NONWOVEN INTERFACING FABRICS: A COMPARISON OF FUSIBLE AND NONFUSIBLE INTERFACING FABRICS AFTER LAUNDERING

by

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B.S., Kansas State University, 1971

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles,
and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

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ABSTRACT

Two fusible and two nonfusible nonwoven interfacing fabrics available commercially were laundered one, five and ten times. The physical properties at each laundry level were measured according to standard ASTM and AATCC test methods and compared to the physical properties of the fabric before washing. The parameters tested were dimensional change in the machine and cross machine direction, thickness, weight, over-all flexural rigidity, bursting strength, breaking load in the machine direction, elongation, flat abrasion resistance and flex abrasion resistance.

All of the fabrics appeared to be chemically bonded nonwoven fabrics constructed with a uni-directional web arrangement. Two of the fabrics were a blend of nylon and polyester and two of the fabrics were a blend of nylon, polyester and rayon. Both of the fusible fabrics contained a coating of polyamide fusing agent on the reverse side.

The results from the physical testing showed there were significant differences between the two fusible fabrics and the two nonfusible fabrics in all physical properties except apparent elongation where no significant difference could be detected. In addition, there were significant differences between the two types of fabrics in all parameters tested except in flex abrasion resistance. None of the fabrics excelled in every parameter; therefore, the qualities desired of an interfacing fabric should be evaluated and the most suitable fabric chosen for that application.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. Theresa Perenich, Head of the Department of Clothing, Textiles, and Interior Design for her encouragement and technical advice in the preparation of this thesis. The suggestions and assistance offerred by Dr. Arlin Feyerherm, Department of Statistics and Dr. Barbara Reagan, Department of Clothing, Textiles, and Interior Design are greatly appreciated. Gratitude is extended to Mr. Ludwig Villasi, Department of Clothing Textiles and Interior Design for serving on the graduate committee.

In addition, the author wishes to thank International Paper and Stacy Fabrics Corporation for providing the fabrics used in this research.

Finally, a special thanks must be expressed to Ronald for his support, encouragement, and tolerance.

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INTRODUCTION

The use of fusible interfacing fabrics by garment manufacturers has increased in recent years (21:533). These fabrics are now available to home sewers and questions have arisen concerning their use and performance in comparison with conventional nonwoven interfacing fabrics.

In the clothing industry, a fusible interfacing is described as consisting of a base cloth (which in this case is a bonded fiber fabric) coated on one or both sides with a synthetic resin. Under the application of heat and pressure, the resin melts and adheres the interfacing to the garment fabric (23:206). The advantages of fusible interfacings enumerated by Starr (23:206) are that the use of fusibles provides a simplified method of applying the interfacing fabric to the garment fabric which replaces a sewing operation with a simple pressing operation. Greater control of hard to handle fabrics and a reduction in distortions from machine sewing are possible. Applications where traditional methods of interfacing garments were previously employed by garment manufacturers are now being replaced with fusible interfacings (23:205).

Interfacing fabrics are used to add strength, support and stiffness to selected areas of a garment. Nonwoven interfacing fabrics have been used extensively for this purpose because of their convenience. One of the newest innovations for interfacing a garment is a fusible nonwoven interfacing fabric (23:205).

Research on nonwoven interfacings is needed to provide the consumer with criteria for selecting a specific type of interfacing with the most desirable qualities for a specific application. The construction characteristics and the physical properties of the fusible nonwoven interfacing fabrics need to be evaluated and compared with the traditional nonfusible nonwoven interfacings. A comparison of the physical properties of these fabrics after laundering is necessary to obtain information about the suitability of an interfacing for a specific application, i.e. in a washable fabric. This research was designed to elicit information about stitched-in and fusible nonwoven interfacing fabrics.

In practice, the performance of interfacing fabrics depends upon the garment fabric to which it is sewn or fused. The evaluation of fusible interfacings in combination with a garment fabric requires the development of a standard test procedure for fusing under laboratory conditions. Because of the many variables associated with the fusing process, a laboratory procedure has not been published. Therefore, the experimental fabrics in this research were tested in an unfused state. In addition, standard requirements have not been established for stitched-in or fused nonwoven interfacing fabrics.

The objectives of this research were:

1. To compare the fabric construction characteristics and physical properties of two fusible and two nonfusible nonwoven interfacing fabrics that are commercially available.

2. To determine the effect of repeated launderings on the nonwoven fabrics.

3. To compare the performance of fusible with nonfusible nonwoven interfacing fabrics.

The parameters of dimensional change, thickness, weight, over-all flexural rigidity, bursting strength, breaking load, elongation, flat abrasion resistance and flex abrasion resistance were included in this study.

The following assumptions were made for this research:

1. The differences between the two fusible and the two nonfusible nonwoven interfacing fabrics after subsequent launderings will be detectable by changes in dimensional stability, thickness, weight, flexural rigidity, bursting strength, breaking load, elongation, flat abrasion resistance and flex abrasion resistance.

2. Not all nonwoven interfacing fabrics have the same physical and chemical properties.

The limitations imposed on the study are as follows:

1. Fabric choice was limited to polyester and nylon blend nonwoven interfacing fabrics of medium weight which were commercially available in the Manhattan, Kansas area.

2. Treatment was limited to laundering and drying procedures under controlled conditions.

To clarify the meaning of the term "nonwoven" as used in this research, the following definition from ASTM (5) has been used:

> Fabric, nonwoven - a structure produced by bonding or the interlocking of fibers, or both, accomplished by mechanical, chemical thermal, or solvent means and the combinations thereof. The term does not include paper or fabrics that are woven, knitted, tufted, or those made by wool or other fleting processes.

Other definitions which were essential for this experimental work were "machine" direction which may be substituted for warp and "cross machine" direction which corresponds to the filling direction in a woven fabric (5).

The following hypotheses were offered for this research:

1. There will be no significant differences between the two fusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength, (f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

2. There will be no significant differences between the two nonfusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength, (f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

3. There will be no significant differences between the two fusible and two nonfusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength, (f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

REVIEW OF LITERATURE

Nonwoven fusible interfacings were developed in the twentieth century. Prior to that time, nonfusible interfacings were used widely in commercial and home sewing. Interlining, a term used concurrently with interfacing in the literature, was usually made of buckram (16:68) until the nineteenth century when hair cloth was introduced (16:68).

The first fusible interlining was developed in 1912 by Frederick Hansing. In the patent, he described his invention as "...the application of an adhesive preparation to the surface of a woven fabric...so that the fabric may subsequently be caused to adhere to another fabric and it relates more particularly to the method of applying the adhesive to the surface of canvas...used for stiffening and retaining the shape of garments." He did not disclose the chemical composition of the adhesive (16:68).

The traditional method of interfacing application was by sewing the interlining into the garment (9:1325). It was not until 1951, when the clothing industry realized the need for an alternative to basting for attaching interlinings, that Sydney Morgan and Harold Rose developed and marketed the first fusible interlining (16:68). This product, known as Staflex, was a woven cotton fabric with a continuous coating of thermoplastic adhesive (14:3).

In 1952, a nonwoven fabric was developed and sold under the trade name of Pellon. The fabric was a blend of nylon, cotton and rayon and was bonded by a nitrile rubber formulation. Because of its weight, strength and resiliency, Pellon was found to be an excellent interlining fabric (7:3).

Fusible nonwoven interfacing fabrics were introduced by Pellon Corporation as early as 1962 (18:17).

The nonwoven fusible industry has grown so that in 1975, 12.5 percent of the total use of interlining yardage in the United States was composed of fusible interlinings (25:20). Of that amount, 40 percent were nonwoven fusible fabrics (10:24).

A fusible interlining consists of two components: the base fabric and the adhesive coating. The base cloth may be of a variety of specially prepared woven or nonwoven substrates. The resin adhesive may be any thermoplastic or pseudo-thermoplastic material and may be applied to the base cloth in a variety of methods (22:619).

