interlining 8336, when evaluated for puckering, cracking, blistering, and pilling, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

R3: Will there be differences in appearance of wool fabric fused with nonwoven fusible interlining 9016, when evaluated for puckering, cracking, blistering, and pilling, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

R4: Will there be differences in appearance of wool fabric fused with nonwoven fusible interlining 8246, when evaluated for puckering, cracking, blistering, and pilling, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

R5: Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven fusible interlining 5423, when evaluated for puckering, cracking, blistering, and pilling, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

R6: Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven fusible interlining 5025, when evaluated for puckering, cracking, blistering, and

pilling, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Limitations of the Study

Limitations for the study were the following:

1. Resin formulations for the fusible interlinings were confidential based on the interlining manufacturer's policy.

2. Nonwoven fusible interlinings used were currently available in the apparel industry and were selected by the interlining manufacturer's in-house sales representative, experienced in interlining selection, for appropriateness of application based on the weight of the fabrication.

Delimitations

The following limitations were applied to this study:

1. Nonwoven fusible interlinings were limited to those produced for use in the apparel manufacturing industry.

2. Drycleaning methods were limited to the use of perchloroethylene solvent and wetcleaning technologies.

3. Shell fabrics selected for the study were a twill weave 100% lyocell, a twill weave100% wool, and a 60% mohair/40% wool blend.

4. Nonwoven fusible interlinings were limited to those most commonly used with twill-weave lyocell, twill-weave wool, and plain-weave mohair/wool fabrics.

Definition of Terms

Application. Bonding a fusible interlining to the back side of a shell fabric (Brown, 1992).

Back-bleed/strike-back. Over-liquefied adhesive that seeps into the surface of the interlining during fusing caused by too high of a fusing temperature, too much pressure, or too long of a fusing time (Freudenberg Nonwovens, 1992).

Ballast. Thirty-six inch square pieces of hemmed bleached cotton sheeting or 50/50 polyester/cotton bleached and mercerized poplin used to bring the total load weight of textiles needed to the amount specified in the cleaning procedure (AATCC, 1995).

Bleed-through/strike-through. Liquefied adhesive that seeps through the face of the shell fabric during fusing caused by too high of a fusing temperature, too much pressure, or too long of a fusing time (Freudenberg Nonwovens, 1992).

Blister. A bulge, bubble, swelling or similar surface condition on either the face or back of a fused fabric (ASTM, 1995).

Block fusing. Bonding a shell fabric to a fusible interlining before garment pieces are cut to stabilize lightweight, stretchy, or loosely woven fabrics and allow for ease of cut (Freudenberg Nonwovens, 1992).

Bond strength. The tensile force measured in ounces per 1 inch of width required to separate the bond between a fusible interlining and a shell fabric measured (AATCC, 1995).

Computer dot. Applying paste-printed resin to interlining substrates, by using a computer-generated random dot pattern to eliminate the moiré effect created when fusing

twill-weave fabrics with interlinings printed with traditional resin patterns; a process exclusive to Freudenberg Nonwovens (Freudenberg Nonwovens, 1995).

Conventional fusing. The process in which a single layer of interlining, cut slightly smaller than a garment piece is bonded to a shell fabric at a specified temperature, time, and pressure (Freudenberg Nonwovens, 1992).

Cracking. The sharp creases that appear on either the shell fabric side or the interlining side of fused fabrics after subjected to cleaning processes (ASTM, 1995).

Criss-cross. The process in which fiber web is laid to create a nonwoven substrate. The fiber distribution in balanced in the machine direction (of the interlining) and in the cross direction (diagonal) (Freudenberg Nonwovens, 1995).

Delamination. The breakdown of the adhesive bond between an interlining and a shell fabric; can occur during and/or after steaming, laundering, or drycleaning, and finishing procedures (Freudenberg Nonwovens, 1992).

Drycleaning. Cleaning garments in organic solvents or hydrocarbon compounds used to remove dirt, soil, and most spots and stains (Dan River, 1992).

Extended range fusibles (ERF®). Fusible interlinings with an extended fusing range as low as 220 degrees Fahrenheit that are intended for less sophisticated electric or steam fusing equipment. ERF® fusible interlinings are used for bonding fabrics where shrinkage during the fusing process could be a problem (Freudenberg Nonwovens, 1995).

Engineered. A process for manufacturing complex nonwoven substrates and resins for the development of nonwoven fusible interlinings.

Fused fabric. Bonded fabric created by adhering a nonwoven fusible interlining to a shell fabric (ASTM, 1995).

Fusing. Bonding a single layer of interlining and shell fabric together at a specified temperature, time, and pressure according to the selected interlining (Freudenberg Nonwovens, 1992).

Fusing temperature. The temperature reading taken between a fusible interlining and a shell fabric during the fusing process. The appropriate temperature is determined by the specific interlining selected (Freudenberg Nonwovens, 1992).

Fusing time. The duration of time a shell fabric and interlining remain under heat and pressure in a fusing machine to achieve a proper bond (Freudenberg Nonwovens, 1992).

Fusing pressure. The amount of force exerted by a fusing machine on the interlining during fusing, expressed as pounds per square inch (psi) or bar (Freudenberg Nonwovens, 1992).

Fusible interlining. A knit, nonwoven, weft, or woven fabric with an adhesive applied to one side for the sole purpose of bonding to a shell fabric (Freudenberg Nonwovens, 1992).

Incompatible shrinkage. The difference in shrinkage between a shell fabric and a fusible interlining when exposed to heat, moisture, dry cleaning, and/or laundering; one fabric shrinks more than the other (Freudenberg Nonwovens, 1992).

Launder. A process of cleaning fabrics through the use of a standard washing machine and dryer.

Lyocell. An alternative to the name rayon. ". . .a manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups. Where the fiber is composed of cellulose precipitated from an organic solution in which no substitution of the hydroxyl groups takes place and no chemical intermediates are formed, the term *lyocell* may be used as a generic description of the fiber" (Warner, 1996, p. 1).

Moiré effect. A problem that occurs when the face of the shell fabric appears water spotted or striped due to the alignment of the adhesive pattern on the shell or interlining fabric. Weft-insertion interlinings and twill weave fabrics tend to cause this effect (Freudenberg Nonwovens, 1992).

Multiple variable fusibles (MVF®). Fusible interlinings that have an extended fusing range from 240-290 degrees Fahrenheit, designed for a variety of fusing machines and fusing conditions (Freudenberg Nonwovens, 1995).

Nonwoven interlining. A nonwoven substrate that is sprayed, printed, or sintered with a fusible adhesive (Cooklin, 1990).

Open application. The process in which an interlining is fused to a shell fabric facing in an unlined garment.

Pilling. Bunches or balls of tangled fibers that form on the surface of the interlining of the fused fabric (ASTM, 1995).

Puckering. A wavy, three-dimensional effect indicated by closely spaced wrinkles on either side of a fused fabric (ASTM, 1995).

Shell fabric. The outer or face fabric from which a garment is constructed.

Sintered. A speckled or granular adhesive resin coating applied to low-priced nonwoven interlinings (Solinger, 1980).

Wetcleaning. A process used for machine cleaning sensitive textiles in water by professionals using a special technology and detergents that lead to minimal fabric shrinkage and damage, followed by an appropriate tumble drying and restorative finishing process; typically comprises some form of steam treatment and/or hot pressing (European Wet Cleaning Committee, 1996).

CHAPTER II

REVIEW OF RELATED LITERATURE

Chapter II discusses several aspects of apparel interlinings. Topics addressed in the review of literature include (a) history of nonwoven fusible interlinings, (b) production of nonwoven fusible interlinings, (c) methods of application, (d) laundering and drycleaning of nonwoven fusible interlinings, and (e) cleaning processes.

History of Nonwoven Fusible Interlinings

According to Cooklin (1990), the ancient Egyptians were the first to use interlinings for stiffening clothing and hats in approximately 3000-4000 BC. Textiles used by the ancient Egyptians were heavy woven fabrics stiffened with metallic threads of gold or precious metals. Cooklin (1990) stated, "Until the nineteenth century, buckram, a coarse cotton fabric stiffened with glue, was widely used as an interlining" (p. 7). Fabric woven with animal hair soon replaced buckram to stiffen fabrics and was used for over 150 years as an interlining (Cooklin, 1990). Prior to the 20th century, women's apparel was shaped and supported by under-structures including bustles, crinolines, hoops, panniers, and whale bone (Mickle, 1976). The first interlinings of the 1920s were constructed of stiffly woven textiles. As time progressed, new technologies in interlinings were introduced (Freudenberg Nonwovens, 1989).

Nonwoven engineered textiles have been manufactured since 1849. However, nonwoven textiles were not introduced into the apparel industry until 1942 (Freudenberg Nonwovens, 1989). Nylon was the first synthetic fiber produced in a laboratory setting and the development of polyester soon followed. Due to the production and of use of synthetic fibers to manufacture clothing, pressure was placed on textile producers to create interlinings that matched the characteristics of the garment's shell fabric. Fusible interlinings were introduced as a solution for manufacturing apparel made from synthetic fibers (Cooklin, 1990). Three technologies were used to develop fusible interlinings: (a) development of base cloths or substrates, (b) development of resins or adhesives for bonding, and (c) development of machinery used to bond fusible interlinings to shell fabrics (Cooklin, 1990).

Following World War II, shortages of traditional fabrics brought about the development of nonwoven interlinings (Cooklin, 1990). "Fusibles were first introduced on a large scale in the 1950s, and they started what has been called the third clothing revolution, the other two being the discovery of weaving and the invention of the sewing machine" (Cooklin, 1990, p. cover). Although fusible interlinings were introduced in the late 1950s, it was not until the latter part of the 1960s that these interlinings began to gain acceptance for minor applications, such as tapes and stays (Schmida, 1990). In the 1950s fusible interlinings were used for stiffening men's collars and cuffs in dress shirts, but had problems with delamination after laundering or drycleaning (Cooklin, (1990). The fusible interlining applications were limited because the base fabric was designed for use as a

sew-in, not as a fusible product. Interlining producers simply applied a scatter-coated, adhesive resin to the sew-in substrates (Schmida, 1990).

The first resins used in fusible interlinings were polyvinyl chlorides and polyethylene. Due to the inconsistency of these resins during laundering or drycleaning, use was limited to budget-priced tailored clothing (Schmida, 1990). Schmida (1990) further added, "... in addition, powdered fusibles were replaced with pastes that allow blending and new 'chemistries'. The resultant fusibles were able to perform well with a wide variety of tailored clothing fabrics" (p. 104).

In the 1970s and early 1980s, new fabric finishing technologies were introduced to improve the performance of woven textiles and their aesthetic appeal. An alternative to woven fusible products was also introduced. These weft-insertion knits provided the market with a softer fusible interlining, in contrast to the stiff woven interlinings available in the past.

By the mid-1980s, significant changes were taking place in the apparel industry. Schmida (1990) stated, "Imports accounted for 25% of all retail sales of tailored clothing" (p. 104). Lifestyle changes brought a demand for softer tailored apparel and began a trend toward softer tailored garments, fabrics, and acceptance of engineered garments at the retail level (Schmida, 1990). Newly engineered textiles created new challenges for apparel manufacturers and interlining producers such as tailoring lighter softer fabrics. According to Schmida (1990), interlining producers were challenged not only to create

fusible interlinings that were compatible with the new shell fabrics, but to also develop applications to ease the manufacturing process to enhance the quality of the garment.

The technology of the 20th century has surpassed the supported understructures of previous centuries and their stiffly woven interlinings. Interlinings are now available in the form of sew-in or fusible products constructed of knit, nonwoven, and woven substrates. Due to significant improvements in the manufacturing process of woven and weft-insertion substrates, several changes were made. High speed looms enabled manufacturers to increase production efficiencies, and new knitting and finishing technologies allow producers to make more finely woven and knitted base fabrics softer (Schmida, 1990).

The most significant changes in interlinings have taken place in nonwoven textile products. Nonwoven textiles are made directly from raw fibers. Nonwovens differ from other textiles or surface structures that require fibers to be spun into yarns before they are woven or braided or knitted into the finished product (Freudenberg Nonwovens, 1978). Freudenberg Nonwovens (1978), "Nonwovens are formed by bonding fibers into structures through chemical, mechanical, or thermal processes selected for their affinity to the fibers employed" (p. 4). Many industries use nonwoven engineered products, ranging from environmental and industrial materials to medical supplies (Freudenberg Nonwovens, 1978).

Production of Nonwoven Fusible Interlinings

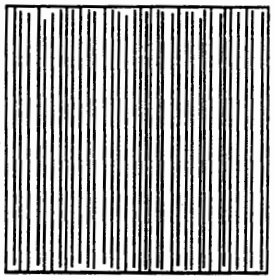
Price and Cohen (1994) define nonwoven fabrics as, "textile materials made directly from fibers held together as a fabric by adhesive, heat fusion (if thermoplastic

fibers) or through entanglement of the fibers" (p. 227). The primary fibers used to produce nonwoven fabrics are rayon, nylon, polyester, and acrylic; however other fibers such as olefin, vinyon, cotton, and acetate can be used. Nonwoven fabrics are manufactured as either disposable or durable. Durable nonwoven products are used for apparel interlinings. Other uses for durable interlinings include carpet backings, tiles on the space shuttle, and subsoil covers for road-beds (Price & Cohen, 1994).

Web Formation

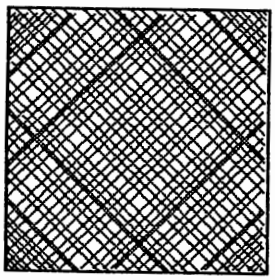
The three processes for web formation of nonwoven substrates are dry-laid, wet-laid, and spun-bonded. Dry-laid web formations can be created through a mechanical action or an air jet. The mechanical method passes fibers through an opening and orienting machine and deposits the fibers onto a moving conveyor belt. The angle at which the card is laid enables the following types of webs to be produced: (a) unidirectional--the card is laid parallel with the direction of the conveyor, (b) cross-laid--the card is laid at right angles to the direction of the conveyor, or (c) criss-cross--the card is laid in a combination of the unidirectional and cross-laid methods (this technology is unique to Freudenberg Nonwovens) (Freudenberg Nonwovens-Pellon®, 1992). See Figure 1 for illustrations of unidirectional, cross-laid, and criss-cross web formations. The other method of dry-laid web formation is air-laid. Air-laid web formation blows individual fibers onto a screen; therefore, the fibers are oriented randomly. The formed web has neither parallel nor transverse orientation. The air-laid process is the most commonly used because it provides a good balance between handle, strength,

Unidirectional Web Formation



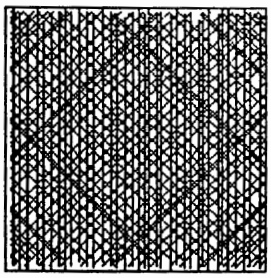
Fibers in the web are aligned in the machine direction.

Cross-laid Web Formation



Fibers in the web are aligned at right angles to the machine direction.

Criss-cross Web Formation



Fibers in the web are aligned in the machine direction and in the cross direction.

Figure 1. Illustrations of unidirectional, cross-laid, and criss-cross web formations.

and elasticity (Cooklin, 1990).

Wet-laid web formation suspends fibers in a liquid and feeds the card onto a conveyor screen which forms the web. The liquid is then removed through the use vacuums positioned under the screen. The result is a three-dimensional web formation. This process is similar to that of paper-making. Wet-laid web formations are typically 'boardy', but provide high strength (Cooklin, 1990).

Spun-bonded web formations are created by melting and extruding a polymer through a system of rotating spinnerets. The extruded filaments are drawn by air onto a conveyor to form a web. This type of web is typically reserved for use as sew-in interlinings (Cooklin, 1990).

Bonding Web Formations

Once the fibers are laid into a web formation, the fibers need to be bonded. Three types of processes are used to bond the web formation: mechanical bonding, chemical bonding, and thermal bonding.

Mechanical Bonding

The most common form of mechanical bonding is needle punch or felting. Needle-punched substrates are produced by piercing a fiber web with barbed needles that penetrate the fabric and lock the fibers together. The other form of mechanical bonding utilizes high-pressure water jets that spray the fiber web and locks the fibers together as the web moves along a perforated conveyor belt (Cooklin, 1990).