Base Fabric

Nonwoven fabrics for interfacings are usually composed of synthetic fibers or viscose rayon fibers (8:67) which are chemically bonded or needle-punched (1:180). A brief summary of the methods of web formation for nonwoven fabrics is essential to fully understand the properties of nonwoven interfacings. The characteristics of each type of web formation are described by Aass (2:180) and Baxter (6:36) as follows:

1. Uni-directional or Parallel-laid -- The fibers are laid parallel along the length of the fabric. This type of web formation produces high strength in the warp direction and low strength or high stretch in the filling direction. Uni-directional fabrics also have greater stiffness in the machine direction (8:68).

2. Multi-directional -- The fibers are laid or air-blown in a random web which produces a fabric with good strength in all directions.

3. Biasable -- The fibers are laid at an angle which produces moderate strength in all directions for the fabric.

4. Spunbonded -- This nonwoven fabric is produced by extruding the filaments in a random manner onto a surface to produce a fabric with excellent strength in all directions.

The properties of an interlining fabric to be considered are bulk, weight, resilience, drape, shrinkage and color (8:67). Because of the nature of the manufacture of nonwoven fabrics, nonwovens may be infinitely engineered to meet a wide variety of specific needs for interlining fabrics (17:40). Nonwoven interfacing fabrics are designed and constructed for fusing (15:127). The advantages of nonwovens as interlining fabrics are that they are easy to cut and shape. Nonwovens also give bulk at low weight with adequate strength and shrinkage characteristics (10:24). In addition, they are designed to be washable, dry-cleanable and crush-resistant (17:40).

The dimensional stability of the base fabric is the most important criterion for performance in use. Shrinkage of an interlining fabric caused by washing or dry cleaning after it has been fused to another fabric can produce bubbling or local delamination (15:127). A tolerance of between 1-2 percent launderability shrinkage of the two fabrics is acceptable. If the interlining does not shrink, this could be a disadvantage (14:9). The use of fusible interlinings can stabilize and control the shrinkage of the garment fabric to a degree, but the best choice for an interlining fabric is one that is compatible with the garment fabric in shrinkage due to washing and dry-cleaning (12:102). Also, shrinkage does not occur at the same rate in the machine and cross-machine directions; therefore, the garment should be designed with this taken into consideration (2: 114).

After the fibrous web of the nonwoven fabric has been bonded, the production of stitched-in nonwoven interlinings is completed. The manufacture of fusible interlinings requires the additional step of applying the adhesive coating.

Adhesive Coating

The adhesive coating on fusible interlinings is a thermoplastic component which melts or softens with the application of heat thereby forming a bond between the interlining and the outer fabric (8:67). The thermoplastic adhesive hardens when cooled and softens again if heat is reapplied (14:3).

Several requirements are placed on the thermoplastic adhesives used for fusible interlinings which are enumerated as follows:

1. Thermoplastic adhesives must melt in the temperature range of 100°C to 180°C and maintain flexibility (8:67). The melting point and the bonding range must be such that the adhesive will be suitable for most textiles so that the fusing operation will not damage the fibers (24:184).

2. The resin must have restricted flow and stickiness in a heated state but should not be tacky at room temperature (24:184).

3. The polymer must be resistant to aging so that it can have an extended shelf life and can be fused at a later date without becoming hard or brittle (24:184). The chemical adhesive properties must be such that they are insensitive to storage (15:126).

4. The thermoplastic resin must be colorless and not yellow when exposed to heat or light (24:184).

5. The resin must produce a strong bond with a low resin add-on (22:625).

6. The polymer must be resistant to drycleaning and washing temperatures

and solvents without affecting the bond (22:625).

7. The thermoplastic adhesive must have low resin migration properties so that the resin will not strike through to the surface of the outer fabric when fused and will not strike back which would cause the interlining not to adhere to the outer fabric (22:625).

8. The polymer must possess some latitude in bonding conditions (22:625) and provide a reliable bonding application (24:184).

9. The resin must be resistant to permanent-press treatment at 185°C (8:67).

10. The adhesive coating should not affect the hand of the fabric, yet it should stiffen if required (24:184).

11. All of the above features should be available at a low cost (22:625).

A variety of adhesives are currently used for fusible interfacing bonding systems including the following: high density and low density polyethylene; polyvinyl acetate; copolymers based on ethylene and vinyl acetate (EVA); partially or completely saponified EVA copolymers; plasticized copolymers based on vinyl chloride and vinyl acetate (PVC); and polyamide (24:184). Each resin has its own distinct properties which enables it to be engineered into a product suitable for a specific application depending upon the performance requirements. Kartun (16:70) describes the criteria for choosing a particular resin as "...neatly poised between drycleanability, washability, adhesion level, acceptable fusing conditions, acceptable flow characteristics in the light of the base cloth and garment fabrics involved, and cost." Other considerations are whether the interfacing will be sewn all around after fusing and whether the fusible fabric will be used with a heavy weight or light weight fabric (15:127).

Stukenbrock (24:190) describes the fusing characteristics of the most commonly used thermoplastic resins in the following table:

Table 1. Properties of Fusible Materials

Chemical Composition	Melting Range	Fusing Temp.	Repeatable Fusing	Fastness to Dry-cleaning	Fastness to Washing
Polyvinyl acetate	80-95	120-150	yes	only white spirit	mild wash
High density Polyethylene	100-120	130-160	yes	satisfactory	mod. wash
Low density Polyethylene	125-136	170-190	yes	very good	very good
EVA Copolymers	75-90	100-120	yes	moderate	mild wash
Modified EVA	105-115	steam or 110-160	yes	very good	good
Plasticised PVC	100-120	130-150	possibly	good	good
Polyamide	90-120	150-170	yes	very good	good

The polyamide fusing agents compose approximately 20 grams per square meter of the total weight of a fusible interlining fabric. The polyamides produce the strongest adhesion, but they are also the most expensive bonding agent (24:189). Polyamide fusing agents may be based on polyamide copolymers, terpolymers or plasticised polyamides (15:126). The copolymers are based on the high melting point copolyamides of nylon 6 and 6-6. These copolymers have a softening point of approximately 180°C which is too high for most clothing applications (20:83).

The copolymer may be modified with the addition of plasticisers to give it suitable flow and fusing characteristics. The plasticised polyamides can be fused at lower temperatures in the presence of steam because the steam acts as a plasticizer (15:126). The resulting adhesive is hard with decreased adhesion but less pressure is necessary to fuse. Water can cause embrittlement of the modified high melting point adhesives (20:83). A lower fusing temperature is accomplished when the polyamide is in the form of dry fusible powders. A small percentage of unreacted monomer is present which acts as a plasticiser during fusing or an external plasticiser may be incorporated into the polyamide (15:127).

The terpolymers are based on the low melting point polyamides built-up from nylon 6, 6-6 and 12. With the addition of nylon 12, the fusing temperature may be lowered to as low as 125°C (19:31) with a high bond strength (20:83). This also results in a reduction of water absorption potential which not only imparts improved laundering properties to the resin but also improves the resistance to dry cleaning. A common practice in drycleaning is to add water to the solvent to intensify the cleaning power of the solvent. A distinct advantage of polyamide based heat seal resins is their resistance to perchloroethylene and trichloroethylene drycleaning solvents (19:31). Water may still cause embrittlement but the bonded fabric will normally withstand washing temperatures up to approximately 60°C (20:83). Strike-through or strike-back may be a major disadvantage of fast fuse polymer formations in combination with light fabrics (15:127).

To achieve the desired qualities in the fused garment, the proper resin type must be selected and combined with the optimum physical form. The properties of the resin and the application method are combined in the composite fabric. The methods by which the resin is applied to the interlining fabric and the resulting fabric characteristics are described by Jones (14:6) and Aass (1:114) as follows:

1. Continuous Coated -- This method was introduced in 1950 and involves the application of the adhesive in a continuous over-all coating on the base fabric. A composite structure which is very stiff but with a very high bond strength is produced.