Chemical Bonding

The three types of chemical adhesives used in chemical bonding are nitrile rubber, acrylic, and styrene butadiene. These chemical adhesives have advantages and disadvantages. Nitrile rubber provides good draping qualities but tends to yellow over time. Acrylic binders produce white substrates, but tend to add stiffness to the nonwoven substrate. Styrene butadiene, commonly used to bond low-cost interlinings, is limited to laundering care methods (Cooklin, 1990). According to Cooklin (1990), "the chemical-bonding agent not only preserves the formation of the fibers for the life of the garment but also imparts softness and drape to the fabric"(p. 20).

The four methods of chemical bonding are impregnation, spraying, foaming, and printing. Impregnation bonding feeds a fiber web through a bath of chemical binder where the web is saturated with chemicals. The fiber web is then drawn from the chemical bath and squeezed between two rollers to remove any excess binder. The saturated fiber web is laid to dry at the appropriate temperature to bond the fibers together, forming a nonwoven substrate (Cooklin, 1990).

Spray bonding utilizes a conveyor with a high pressure vacuum. As the fiber web moves along the conveyor, a chemical binder is sprayed onto the web and any excess binder is suctioned through the conveyor. The chemical binder penetrates the fiber web and permanently bonds the nonwoven substrate (Cooklin, 1990).

Foaming is the process where a foamed binder is used to saturate the fiber web. The foam causes the fibers to interlock in a consistent form. After the web is dried, the result is a nonwoven substrate (Cooklin, 1990).

The final chemical bonding process is print bonding. A fiber web is passed under an engraved roller that is saturated with binder. The fiber web is interlocked and bonded together by the pattern on the roller (Cooklin, 1990).

Thermal Bonding

Thermal bonding is achieved through blending the web fibers with a low-melt adhesive powder. The web is then heated, causing the thermoplastic adhesive powder to melt and bond the fibers together, forming a nonwoven substrate (Cooklin, 1990).

Resins

Resins, according to Cooklin (1990), ". . .are applied to substrates in three different densities; low, medium, and high, where the degree of density refers to the actual mass per unit volume of the resin material itself. It is this physical density to which the melting point of the resin and its resistance to dry-cleaning solvents are related. As a general rule, the higher the density, the greater is the resistance to dry-cleaning solvents" (p. 25). The resins most commonly used in fusible interlinings are polyethylene and polyamide. Polyethylene has excellent launderability and a low melt temperature, and polyamide has good launder and drycleanability and is steam activated (Precision Custom

Coatings Inc., 1996). Polyethylene resins with low and medium densities are used for launderable garments where as, high-density polyethylene resins are both launderable and drycleanable (Cooklin, 1990). Higher melting polyamide resins provide a bond that is drycleanable and launderable up to 60 degrees Celsius, while lower melting polyamide resins are restricted to only dryclean methods (Cooklin, 1990).

Resin Coating/Adhesive Application

Coating, as defined by Cooklin (1990), "is the process whereby the thermoplastic resin is deposited and secured onto the substrate material" (p. 33). There are several coating methods currently being used today. The three types most widely used are paste printing, dry-dot printing, and scatter or sintered coating. Each method employs a specific particle-size fraction of the resin. Resin powders are created through the use of ambient and freeze-grinding techniques. Once the resin is ground into a powder, a complex sieving technique is used to separate the various particle sizes, designated by microns or micrometers (one-millionth of a meter). The resin powder micron range for paste printing is 80 microns or less, dry-dot printing is a range between 80 and 200 microns, and scatter or spray sinter coating is a range between 150 and 350 microns (Cooklin, 1990).

Scatter or Sintered Coating

Scatter coating is applied to the base fabrics by scattering heads that electronically control the amount of resin applied to the substrate as it passes below on a conveyor. The scatter-coated substrate is then moved through an oven where the resin is softened from

the heat and pressed into the base cloth. This method is the most inexpensive way for coating a substrate; however, the end product is not as uniform and pliable as the printed coatings (Cooklin, 1990).

Dry-dot Printing

In dry-dot printing the resin powder is applied to a roller that is engraved with small indentations. The base cloth is passed over a heated roller and against the engraved roller containing the adhesive resin. The heat from the first roller is transferred to the substrate and softens the resin causing the adhesive to adhere to the base cloth in the form of dots (Cooklin, 1990). The number and size of indentations on the roller are determined by the required concentration of the resin needed. Generally speaking, flat weave light weight fabrics require many small adhesive dots, where as, flat weave heavy weight fabrics need a larger dot that is fewer in number. The engraved dots can range from two to nine dots per square centimeter. Cooklin (1990) explained, "there has to be sufficient resin to penetrate the fibre surface of the top-cloth to the depth required in order to produce a satisfactory bond strength" (p. 35). Dry-dot printing generally creates a higher quality fusible interlining than scatter or sinter coated substrates (Cooklin, 1990).

Paste Printing

The resin powder is formed into a paste by mixing it with water and other wetting agents. As the base cloth moves along a conveyor belt a cylindrical printing screen is used to apply the adhesive paste to the base fabric in the form of dots. Heat is applied after

printing to evaporate the water and to solidify the resin dots and bond them to the base cloth (Cooklin, 1990).

Paste printing produces a perfectly shaped dot, which in turn creates a high quality fusible interlining. This type of coating is used for creating the finer-print dots needed for top-collar interlinings for shirts and for use with light weight silks and microfibers, and sheer fabrics (Cooklin, 1990).

Methods of Application

All fusible interlinings have specific requirements of temperature, time, and pressure for proper bond application. Cooklin (1990) explained, "Each resin type has its own specific characteristics, and these have to be considered in relation to: (a) the style of the garment being produced, (b) the top-cloth and the handle required, (c) the fusing equipment available in the factory, (d) the base cloth of the fusible, (e) the over-all cost, [and] (f) the durability to washing or dry-cleaning or both" (p. 27).

Interlinings can be used in several or all parts of a garment, depending on the look desired, the type of interlining selected, the shell fabric, the desired drape, and construction of the garment. Interlinings are used to stabilize a loosely woven fabric, to add support, crispness, or structure, to add strength in a high stress area of a garment, and as tapes and stays (Schmida, 1990).

Brown (1992) stated, "Because the fusing process is so well adapted to mass production, most tailoring is done with fusible interfacings (except in high-price lines,

where sew-in interfacings are sometimes used)" (p. 180). Fusible interlinings are more cost effective in mass production because they are less costly to apply to fabrics than sew-in interlinings.

Prior to production, the apparel manufacturer must test and evaluate the behavior of interlinings and shell fabrics during fusing, drycleaning, laundering, and pressing or steaming (Ajemian, 1994). The three key elements needed when fusing interlinings are heat, time, and pressure. According to Ajemian (1994), the following testing procedures are used to determine the proper fusing conditions: (a) hand, (b) bond strength, (c) bond strength after laundering or drycleaning, (d) shrinkage test, (e) shrinkage during fusing, (f) shrinkage during laundering or drycleaning, (g) strike back and strike through, and (h) surface appearance. Determining the proper fusing conditions prior to production allows the apparel manufacturer to avoid unexpected problems after production (Ajemian, 1994). Fortress (1990) explained, "only through pre-testing of garments in dry cleaning can the manufacturer avoid complaints and possible citation by the Federal Trade Commission" (p. 26).

Laundering and Drycleaning of Nonwoven Fusible Interlinings

It is important for interlinings to withstand the same wear and care methods as the shell fabric used to produce the garment (Brown, 1992). Due to special requirements of tailored clothing, which contain fusible interlinings, Fortress (1990) explained, "The Clothing Manufacturers Association-USA has recommended to their members that they permanently attach the following care instructions to the garment: Professionally Dry

Clean Only, Use Low Moisture (in solvent), Utility Press" (p. 24). Fortress (1990), stated the following:

> The Federal Trade Commission, the agency responsible for the Care Labeling Regulation, holds the manufacturer responsible for assuring that the garment can be safely refurbished by the instructions on the care label. In the event that the FTC cites a manufacturer or an importer for the failure to produce garments that perform in an acceptable manner when care instructions are followed, evidence is required to demonstrate that the manufacturer or importer has tested garments to assure the accuracy of the care instructions (p. 26).

The two major trade associations for the fabric care industry are the International Fabricare Institute (IFI) and the Neighborhood Cleaners Association (NCA). These trade associations publish statistical analysis on approximately 50,000 garments that have been sent in by members resulting from consumer complaints. Approximately 39% of the complaints are due to fault of the manufacturer, about 34-41% are due to the lack of responsibility by the consumer, drycleaners are responsible for 15-16%, and the remaining 4% cannot be determined (International Fabricare Institute, 1997 & Fortress, 1990). Fortress (1990) stated that most of the complaints that assign fault to the manufacturer were related to color loss, color transfer, delamination, shrinkage, or other defects that occur during manufacturing.

In the late 1980s and early 1990s, two important factors surfaced in the tailored-clothing industry. The performance of fusible interlinings was improved, and the aesthetics and diversity of products were widely expanded (Schmida, 1990). As Schmida (1990) stated, " The progressive U.S. clothing manufacturers have recognized that the

careful selection of fusibles for various end use characteristics can materially improve garment quality and production efficiency" (p. 112).

Constant technological advancement in the textile industry have spurred the need for textile structures with special features or properties not attainable in the conventional woven, knit, or fiber web structures. Many nonwoven textiles have been developed in order to simulate woven, knits, and weft-insertion products, while providing properties not readily available with the use of these forming technologies. Inherent problems with fusible interlinings, such as delamination, rippling or bubbling, moiré effect, and strike back or strike through, also can be avoided by using products developed for specific applications, fabrics, and cleaning methods.

Cleaning Processes

The selection of a cleaning process for apparel depends on the fabric construction, fiber content, garment type (i.e. tailored clothing, evening wear, lingerie, active wear, etc.) and ornamentation. Three types of cleaning processes that are discussed in this chapter include: (a) laundering, (b) drycleaning, and (c) wetcleaning.

Laundering

Laundering is an aqueous cleaning process typically used for cleaning fabrics made of cotton, polyester, cotton/polyester blends, some rayon, silk and wool, and most nontailored garments. The stains that are removed easily in laundering are water soluble

(i.e. perspiration, blood, wine, and any stain that does not contain oil or grease) (Haefele, Davis, Fortress, Hunter, & St. John, 1973).

Cleaning Agents

The main ingredients used in laundering are water and detergent (Price & Cohen, 1994). Detergents are made up of surfactants, builders, silicates, anti-redeposition agents, perfumes, and colorants. Some detergents may also contain enzymes, bleaches, and/or bacteriastats or bacteriacides. Surfactants are the ingredient that helps break up stains and lifts them off the fabric. Enzymes are also used to help break down stains such as protein. Anti-redepostion agents hold the soils in suspension in the wash water so they are not redeposited back onto the clothing. Builders are added to soften the water and raise the pH level. Silicates do not play an active role in the cleaning of a garment, although they do protect the washing machine from corrosion. Perfumes and colorants are also added to detergents to make them more aesthetically appealing to the consumer (The Soap and Detergent Association, 1994; Haefele et. al., 1973).

Laundering Machinery

The machinery used in the laundering process is the washing machine and dryer. There are two types of washing machines, top-loading and front-loading. Front loading machines have a washing basket set on a horizontal axis and the clothing tumbles as it is washed. In contrast, top-loading machines are built on a vertical axis. This allows the clothing to be agitated rather than tumbled. The washing machine has a rinse cycle where

the wash water is drained and fresh water is pumped in to flush out the detergent from the garments. The clothes then go through a spin cycle which allows the water to be extracted from the garments before they are placed into a separate drying machine. The dryer them tumbles the clothes in a heated chamber of air, which allows air to flow in and around the garments. Some dryers have timers that alert the operator that the clothes are dry, while newer machines have moisture sensors that automatically shut the dryer off when the moisture level is very low and clothes are dry. The cleaning solution is then discharged into the sewer after use (Haefele et. al., 1973).

Drycleaning

Drycleaning is a process that uses a nonaqueous solvent to clean fabrics that are made of wool, mohair, silk, linen, rayon, and acetate. Specific types of garments that typically require drycleaning are tailored apparel, special occasion dresses/attire, and any garment with a special treatment that can not be refurbished using standard laundering methods (Price & Cohen, 1994).

Cleaning Solvents

The chemicals involved in drycleaning are perchloroethylene (perc) and petroleum based solvents which are very good at removing oily-based stains. Charged drycleaning solvents are solvents having a minimal amount of moisture (water) added in order to remove water-soluble stains. These solvents are distilled to remove any soils, oils, and nonvolatile residue removed from fabrics during the cleaning process. Distillation of the

solvents is necessary in order to prevent the redeposition of soils and residue onto the cleaned garments (Price & Cohen, 1994).

Drycleaning Machinery

The machinery used for drycleaning consists of a perforated cylinder and a shell that contains this cylinder. The clothes are placed inside the perforated cylinder and the solvent is contained in the shell. The garments are placed inside the perforated cylinder and they are wet with solvent. The cleaning action is a rocking back and forth motion or a tumbling action. Once the cleaning is finished the clothes may go through a rinse cycle and then the dry cycle begins. The clothing remains inside the same chamber where it was cleaned so the solvent is contained within the machine. As warm air is circulated through the chamber, the solvent is evaporated, recovered, and reused. The garments are then steamed or pressed and hung to allow any residual solvent to be evaporated from fabric before the customers retrieve the garments (C. L. Riggs, personal communication, April 11, 1995).

Wetcleaning

Wetcleaning is an evolving technology that uses water and detergent to clean garments normally recommended for drycleaning care methods. Wetcleaning, like laundering, can easily remove stains that are water-soluble. The four elements needed for wetcleaning are a washer-extractor that rotates at a slower cylinder speed than the standard washing machine used in laundering, specialized detergents, recirculation of

cleaning solution, and carefully controlled drying conditions. All of these elements are necessary to the wetcleaning process (Almstrom, 1996).

Cleaning Agents

The detergent used for the wetcleaning process is condensation products of natural fatty acids, coco fatty acid derivatives, natural-equivalent complex formers, enzymes, dye stabilizers, microbicides, and perfume. This detergent is mild and very effective at breaking up fats and pigments without washing action, protects against felting and shrinkage of (albuminous and cellulosic) textiles, improves stability of dyes, and disinfects (Kreussler, 1997). The generic version is Shell Neodol® 23-6.5, an ethoxylate $H(CH_2)_{13}O(CH_2CH_2O)_7H$ (C. L. Riggs, personal communication, January 16, 1997).

Wetcleaning Machinery

The wetcleaning System consists of a commercial reversibly-rotating, cage-type, horizontal-axis, washer-extractor machine (specifically manufactured for wetcleaning) and a moisture-controlled dryer. The washer-extractor cylinder speed is much slower than the standard washing machine used in laundering and also recirculates the cleaning solution (Almstrom, 1996).

CHAPTER III

METHODOLOGY

Chapter III discusses the methodology used for the study. Topics addressed include (a) research design, (b) selection of the sample, (c) measurements, (d) research procedure, and (e) data analysis.

Research Design

The study utilized true experimental research with a pretest-posttest control group design. The two sets of independent variables for the study were (a) fabric/interlining combinations (lyocell fused with interlining 5025 and interlining 8336, wool fused with interlining 9016 and interlining 8246, mohair/wool blend fused with interlining 5423 and interlining 5025 and (b) cleaning methods (drycleaning and wetcleaning). The dependent variables were bond strength, dimensional stability, and appearance, which varied by cleaning method, fabrication, and interlining selection.

Selection of Sample

The sample group of fabric/interlining combinations consisted of a twill-weave a twill-weave 100% lyocell, 100% worsted wool, and a plain-weave 60% mohair/40% wool blend suiting fabrics, 60 inches in width, recommended to be cleaned by dryclean care methods, fused with appropriate interlinings, and categorized within the better

price range. The fabrics were selected and purchased from fabric jobbers on Perth Street in Dallas, Texas to ensure the selected fabric sample would include fabrics used by apparel manufacturers. Six nonwoven fusible interlinings were selected. Two interlinings in the better price-range were selected for each fabric type; the sample interlinings were appropriate to the weight of the identified fabrics. The nonwoven fusible interlinings were donated by the leading nonwoven interlining producer in the world and selected by one of the producer's in-house sales representatives having a minimum of five years experience with interlining selection.