2. Powder or Sinter Coating -- In this process developed in 1957, a thin layer of powdered resin is sprinkled over the base cloth. The particles are adhered to the fabric by a sintering or melting process. The larger particles when fused, provide a discontinuous bond which imparts a softer hand to the composite fabric.

3. Paste Print Coating -- Introduced in 1964, this process involves the application of a fusible resin dot in a precise pattern by engraved rollers, rotary screens or other paste printing methods. The dots may also be applied by needles which penetrate the fabric and as the needles are withdrawn, they deposit the dots (9:1325). The resin may be left in dots or spread over the entire surface of the base fabric with a doctor blade. This application method has the advantage of controlling the amount of resin per square inch resulting in a soft, natural hand.

4. Hot Melt Application -- Molten resin is applied directly or indirectly to the base cloth in a pattern with engraved rolls. Higher production speeds and an elimination of the grinding process are possible with this method (3:71).

5. Powder Print Coating -- In this method developed in 1964, thermoplastic adhesives are deposited in a dry fine powder onto the base cloth in a dot pattern instead of in the random methods described previously. The

fabric is then sintered by infrared heaters to fix the resin to the cloth. This process controls the amount of resin per square inch to produce a composite structure with a soft hand.

6. Preformed Fusible Net -- A net of resin dots connected by thin filaments may be applied to a base fabric alone or may be used to adhere two fabrics together. With the application of heat and pressure, the filaments shrink into the dots leaving a coating of resin dots alone.

7. Spray Coating -- A fusible resin is deposited in a random manner by spraying the base fabric with molten resin or resin combined with solvents. The resin is arranged in small drops which are then dried. The random arrangement of the adhesive provides for discontinuous fusing properties and has the advantage of a soft hand in the composite fabric.

8. Air Doctor Method -- Resin powder is spread over the base fabric by a doctor blade and is melted and fixed by a heating process.

Pellon has developed what is called a Computer Dot Polyamide Print Fusing System. In the system, a computer prepares the layout of the printed dots so there will be no repeat of the dot pattern. This system eliminates the moiré effect encountered with regularly placed dots (13:70).

Variables Influencing the Properties of Nonwoven Fabrics

The properties of a chemically bonded nonwoven interfacing fabric are affected by the same factors that apply to any adhesively bonded fabric. El-Behery (11:8) enumerates the important factors in determining the properties of chemically bonded nonwoven fabrics as follows:

1. Web weight .
2. Fiber orientation in web.

3. Type of adhesive.

4. Amount of adhesive.

5. Method of application of adhesive.

6. The degree of compression of the web before and during the stabilization of the adhesive by curing or drying.

7. Fiber mechanical properties.

8. Fiber fineness.

9. Fiber length - influenced by fiber breakage during bonding process.

10. Fiber friction.

PROCEDURES

Nonwoven Interfacing Fabric

Four different types of nonwoven interfacing fabrics available for home sewing were evaluated in this study. Two of the fabrics were coated on one side with a polyamide fusing agent and two fabrics were not fusible. All of the fabrics were labeled as medium or comparable weights by the manufacturers. A summary of the fabric type, fiber content and physical characteristics of each fabric is given in Table 2. Plate 1 (Appendix A) contains a sample of each test fabric.

Table 2. Construction Characteristics of Test Fabrics

Fabric	Fabric Type	Fiber Content	Average Width	Average Weight	Average Thickness
A	Fusible	70% Nylon 20% Polyester 10% Rayon	61.6 cm.	6.58 mg/cm^2	.0167 in.
B	Fusible	50% Nylon 50% Polyester	55.9 cm.	7.18 mg/cm^2	.0183 in.
C	Nonfusible	70% Nylon 20% Polyester 10% Rayon	66.0 cm.	4.63 mg/cm^2	.0133 in.
D	Nonfusible	50% Nylon 50% Polyester	117.3 cm.	4.58 mg/cm^2	.0090 in.

The average width was calculated according to the procedure in ASTM

Designation D 1910-64, using the method specified for a short specimen removed from a full bolt.

Fabrics A and C were obtained from the same manufacturer but Fabrics B and D were produced by different manufacturers. The fabrics were chosen with similar fiber content so this factor would be limited as a source of variation.

The polyamide coating was applied in a dot pattern on Fabric B while the fusing agent for Fabric A was applied randomly in small particles (Plate 1, Appendix A). Fabrics C and D did not have a polyamide coating on either side.

Test Fabric Preparation

Twenty-four samples which measured 15 in. x 15 in. were cut from each test fabric using an aluminum template. The samples were staggered across the width of the fabric so that each sample contained different machine and cross machine fibers. No sample was taken closer than one-tenth the total width from the edge of the fabric. After completing the dimensional change, weight and thickness measurements, the specimens were cut into the appropriate sizes for the remainder of the physical tests. No two machine or cross machine specimens were taken from the same machine or cross machine direction. Plate 2 (Appendix B) illustrates the plan for sample division.

Physical Tests

Test methods and exceptions specified in ASTM Designation D 1117-74, "Standard Methods of Testing Nonwoven Fabrics," were used to evaluate the test fabrics. All of the procedures except the laundering were conducted in a standard atmosphere for testing ($70 \pm 2^{\circ}F$ temperature, $65 \pm 2\%$ relative humidity). All of the samples reached moisture equilibrium prior to testing.

Dimensional Change. AATCC Test Method 96-1975 was used to determine the dimensional change of the test fabrics after one, five and ten laundry cycles. Three samples were selected for each wash cycle and three were retained as controls from each fabric. The samples were randomly assigned to the specific wash cycle using a Table of Random Numbers and were coded with indelible ink. One replication was conducted for each of the tests.

To measure the dimensional change, three bench marks were placed ten inches apart along the machine and cross machine directions of each sample. An aluminum template was used to position the marks uniformly. Plate 2 (Appendix B) illustrates the position of the bench marks.

The samples were subsequently laundered for the specified number of cycles in a Najort Wash Wheel. Washing procedure II and drying procedure E of AATCC Test Method 96-1975 were used. The specific requirements of these procedures are shown in Table 3.

The wash water was maintained at an average temperature of 124°F and the two rinse temperatures averaged 105°F. Sixty-four grams of AATCC Standard Detergent WOB (without optical brightener) were used for each wash cycle. The spin cycle of an automatic washer was used as a centrifuge. The laundry procedures were repeated for the replication.

The samples were dried for 15 minutes in an automatic dryer with an average drying temperature of 57°F. The temperature of the exhaust was measured to determine the average drying temperature. Specimens were removed from the load after the specified number of cycles and ballast was added to maintain a 3 ± 1/4 pound load.

After the samples were conditioned for a minimum of four hours, the dimensional change was measured in both the machine and cross machine directions using a knit shrinkage gauge ruler which was marked directly in percent shrinkage. The amount of shrinkage was recorded to the nearest 0.5 percent and three readings from each direction were averaged.

Table 3. Laundering Test Procedure (AATCC Test Method 96-1975)

Procedure	Designation	Requirements	
Washing Procedure	II	Wash Cycle	
		Suds Time	30 min.
		Cycle Temperature	120-129F
		First Rinse	
		Time	5 min.
		Temperature	100-109F
		Second Rinse	
		Time	10 min.
		Temperature	100-109F
Drying Procedure	E	Tumble Dry	
Restoration Procedure	None		

Thickness. A total of ten thickness measurements from the three specimens for each laundry cycle were determined according to ASTM Designation D 1777-64. The 15 inch square was not cut for these measurements. The positions of the measurements were chosen randomly on the fabric. A Frazier Compressometer equipped with a round presser foot one inch in diameter was used for the thickness measurements. The pressure was increased to one pound per square inch at which point the standard thickness was read. The loading time to full load was 5 seconds and another 5 second interval was allowed for the Compressometer to reach equilibrium before the reading was taken. The measurements were recorded to the nearest 0.001 inch.

Weight. Each specimen was weighed before the laundering procedure on a Mettler balance according to the procedures in ASTM Designation D 1910-64 using the method applicable for a small sample. After the laundered samples were conditioned for a minimum of four hours, the samples were re-weighed to determine the percent weight change. The weights were calculated in milligrams per square centimeter (mg/cm^2).

Flexural Rigidity. The Cantilever Test in ASTM Designation D 1388-64, Option A, was employed to determine the stiffness of the fabrics after the specific laundry cycles. The apparatus used in this test was the Drape-Flex Stiffness Tester. A total of four machine and four cross machine test specimens were cut from the three test samples for each cycle (Plate 2, Appendix B). The length of the overhang for each side and each end of the specimen was determined and these measurements were averaged together for both the machine and cross machine direction. The bending length, flexural rigidity for both directions and over-all flexural rigidity were calculated according to the following formulas:

$$\text{Bending Length, } c = O/2$$

where: O = length of overhang, cm.

$$\text{Flexural Rigidity, } G = W \times c^3$$

where: W = weight per unit area, mg/cm^2

$$\text{Over-all Flexural Rigidity, } G_o = \sqrt{G_M \times G_{XM}}$$

where: G_M = machine flexural rigidity

G_{XM} = cross machine flexural rigidity

Breaking Load. The breaking strength of five conditioned samples from the machine direction for each laundry cycle were tested according to ASTM Designation D 1682-64 using the one-inch cut strip method. The measurements were made on a Scott Constant-rate-of-extension (C.R.E.) Tester equipped with 3 inch clamps (3 in. x 1 in.) with a 3 inch jaw separation. The crosshead speed was adjusted to maintain a 20 $\pm$ 3 second breaking time. A 500 kilogram load cell with a working range of X0.1 and X0.02 were used. The maximum load obtainable with a X0.1 working range was 50 kilograms (kg) and 10 kg with the working range set at X0.02. The cross machine direction was not tested because the breaking load did not register within the acceptable range on the lowest working range. The final measurements on the autographic recording chart were converted to kilograms per chart division by the appropriate chart division equivalent for the particular working range.

Elongation. The elongation recorded on the Scott C.R.E. Tester was used to compute the apparent elongation for the samples cut in the machine direction. The procedure followed for this measurement was specified in ASTM Designation D 1682-64. The following formula was used to compute the apparent elongation:

$$\text{Apparent Elongation, \% per cm.} = \frac{\text{Chart Measurement}}{\text{Jaw Separation} \times \dfrac{\text{Chart Speed}}{\text{Crosshead Speed}}} \times 100$$

The chart measurement, which was in inches, was converted to centimeters by multiplying by 2.54. The jaw separation was in all cases 3 inches or 7.62 centimeters and the chart speed was 25.4 centimeters per minute. The crosshead speed was adjusted to maintain the proper breaking time, therefore, the crosshead speed varied with each fabric.

Bursting Strength. The Scott C.R.E. Tester with the ball burst attachment was used to determine the bursting strength of ten specimens for each laundry cycle according to ASTM Designation D 231-62. The samples were clamped into the ball burst attachment without cutting the samples from the fabric. Plate 2 (Appendix B) illustrates the areas from which the measurements were taken. The same methods as described in the breaking strength procedure was used to convert the chart divisions to kilograms. A breaking time of 20 ± 3 seconds was maintained throughout the testing.

Flat Abrasion Resistance. The inflated diaphragm method specified in ASTM Designation D 1175-71 was used to assess the flat abrasion resistance of five samples from each laundry cycle. A CSI Stoll Quartermaster Universal Wear Tester was used to determine the number of cycles necessary to abrade a hole in the specimen at which point electrical contact stopped the machine. The side of the fusible fabrics without the polyamide fusing agent was placed next to the emery paper abradant. The samples were subjected to multidirectional abrasion under a 1/2 pound load on the abradant plate with the diaphragm inflated to 4 pounds per square inch air pressure.

During the test, the pills of matted fibers were not removed from the abrasion area because it was determined that this would not represent actual wear conditions.

Flexing and Abrasion Resistance. The CSI Stoll Quartermaster Universal Wear Tester equipped with a flexing bar was used for flexing and abrasion resistance measurements according to ASTM Designation D 1175-71. Five samples from each laundry cycle were subjected to unidirectional reciprocal folding and rubbing over a flexing bar with 4 pounds of tension and 1 pound of pressure. The flexing bar, pressure plate and reciprocating plate were cleaned with tetrachloroethylene after each specimen was tested. The number of flex cycles required to rupture the specimens was determined for the machine direction only for each of the samples. The samples cut from the cross machine direction were too weak to be clamped around the flexing bar under the required pressure. The side of the fusible fabrics without the polyamide coating was placed next to the flexing bar because this side probably would recieve the most abrasion when functioning within a garment.

Statistical Analysis. Analysis of variance at a .05 level of significance was performed to evaluate the significant changes between the fabrics due to the laundering procedure. The Least Significant Difference (L.S.D.) procedure was used to analyze the independent variables and interactions which were found to be significant in the analysis of variance thereby determining where the significant differences actually occurred. The analyses were done with the aid of the statistical computer program Arrdvark, which was obtained from the Kansas State University Computer Center.

RESULTS AND DISCUSSION

Dimensional Change

The analysis of variance performed on the dimensional change measurements in the machine direction of the fabrics is contained in Table 4.

Table 4. Analysis of Variance - Machine Direction Dimensional Change

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.001158	0.037	0.851
Type of Fabric (T)	1	6.862247	218.121	0.000 *
Fiber Content (F)	1	0.001157	0.037	0.851
Laundry Cycle (L)	2	1.572912	49.996	0.000 *
T x F	1	0.843741	26.819	0.000 *
T x L	2	0.042824	1.361	0.296
L x F	2	0.008102	0.258	0.777
T x F x L	2	0.010417	0.331	0.725
Error	11	0.031461		

*.05 level of significance

As can be seen from Table 4, the significant independent variables were the types of fabric (F = 218.121) and the laundry cycles (F = 49.996). The second order interaction types of fabric x fiber content (F = 26.819) was also found to be significant.

The means for the dimensional change in the machine direction of the fabrics are shown in Table 5.

Table 5. Dimensional Change Means (in percent) in Machine Direction of the Fabrics.

	Laundry Cycle 1	5	10	Over-all Means
Fusibles				
Fabric A	1.00	1.50	1.75	1.42
Fabric B	0.67	1.00	1.50	1.06
Means	0.83	1.25	1.63	1.24
Nonfusibles				
Fabric C	1.58	2.25	2.50	2.11
Fabric D	1.92	2.67	2.92	2.50
Means	1.75	2.46	2.71	2.31
Over-all Means	1.29	1.85	2.17	

According to the test of Least Significant Difference (L.S.D.) the difference in the means of 1.07 percent (%) for machine direction dimensional change for the fusibles (1.24%) and nonfusibles (2.31%) was highly significant. In addition the differences in the means for one (1.29%), five (1.85%) and ten (2.17%) laundering cycles were significant.

For the two fusibles, the mean dimensional change for Fabric A (1.42%) was significantly higher than For Fabric B (1.06%) according to the L.S.D. test. For the two nonfusibles, the over-all shrinkage for Fabric D (2.50%) was significantly higher than for Fabric C (2.11%) at a .05 significance level. It can also be observed from Table 5 that Fabric D had greater shrinkage after each of the laundry cycles than any of the other fabrics.

Table 6 contains the results of the analysis of variance performed on the percent dimensional change measurements in the cross machine direction of the fabrics.

Table 6. Analysis of Variance - Cross Machine Direction Dimensional Change.

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.560186	25.113	0.000 *
Type of Fabric (T)	1	4.449074	199.450	0.000 *
Fiber Content (F)	1	2.666683	119.546	0.000 *
Laundry Cycle (L)	2	0.563659	25.269	0.000 *
T x F	1	1.337961	59.980	0.000 *
T x L	2	0.327544	14.684	0.001 *
L x F	2	0.072916	3.269	0.077
T x F x L	2	0.008102	0.363	0.703
Error	11	0.022307		

* .05 level of significance

As can be seen from Table 6, the significant independent variables were types of fabric (F = 199.450), fiber content (F = 119.546), laundry cycles (F = 25.269) and replication (F = 25.113). The second order interactions of types of fabric x fiber content (F = 59.980) and types of fabric x laundry cycles (F = 14.684) were also found to be significant at a .05 level of significance.