Measurements

Bond strength, dimensional stability, and appearance, including puckering, cracking, blistering, and pilling were measured. The researcher conducted and evaluated all measurements and tests.

Bond Strength

The apparatus used to measure bond strength between fused shell fabrics and interlinings was an Instron® tensile testing machine, model number 4202. The test method followed for bond strength was ASTM D 2724 Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics-Strength of Bond Test. A description of the bond strength test procedure follows:

1. Separate each bond strength specimen across the top width of the specimen measuring down 1 inch.

2. Secure the shell fabric of the fused specimen the upper clamp of the tensile testing machine with the warp direction of the fabric running parallel with the closed clamping surface.

3. Secure the interlining of the fused specimen in the lower clamp of the tensile testing machine with the warp direction of the fabric running parallel with the closed clamping surface.

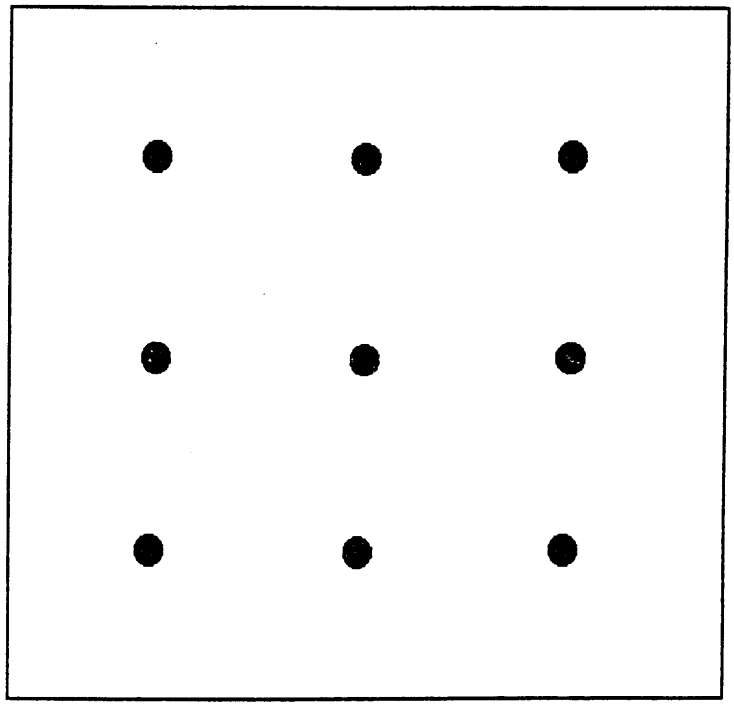
4. Operate the tensile testing machine at a pulling speed of 12 $\pm$ 0.5 inches per minute.

5. Determine the bond strength to the nearest 0.05 pounds of force as the average of the five lowest and five highest peak loads of resistance per inch of width, registered for 4 inches of delamination.

6. Report bond strength in pounds per inch of width as the average strength of the test specimens, as stated on the print out from the tensile testing machine. Repeat steps 1-5 for each of the remaining specimens (ASTM, 1995).

Dimensional Stability

The instruments used to measure dimensional stability were a 10"x10" template for marking fabric specimens (see Figure 2), and a Luftkin 12-foot tape measure, graduated into 0.1 inch increments. The test method followed for dimensional stability was ASTM D 2724 Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics. A description of the dimensional stability test procedure follows:



10" x 10" Template with 5" x 5" Holes for Marking Specimens

Figure 2. Template for marking fabric specimens.

1. Mark the fabric specimens using the template for marking fabrics (3 length and 3 width markings for each specimen) (see Figure 2).

2. Clean the specimens according to specified care methods and remeasure the dimensional markings to determine if any change has occurred.

3. Calculate the shrinkage or growth of each test specimen using an average of the width and an average of the length measurements (per individual specimen) in accordance with the following equation: Shrinkage, % = (A-B)100/A. A = average original measurement between marks, and B = average final measurement between marks. Repeat steps 1-3 for remaining specimens (ASTM, 1995).

Appearance

The appearance of the fabric was evaluated visually in a lighting and evaluation area by using control swatches as references. The researcher visually inspected the bonded specimens and recorded any instances of puckering, cracking, blistering, or pilling. The test methods followed for appearance were AATCC Method 124 Appearance of Fabrics after Repeated Home Laundering and ASTM D 3135 Standard Specification for Performance of Bonded, Fused, and Laminated Apparel Fabrics. When applicable, the specimens were evaluated for pilling using the ASTM Photographic Standards for Random Tumble Pilling and the ASTM Pilling Assessment Cabinet for fabric evaluation. A description of the appearance evaluation procedure follows:

1. Mount the cleaned fused specimens and two control specimens on a viewing board without tension; place the interlining side of the fused specimen toward the evaluator with the warp direction of the fabric in a vertical position. The two control specimens should hang on either side of the cleaned specimen being rated.

2. The evaluation room should be dark. The only light source should be from the evaluation lighting equipment.

3. Record any evidence of puckering, cracking, blistering, or pilling.

4. Rate the specimen for pilling. The specimen should be rated in an apparatus for fabric evaluation using ASTM photographic pilling standards. Repeat steps 1-4 for remaining appearance specimens.

Cleaning Equipment

The wetcleaning research equipment for the study was the Unimac wetcleaning System, model number UF230W, consisting of a commercial, reversibly-rotating cage-type, horizontal-axis, washer-extractor machine specifically manufactured for wetcleaning, with a 50-pound load capacity and a reversing moisture-controlled dryer. The generic detergent used for the wetcleaning process was Shell Neodol® 23-6.5 which is an alcohol ethoxylate $H(CH_2)_{13}O(CH_2CH_2O)_7H$.

The drycleaning research equipment used for the study was the Bowe Passat drycleaning machine with a 46-pound load capacity, model number P546. The solvent

used for the drycleaning process was tetrachloroethylene or perchloroethylene (perc).

Collection of the Data

The study began with three fabrics, lyocell, wool, and mohair/wool blend. Each fabric was 60 inches in width and 548 inches in length. Table 1 indicates the number of specimens, type of specimen (unfused or fused), and interlining selection for fabric used for each type of test.

Sample Preparation

Two 60" x 58" lengths were cut from each of the three fabrics and set aside for dimensional stability testing on the unfused fabrics. See Figure 3 for a diagram of the layout and size of the unfused and fused specimens used for each bond strength, dimensional stability, and appearance test per fabric/interlining combination. The interlining producer's in-house sales representative selected two commonly sold interlinings, categorized in the better price-range, for each of the three shell fabrics (see Table 2 interlining selection and description). All of the interlinings selected for the study had a criss-cross web formation that was thermally bonded and computer printed resin dots (paste print). The following procedures were used to prepare the fabrics for fusing:

1. Cut four, 60" x 108" lengths from each shell fabric (4 lyocell, 4 wool, and 4 mohair/wool blend).

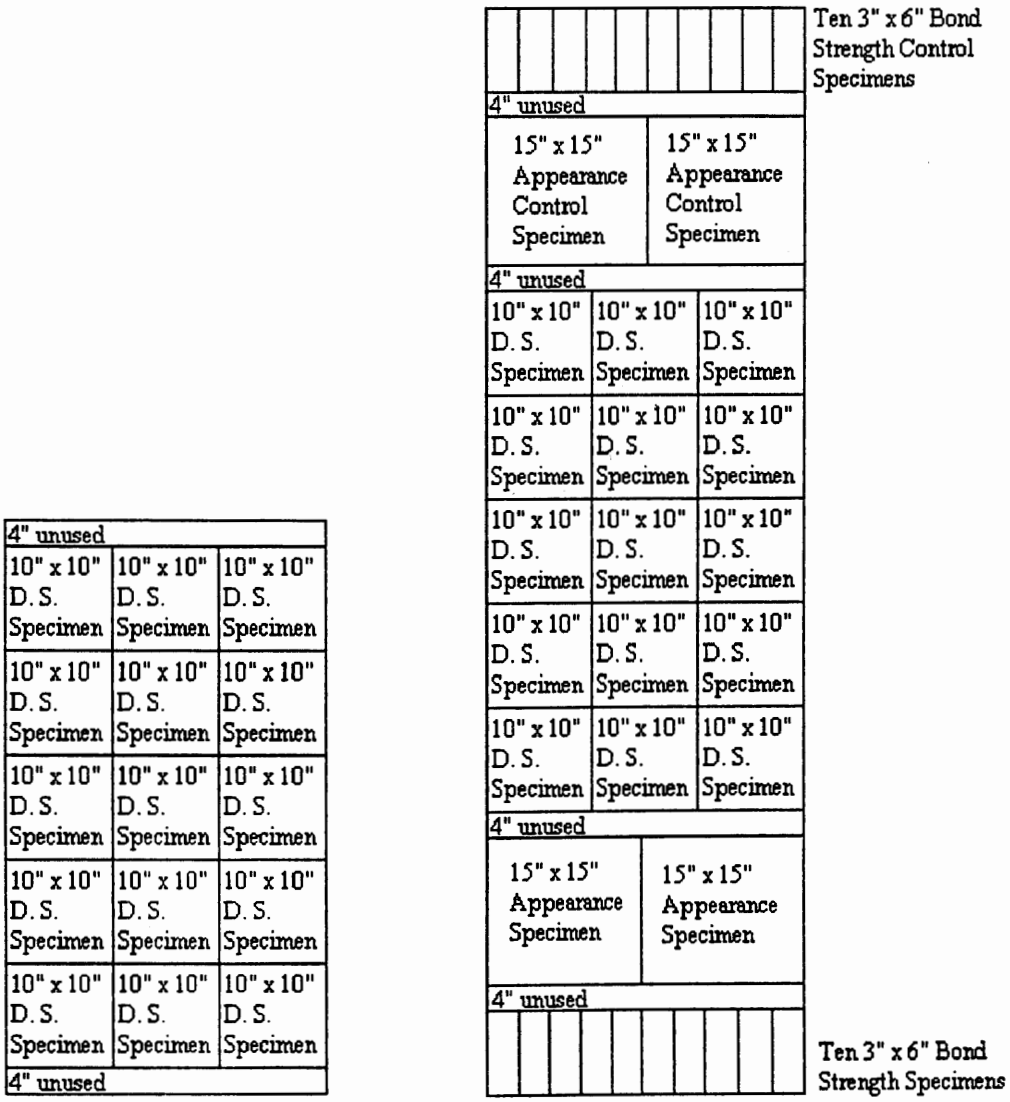
2. Select two (of the four) lyocell 60" x 108" lengths to be fused with interlining 5025.

Table 1

Description of Samples for Study

Fabric/interlining combination	Dimensions of specimen fabrics	Drycleaning specimen no.	Wetcleaning specimen no.
Lyocell unfused [a]	30" x 58"	1	1
Lyocell 5025 [b]	30" x 108"	1	1
Lyocell 8336 [b]	30" x 108"	1	1
Wool unfused [a]	30" x 58"	1	1
Wool 9016 [b]	30" x 108"	1	1
Wool 8246 [b]	30" x 108"	1	1
Mohair/wool unfused [a]	30" x 58"	1	1
Mohair/wool 5423 [b]	30" x 108"	1	1
Mohair/wool 5025 [b]	30" x 108"	1	1

Note. $N = 18$.
[a]$n = 6$. [b]$n = 12$.



Note. D.S. = Dimensional stability

Figure 3. Diagram of the layout and size of the unfused and fused specimens.

Table 2

Interlining Selection and Description

Fabric/interlining combination	Resin type	CP dot size	Weight g/m2
Lyocell 5025	Rayon	52	38.5
Lyocell 8336	ERF® polyamide	37	47.0
Wool 9016	MVF® polyester	37	52.0
Wool 8246	ERF® polyamide	37	52.0
Mohair/wool 5423	Polyamide	110	36.0
Mohair/wool 5025	Rayon	52	38.5

Note. CP = resin application is a random computer-printed (paste) dot; ERF® = low melt fusible; MVF® = multivariable melt fusible.

3. Fuse the remaining two 60" x 108" lengths of lyocell with interlining 8336.

4. Select two (of the four) wool 60" x 108" lengths to be fused with interlining 9016.

5. Fuse the remaining two 60" x 108" lengths of wool with interlining 8246.

6. Select two (of the four) mohair/wool blend 60" x 108" lengths to be fused with interlining 5423.

7. Fuse the remaining two 60" x 108" lengths of mohair/wool blend with interlining 5025.

Fusing

The interlining producer bonded the samples using a continuous fusing press called a return-feed conveyor press. The fusing press was calibrated according to the specified temperature, time, and pressure for each interlining selection to achieve the proper bond. See Table 3 for a description of the fusing conditions for the selected interlinings. The fusible interlining for each 60" x 108" specimen was prepared for fusing by placing a 1" x 60" strip of release paper between the top and bottom edges of the interlining and the shell fabric. The release paper prevented the interlining from fusing to the shell fabric, therefore preparing the specimens for the bond strength tests prior to cleaning (see Table 4). The shell fabric and the interlining were feed through the continuous fusing press on a conveyor and the interlining become bonded to the fabric.

Control Specimens

The six 60" x 58" unfused lengths and the twelve 60" x 108" fused lengths were cut from 60 inches in width to 30 inches in width, so the test specimens would not be cut closer to the selvage than a distance equal to 20% of the fabric width (ASTM D2724, 1995). Ten bond strength specimens were cut 3" x 6" from the top edge of each 30" width x 108" length of bonded fabric (the top end where the release paper was placed during fusing) (see Table 4). These bond strength control specimens were set aside for testing before cleaning. Two 15" x 15" appearance specimens from each fused

fabric/interlining combination were cut from the top of each 30" x 102" specimen (prior to cleaning) and used as controls.

Table 3

Description of Fusing Conditions for Selected Interlinings

Fabric/interlining combination	Heat (Fahrenheit)	Time (seconds)	Pressure (psi-bar)
Lyocell 5025	270 degrees	11	75psi = 5bar
Lyocell 8336	270 degrees	11	75psi = 5bar
Wool 9016	270 degrees	11	75psi = 5bar
Wool 8246	270 degrees	11	75psi = 5bar
Mohair/wool 5423	280 degrees	11	60psi = 4bar
Mohair/wool 5025	290 degrees	11	75psi = 5bar

Note. psi = pounds per square inch; bar = 1 million dynes per square centimeter.

Table 4

Bond Strength Specimens for Study

Fabric/interlining combination	Dimensions of specimen fabrics	Drycleaning specimen no.	Wetcleaning specimen no.
Lyocell 5025 control [a]	3" x 6"	0	0
Lyocell 5025 [b]	3" x 6"	1	1
Lyocell 8336 control [a]	3" x 6"	0	0
Lyocell 8336 [b]	3" x 6"	1	1
Wool 9016 control [a]	3" x 6"	0	0
Wool 9016 [b]	3" x 6"	1	1
Wool 8246 control [a]	3" x 6"	0	0
Wool 8246 [b]	3" x 6"	1	1
Mohair/wool 5423 control [a]	3" x 6"	0	0
Mohair/wool 5423 [b]	3" x 6"	1	1
Mohair/wool 5025 control [a]	3" x 6"	0	0
Mohair/wool 5025 [b]	3" x 6"	1	1

Note. N = 240.
[a]n = 120. [b]n = 120.

Dimensional Stability Specimens

All of the specimens designated for dimensional stability (180 fused and 90 unfused) were marked using a 10" x 10" template for marking dimensional stability fabric specimens (see Figure 2 and Table 5) and an indelible ink pen. Three 5" length measurements and three 5" width measurements were marked on the face side of the unfused specimens and the interlining side of the fused specimens to prepare each specimen for cleaning; following the diagram in Figure 2. All of the 30" x 58" unfused specimens and all of the 30" x 83" fused specimens, designated for cleaning were sewn into a tube (interlining side in) with a 504 overlock stitch (see Figure 4). The specimens to be cleaned were separated into three groups (a) lyocell, (b) wool, and (c) mohair/wool blend. Each group of fabric specimens (lyocell, wool, and mohair/wool blend) was further broken down into two groups (a) dryclean and (b) wetclean. There were six final groups (lyocell dryclean and lyocell wetclean, wool dryclean and wool wetclean, and mohair/wool blend dryclean and mohair/wool blend wetclean). Each of the six groups were cleaned individually according to the specified cleaning method. Ballast material was used to increase the weight of the load to 46 pounds for drycleaning and 50 pounds for wetcleaning, the specified amount needed for the machines used. The specimens were cleaned five times, but not finished in-between cleanings to avoid any damage to the fused specimens caused by steaming. This allowed the specimens to be cleaned and evaluated on their performance to withstand the cleaning solution and mechanical action of the

Table 5

Dimensional Stability Specimens for Study

Fabric/interlining combination	Dimensions of specimen fabrics	Drycleaning specimen no.	Wetcleaning specimen no.
Lyocell unfused [a]	10" x 10"	15	15
Lyocell 5025 [b]	10" x 10"	15	15
Lyocell 8336 [b]	10" x 10"	15	15
Wool unfused [a]	10" x 10"	15	15
Wool 9016 [b]	10" x 10"	15	15
Wool 8246 [b]	10" x 10"	15	15
Mohair/wool unfused [a]	10" x 10"	15	15
Mohair/wool 5423 [b]	10" x 10"	15	15
Mohair/wool 5025 [b]	10" x 10"	15	15

Note. $N = 270$.
[a] $n = 90$. [b] $n = 180$

cleaning machines. Dimensional stability specimens were remeasured after cleaning and recorded. The percent growth or percent shrinkage was calculated for each specimen.

Bond Strength Specimens

Specimens identified as controls for the bond strength tests, were cut into ten, 3" x 6" specimens per fabric/interlining combination and tested for bond strength before

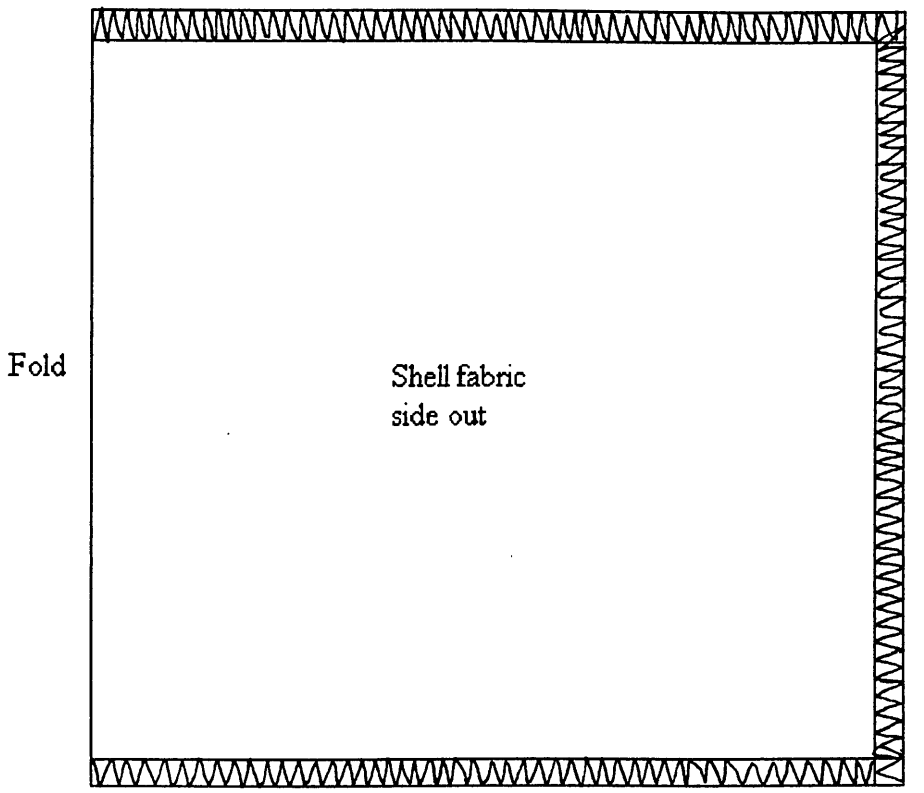


Figure 4. Diagram of stitched fabric tube for cleaning.

cleaning (see Figure 3). On the cleaned specimens (10 specimens per fabric/interlining combination and cleaning method, see Table 4), bond strength tests were performed and average bond strength was calculated for each specimen.

Appearance Specimens

Appearance specimens were evaluated after cleaning for evidence of puckering, cracking, blistering, and pilling (see Table 6). The specimens were rated for pilling using the ASTM photographic standards for random tumble pilling.

Cleaning Process

The fabrics (lyocell, wool, and mohair/wool blend, both fused and unfused) were separated into two groups, one for drycleaning and one for wetcleaning care methods. The drycleaning group was placed on a scale and weighed. Ballast material was added until the load weight equaled 46 pounds. The wetcleaning group was placed on a scale and weighed. Ballast material was added until the load weight equaled 50 pounds.

Drycleaning

A Bowe Passat standard drycleaning machine with a 46-pound load capacity), model number P546 was used. The solvent used for the drycleaning process was tetrachloroethylene or perchloroethylene (perc). The drycleaning load was placed into the drycleaning machine and run for five complete cleaning and drying cycles. See Table 7 for a description of the drycleaning cycles.

Table 6

Appearance Specimens for Study

Fabric/interlining combination	Dimensions of specimen fabrics	Drycleaning specimen no.	Wetcleaning specimen no.
Lyocell 5025 control [a]	15" x 15"	0	0
Lyocell 5025 [b]	15" x 15"	2	2
Lyocell 8336 control [a]	15" x 15"	0	0
Lyocell 8336 [b]	15" x 15"	2	2
Wool 9016 control [a]	15" x 15"	0	0
Wool 9016 [b]	15" x 15"	2	2
Wool 8246 control [a]	15" x 15"	0	0
Wool 8246 [b]	15" x 15"	2	2
Mohair/wool 5423 control [a]	15" x 15"	0	0
Mohair/wool 5423 [b]	15" x 15"	2	2
Mohair/wool 5025 control [a]	15" x 15"	0	0
Mohair/wool 5025 [b]	15" x 15"	2	2

Note. N = 36.
[a] n = 12. [b] n = 24.

Table 7

Description of Drycleaning Cycles

Type of cycle	Time of cycle
Cleaning with filtration	5 minutes
Rinse with circulation	3 minutes
Drying (tumbling)	22 minutes
Deodorizing (tumbling)	18 minutes

Note. The amount of perchloroethylene dispensed during the cleaning cycle is pre set.

Wetcleaning

The wetcleaning research equipment for the study was the Unimac Wetcleaning System, model number UF230W, consisting of a commercial, reversibly-rotating cage-type, horizontal-axis, washer-extractor machine (specifically manufactured for wetcleaning, with a 50-pound load capacity) and a standard moisture controlled dryer. The generic detergent used for the wetcleaning process was Shell Neodol® 23-6.5 which was an alcohol ethoxylate $H(CH_2)_{13}O(CH_2CH_2O)_7H$. The wetcleaning load was placed into the wetcleaning machine and run for one cycle. The load was then placed into the moisture controlled dryer and run for one cycle (until the specimens were dry). After drying, the wetcleaning load was placed back into the wetcleaning machine for its second cleaning cycle. The wetclean specimens were run for five cleaning cycles and five drying cycles. See Table 8 for a description of the wetcleaning cycles.

Table 8

Description of Wetcleaning Cycles

Type of cycle	Agitation	rpm	Temp.	Time	Detergent amount
Bath 1 (cleaning)					
	4 seconds forward 56 seconds off 4 seconds reverse 56 seconds off	26	86° F	6 minutes	95ml
Bath 2 (cleaning)					
	4 seconds forward 56 seconds off 4 seconds reverse 56 seconds off	26	86° F	10 minutes	95ml
Bath 3 (rinsing)					
	4 seconds forward 56 seconds off 4 seconds reverse 56 seconds off	26	86° F	5 minutes	--
Spin	high speed spin	900	--	2 minutes	--
Drying (tumbling)	continually reversing back and forth	--	140° F	7 minutes	--

Bond Strength Testing

The test method followed for bond strength was ASTM D 2724 Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics-Strength of Bond Test. Ten, 3" x 6" bond strength specimens were tested for each fabric/interlining combination before cleaning (see Table 4 for bond strength test specimens for study). After five cleanings,

ten, 3" x 6" bond strength specimens for each interlining combination and cleaning method (dryclean or wetclean) were tested for bond strength. The bond strength test specimens were conditioned for a minimum of four hours in the standard atmosphere for testing textiles as outlined by ASTM D2724 (70 degrees Fahrenheit and 65% humidity). A description of the bond strength test procedure for this study follows:

1. Separate each 3" x 6" bond strength specimen across the top width of the specimen measuring down one inch.

2. Secure the shell fabric of the fused specimen in the upper clamp of the tensile testing machine with the warp direction of the fabric running parallel with the closed clamping surface.

3. Secure the interlining of the fused specimen in the lower clamp of the tensile testing machine with the warp direction of the fabric running parallel with the closed clamping surface.

4. Operate the tensile testing machine at a pulling speed of 12 ± 0.5 inches per minute.

5. Determine the bond strength to the nearest 0.05 pounds of force as the average of the five lowest and five highest peak loads of resistance per inch of width, registered for 4 inches of delamination.

6. Report the bond strength in pounds per inch of width as the average strength of the test specimens, as stated on the print-out from the tensile testing machine. Steps 1-5 were repeated for each of the remaining specimens (ASTM, 1995).

Data were recorded on a bond strength report form that included specimen identification number, cleaning method (original state, dryclean, or wetclean), and average bond strength. See Appendix A for bond strength report form.

Dimensional Stability Testing

The measuring instruments for dimensional stability was a 10" x 10" template for marking dimensional stability fabric specimens (see Figure 2), and a Luftkin 12-foot tape measure, graduated into 0.1 inch increments. Fifteen 10" x 10" dimensional stability squares were measured for all of the unfused shell fabrics and fabric/interlining combinations for drycleaning. Fifteen 10" x 10" dimensional stability squares were measured for all of the unfused shell fabrics and fabric/interlining combinations for wetcleaning, as well as fifteen 10" x 10" unfused shell fabrics (15 lyocell, 15 wool, and 15 mohair/wool blend). These 15 unfused shell fabric specimens were tested for dimensional stability to determine the percent growth or shrinkage of the fabric. See Table 5 dimensional stability specimens for study. The description of the dimensional stability test procedure for this study was as follows:

1. Mark the fabric specimens using the template for marking fabric specimens (see Figure 2) (three 5" length measurements and three 5" width measurements for each specimen).

2. A black indelible marker was used so the markings would remain on the fabric through the cleanings.

3. Sew the specimens into a tube using a 504 overlock stitch (see Figure 4) and clean according to specified cleaning methods (dryclean or wetclean) and remeasure to determine if any dimensional change has occurred.

4. Calculate the shrinkage or growth of each test specimen using an average of the width and an average of the length measurements (per individual specimen) in accordance with the following equation: Shrinkage, % = (A-B)100/A. A = average original measurement between marks, and B = average final measurement between marks. Steps 1-3 will be repeated for the remaining specimens (ASTM, 1995).

Data were recorded on a dimensional stability report form that included specimen identification number, cleaning method, measurement before cleaning (5" x 5"), measurement after cleaning, and percent shrinkage. See Appendix B for dimensional stability report form.

Appearance Testing

The researcher visually inspected each 15" x 15" appearance specimen after cleaning and recorded any evidence of puckering, cracking, blistering or pilling. The samples were evaluated for pilling using ASTM Photographic Standards for Random Tumble Pilling and the ASTM Pilling Assessment Cabinet for fabric evaluation. The description of the appearance evaluation procedure for this study was as follows:

1. Mount each cleaned appearance specimen and two controls without tension on a viewing board with the warp direction of the fabric in a vertical position. The two

control specimens were hung on either side of the cleaned specimen being rated. Only one cleaned appearance specimen was mounted at a time between two control specimens.

2. The evaluation room was dark. The only light source should be from the evaluation lighting equipment.

3. Record any evidence of puckering, cracking, blistering, or pilling.

The specimens were rated for pilling in an apparatus for fabric evaluation (see Figure 5) using ASTM photographic pilling standards. Steps 1-4 were repeated for the remaining appearance specimens.

Data were recorded on an appearance report form that included specimen identification number, cleaning method (dryclean or wetclean), an area to check off problems with puckering, cracking, blistering and pilling, and an area to record the pilling rating. See Appendix C for the appearance report form.

Data Analysis

The statistical analysis for the study was evaluated according to the data gathered for each of the following tests: bond strength, dimensional stability, and appearance. Statistical tests used for the study included a one-way ANOVA, ANOVA with repeated measures, and descriptive statistics. The statistical tests for the study were run at an alpha level of .01. Frequencies and percentages were calculated for all appearance samples for the occurrence of puckering, cracking, blistering, and pilling.

Statistical analysis for each hypothesis for the study is listed below:

H1: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependant variable was bond strength. The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all lyocell/5025 combination specimens. The statistical test used to analyze the data for this hypothesis was a one-way ANOVA.

H2: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fabric fused with interlining 8336, and drycleaning and wetcleaning care methods. The dependant variable was bond strength. The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all lyocell/8336 combination specimens. The statistical test used to analyze the data for this hypothesis was a one-way ANOVA.

H3: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fabric fused with interlining 9016, and drycleaning and wetcleaning care methods. The dependant variable was bond strength.

The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all wool/9016 combination specimens. The statistical test used to analyze the data for this hypothesis was a one-way ANOVA.

H4: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fabric fused with interlining 8246, and drycleaning and wetcleaning care methods. The dependant variable was bond strength. The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all wool/8246 combination specimens. The statistical test used to analyze the data for this hypothesis was a one-way ANOVA.

H5: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fabric fused with interlining 5423, and drycleaning and wetcleaning care methods. The dependent variable was bond strength. The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all mohair/wool blend/5423 combination specimens. The statistical test used for this hypothesis was a one-way ANOVA.

H6: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependent variable was bond strength. The scores were the average pounds of force of resistance per inch of width registered for 4 inches of delamination on all mohair/wool blend/5025 combination specimens. The statistical test used to analyze the data for this hypothesis was a one-way ANOVA.

H7a: For unfused lyocell fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables for were unfused lyocell, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all unfused lyocell specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H7b: For unfused lyocell fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables for were unfused lyocell, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all unfused lyocell specimens. The

statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H8a: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all lyocell/5025 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H8b: For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all lyocell/5025 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H9a: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fused with interlining 8336, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all lyocell/8336 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H9b: For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were lyocell fused with interlining 8336, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all lyocell/8336 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H10a: For unfused wool fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were unfused wool, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all unfused wool specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H10b: For unfused wool fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were unfused wool, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all unfused wool specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H11a: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fused with interlining 9016, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all wool/9016 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H11b: For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fused with interlining 9016, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all wool/9016 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H12a: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fabric fused with interlining 8246, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all wool/8246 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H12b: For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were wool fabric fused with interlining 8246, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all wool/8246 combination specimens. The statistical test used to analyze the data for this hypothesis was an ANOVA with repeated measures.

H13a: For unfused mohair/wool blend fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were unfused mohair/wool blend and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all unfused mohair/wool blend specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

H13b: For unfused mohair/wool blend fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were unfused mohair/wool blend and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all unfused mohair/wool blend

specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

H14a: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fused with interlining 5423, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all mohair/wool blend/5423 combination specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

H14b: For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fused with interlining 5423, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all mohair/wool blend/5423 combination specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

H15a: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the length direction of the fabric. The scores were an average of the percent shrinkage or growth in the length direction of a 10"x10" block of fabric on all mohair/wool blend/5025 combination specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

H15b: For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

The independent variables were mohair/wool blend fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependent variable was dimensional stability in the width direction of the fabric. The scores were an average of the percent shrinkage or growth in the width direction of a 10"x10" block of fabric on all mohair/wool blend/5025 combination specimens. The statistical test used to analyze data for this hypothesis was an ANOVA with repeated measures.

Statistical analysis for each research question were as follows:

R1: Will there be differences in the appearance of lyocell fabric fused with nonwoven fusible interlining 5025, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when inspected for puckering, cracking, blistering, and pilling?

The independent variables were lyocell fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the amount if pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

R2: Will there be differences in the appearance of lyocell fabric fused with nonwoven fusible interlining 8336, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when evaluated for puckering, cracking, blistering, and pilling?