The means for the dimensional change in the cross machine direction of the fabrics are shown in Table 7.

Table 7. Dimensional Change Means (in percent) in the Cross Machine Direction of the Fabrics.

	Laundry Cycle 1	Laundry Cycle 5	Laundry Cycle 10	Over-all Means
Fusibles				
Fabric A	1.08	1.33	1.42	1.28
Fabric B	0.17	0.25	0.00	0.14
Means	0.62	0.79	0.71	0.71
Nonfusibles				
Fabric C	1.08	1.83	2.08	1.67
Fabric D	1.00	1.67	1.75	1.47
Means	1.04	1.75	1.92	1.57
Over-all Means	0.83	1.27	1.31	

According to the L.S.D. the difference in the means of 0.86% for cross machine dimensional change for the fusibles (0.71%) and nonfusibles (1.57%) was significant with the nonfusibles exhibiting the greatest amount of shrinkage. In addition, according to the L.S.D. the differences in the means between the laundry cycles were significant after one laundry cycle (0.83%) but non-significant between five (1.27%) and ten (1.31%) laundry cycles. For the fusibles, the differences among the means for one (0.62%), five (0.79%) and ten (0.71%)

laundry cycles were not significant. On the other hand, the difference in the means for the nonfusibles was significant between one (1.04%) and five (1.75%) laundry cycles while the differences between five (1.75%) and ten (1.92%) cycles was non-significant. This indicates that the dimensional change for the nonfusibles increased with each laundry cycle, but that the shrinkage had leveled off between the fifth and tenth washing while the shrinkage for the fusibles was not significant at any of the washing levels.

For the two fusibles, the mean dimensional change for Fabric A (1.28%) was significantly higher than for Fabric B (0.14%) as shown by the L.S.D. This is the same relationship reported in the machine direction dimensional change. The L. S. D. showed that the for two nonfusibles, Fabric C (1.67%) exhibited a significantly higher shrinkage than Fabric D (1.47%) at a .05 level of significance. It can also be observed from Table 7 that Fabric C had greater shrinkage at the fifth and tenth level of laundering.

A significant difference in the means of 0.3 percentage points for the replications as found by the L.S.D. showed that the variables associated with the laundry procedures may have been a source of variation. An explanation of this difference may be that the replications were run at a separate time.

In all cases, the dimensional change in the cross machine direction was less than in the machine direction. It appears that the greatest amount of shrinkage occurred in the direction in which the fibers were arranged in the web formation. These particular fabrics were produced by a uni-directional web arrangement with the fibers laid parallel to the machine direction.

Thickness

The results of the analysis of variance for the thickness measurements are presented in Table 8.

Table 8. Analysis of Variance - Thickness

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.000000	0.894	0.359
Type of Fabric (T)	1	0.000233	1158.617	0.000 *
Fiber Content (F)	1	0.000000	0.224	0.643
Laundry Cycle (L)	3	0.000001	3.195	0.054
T x F	1	0.000068	339.941	0.000 *
T x L	3	0.000001	5.546	0.009 *
L x F	3	0.000002	7.524	0.003 *
T x F x L	3	0.000000	2.359	0.113
Error				

*.05 level of significance

From Table 8, it can be seen that the significant independent variable was types of fabric (F=1158.617). The second order interactions of significance were type of fabric x fiber content (F = 339.941), type of fabric x laundry cycle (F = 5.546) and laundry cycle x fiber content (F = 7.524).

The means for the thickness measurements and the percent change from the untreated specimens are shown in Table 9.

Table 9. Thickness Means (in .0001 inch) and Percent Change of the Fabrics.

	Laundry Cycle 0	1	5	10	Over-all Means
Fusibles					
Fabric A	0.0167	0.0146	0.0145	0.0150	0.0152
Fabric B	0.0183	0.0183	0.0182	0.0174	0.0180
Means	0.0175	0.0165	0.0163	0.0162	0.0166
Nonfusibles					
Fabric C	0.0133	0.0125	0.0124	0.0127	0.0127
Fabric D	0.0090	0.0094	0.0099	0.0106	0.0097
Means	0.0111	0.0109	0.0111	0.0116	0.0112
Over-all Means	0.0143	0.0137	0.0137	0.0139	
Percent Change					
Fabric A		-12.6	-13.2	-10.2	
Fabric B		0.0	- 0.5	- 4.9	
Fabric C		- 6.0	- 6.8	- 4.5	
Fabric D		+ 4.4	+10.0	+17.8	

- indicates decrease in thickness from untreated fabric.
+ indicates increase in thickness from untreated fabric.

The L. S. D. showed the differences in the means for the fusibles (0.0166") and the nonfusibles (0.0112") as averaged over the laundry cycles to be highly significant. As shown by the L.S.D., there was a significant difference in the means for the fusibles between the untreated fabric (0.0175") and one laundry cycle (0.0165") but the changes between one (0.0165"), five (0.0163") and ten (0.0162") laundry cycles were non-significant. On the other hand, the difference between the means for the nonfusible fabrics showed a significant change between one (0.0109") and ten (0.0116") laundry cycles. The L.S.D. with a .05 protection level showed that the over-all differences between the thickness measurements after the various laundry cycles (0.0143", 0.0137", 0.0137" and 0.0139" respectively) were not significant.

For the two fusibles, the difference in the means for Fabric B (0.0180") was significantly higher than for Fabric A (0.0152") as shown by the L.S.D.. For the two nonfusibles, the L.S.D. indicated that the difference in the means of Fabric C (0.0127") and Fabric D (0.0097") was significant at a .05 protection level with Fabric C being the thickest after treatment.

As can be seen in Table 9, Fabric B was the thickest (0.0183") of the untreated fabrics and remained the thickest after ten washings (0.0174") even though it decreased approximately 5 percent in thickness. All fabrics showed a general decrease in thickness after repeated washings except Fabric D which increased in thickness after five (10.0%) and ten (17.8%) launderings. This corresponds to the behavior of Fabric D in the machine direction dimensional change experiments. Fabric D showed the greatest amount of shrinkage (2.92%) which may have caused the fabric to become thicker. The relationship of the other three fabrics is consistent with the dimensional change results. A loss in thickness may be attributed to a loss of fibers in the laundry process because of differences in fiber bonding methods and resins used. The formation of pills also would eliminate fibers from the fabric. Since the methods of manufacturing were not given by the producing companies, it is not possible to further explain this relationship. As these fabrics were manufactured by three different companies, the differences in the thickness measurements of the untreated fabrics (Table 9) may relate to the differences in manufacutring processes or specifications.

Weight

During the laundry cycles, the polyamide dots from Fabric B flaked off the fabric and became attached to the other interfacing fabrics and the ballast in the machine. All four fabrics showed a high degree of pilling. These pills could have conceivably become dislodged and attached to other fabrics or remained in the water. This would have affected the weight of the specimens after laundering. For the above reasons, weight measurements were determined to be invalid and this portion of the research was discontinued. Table 10 contains only the average weight of the fabrics before laundering.

Table 10. Weight Means (in milligrams per square centimeter) of Fabrics Before Laundering.

	Laundry Cycle 0
Fusibles	
Fabric A	6.575
Fabric B	7.182
Nonfusibles	
Fabric C	4.634
Fabric D	4.576

The differences in the mean weights between each fabric as reported in Table 10 illustrates the varying specifications for these products. There are no standard weight requirements for interfacing fabrics; therefore, a great variation is possible between commercial products. Fabrics A and B were heavier (6.575 and 7.182 mg/cm^2 respectively) than Fabrics C and D (4.634 and 4.576 mg/cm^2 respectively). The additional polyamide fusing agent on Fabrics A and B may have contributed to the additional weight.