The independent variables for research question two were lyocell fabric fused with interlining 8336, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the amount of pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

R3: Will there be differences in the appearance of wool fabric fused with nonwoven fusible interlining 9016, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when evaluated for puckering, cracking, blistering, and pilling?

The independent variables for research question three were wool fabric fused with interlining 9016, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of

puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the amount of pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

R4: Will there be differences in appearance of wool fabric fused with nonwoven fusible interlining 8246, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when evaluated for puckering, cracking, blistering, and pilling?

The independent variables for research question four were wool fabric fused with interlining 8246, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the amount of pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

R5: Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven fusible interlining 5423, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when evaluated for puckering, crack marks, blisters, and pilling?

The independent variables for research question five were mohair/wool blend fabric fused with interlining 5423, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the

amount of pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

R6: Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven fusible interlining 5025, between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings, when evaluated for puckering, crack marks, blisters, and pilling?

The independent variables for research question six were mohair/wool blend fabric fused with interlining 5025, and drycleaning and wetcleaning care methods. The dependant variables were puckering, cracking, blistering, and pilling. The data represented the presence of puckering, cracking, blistering, and pilling. A five-point scale with 5.0 representing no pilling and 1.0 representing severe pilling was used to identify the amount of pilling present after cleaning. Descriptive statistical tests were used to analyze the data.

CHAPTER IV

RESULTS AND FINDINGS

The purpose of the study was to determine whether lyocell, wool, and mohair/wool fabrics, fused to appropriate nonwoven fusible apparel interlinings, would be compatible with wetcleaning technologies when tested for bond strength and dimensional stability, and evaluated for appearance. Data were collected on the unfused fabrics after five drycleanings and after five wetcleanings and on the fused fabrics before cleaning, after five drycleanings, and after five wetcleanings. Data consisted of bond strength scores before and after cleaning, dimensional stability scores of unfused fabrics and fused fabrics after cleaning and appearance ratings of the fused fabrics after cleaning.

The recorded scores were analyzed with Biomedical Data Package (BMDP) statistical programs (Dixon et al., 1993). For all statistical tests, differences were considered representative of significant results at the $p < .01$ probability level. The results of the data are reported in sections: (a) description of the sample, (b) description of bond strength measurements, (c) description of dimensional stability measurements, (d) description of appearance evaluations, and (e) examination of research hypotheses and research questions.

Description of the Sample

The sample group of fabrics consisted of 100% lyocell, 100% worsted wool, and 60% mohair/40% wool blend suiting fabrics, 60 inches in width. The fabrics were

recommended for dryclean care methods, and categorized within the better price range. Six nonwoven apparel fusible interlinings were selected. Two interlinings were chosen for each fabric type; the sample interlinings were appropriate to the weight of the identified fabrics. The nonwoven interlinings were donated by the leading nonwoven interlining producer in the world and selected by one of the in-house sales representatives of the producer.

Description of Bond Strength Measurements

Bond strength was measured in pounds per inch of delamination for all of the fused specimens. Bond strength testing was performed on the fused fabrics before cleaning, after five drycleanings, and after five wetcleanings. The bond strength testing sample group consisted of 240 specimens. Ten control specimens were cut from each fabric/interlining selection before cleaning. After five drycleanings, 10 specimens were cut from each fabric/interlining combination. After five wetcleanings, 10 specimens were cut from each fabric/interlining combination. The data collected on bond strength were measured following the procedure in ASTM Test Method D 2724 Standard Test Method for Bonded, Fused, and Laminated Apparel Fabrics-Strength of Bond Test (ASTM, 1995) to determine if the bond strength of the wetcleaned specimens would perform at the same level as the bond strength of the drycleaned specimens.

Lyocell Bond Strength Performance

The lyocell fabric was selected and fused with interlining 5025 and interlining 8336. Bond strength specimens were tested before cleaning, after drycleaning, and after

wetcleaning processes. An Instron® tensile testing machine was used to measure the force in pounds required to separate the shell fabric from the interlining for a distance of 4 inches.

A one-way analysis of variance (ANOVA) was used to indicate differences in bond strength between cleaning methods. The ANOVA was used to measure the effect of the experimental treatments (dryclean versus wetclean care methods) on the specimens (fused fabric/interlining combinations). For all statistical tests, differences were considered significant at the .01 probability level.

The average bond strength for lyocell fused to 5025 after five drycleanings was 4.15 pounds of force. The percentage change between the lyocell fused to 5025 before drycleaning and after five drycleanings was an increase of 41.76% in bond strength. The average bond strength for lyocell fused to 5025 after five wetcleanings was 3.19 pounds of force. The percentage change between the lyocell fused to 5025 before wetcleaning and after five wetcleanings was a decrease of 11.69% in bond strength. Significance in bond strength was indicated by a one-way ANOVA between specimens that were drycleaned and specimens that were wetcleaned ($\underline{F}$ (3, 36) = 19.67, $\underline{p} < .01$). For the range in bond strength scores, mean, standard deviation, and standard error of the mean scores for lyocell fused with 5025 between drycleaning and wetcleaning processes, see Table 9.

The average bond strength for lyocell fused to 8336 after five drycleanings was 3.63 pounds of force. The percentage change between the lyocell fused to 8336 before drycleaning and after five drycleanings was an increase of 155.63% in bond strength.

The average bond strength for lyocell fused to 8336 after five wetcleanings was 1.21 pounds of force. The percentage change between the lyocell fused to 8336 before wetcleaning and after five wetcleanings was a decrease of 55.59% in bond strength. Significance in bond strength at the $p < .01$ level was found between specimens that were drycleaned and specimens that were wetcleaned (F (3, 36) = 129.05, $p < .01$). For the range in bond strength scores, mean, standard deviation, and standard error of the mean scores for lyocell fused with 8336 between drycleaning and wetcleaning processes, see Table 9.

Table 9

Description of Bond Strength for Fused Lyocell Fabric After Drycleaning and After Wetcleaning Processes

Interlining	n	Range of bond strength scores	M	SD	S.E.M
5025	40	2.36 – 4.77	3.47	0.59	0.094
8336	40	0.96 – 4.13	2.26	1.05	0.167

Note. Range = minimum and maximum scores gathered for bond strength.

Wool Bond Strength Performance

The wool fabric was selected and fused with interlining 9016 and interlining 8246. Bond strength specimens were tested before cleaning, after drycleaning, and after wetcleaning processes. An Instron® tensile testing machine was used to measure the force in pounds that it took to separate the shell fabric from the interlining for a distance of 4 inches.

A one-way analysis of variance (ANOVA) was used to indicate differences in bond strength between cleaning methods. The ANOVA was used to measure the effect of the experimental treatments (dryclean versus wetclean care methods) on the specimens (fused fabric/interlining combinations). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

The average bond strength for wool fused to 9016 after five drycleanings was 3.56 pounds for force. The percentage change between the wool fused to 9016 before drycleaning and after five drycleanings was a decrease of 37.71% in bond strength. The average bond strength for wool fused to 9016 after five wetcleanings was 5.17 pounds of force. The percentage change between the wool fused to 9016 before wetcleaning and after five wetcleanings was a decrease of 10.74% in bond strength. Significance in bond strength at the $p < .01$ level was found between specimens that were drycleaned and specimens that were wetcleaned (F (3, 36) = 24.38, $p < .01$). For the range in bond strength scores, mean, standard deviation, and standard error of the mean scores for wool fused with 9016 between drycleaning and wetcleaning processes, see Table 10.

The average bond strength for wool fused to 8246 after five drycleanings was 2.33 pounds of force. The percentage change between the wool fused to 8246 before drycleaning and after five drycleanings was a decrease of 25.54% in bond strength. The average bond strength for wool fused to 8246 after five wetcleanings was 2.31 pounds of force. The percentage change between the wool fused with 8246 before wetcleaning and after five wetcleanings was a decrease of 22.86% in bond strength. No significance in

Table 10

Description of Bond Strength for Wool Fabric Fused With 9016 After Drycleaning and After Wetcleaning Processes

Interlining	n	Range of bond strength scores	M	SD	S.E.M
9016	40	2.57 – 6.76	5.06	1.13	0.176

Note. Range = minimum and maximum scores gathered for bond strength.

bond strength at the $p < .01$ level was found between drycleaned and wetcleaned specimens.

Mohair/Wool Bond Strength Performance

The mohair/wool fabric was selected and fused with interlining 5423 and interlining 5025. Bond strength specimens were tested before cleaning, after drycleaning, and after wetcleaning processes. An Instron® tensile testing machine was used to measure the force in pounds that it took to separate the shell fabric from the interlining for a distance of 4 inches.

A one-way analysis of variance (ANOVA) was used to indicate differences in bond strength between cleaning methods. The ANOVA was used to measure the effect of the experimental treatments (dryclean versus wetclean care methods) on the specimens (fused fabric/interlining combinations). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

The average bond strength for mohair/wool fused to 5423 after five drycleanings was 3.00 pounds of force. The percentage change between the wool fused to 5423 before

drycleaning and after five drycleanings was an increase of 16.67% in bond strength. The average bond strength for mohair/wool fused to 5423 after five wetcleanings was 1.85 pounds of force. The percentage change between the mohair/wool fused to 5423 before wetcleaning and after five wetcleanings was a decrease of 18.29% in bond strength. Significance in bond strength at the $p < .01$ level was found between specimens that were drycleaned and specimens that were wetcleaned (F (3, 36) = 36.94, $p < .01$). For the range in bond strength scores, mean, standard deviation, and standard error of the mean scores for mohair/wool fused with 5423 between drycleaning and wetcleaning processes, see Table 11.

The average bond strength for mohair/wool fused to 5025 after five drycleanings was 0.54 pounds of force. The percentage change between the mohair/wool fused to 5025 before drycleaning and after five drycleanings was a decrease of 44.46% in bond strength. The average bond strength of mohair/wool fused to 5025 after five wetcleanings was 0.87 pounds of force. The percentage change between the mohair/wool fused to 5025 before wetcleaning and after five wetcleanings was an increase of 34.56% in bond strength. Significance in bond strength at the $p < .01$ level was found between specimens that were drycleaned and specimens that were wetcleaned (F (3, 36) = 14.39, $p < .01$). For the range in bond strength scores, mean, standard deviation, and standard error of the mean scores for mohair/wool fused with 5025 between drycleaning and wetcleaning processes, see Table 11.

Table 11

Description of Bond Strength for Fused Mohair/Wool Fabric After Drycleaning and After Wetcleaning Processes

Interlining	n	Range of bond strength scores	M	SD	S.E.M
5423	40	1.55 – 3.32	2.42	0.49	0.077
5025	40	0.26 – 1.23	0.76	0.23	0.038

Note. Range = minimum and maximum scores gathered for bond strength.

Description of Dimensional Stability Measurements

Dimensional stability was computed for percentage change after five drycleanings and after five wetcleanings on all of the unfused fabrics and fabric/interlining combinations. The sample for dimensional stability consisted of 90, 10" x 10" unfused fabric specimens, (15 for drycleaning and 15 for wetcleaning per fabric), and 180, 10" x 10" fused fabric/interlining specimens (15 for drycleaning and 15 for wetcleaning per fabric/interlining combination). Three length and three width 5" measurements were taken for each of the 10" x 10" specimens. The data collected for dimensional stability were measured following ASTM D 2724 Standard Test Method for Bonded, Fused, and Laminated Apparel Fabrics (ASTM, 1995) to determine if the wetcleaned specimens would perform at the same level as the drycleaned specimens.

Dimensional Stability of Lyocell

The unfused lyocell fabric and lyocell fused with interlining 5025 and interlining 8336 were selected for dimensional stability testing. The dimensional stability test

specimens were marked before cleaning and measured after drycleaning, and after wetcleaning processes. The percentage change was calculated for the tested specimens after drycleaning and after wetcleaning processes.

An ANOVA with repeated measures was used to indicate differences in dimensional stability between cleaning methods. The length and width dimensional stability measurements were analyzed in separate hypotheses. The ANOVA with repeated measures was used to measure the same specimens before and after cleaning (dryclean or wetclean care methods). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

The average dimensional change in the length direction of the unfused lyocell fabric after five drycleanings was 1.80% shrinkage, and after five wetcleanings was 5.88% shrinkage. The average dimensional change in the width direction of the unfused lyocell fabric after five drycleanings was 1.73% shrinkage, and after five wetcleanings was 1.68% shrinkage.

The average dimensional change in the length direction of the lyocell fused with 5025 after five drycleanings was 1.51% shrinkage, and after five wetcleanings was 4.84% shrinkage. The average dimensional change in the width direction of the lyocell fused with 5025 after five drycleanings was 1.17% shrinkage, and after five wetcleanings was 0.77% shrinkage.

The average dimensional change in the length direction of the lyocell fused with 8336 after five drycleanings was 1.17% shrinkage, and after five wetcleanings was 5.42% shrinkage. The average dimensional change in the width direction of the lyocell fused

with 8336 after five drycleanings was 1.04% shrinkage, and after five wetcleanings was 0.95% shrinkage.

Dimensional Stability of Wool

The unfused wool fabric and wool fused with interlining 9016 and interlining 8246 were selected for dimensional stability testing. The dimensional stability test specimens were marked before cleaning and measured after drycleaning, and after wetcleaning processes. The percentage change was calculated for the tested specimens after drycleaning and after wetcleaning processes.

An ANOVA with repeated measures was used to indicate differences in dimensional stability between cleaning methods. The length and width dimensional stability measurements were analyzed in separate hypotheses. The ANOVA with repeated measures was used to measure the same specimens before and after treatment (dryclean or wetclean care methods). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

The average dimensional change in the length direction of the unfused wool, after five drycleanings was 0.06% shrinkage, and after five wetcleanings was 0.51% shrinkage. The average dimensional change in the width direction of the unfused wool after five drycleanings was 0.37% shrinkage, and after five wetcleanings was 0.77% shrinkage.

The average dimensional change in the length direction of the wool fused with 9016 after five drycleanings was 0.75% shrinkage, and after five wetcleanings was 1.31%

shrinkage. The average dimensional change in the width direction of the wool fused with 9016 after five drycleanings was 0.11% shrinkage, and after five wetcleanings was 0.35% shrinkage.

The average dimensional stability in the length direction of the wool fused with 8246 after five drycleanings was 0.42% shrinkage, and after five wetcleanings was 0.97% shrinkage. The average dimensional stability in the width direction of the wool fused with 8246 after five drycleanings was 0.04% shrinkage, and after five wetcleanings was 0.80% shrinkage.

Dimensional Stability of Mohair/Wool

The unfused mohair/wool fabric and mohair/wool fused with interlining 5423 and interlining 5025 were selected for dimensional stability testing. The dimensional stability test specimens were marked before cleaning and measured after drycleaning, and after wetcleaning processes. The percentage change was calculated for the tested specimens after drycleaning and after wetcleaning processes.

An ANOVA with repeated measures was used to indicate differences in dimensional stability between cleaning methods. The length and width dimensional stability measurements were analyzed in separate hypotheses. The ANOVA with repeated measures was used to measure the same specimens before and after cleaning (dryclean or wetclean care methods). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

The average dimensional stability in the length direction of the unfused mohair/wool fabric after five drycleanings was 0.64% shrinkage, and after five wetcleanings was 1.71% shrinkage. The average dimensional stability in the width direction of the unfused mohair/wool fabric after five drycleanings was 0.02% shrinkage and after five wetcleanings was 1.97% shrinkage.

The average dimensional stability in the length direction of the mohair/wool fused with 5423 after five drycleanings was 0.48% shrinkage, and after five wetcleanings was 1.28% shrinkage. The average dimensional stability in the width direction for mohair/wool fused with 5423 after five drycleanings was 0.00% shrinkage, and after five wetcleanings was 0.75% shrinkage.

The average dimensional stability in the length direction of the mohair/wool fused with 5025 after five drycleanings was 0.20% shrinkage, and after five wetcleanings was 2.13% shrinkage. The average dimensional stability in the width direction of the mohair/wool fused with 5025 after five drycleanings was 0.17% shrinkage, and after five wetcleanings was 1.20% shrinkage.

Description of Appearance Evaluations

Appearance was evaluated visually for all of the fabric/interlining combinations after five drycleanings and after five wetcleanings. The specimens were inspected for presence of puckering, cracking, blistering, and pilling. The test methods followed for appearance were AATCC Method 124 Appearance of Fabrics after Repeated Home Laundering (AATCC, 1995) and ASTM D 3135 Standard Specification of Performance

of Bonded, Fused, and Laminated Apparel Fabrics (ASTM, 1995). The specimens were evaluated using ASTM Photographic Standards for Random Tumble Pilling and ASTM Pilling Assessment Cabinet for Fabric Evaluation (ASTM, 1995).

Appearance of Lyocell

A Lyocell fabric was selected and fused with interlining 5025 and interlining 8336. The appearance specimens were cleaned and visually evaluated against control specimens after drycleaning and after wetcleaning for presence of puckering, cracking, blistering, and pilling.

Descriptive statistics were used to indicate differences in appearance between dryclean and wetclean processes. The presence of puckering, cracking, blistering, and pilling were recorded as *yes*, indicating the characteristic was exhibited or *no*, indicating the specimen did not exhibit the characteristics. A pilling rating was assigned for all of the appearance specimens. The ratings were based on a 5-point scale with 5.0 representing no pilling and 1.0 representing severe pilling.

The lyocell specimens fused with 5025 and lyocell specimens fused with 8336 did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. The lyocell specimens fused with 5025 and lyocell specimens fused with 8336 received ratings of 5.0 for pilling (on a 5-point scale with 5.0 representing no pilling and 1.0 representing severe pilling.) after drycleaning and after wetcleaning processes.

Appearance of Wool

A wool fabric was selected and fused with interlining 9016 and interlining 8246. The appearance specimens were cleaned and visually evaluated against control specimens after drycleaning and after wetcleaning for presence of puckering, cracking, blistering, and pilling.

The wool specimens fused with 9016 and wool specimens fused with 8246 did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. The wool specimens fused with 9016 and wool specimens fused with 8246 received ratings of 5.0 for pilling after drycleaning and after wetcleaning processes.

Appearance of Mohair/Wool

A mohair/wool fabric was selected and fused with interlining 5423 and interlining 5025. The appearance specimens were cleaned and visually evaluated against control specimens after drycleaning and after wetcleaning for presence of puckering, cracking, blistering, and pilling.

The mohair/wool specimens fused with 5423 and mohair/wool specimens fused with 5025 did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. The mohair/wool specimens fused with 5423 and mohair/wool specimens fused with 5025 received ratings of 5.0 for pilling after drycleaning and after wetcleaning processes.

Examination of Research Hypotheses and Research Questions

Fifteen directional hypotheses and six research questions were proposed and tested for the study. Results of the statistical analyses provided the justification for accepting or rejecting the hypotheses and answering the research questions. For all statistical tests, differences were considered representative of significant results at the $p < .01$ probability level.

Bond Strength

Hypotheses 1 through 6 examined bond strength. These hypotheses were designed to determine if differences existed between dryclean and wetclean care methods on bond strength. Bond strength was measured for each of the fabric/interlining combinations: (a) lyocell fused with 5025, (b) lyocell fused with 8336, (c) wool fused with 9016, (d) wool fused with 8246, (e) mohair/wool fused with 5423, and (f) mohair/wool fused with 5025.

A one-way analysis of variance (ANOVA) was used to indicate differences in bond strength between cleaning methods. The ANOVA was used to measure the effect of the experimental treatments (dryclean versus wetclean care methods) on the specimens (fused fabric/interlining combinations). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

Hypothesis 1

For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated significant differences existed in bond strength scores between drycleaning and wetcleaning processes after five cleanings for lyocell fused with 5025 (F (3, 36) = 19.67, $p < .01$); therefore Hypothesis 1 was accepted. For a summary of the ANOVA for lyocell fused with 5025 after cleaning, see Table 12.

Hypothesis 2

For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated significant differences existed in bond strength scores between drycleaning and wetcleaning processes for lyocell fused with 8336 (F (3, 36) = 129.05, $p < .01$); therefore Hypothesis 2 was accepted. For a summary of the ANOVA for lyocell fused with 8336 after drycleaning and after wetcleaning, see Table 12.

Table 12

ANOVA Summary of Bond Strength Scores for Fused Lyocell After Drycleaning and After Wetcleaning Processes

	Fusible 5025				Fusible 8336			
Source	SS	df	MS	F	SS	df	MS	F
Cleaning	8.55	3	2.85	19.67*	39.59	3	13.19	129.05*
Error	5.21	36	0.14		03.68	36	00.10	

*$p < .01$

Hypothesis 3

For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated significant differences existed in bond strength scores between drycleaning and wetcleaning processes for wool fused to 9016 (F (3, 36) = 24.38, $p < .01$); therefore Hypothesis 3 was accepted. For a summary of the ANOVA for fused wool after drycleaning and after wetcleaning, see Table 13.

Table 13

ANOVA Summary of Bond Strength Scores for Wool Fused With 9016 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	32.37	3	10.79	24.38*
Error	15.93	36	00.44	

*$p < .01$

Hypothesis 4

For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated no significant differences existed in bond strength scores between drycleaning and wetcleaning processes for wool fused to 8246 (F (3, 36) = 45.93, ns); therefore Hypothesis 4 was rejected.

Hypothesis 5

For mohair/wool fabric fused with nonwoven fusible interlining 5423, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated significant differences existed in bond strength scores between drycleaning and wetcleaning processes for mohair/wool fused with 5423, (F (3, 36) = 36.94, $p < .01$); therefore Hypothesis 5 was accepted. For a summary of the ANOVA for fused mohair/wool after drycleaning and after wetcleaning, see Table 14.

Hypothesis 6

For mohair/wool fabric fused with nonwoven fusible interlining 5025, there will be significant differences in bond strength scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

A one-way ANOVA test indicated significant differences existed in bond strength scores between drycleaning and wetcleaning processes for mohair/wool fused with 5025, (F (3, 36) = 14.39, $p <.01$); therefore Hypothesis 6 was accepted. For a summary of the ANOVA for fused mohair/wool after drycleaning and after wetcleaning, see Table 14.

Dimensional Stability

Hypotheses 7a through 15b examined dimensional stability. These hypotheses were designed to determine if differences existed between dryclean and wetclean care methods on dimensional stability. Dimensional stability was measured for each of the unfused fabrics and fabric/interlining combinations: (a) unfused lyocell, (b) lyocell fused

Table 14

ANOVA Summary of Bond Strength Scores for Fused Mohair/Wool After Drycleaning and After Wetcleaning Processes

	Fusible 5423				Fusible 5025			
Source	SS	df	MS	F	SS	df	MS	F
Cleaning	7.06	3	2.35	36.94*	1.21	3	0.40	14.39*
Error	2.29	36	0.06		1.01	36	0.02	

*$p < .01$

with 5025, (c) lyocell fused with 8336, (d) unfused wool, (e) wool fused with 9016, (f) wool fused with 8246, (g) unfused mohair/wool, (h) mohair/wool fused with 5423, and (i) mohair/wool fused with 5025.

An ANOVA with repeated measures was used to indicate differences in dimensional stability between cleaning methods. The length and width dimensional stability measurements were analyzed in separate hypotheses. The ANOVA with repeated measures was used to measure the same specimens before and after treatment (dryclean or wetclean care methods). For all statistical tests, differences were considered representative of significant results at the .01 probability level.

Hypothesis 7a

For unfused lyocell fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for unfused lyocell (F (1, 28) = 620.40, $p < .01$); therefore Hypothesis 7a was accepted. For a summary of the ANOVA with repeated measures for unfused lyocell after drycleaning and after wetcleaning, see Table 15.

Table 15

ANOVA Summary of Dimensional Stability Length Scores for Unfused Lyocell After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	376.17	1	376.17	620.40*
Error	016.97	28	000.60	

*$p < .01$

Hypothesis 7b

For unfused lyocell fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated no significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for unfused lyocell (F (1, 28) = 0.04, ns). Hypothesis 7b was rejected.

Hypothesis 8a

For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between cleaning methods for lyocell fused with 5025 (F (1, 28) = 320.77, $p < .01$); therefore Hypothesis 8a was accepted. For a summary of the ANOVA with repeated measures for lyocell fused with 5025 after drycleaning and after wetcleaning, see Table 16.

Table 16

ANOVA Summary of Dimensional Stability Length Scores for Lyocell Fused With 5025 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	250.00	1	250.00	320.77*
Error	021.82	28	000.77	

*$p < .01$

Hypothesis 8b

For lyocell fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated no significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for lyocell fused with 5025 (F (1, 28) = 3.64, ns). Hypothesis 8b was rejected.

Hypothesis 9a

For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for lyocell fused with 8336 (F (1, 28) = 622.85, $p < .01$); therefore Hypothesis 9a was accepted. For a summary of the ANOVA with repeated measures for lyocell fused with 8336 after drycleaning and after wetcleaning, see Table 17.

Table 17

ANOVA Summary of Dimensional Stability Length Scores for Lyocell Fused With 8336 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	405.34	1	405.34	622.85*
Error	018.22	28	000.65	

*$p < .01$

Hypothesis 9b

For lyocell fabric fused with nonwoven fusible interlining 8336, there will be significant differences in width dimensional stability scores between specimens subjected to

drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated no significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for lyocell fused with 8336 (F (1, 28) = 0.14, ns). Hypothesis 9b was rejected.

Hypothesis 10a

For unfused wool fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for unfused wool (F (1, 28) = 16.87, $p < .01$); therefore Hypothesis 10a was accepted (see Table 18). A Tukey post hoc multiple comparison test indicated that there were no significant differences between the three length measurements after drycleaning and after wetcleaning processes (F (1, 28) = 5.41, ns); however, the overall length dimensional change for the unfused wool fabric after drycleaning was significantly different than after wetcleaning. According to Glass and Hopkins (1996), when nothing is significant on the post hoc test, the two means farthest apart shall be declared as significantly different (M1, – 0.43 and M3, – 0.13).

Hypothesis 10b

For unfused wool fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Table 18

ANOVA Summary of Dimensional Stability Length Scores for Unfused Wool After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	4.44	1	4.44	16.87*
Error	7.37	28	0.26	

*$p < .01$

An ANOVA with repeated measures test indicated significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for unfused wool (F (1, 28) = 12.06, $p < .01$); therefore Hypothesis 10b was accepted. For a summary of the ANOVA with repeated measures for unfused wool after drycleaning and after wetcleaning, see Table 19.

Table 19

ANOVA Summary of Dimensional Stability Width Scores for Unfused Wool After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	3.60	1	3.60	12.06*
Error	8.35	28	0.29	

*$p < .01$

Hypothesis 11a

For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in length dimensional stability scores between specimens subjected to

drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for wool fused to 9016 (F (1, 28) = 16.26, $p < .01$); therefore Hypothesis 11a was accepted. For a summary of the ANOVA with repeated measures for wool fused with 9016 after drycleaning and after wetcleaning, see Table 20.

Table 20

ANOVA Summary of Dimensional Stability Length Scores for Wool Fused With 9016 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	06.94	1	6.94	16.26*
Error	11.95	28	0.42	

*$p < .01$

Hypothesis 11b

For wool fabric fused with nonwoven fusible interlining 9016, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated no significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for wool fused to 9016 (F (1, 28) = 2.95, ns). Hypothesis 11b was rejected.

Hypothesis 12a

For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for wool fused to 8246 (F (1, 28) = 20.93, $p < .01$). There was a significant interaction between length and cleaning (drycleaning and wetcleaning combined) (F (2, 56) = 5.28, $p < .01$). For a summary of the ANOVA with repeated measures for wool fused with 8246 after drycleaning and after wetcleaning, see Table 21. A Tukey post hoc multiple comparison test indicated that significant differences existed between the three length scores after drycleaning and after wetcleaning processes (F (1, 28) = 3.05, $p < .01$). However, although statistical differences were found between the length scores after drycleaning and after wetcleaning processes, the researcher determined no logical significance existed; therefore Hypothesis 12a was rejected. For a summary of the Tukey post hoc comparison of significant mean differences for dimensional stability length scores for wool fused with 8246 after drycleaning and after wetcleaning, see Table 22.

Hypothesis 12b

For wool fabric fused with nonwoven fusible interlining 8246, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Table 21

ANOVA Summary of Dimensional Stability Length Scores for Wool Fused With 8246 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	06.94	1	6.94	20.93*
Length	01.40	2	0.70	03.05*
Length x cleaning	02.42	2	1.21	05.28*
Error	12.84	56	0.22	

*$p < .01$

Table 22

Tukey Post Hoc Comparison of Significant Mean Differences for Dimensional Stability Length Scores for Wool Fused With 8246 After Drycleaning and After Wetcleaning Processes

	Drycleaning length 1 score	Drycleaning length 2 score	Drycleaning length 3 score
Wetcleaning length 1 score	0.93*	0.66*	0.73*
Wetcleaning length 2 score	0.86*	--	0.66*
Wetcleaning length 3 score	--	--	--

*$p < .01$

An ANOVA with repeated measures test indicated significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for wool fused to 8246 (F (1, 28) = 50.58, $p < .01$). A Tukey post hoc multiple comparison test indicated that there were no significant differences between the three width measurements after drycleaning and after wetcleaning processes for wool fused with 8246 (F (1, 28) = 7.0, ns); however, the overall width dimensional change in the width of the wool fused with 8246 after drycleaning was significantly different than after wetcleaning. According to Glass and Hopkins (1996), when nothing is significant on the post hoc test, the two means farthest apart shall be declared as significantly different (M2, – 0.56 and M3, – 0.20). Hypothesis 12b was accepted. For a summary of the ANOVA with repeated measures for wool fused with 8246 after drycleaning and after wetcleaning, see Table 23.

Table 23

ANOVA Summary of Dimensional Stability Width Scores for Wool Fused With 8246 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	12.84	1	12.84	50.58*
Width	02.28	2	01.14	07.00*
Width x cleaning	00.55	2	00.27	01.70
Error	09.15	56	00.16	

*$p < .01$

Hypothesis 13a

For unfused mohair/wool blend fabric, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for unfused mohair/wool (F (1, 28) = 37.95, $p < .01$); therefore Hypothesis 13a was accepted. For a summary of the ANOVA with repeated measures for unfused mohair/wool fabric after drycleaning and after wetcleaning, see Table 24.

Table 24

ANOVA Summary of Dimensional Stability Length Scores for Unfused Mohair/Wool After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	25.60	1	25.60	37.95*
Error	18.88	28	00.67	

Note. *$p < .01$

Hypothesis 13b

For unfused mohair/wool blend fabric, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for unfused mohair/wool blend fabric (F (1, 28) = 363.81, $p < .01$); therefore Hypothesis 13b

was accepted. For a summary of the ANOVA with repeated measures for unfused mohair/wool fabric after drycleaning and after wetcleaning, see Table 25.

Table 25

ANOVA Summary of Dimensional Stability Width Scores for Unfused Mohair/Wool After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	86.04	1	86.04	363.81*
Error	06.62	28	00.23	

*$p < .01$

Hypothesis 14a

For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for mohair/wool fused to 5423 (F (1, 28) = 24.45, $p < .01$); therefore Hypothesis 14a was accepted. For a summary of the ANOVA with repeated measures for mohair/wool fused with 5423 after drycleaning and after wetcleaning, see Table 26.

Table 26

ANOVA Summary of Dimensional Stability Length Scores for Mohair/Wool Fused With 5423 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	14.40	1	14.40	24.45*
Error	16.48	28	00.58	

*$p < .01$

Hypothesis 14b

For mohair/wool blend fabric fused with nonwoven fusible interlining 5423, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for mohair/wool fused to 5423 (F (1, 28) = 32.76, $p < .01$); therefore Hypothesis 14b was accepted. For a summary of the ANOVA with repeated measures for mohair/wool fused with 5423 after drycleaning and after wetcleaning, see Table 27.

Hypothesis 15a

For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in length dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in length dimensional stability scores between drycleaning and wetcleaning processes for

Table 27

ANOVA Summary of Dimensional Stability Width Scores for Mohair/Wool Fused with 5423 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	12.84	1	12.84	32.76*
Error	10.97	28	00.39	

*$p < .01$

mohair/wool fused with 5025 (F (1, 28) = 535.18, $p < .01$); therefore Hypothesis 15a was accepted. For a summary of the ANOVA with repeated measures for mohair/wool fused with 5025 after drycleaning and after wetcleaning, see Table 28.