Flexural Rigidity

The means for the machine and cross machine flexural rigidity at each laundry cycle are reported in Table 11.

Table 11. Machine and Cross Machine Flexural Rigidity (in milligrams per centimeter) of the Fabrics.

	Laundry Cycle			
	0	1	5	10
	Machine Flexural Rigidity			
Fabric A	309.647	219.652	167.705	147.031
Fabric B	976.394	603.947	351.071	280.266
Fabric C	288.464	171.156	134.408	103.998
Fabric D	512.779	167.160	107.049	79.662
	Cross Machine Flexural Rigidity			
Fabric A	45.770	32.693	24.340	19.982
Fabric B	71.030	46.263	28.334	18.169
Fabric C	38.318	21.346	17.002	13.910
Fabric D	25.590	12.976	10.265	6.760

It is readily apparent from Table 11 that the mean flexural rigidity in the machine direction was much greater in every instance than the mean flexural rigidity in the cross machine direction. This corresponds to the uni-directional method of web formation. In these particular fabrics, the fibers were arranged parallel to the machine direction which would make the fabrics stiffer in this direction.

An analysis of variance was performed on the over-all flexural rigidity only and is contained in Table 12.

Table 12. Analysis of Variance - Over-all Flexural Rigidity.

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	10.922335	0.458	0.509
Type of Fabric (T)	1	25849.718750	1083.571	0.000 *
Fiber Content (F)	1	7552.175781	316.573	0.000 *
Laundry Cycle (L)	3	16892.289063	708.092	0.000 *
T x F	1	12279.675781	514.740	0.000 *
T x L	3	1128.801758	47.317	0.000 *
L x F	3	2281.795410	95.648	0.000 *
T x F x L	3	1072.209229	44.945	0.000 *
Error	15	23.856049		

* .05 level of significance

As can be seen in Table 12, the significant independent variables were type of fabric (F = 1083.571), fiber content (F = 316.573) and laundry cycle (F = 708.092). The second order interactions of significance were type of fabric x fiber content (F = 514.740), type of fabric x laundry cycle (F = 47.317) and laundry cycle x fiber content (F = 95.648). The third order interaction of type of fabric x fiber content x laundry cycle (F = 44.945) was also found to be significant at a .05 level of significance.

The means for the over-all flexural rigidity measurements and the percent change from the untreated fabric are presented in Table 13.

Table 13. Over-all Flexural Rigidity Means (in milligrams per centimeter) and Percent Change of the Fabrics.

	Laundry Cycle				Over-all
	0	1	5	10	Means
Fusibles					
Fabric A	119.047	84.732	63.887	54.199	80.466
Fabric B	263.334	167.086	99.713	71.347	150.370
Means	191.191	125.909	81.800	62.773	115.418
Nonfusibles					
Fabric C	105.060	60.402	47.709	38.034	62.801
Fabric D	114.551	46.549	33.101	23.189	54.348
Means	109.805	53.476	40.405	30.611	58.574
Over-all Means	150.498	89.692	61.102	46.692	
		Percent Change			
Fabric A		-28.8	-46.3	-54.4	
Fabric B		-36.5	-62.1	-72.9	
Fabric C		-42.5	-54.6	-63.8	
Fabric D		-59.4	-71.1	-79.8	

- indicates decrease in over-all flexural rigidity from untreated fabric.

The L. S. D. showed that the differences between the means of the fusibles (115.418 mg/cm) and nonfusibles (58.574 mg/cm) were significant with a .05

protection level. In addition, the L.S.D. showed a significant decrease in stiffness at one (89.692 mg/cm), five (61.102 mg/cm) and ten (46.692 mg/cm) laundry cycles from the untreated fabric (150.498 mg/cm). The decreases in over-all flexural rigidity for the fusible and nonfusible fabrics at each treatment level was shown to be significant by the L.S.D. at a .05 level of significance (Table 13).

For the two fusibles, the difference in the means as analyzed by the L.S.D. was significant with Fabric B (150.370 mg/cm) being stiffer than Fabric A (80.466 mg/cm). For the two nonfusibles, Fabric C (62.801 mg/cm) had a significantly higher over-all flexural rigidity than Fabric D (54.348 mg/cm).

As can be observed in Table 13, each fabric decreased in over-all flexural rigidity after each laundry cycle. The differences in the means between the fifth and tenth laundry cycles for Fabric A (63.887 and 54.199 mg/cm respectively) and D (33.101 and 23.189 mg/cm respectively) were determined by the L.S.D. to be non-significant. Of the untreated fabrics, Fabric B was the stiffest and maintained the highest over-all flexural rigidity after ten laundry cycles even though it exhibited a 72.9 percent decrease from the untreated fabric. This corresponds with previous results related to thickness in which Fabric B was the thickest fabric with the highest weight per unit area. Table 13 shows that the greatest percent change after ten launderings was demonstrated by Fabric D (79.8%) and the least change occurred in Fabric A (54.4%).

The stated purpose of interfacing fabrics is to add stiffness to areas of a garment. The results indicated that the original stiffness of a garment section interfaced with any of these fabrics might become less stiff after repeated washings. Based on this research, Fabric B should have the most stiffness after ten washings while Fabric D should have the most change in stiffness at the same washing level.

Bursting Strength

The analysis of variance for the changes in bursting strength is contained in Table 14.

Table 14. Analysis of Variance - Bursting Strength.

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.068268	0.395	0.539
Type of Fabric (T)	1	13.611126	78.816	0.000 *
Fiber Content (F)	1	2.951236	17.089	0.001 *
Laundry Cycle (L)	3	0.450483	2.609	0.090
T x F	1	41.984726	243.114	0.000 *
T x L	3	0.744156	4.309	0.022 *
F x L	3	0.299872	1.736	0.202
T x F x L	3	0.162893	0.943	0.444
Error	15	0.172695		

*.05 level of significance

As can be seen from Table 14, the significant independent variables were type of fabric (F = 78.816) and fiber content (F = 17.089). The second order interactions of type of fabric x fiber content (F = 243.114) and type of fabric x laundry cyclies (F = 4.309) were also found to be significant at the .05 level of significance.

The means of the bursting strength measurements and the percent change at each washing level is shown in Table 15.

Table 15. Bursting Strength Means (in kilograms) and Percent Change of the Fabrics.

	Laundry Cycle 0	1	5	10	Over-all Means
Fusibles					
Fabric A	6.67	7.95	7.75	7.80	7.54
Fabric B	4.11	5.03	4.84	4.60	4.64
Means	5.39	6.49	6.30	6.20	6.09
Nonfusibles					
Fabric C	6.81	6.48	6.25	6.69	6.56
Fabric D	8.39	8.76	8.27	7.54	8.24
Means	7.60	7.62	7.26	7.11	7.40
Over-all Means	6.49	7.05	6.78	6.66	
Percent Change					
Fabric A		+19.1	+16.2	+16.9	
Fabric B		+22.4	+17.8	+11.9	
Fabric C		- 4.8	- 8.2	- 1.8	
Fabric D		+ 4.4	- 1.4	-10.1	

- indicates a decrease in bursting strength from the untreated fabric.
+ indicates an increase in bursting strength from the untreated fabric.

The L.S.D. determined that the difference in the means of 1.31 kilograms (kg) for the types of fabric was significant with the nonfusibles having a significantly higher bursting strength (7.40 kg) than the fusibles (6.09 kg). The analysis by L.S.D. also showed that the differences in the means at one (7.05 kg), five (6.78 kg) and ten (6.66 kg) laundry cycles were not significantly different from the mean for the untreated fabric (6.49 kg). The differences between the means for each cycle of the nonfusibles (7.60, 7.62, 7.26 and 7.11 kg respectively) were non-significant (Table 14). On the other hand, for the fusible fabrics, there was a significant difference between one (6.49 kg), five (6.30 kg) and ten (6.20 kg) laundry cycles from the untreated fabric (5.39 kg).

The differences in the means for the two fusible fabrics as analyzed by the L.S.D. showed Fabric A to have a significantly higher bursting strength (7.54 kg) than Fabric B (4.64 kg) at a .05 protection level. For the two nonfusibles, Fabric D had a significantly higher bursting strength (8.24 kg) than Fabric C (6.56 kg).

From Table 15, it can be observed that both of the fusible fabrics increased in bursting strength by approximately 17 and 12 percent while the two nonfusible fabrics decreased after ten laundry cycles by approximately 1 to 10 percent. Fabric D maintained the highest bursting strength at each level of treatment except the tenth laundry cycle even though it decreased approximately 10% in strength after ten washings. Fabric B had the lowest bursting strength at each treatment level (Table 15).

Breaking Load in the Machine Direction

Table 16 contains a summary of the analysis of variance for the machine direction breaking load measurements of the fabrics.

Table 16 - Analysis of Variance - Breaking Load

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.163875	3.376	0.086
Type of Fabric (T)	1	4.388206	90.412	0.000 *
Fiber Content (F)	1	1.275984	26.290	0.000 *
Laundry Cycle (L)	3	0.292511	6.027	0.007 *
T x F	1	15.276550	314.748	0.000 *
T x L	3	0.094913	1.956	0.164
F x L	3	0.364028	7.500	0.003 *
T x F x L	3	0.293950	6.056	0.007 *
Error	15	0.048536		

*.05 level of significance

From Table 16, it can be observed that the significant independent variables were type of fabric (F = 90.412), fiber content (F = 26.290) and laundry cycle (F = 6.027). The second order interactions of type of fabric x fiber content (F = 314.748) and fiber content x laundry cycles (F = 7.500) was also found to be significant. The significant third order interaction was type of fabric x fiber content x laundry cycles (F = 6.056).

The means and percent change for each fabric at the various treatment levels are summarized in Table 17.

Table 17. Breaking Load Means (in kilograms per centimeter) and Percent Change of the Fabrics.

	Laundry Cycles 0	1	5	10	Over-all Means
Fusibles					
Fabric A	5.71	5.58	5.73	5.56	5.65
Fabric B	3.38	4.37	4.05	3.67	3.87
Means	4.55	4.98	4.90	4.61	4.76
Nonfusibles					
Fabric C	4.85	4.97	5.08	5.13	5.01
Fabric D	6.34	6.47	5.91	5.24	5.99
Means	5.59	5.72	5.50	5.18	5.50
Over-all Means	5.07	5.35	5.20	4.90	
Percent Change					
Fabric A		- 2.3	+ 0.4	-2.6	
Fabric B		+29.3	+19.8	+8.6	
Fabric C		+ 2.5	+ 4.7	+5.8	
Fabric D		+ 2.1	- 6.8	-17.3	

- indicates decrease in breaking load from untreated fabric.
+ indicates increase in breaking load from untreated fabric

The L.S.D. statistical analysis of the two types of fabrics showed the difference in the means of 0.8 kilograms per centimeter (kg/cm) to be significant with the nonfusibles having a higher breaking load (5.50 kg/cm) than the fusibles (4.76 kg/cm). The L.S.D. analysis of the differences in the means of all fabrics at each washing level found a significant gain in strength at the first (5.35 kg/cm) washing level and a significant decrease in breaking load at the fifth (5.20 kg/cm) and tenth (4.90 kg/cm) washing level even though there was no significant difference between the breaking load measurements for the samples washed ten times (4.90 kg/cm) as compared to the strength of the untreated fabric (5.07 kg/cm). (Table 17).

According to the L.S.D. analysis of the difference in the means of the two fusible fabrics, Fabric A had a higher mean breaking load (5.65 kg/cm) than Fabric B (3.87 kg/cm). The same analysis for the two nonfusibles determined that Fabric D had a significantly higher breaking load (5.99 kg/cm) than Fabric C (5.01 kg/cm).

The results contained in Table 17 indicate that Fabric D had the highest breaking load measurement (6.34 kg/cm) of the untreated fabrics but that it decreased approximately 17 percent after ten launderings. Fabric A maintained the highest breaking load measurement after ten launderings (5.56 kg/cm) with a decrease in strength of only 2.6 percent.

The L.S.D. analysis of the third order interaction showed no significant differences in the means for Fabrics A and C at each washing level (Table 17). Fabric B increased significantly in strength after one laundering, however, there was no significant difference in the means between the untreated fabric (3.38 kg/cm) and the fabric washed ten times (3.67 kg/cm). Fabric D increased in strength with one washing and then decreased significantly; however, the difference between the measurements of the fifth (5.91 kg/cm) and tenth (5.24 kg/cm) laundry cycle was not significant.

Elongation

The analysis of variance for the apparent elongation measurements is contained in Table 18.

Table 18. Analysis of Variance - Apparent Elongation.

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	0.112309	0.080	0.782
Type of Fabric (T)	1	75.018539	53.242	0.000 *
Fiber Content (F)	1	521.675781	370.244	0.000 *
Laundry Cycle (L)	3	13.328720	9.460	0.001 *
T x F	1	2.596831	1.843	0.195
T x L	3	1.475801	1.047	0.400
L x F	3	4.544767	3.226	0.053
T x F x L	3	3.922197	2.784	0.077
Error	15	1.409003		

*.05 level of significance

As shown in Table 18, the significant independent variables were types of fabric (F = 53.242), fiber content (F = 370.244) and laundry cycle (F = 9.460). None of the second order and third order interactions were significant at the .05 level of significance.

The means and percent change in apparent elongation for each fabric at the various levels of treatment are reported in Table 19.

Table 19. Apparent Elongation Means (in percent per centimeter) and Percent Change in the Fabrics.

	Laundry Cycle 0	1	5	10	Over-all Means
Fusibles					
Fabric A	38.38	39.17	39.90	38.85	39.07
Fabric B	27.01	33.85	31.37	29.49	30.43
Means	32.70	36.51	35.63	34.17	34.75
Nonfusibles					
Fabric C	39.70	41.80	42.19	42.58	41.57
Fabric D	33.31	35.02	34.96	32.95	34.06
Means	36.50	38.41	38.58	37.77	37.81
Over-all Means	34.60	37.46	37.11	35.97	
Percent Change					
Fabric A		+ 2.1	+ 2.8	+ 1.2	
Fabric B		+25.3	+16.1	+ 9.2	
Fabric C		+ 5.3	+ 6.3	+ 7.3	
Fabric D		+ 5.1	+ 5.0	- 1.1	

\- indicates a decrease in apparent elongation from untreated fabric.
\+ indicates an increase in apparent elongation from untreated fabric.

The L.S.D. analysis for the type of fabric variable showed a significant difference of 3.06 percent per centimeter (%/cm) in the means with the non-fusibles having a significantly higher apparent elongation (37.81 %/cm) than the fusibles (34.75 &/cm). In addition, the L.S.D. analysis of the laundry cycle variable showed a significant increase in apparent elongation from the untreated fabric (34.60 %/cm) to the first washing (37.46 %/cm). The apparent elongation decreased between the fifth (37.11 %/cm) and tenth (35.97 %/cm) laundry cycle but the difference was not significant (Table 19).

There were no significant differences between the mean apparent elongation measurements for the two fusible and two nonfusible fabrics as shown by the L.S.D. at a .05 protection level.

The means reported in Table 19 indicate that Fabric C performed the best in the apparent elongation experiments with the highest initial apparent elongation (39.70 %/cm) and the highest apparent elongation after ten laundry cycles (42.58 %/cm). Fabric B exhibited the most change after one (25.3 % change), five (16.1 % change) and ten (9.2 % change) washings and ranked the lowest (29.49 %/cm) in apparent elongation after treatment.

An interesting observation was made in conducting the strength and elongation experiment. The samples did not break at the point where the peak load was recorded on the C.R.E. chart. The fibers pulled apart and lost effective strength without actually breaking the sample. Also, the weakened area became very tacky to the touch. Possibly enough heat was generated by fiber friction in the break that the thermoplastic fibers or resins softened or a breakdown in the resin occurred.