Table 28

ANOVA Summary of Dimensional Stability Length Scores for Mohair/Wool Fused With 5025 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	84.10	1	84.10	535.18*
Error	04.40	28	00.15	

*$p < .01$

Hypothesis 15b

For mohair/wool blend fabric fused with nonwoven fusible interlining 5025, there will be significant differences in width dimensional stability scores between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

An ANOVA with repeated measures test indicated significant differences existed in width dimensional stability scores between drycleaning and wetcleaning processes for mohair/wool fused with 5025 (F (1, 28) = 41.72, $p < .01$); therefore Hypothesis 15b was accepted. For a summary of the ANOVA with repeated measures for mohair/wool fused with 5025 after drycleaning and after wetcleaning, see Table 29.

Table 29

ANOVA Summary of Dimensional Stability Width Scores for Mohair/Wool Fused With 5025 After Drycleaning and After Wetcleaning Processes

Source	SS	df	MS	F
Cleaning	23.51	1	23.51	41.72*
Error	15.77	28	00.56	

*$p < .01$

Appearance

Six research questions were used to determine changes in appearance after cleaning. Appearance was visually evaluated for presence of puckering, cracking, blistering, and pilling for specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings. These research questions were designed to determine if changes in the fused fabric surfaces existed between dryclean and wetclean care methods on appearance. Appearance was evaluated for each of the fused fabric/interlining combinations: (a) lyocell fused with 5025, (b) lyocell fused with

8336, (c) wool fused with 9016, (d) wool fused with 8246, (e) mohair/wool fused with 5423, and (f) mohair/wool fused with 5025.

Descriptive statistics were used to indicate differences in appearance between dryclean and wetclean processes. The presence of puckering, cracking, blistering, and pilling were recorded as *yes*, indicating the characteristic was exhibited or *no*, indicating the specimen did not exhibit the characteristics. A pilling rating was assigned for all of the appearance specimens. The ratings were based on a 5-point scale with 5.0 representing no pilling and 1.0 representing severe pilling.

Research Question 1

Will there be differences in appearance of lyocell fabric fused with nonwoven interlining 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Lyocell fabric fused with 5025 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the lyocell specimens fused with 5025 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of lyocell fabric fused with 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Question 2

Will there be differences in appearance of lyocell fabric fused with nonwoven interlining 8336, when evaluated for puckering, cracking, blistering, and pilling between specimens

subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Lyocell fabric fused with 8336 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the lyocell specimens fused with 8336 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of lyocell fabric fused with 8336, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Question 3

Will there be differences in appearance of wool fabric fused with nonwoven interlining 9016, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Wool fabric fused with 9016 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the wool specimens fused with 9016 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of wool fabric fused with 9016, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Question 4

Will there be differences in appearance of wool fabric fused with nonwoven interlining 8246, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Wool fabric fused with 8246 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the wool specimens fused with 8246 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of wool fabric fused with 8246, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Question 5

Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven interlining 5423, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Mohair/wool blend fabric fused with 5423 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the mohair/wool specimens fused with 5423 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of mohair/wool fabric fused with 5423, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Research Question 6

Will there be differences in appearance of mohair/wool blend fabric fused with nonwoven interlining 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings?

Mohair/wool blend fabric fused with 5025 did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning processes. All of the mohair/wool specimens fused with 5025 received a rating of 5.0 for pilling after drycleaning and after wetcleaning processes. No differences were found in appearance of mohair/wool fabric fused with 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings.

Summary of Results

The purpose of the study was to determine whether twill-weave lyocell, twill-weave wool, and plain-weave mohair/wool fabrics, fused to appropriate interlinings, would be compatible with wetcleaning technologies when tested for bond strength and dimensional stability, and evaluated for appearance. Appearance was evaluated visually for puckering, cracking, blistering, and pilling.

Statistical significance was found for all of the hypotheses except 4, 7b, 8b, 9b, 11b, and 12b. Hypotheses 1 through 6 addressed bond strength of the fabric/interlining combinations after five drycleanings and after five wetcleanings. These hypotheses

(H1 - H6) were analyzed using a one-way ANOVA, testing for differences between the two cleaning methods. Hypotheses 7a through 15b addressed dimensional stability of the unfused fabrics and the fused fabric/interlining combinations after five drycleanings and after five wetcleanings. These hypotheses (7a-15b) were analyzed using an ANOVA with repeated measures, testing for differences between the two cleaning procedures before and after five cleanings. Descriptive statistics were used to analyze the six research questions for the study.

Summary of Bond Strength

Bond strength of the lyocell fabric fused with 5025 and lyocell fused with 8336 both became stronger after drycleaning and weaker after wetcleaning (H1 and H2). Bond strength of the wool fabric fused with 9016 and wool fused with 8246 both lost more bond strength after drycleaning than after wetcleaning (H3 and H4). Bond strength of the mohair/wool blend fabric fused with 5423 became stronger after drycleaning and weaker after wetcleaning (H5). On the other hand, bond strength of the mohair/wool blend fabric fused with 5025 became weaker after drycleaning while becoming stronger after wetcleaning (H6).

Summary of Dimensional Stability

All of the lyocell fabrics, fused and unfused, demonstrated higher shrinkage in the length direction after wetcleaning than after drycleaning (H7a, H8a, H9a). However, there was no significant difference in the dimensional stability scores for all lyocell specimens in the width direction after drycleaning and after wetcleaning (H7b, H8b,

H9b). Unfused wool fabric demonstrated higher shrinkage in the length and in the width directions after wetcleaning than after drycleaning (H10a and H10b). Wool fabric fused with 9016 demonstrated higher shrinkage in the length direction after wetcleaning (H11a). However, there was no significant difference in the dimensional stability scores for the wool fused with 9016 after drycleaning and after wetcleaning (H11b). Dimensional stability of wool fabric fused with 8246 demonstrated higher shrinkage in both the length and width directions after wetcleaning than after drycleaning (12a and 12b). Unfused mohair/wool and fused mohair/wool fabrics demonstrated higher shrinkage in both the length and width directions after wetcleaning than after drycleaning (H13a through 15b).

Summary of Appearance

Appearance was evaluated for all of the fabric/interlining combinations after drycleaning and after wetcleaning processes. The specimens were visually evaluated for presence of puckering, cracking, blistering, and pilling. None of the fabric/interlining combinations exhibited puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. All of the appearance specimens (lyocell, wool, and mohair/wool fused fabric/interlining combinations) received a perfect rating of 5.0 on a scale of 1.0 - 5.0 (5.0 representing no pilling).

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Environmental Protection Agency (EPA) is searching for ways to limit the use and exposure of toxic chemicals such as perchloroethylene (perc) for drycleaning purposes. New wetcleaning technologies are being tested along with new systems for treating waste water and controlling the release of perc into the environment. Wetcleaning is an environmentally safe alternative to solvent-based cleaning which utilizes controlled application of detergents and water. In a effort to provide interlining producers with information on how currently used nonwoven fusible interlining products perform when cleaned by wetcleaning technologies in comparison to current drycleaning, the study results indicated whether new technologies for fusible interlinings needed to be further researched and developed in order to maintain bond strength, shape, and appearance when fused to lyocell, wool, and mohair/wool blend fabrics.

The purpose of the study was to determine whether twill-weave lyocell, twill-weave wool, and plain-weave mohair/wool fabrics, fused to appropriate nonwoven fusible apparel interlinings, would be compatible with wetcleaning technologies when tested for bond strength and dimensional stability, and evaluated for appearance. Appearance evaluation was conducted by inspection the surface of the fused fabric after drycleaning and after wetcleaning for puckering, cracking, blistering, and pilling.

Summary of Research Procedures

The study was conducted using three fabrics, lyocell, wool, and mohair/wool blend. Two nonwoven fusible interlinings were selected to be bonded to each fabric separately and the fabrics and interlinings were professionally bonded. Two lengths of each unfused fabric were cut and tested to measure the dimensional stability of the unfused fabric. Specimens designated as controls for bond strength testing were cut and tested before cleaning. Dimensional stability test specimens were marked and sewn into tubes to prepare them for cleaning. Appearance evaluation control specimens were cut and set aside for rating the specimens after cleaning. All of the specimens designated for cleaning were separated into specimens for drycleaning and specimens for wetcleaning. Each unfused fabric and fabric interlining/combination was cleaned five times (either by a dryclean or wetclean care method).

An Instron® tensile testing machine was used to measure the pounds of force to separate the fusible interlining from the shell fabric. Data were collected for bond strength before and after five drycleanings and before and after five wetcleanings. Both length and width measurements were evaluated for dimensional stability. Data were collected for dimensional stability after five drycleanings and after five wetcleanings for each fabric/interlining combination and for all unfused fabrics. Appearance was evaluated for puckering, cracking, blistering, and pilling; evaluations were conducted for appearance of the fabric/interlining combinations after five drycleanings and after five wetcleanings. The recorded scores for bond strength and dimensional stability were

examined with a variety of BMDP statistical programs (Dixon et al., 1993). Descriptive statistics were used to analyze the data collected for appearance.

Summary of Findings

There were 240 bond strength specimens tested from six fabric/interlining combinations; of these,120 were control specimens that did not receive any cleaning treatment. Sixty bond strength specimens were drycleaned and an additional 60 specimens were wetcleaned. All bond strength scores collected for 240 specimens provided usable data. There were 270 dimensional stability specimens tested for the study; 90 from three unfused fabrics, and 180 from the six fabric/interlining combinations. Three length and three width measurements were recorded for all 270 dimensional stability specimens. All of the dimensional stability scores collected for the study were usable data. There were 36 appearance specimens tested from the six fabric/interlining combinations, 12 of the specimens were controls. All of the appearance ratings were useable data. The research findings from the data collected for the study were summarized according to bond strength, dimensional stability, and appearance.

Bond Strength

1. Lyocell fabric fused with interlining 5025 and lyocell fused with interlining 8336 increased in bond strength after drycleaning and decreased in bond strength after wetcleaning.

2. Wool fabric fused with interlining 9016 increased in bond strength after drycleaning and decreased in bond strength after wetcleaning.

3. Wool fabric fused with interlining 8246 decreased in bond strength after drycleaning and decreased in bond strength after wetcleaning.

4. Mohair/wool fabric fused with interlining 5423 increased in bond strength after drycleaning and decreased in bond strength after wetcleaning.

5. Mohair/wool fabric fused with interlining 5025 decreased in bond strength after drycleaning and increased in bond strength after wetcleaning.

Dimensional Stability

1. Unfused lyocell, lyocell fused with interlining 5025, and lyocell fused with interlining 8336 exhibited lower shrinkage in the length direction after drycleaning than after wetcleaning.

2. Unfused lyocell, lyocell fused with interlining 5025, and lyocell fused with interlining 8336 exhibited higher shrinkage in the width direction after drycleaning than after wetcleaning.

3. Unfused wool, wool fused with interlining 9016, and wool fused with interlining 8246 exhibited lower shrinkage in the length direction after drycleaning than after wetcleaning.

4. Unfused wool, wool fused with interlining 9016, and wool fused with interlining 8246 exhibited lower shrinkage in the width direction after drycleaning than after wetcleaning.

5. Unfused mohair/wool, mohair/wool fused with interlining 5423, and mohair/wool fused with interlining 5025 exhibited lower shrinkage in the length direction after drycleaning than after wetcleaning.

6. Unfused mohair/wool, mohair/wool fused with interlining 5423, and mohair/wool fused with interlining 5025 exhibited lower shrinkage in the width direction after drycleaning than after wetcleaning.

Appearance

1. Lyocell fused with interlining 5025 and lyocell fused with interlining 8336 did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. Lyocell fused with interlining 5025 and lyocell fused with interlining 8336 received ratings of 5.0 for pilling (on a five-point scale with 5.0 being representative of no pilling and 1.0 representing severe pilling) after drycleaning and after wetcleaning processes.

2. Wool fused with interlining 9016 and wool fused with interlining 8246 did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes. Wool fused with interlining 9016 and wool fused with interlining 8246 received ratings of 5.0 for pilling (on a five-point scale with 5.0 being representative of no pilling and 1.0 representing severe pilling) after drycleaning and after wetcleaning processes.

3. Mohair/wool fused with interlining 5423 and mohair/wool fused with interlining 5025 did not exhibit presence of puckering, cracking, blistering, or pilling

after drycleaning or after wetcleaning processes. Mohair/wool fused with interlining 5423 and wool fused with interlining 5025 received ratings of 5.0 for pilling (on a five-point scale with 5.0 being representative of no pilling and 1.0 representing severe pilling) after drycleaning and after wetcleaning processes.

Hypotheses

1. There were statistically significant differences in bond strength scores between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for lyocell fused with nonwoven fusible interlining 5025 (H1).

2. There were statistically significant differences in bond strength scores between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for lyocell fused with nonwoven fusible interlining 8336 (H2).

3. There were statistically significant differences between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for wool fused with nonwoven fusible interlining 9016 (H3).

4. No statistically significant differences were found in bond strength scores between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for wool fused with nonwoven fusible interlining 8246 (H4).

5. There were statistically significant differences in bond strength scores between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for mohair/wool fused with nonwoven fusible interlining 5423 (H5).

6. There were statistically significant differences in bond strength scores between specimens subjected to drycleaning and specimens subjected to wetcleaning processes after five cleanings for mohair/wool fused with nonwoven fusible interlining 5025 (H6).

7. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused lyocell fabric (H7a).

8. No statistically significant differences were found in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused lyocell fabric (H7b).

9. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for lyocell fused with 5025 (H8a).

10. No statistically significant differences were found in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for lyocell fused with 5025 (H8b).

11. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for lyocell fused with 8336 (H9a).

12. No statistically significant differences were found in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for lyocell fused with 8336 (H9b).

13. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused wool fabric (H10a).

14. There were statistically significant differences in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused wool fabric (H10b).

15. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for wool fused with 9016 (H11a).

16. No statistically significant differences were found in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for wool fused with 9016 (H11b).

17. No statistically significant differences existed in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for wool fused with 8246 (H12a).

18. There were statistically significant differences in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for wool fused with 8246 (H12b).

19. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused mohair/wool (H13a).

20. There were statistically significant differences in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for unfused mohair/wool (H13b).

21. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for mohair/wool fused with 5423 (H14a).

22. There were statistically significant differences in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for mohair/wool fused with 5423 (H14b).

23. There were statistically significant differences in length dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for mohair/wool fused with 5025 (H15a).

24. There were statistically significant differences in width dimensional stability scores between specimens subjected to drycleaning and specimens subjected to wetcleaning after five cleanings for mohair/wool fused with 5025 (H15b).

Research Questions

1. No differences were found in appearance of lyocell fabric fused with 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R1).

2. No differences were found in appearance of lyocell fabric fused with 8336, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R2).

3. No differences were found in appearance of wool fabric fused with 9016, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R3).

4. No differences were found in appearance of wool fabric fused with 8246, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R4).

5. No differences were found in appearance of mohair/wool fabric fused with 5423, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R5).

6. No differences were found in appearance of mohair/wool fabric fused with 5025, when evaluated for puckering, cracking, blistering, and pilling between specimens subjected to drycleaning processes and specimens subjected to wetcleaning processes after five cleanings (R6).

Interpretation of Results

Interpretation of the results for the study are discussed in the following sections: (a) bond strength, (b) dimensional stability, and (c) appearance.

Bond Strength

Acceptability of the bond strength results was based on general specification requirements outlined by the largest volume interlining producer in the world, Freudenberg Nonwovens. The term *general* was used because there are many factors that can effect the bond strength specifications used by an apparel manufacturer or interlining producer. Every interlining product has its own specifications. These specifications will vary between interlining producers, from product to product, from different types of fusing equipment, price range, and application of the interlining in the garment (A. Frederiksen, personal communication, March 23, 1998).

ASTM D 3135, Standard Specification for Performance of Bonded, Fused, and Laminated Apparel Fabrics provides specifications for wet bond strength, not dry bond strength. ASTM D 2724, Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics states that bond strength testing can be performed on dry or wet specimens. The wet bond strength method is not used in the industry by interlining producers to measure the bond between shell fabrics fused with interlinings (A. Frederiksen, personal communication, March 23, 1998) because the test requires the samples to be saturated in perchloroethylene (perc) or water and tested in the wet state rather than dry. The researcher believes that ASTM should revise the test method to

provide an alternative method for testing specimens in perc to meet requirements of the Environmental Protection Agency (EPA) for open container usage of this chemical. Furthermore, ASTM should provide specifications for dry bond strength as well as wet bond strength (specimens saturated in water) because both are acceptable methods for determining bond strength, although dry bond strength is more commonly used.

Wetcleaning specifications have not been determined by ASTM or by Freudenberg Nonwovens because the cleaning process is so new, therefore the laundering specification was used to represent wetcleaning processes because laundering (water-based cleaning method which uses detergents and agitation to remove soils) more closely portrays the wetcleaning process than drycleaning. For bond strength specifications designated by Freudenberg Nonwovens, see Table 30.

Table 30

General Specifications for Bond Strength

Characteristics	Requirements in lbs. of force
Drycleaning bond strength	1.5 Minimum
Laundering bond strength	1.5 Minimum

Note. Laundering specifications in this table represent requirements used for wetcleaning.

The average bond strength for lyocell fused with 5025 after drycleaning was 4.51 pounds of force and after wetcleaning was 3.19 pounds of force. Lyocell fused with 5025

exceeded the minimum specifications for bond strength after drycleaning and after wetcleaning according to Freudenberg Nonwovens.

The average bond strength for lyocell fused with 8336 after drycleaning was 3.63 pounds of force and after wetcleaning was 1.20 pounds of force. Lyocell fused with 8336 exceeded the minimum specification for bond strength after drycleaning but failed to meet the minimum specification for bond strength after wetcleaning according to Freudenberg Nonwovens.

The average bond strength for wool fused with 9016 after drycleaning was 3.56 pounds of force and after wetcleaning was 5.17 pounds of force. Wool fused with 9016 exceeded the minimum specifications for bond strength after drycleaning and after wetcleaning according to Freudenberg Nonwovens.

The average bond strength for wool fused with 8246 after drycleaning was 2.33 pounds of force and after wetcleaning was 2.31 pounds of force. Wool fused with 8246 exceeded the minimum specifications for bond strength after drycleaning and after wetcleaning according to Freudenberg Nonwovens.

The average bond strength for mohair/wool fused with 5423 after drycleaning was 3.00 pounds of force and after wetcleaning was 1.85 pounds of force. Mohair/wool fused with 5423 exceeded the minimum specifications for bond strength after drycleaning and after wetcleaning according to Freudenberg Nonwovens.

The average bond strength for Mohair/wool fused with 5025 after drycleaning was 0.54 pounds of force and after wetcleaning was 0.87 pounds of force. Mohair/wool

fused with 5025 failed to meet the minimum specification for bond strength after drycleaning and after wetcleaning according to Freudenberg Nonwovens.

Dimensional Stability

Acceptability of the dimensional stability results was based on ASTM D 3780 Standard Performance for Men's and Boy's, Woven Dress Suit Fabrics and Woven Sportswear Jacket, Slacks, and Trouser Fabrics and ASTM D 4155 Standard Performance for Women's and Girl's Woven Sportswear, Shorts, Slacks, and Suiting Fabrics (ASTM, 1995). The types of cleaning selected from the ASTM specifications were drycleaning and laundering. ASTM has not determined specifications for wetcleaning processes, therefore, the laundering specification was used to represent wetcleaning because laundering (water-based cleaning method which uses detergents and agitation to remove soils) more closely portrays the wetcleaning process than drycleaning. For ASTM designated specifications for dimensional change, see Table 31.

Table 31

Specification Requirements for Dimensional Stability

Characteristics	Requirements
Drycleaning dimensional change	2.0% maximum
Laundering dimensional change	3.0% maximum

Note. Laundering specifications in this table represent requirements used for wetcleaning. The specifications for dimensional change represent length and width directions of the fabric.

In this study, unfused lyocell fabric shrunk at a lower percentage in the length direction after drycleaning (1.80%) than after wetcleaning (5.88%). Therefore, according to ASTM specifications, the unfused lyocell would be considered unacceptable after being subjected to wetcleaning processes for use in apparel suiting products because shrinkage in the length direction exceeded the 3.0% maximum allowed. On the other hand, unfused lyocell had a higher shrinkage percentage in the width direction after drycleaning (1.73 %) than after wetcleaning (1.68%). No statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for unfused lyocell and the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Lyocell fused with 5025 shrunk at a lower percentage in the length direction after drycleaning (1.51%) than after wetcleaning (4.84%). Therefore, according to ASTM specifications, lyocell fused with 5025 would be considered unacceptable after being subjected to wetcleaning processes for use in apparel suiting products because shrinkage in the length direction exceeded the 3.0% maximum allowed. On the other hand, the lyocell fused with 5025 had a higher shrinkage percentage in the width direction after drycleaning (1.17%) than after wetcleaning (0.77%). No statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for lyocell fused with 5025 and the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Lyocell fused with 8336 shrunk at a lower percentage in the length direction after drycleaning (1.17%) than after wetcleaning (5.42%). Therefore, according to ASTM

specifications, lyocell fused with 8336 would be considered unacceptable after being subjected to wetcleaning processes for use in apparel suiting products because shrinkage in the length direction exceeded the 3.0% maximum allowed. On the other hand, the lyocell fused with 8336 had a higher shrinkage percentage in the width direction after drycleaning (1.04%) than after wetcleaning (0.95%). No statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for lyocell fused with 8336 and the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Unfused wool fabric shrunk at a lower percentage in the length direction after drycleaning (0.06%) than after wetcleaning (0.51%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for unfused wool, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Unfused wool shrunk at a lower percentage in the width direction after drycleaning (0.37%) than after wetcleaning (0.77%). Although statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for unfused wool, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Wool fabric fused with 9016 shrunk at a lower percentage in the length direction after drycleaning (0.75%) than after wetcleaning (1.31%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for wool fused with 9016, the shrinkage after

drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Wool fused with 9016 shrunk at a lower percentage in the width direction after drycleaning (0.11%) than after wetcleaning (0.35%). No statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for wool fused with 9016 and the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Wool fabric fused with 8246 shrunk at a lower percentage in the length direction after drycleaning (0.42%) than after wetcleaning (0.97%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for wool fused with 8246, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Wool fused with 8246 shrunk at a lower percentage in the width direction after drycleaning (0.04%) than after wetcleaning (0.80%). Although statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for wool fused with 8246, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Unfused mohair/wool fabric shrunk at a lower percentage in the length direction after drycleaning (0.64%) than after wetcleaning (1.71%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for unfused mohair/wool, the shrinkage after

drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Unfused mohair/wool shrunk at a lower percentage in the width direction after drycleaning (0.02%) than after wetcleaning (1.97%). Although statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for unfused mohair/wool, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Mohair/wool fabric fused with 5423 shrunk at a lower percentage in the length direction after drycleaning (0.48%) than after wetcleaning (1.28%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for mohair/wool fused with 5423, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Mohair/wool fused with 5423 shrunk at a lower percentage in the width direction after drycleaning (0.00%) than after wetcleaning (0.75%). Although statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for mohair/wool fused with 5423, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Mohair/wool fabric fused with 5025 shrunk at a lower percentage in the length direction after drycleaning (0.20%) than after wetcleaning (2.13%). Although statistical significance was found for dimensional change in the length direction between drycleaning and wetcleaning processes for mohair/wool fused with 5025, the shrinkage

after drycleaning and after wetcleaning was within tolerance according to ASTM specifications and therefore, would be acceptable for apparel suiting products. Mohair/wool fused with 5025 shrunk at a lower percentage in the width direction after drycleaning (0.17%) than after wetcleaning (1.20%). Although statistical significance was found for dimensional change in the width direction between drycleaning and wetcleaning processes for mohair/wool fused with 5025, the shrinkage after drycleaning and after wetcleaning was within tolerance according to ASTM specifications.

Appearance

Through visual examination procedures followed for AATCC Method 124 Appearance of Fabrics After Repeated Home Laundering (AATCC, 1995) and ASTM D 3135 Standard Specification of Performance of Bonded, Fused, and Laminated Apparel Fabrics (ASTM, 1995), evidence of puckering, cracking, blistering, and pilling were not visible from the designated viewing distance of 4 feet.

However, after examining the specimens from a viewing distance of 12 inches, evidence of blistering was observed on the lyocell fabric fused with 5025 after wetcleaning. Lyocell fabric fused with 8336 exhibited blistering after drycleaning and after wetcleaning when examined from a viewing distance of 12 inches. Lyocell fabric fused with 8336 also exhibited blistering after wetcleaning when examined from a viewing distance of 12 inches. The researcher believes that the natural creased surface of the lyocell fabric may have disguised problems with blistering of the fused fabrics after

drycleaning or after wetcleaning processes when visually examined at a viewing distance of 4 feet.

The remaining wool and mohair/wool fabric/interlining combinations did not exhibit presence of puckering, cracking, blistering, or pilling after drycleaning or after wetcleaning processes when examined from a viewing distance of 12 inches. The researcher believes that a viewing distance of 4 feet may need to be reviewed by AATCC and ASTM, for the purpose of examining fabrics that are fused, bonded, or laminated, because presence of puckering, cracking, blistering or pilling may not be visible from the designated viewing distance, as indicated in this study.

Conclusions and Implications

Based on the analyses of the data and interpretation of the findings, the following conclusions are drawn:

1. Lyocell fused with 5025 performes at acceptable levels for bond strength after drycleaning and after wet cleaning. Although the bond strength was lower after wetcleaning than after drycleaning, both of the cleaning methods are acceptable for lyocell fused with 5025.

2. Lyocell fused with 8336 performes at an acceptable level for bond strength after drycleaning, but failed to meet the minimum specifications for bond strength after wetcleaning. The data indicates that wetcleaning processes are not suitable for lyocell fused with 8336 and should be drycleaned to maintain adequate bond strength.

3. Wool fused with 9016 performes at acceptable levels for bond strength after drycleaning and after wetcleaning. Although the bond strength was lower after drycleaning processes than after wetcleaning both of the cleaning methods are acceptable for wool fused with 9016. In this case, the data indicates wool fused with 9016 exhibited better bond strength performance after wetcleaning than after drycleaning processes.

4. Wool fused with 8246 performes at acceptable levels for bond strength after drycleaning and after wetcleaning. The data indicated virtually no difference in bond strength performance of wool fused with 8246 after drycleaning and after wetcleaning processes. Both cleaning methods are acceptable for wool fused with 8246 when tested for bond strength.

5. Mohair/wool fused with 5423 performes at acceptable levels for bond strength after drycleaning and after wetcleaning. Although the bond strength was lower after wetcleaning than after drycleaning both of the cleaning methods are acceptable for mohair/wool fused with 5423.

6. Mohair/wool fused with 5025 failed to perform at acceptable levels for bond strength after drycleaning and after wetcleaning. Both cleaning methods are unacceptable for mohair/wool fused with 5025 when tested for bond strength. The data indicates that neither drycleaning nor wetcleaning processes were suitable for the fabric/interlining combination of mohair/wool fused with 5025. Alternative interlinings should be fused to the mohair/wool fabric and tested for bond strength after drycleaning and wetcleaning processes to find another interlining besides 5423 that will maintain adequate bond strength after cleaning.

7. Unfused lyocell, lyocell fused with 5025, and lyocell fused with 8336 did not perform at acceptable levels for dimensional change in the length direction after wetcleaning, but performed at acceptable levels after drycleaning. However, dimensional change in the width direction for unfused lyocell, lyocell fused with 5025, and lyocell fused with 8336 performed at acceptable levels after drycleaning and after wetcleaning processes. The researcher believes lyocell would most likely perform below standard after wetcleaning due to the shrinkage of some rayon fabrics after laundering; this was precisely the reason for its inclusion in the study. Fusing lyocell fabric with 5025 or 8336 improved the shrinkage of the fabric slightly but not enough to make the dimensional change acceptable after wetcleaning processes.

8. Unfused wool, wool fused with 9016, and wool fused with 8246 perform at acceptable levels for dimensional change in the length and width directions after drycleaning and after wetcleaning processes and exceeded the expectations of the researcher.

9. Unfused mohair/wool, mohair/wool fused with 5423, and mohair/wool fused with 5025 perform at acceptable levels for dimensional change in the length and the width directions after drycleaning and after wetcleaning. The researcher was surprised to find that the performance of the mohair/wool blend fabric, on average, had higher shrinkage than the wool in the length and width directions after drycleaning and after wetcleaning for the unfused fabrics as well as the fabric/interlining combinations. The researcher thought that the mohair/wool fabric would have performed better than the

wool after wetcleaning because the mohair fibers have a smooth surface unlike wool fibers that have scales and typically cause felting during laundering processes.

10. According to AATCC 124 and ASTM D 3135 test methods designated for rating appearance, the fabric/interlining combinations for the study did not exhibit presence of puckering, cracking, blistering, or pilling. However, after closer evaluation, the researcher did see presence of blistering on the lyocell fused with 5025 after wetcleaning. The lyocell fabric fused with 8336 also exhibit presence of blistering after drycleaning and after wetcleaning. All of the fused wool specimens and all of the fused mohair/wool specimens did not exhibit presence of puckering, cracking, blistering or pilling after drycleaning or after wetcleaning when examined at a closer distance.

11. In order to predict the success rate of wetcleaning, further research should be performed to evaluate a wider range of fabrics (fiber content and construction) and interlining products on the market. Overall, the researcher was very pleased with the performance of the unfused and fused wool and mohair/wool fabrics after drycleaning and after wetcleaning processes.

Recommendations

Recommendations for further study are as follows:

1. Further research is needed to test a wide variety of fused fabrics in piece-goods form, recommended for dryclean care methods, and tested for bond strength and dimensional stability, and evaluated for appearance after wetcleaning and finishing processes (pressing).

2. Further research is needed to test a variety of fused fabrics in garment form, recommended for dryclean care methods, and tested for dimensional stability, and evaluated for appearance after drycleaning and after wetcleaning processes to determine the performance of the fabric/interlining combinations in garment applications.

3. Research is needed to test fabrics recommended for dryclean care methods for color permanence to wetcleaning when evaluated for staining onto other fibers to determine if bleeding of dyes will pose a problem to garments or fabrics cleaned in the same load when subjected to wetcleaning processes.

4. Research is needed to test consumer preference to overall appearance of garments refurbished through drycleaning care methods and wetcleaning care methods to determine if the consumer can see a visual difference in the two methods of cleaning. This research could determine if consumer preference between cleaning methods will exist based on overall aesthetic appearance of the cleaned garments.

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APPENDICIES

APPENDIX A

Bond Strength Report Form

Bond Strength Report Form

Specimen ID: _____

Dryclean Control Specimens	Drycleaned Specimens	Wetclean Control Specimens	Wetcleaned Specimens
1. _____	1. _____	1. _____	1. _____
2. _____	2. _____	2. _____	2. _____
3. _____	3. _____	3. _____	3. _____
4. _____	4. _____	4. _____	4. _____
5. _____	5. _____	5. _____	5. _____
6. _____	6. _____	6. _____	6. _____
7. _____	7. _____	7. _____	7. _____
8. _____	8. _____	8. _____	8. _____
9. _____	9. _____	9. _____	9. _____
10._____	10._____	10._____	10._____

APPENDIX B

Dimensional Stability Report Forms

Dimensional Stability Report Form

Specimen ID: _____

Cleaning Method: _____

LENGTH	% SHRINKAGE	WIDTH	% SHRINKAGE
Box 1			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 2			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 3			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 4			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 5			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____

Dimensional Stability Report Form

Specimen ID: _____

Cleaning Method: _____

LENGTH	% SHRINKAGE	WIDTH	% SHRINKAGE
Box 6			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 7			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 8			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 9			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 10			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____

Dimensional Stability Report Form

Specimen ID: _____

Cleaning Method: _____

LENGTH	% SHRINKAGE	WIDTH	% SHRINKAGE
Box 11			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 12			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 13			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 14			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____
Box 15			
1. _____	_____	4. _____	_____
2. _____	_____	5. _____	_____
3. _____	_____	6. _____	_____

APPENDIX C

Appearance Report Form

Appearance Report Form

Specimen ID: _____
Cleaning Method: _____

Presence of:
(circle yes or no)

Puckering
Yes or No

Cracking
Yes or No

Blistering
Yes or No

Pilling
Yes or No

Pilling Rating _____