Flat Abrasion Resistance

The results of the analysis of variance performed on the measurements of flat abrasion resistance are reported in Table 20.

Table 20. Analysis of Variance - Flat Abrasion Resistance.

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	170.202576	0.888	0.361
Type of Fabric (T)	1	3156.151855	16.458	0.001 *
Fiber Content (F)	1	217.359451	1.133	0.304
Laundry Cycle (L)	3	580.644287	3.028	0.062
T x F	1	5528.253906	28.828	0.000 *
T x L	3	298.544434	1.557	0.241
L x F	3	714.380127	3.725	0.035 *
T x F x L	3	525.653809	2.741	0.080
Error	15	191.767380		

*.05 level of significance

As can be seen from Table 20, the significant independent variable was the type of fabric (F = 16.458). The second order interactions of type of fabric x fiber content (F = 28.828) and laundry cycle x fiber content (F = 3.725) were also found to be significant at a .05 level of significance.

Some difficulties were encountered in the physical testing of the flat abrasion resistance of these fabrics with the inflated diaphragm method. The end point could not accurately be measured because the samples were not consistently abraded. The resin in the fabric and the fibers accumulated, without actually forming a pill that could be removed, and interferred with the electrical contact necessary to stop the abrader. The results, therefore, are reported as indicative of the specimens tested only and not of the fabrics in general. This test method would not seem to be suitable for this type of nonwoven fabric even though it is approved by ASTM for nonwoven fabrics.

Table 21 contains a summary of the means and percent change of each fabric according to treatment level.

Table 21. Flat Abrasion Resistance Means (in cycles) and Percent Change of the Fabrics.

	Laundry Cycle 0	1	5	10	Over-all Means
Fusibles					
Fabric A	57.8	62.4	59.9	69.0	62.3
Fabric B	115.7	99.6	58.0	60.1	83.3
Means	86.7	81.0	58.9	64.5	72.8
Nonfusibles					
Fabric C	56.5	88.5	65.0	64.8	68.7
Fabric D	42.4	37.7	35.0	33.7	37.2
Means	49.4	63.1	50.0	49.2	52.9
Over-all Means	68.1	72.0	54.5	56.9	
Percent Change					
Fabric A		+ 8.0	+ 3.6	+19.4	
Fabric B		-13.9	-49.9	-48.1	
Fabric C		+56.6	+15.0	+14.7	
Fabric D		-11.1	-17.5	-20.5	

- indicates decrease in cycles from untreated fabric.
+ indicates increase in cycles from untreated fabric.

The analysis by L.S.D. with a .05 protection level determined that the difference in means between the two types of fabric was significant with the fusibles having a greater mean (72.8 cycles) than the nonfusibles (52.9 cycles). The higher number of cycles necessary to abrade the fusibles may be attributed to the extra coating of polyamide on the reverse side of the fabric. The changes in the flat abrasion resistance at each washing level was found by the L.S.D. to be non-significant (Table 21). This was probably because of the range of the measurements rather than any effect the treatment may have had on the fabrics. The range of the results for this test was in some instances 143 cycles. With a majority of the mean measurements being below 100 cycles, a range of 143 cycles was excessive.

For the two fusibles, the statistical analysis found Fabric B to be significantly higher (83.3 cycles) in flat abrasion resistance than Fabric A (62.3 cycles). The analysis of the difference in means for the two nonfusible fabrics showed Fabric C to have a significantly higher flat abrasion resistance (68.7 cycles) than Fabric D (37.2 cycles).

As can be observed in Table 21, Fabric B had the highest flat abrasion resistance (115.7 cycles) of the untreated fabrics but this fabric also exhibited the greatest amount of decrease in abrasion resistance (48.1%) after ten washings. Fabric A maintained the greatest flat abrasion resistance (69.0 cycles) after ten laundry cycles with an increase of approximately 19 percent.

Flexing and Abrasion Resistance in the Machine Direction

The flexing and abrasion test results showed the same type of inconsistency as experienced in the flat abrasion testing. The variables of the test procedure were controlled as much as possible; therefore, the variation in the test results must be an indication of the great variability found in the fabric itself.

The analysis of variance for the flexing and abrasion resistance measurements are presented in Table 22.

Table 22. Analysis of Variance - Flexing and Abrasion Resistance

Source of Variation	df	Mean Square	F Value	Significance Level
Replication	1	10833.875000	4.543	0.050 *
Type of Fabric (T)	1	4970.015625	2.084	0.169
Fiber Content (F)	1	227339.562500	95.334	0.000 *
Laundry Cycle (L)	3	7209.761719	3.023	0.063
T x F	1	11234.976563	4.711	0.046 *
T x L	3	1767.102783	0.741	0.544
F x L	3	4796.234375	2.011	0.156
T x F x L	3	992.744141	0.416	0.744
Error	15	2384.655518		

*.05 level of significance

As can be seen from Table 22, the significant independent variables were replication (F = 4.543) and fiber content (F = 95.334). The second order interaction of type of fabric x fiber content (F = 4.711) was also found to be significant at a .05 level of significance.

The mean cycles necessary to rupture each fabric in the flexing and abrasion experiment at the various treatment levels and the percent change of the fabrics after treatment are reported in Table 23.

Table 23. Flexing and Abrasion Resistance Means (in cycles to rupture) and Percent Change of the Fabrics.

	Laundry Cycle 0	1	5	10	Over-all Means
Fusibles					
Fabric A	92.2	106.1	116.3	110.8	106.3
Fabric B	209.1	374.1	328.9	337.5	312.4
Means	150.6	240.1	222.6	224.1	209.4
Nonfusibles					
Fabric C	115.2	111.9	112.1	126.4	118.9
Fabric D	195.6	245.6	251.0	307.8	250.0
Means	155.4	178.7	186.5	217.1	184.4
Over-all Means	153.0	209.4	204.6	220.6	
Percent Change					
Fabric A		+15.1	+26.1	+20.2	
Fabric B		+78.9	+57.3	+61.4	
Fabric C		- 2.9	- 2.7	+ 9.7	
Fabric D		+25.6	+28.3	+57.4	

- indicates a decrease in cycles required to rupture from the untreated fabric.
+ indicates an increase in cycles required to rupture from the untreated fabric.

The analysis of the difference in means between the types of fabric by the L.S.D. found no significant difference between the fusibles (209.4 cycles) and the nonfusibles (184.4 cycles).

A difference of approximately 37 cycles in the replications was found by the L.S.D. to be significant. Since the replications were run concurrently under the same conditions, this difference must reflect the variation possible with a chemically bonded fiber structure.

The differences in the means for the two fusible fabrics determined that Fabric B had a significantly greater flex abrasion resistance (312.4 cycles) than Fabric A (106.3 cycles). The L. S. D. analysis of the two nonfusible fabrics found the difference between Fabric C (118.9 cycles) and Fabric D (250.0 cycles) to be significant at a .05 protection level (Table 23).

Table 23 reflects that Fabric B had the most resistance to flexing and abrasion in the unlaundered state (209.1 cycles) which is the same relationship reported in the flat abrasion resistance results. However, in this test, Fabric B increased in abrasion resistance after repeated laundering by approximately 61 percent. Fabric A had the least resistance to flexing and abrasion of the untreated fabrics (92.2 cycles) and after ten laundry cycles (110.8 cycles).

Visual Observations

Several unexpected observations resulted from the experimental procedures. The severe pilling exhibited by the fabrics during the laundry cycles was unanticipated. Because these nonwoven fabrics are thought to be chemically bonded, the fibers may have had more mobility to form pills and this observation may be in line with the nature and method of manufacture of nonwoven fabrics.

Secondly, the polyamide particles partially came off during the laundry cycles in the wash load.

Another observation was that the fabrics were discolored at the ten laundry cycle level. Apparently the nylon fusing agent and the nylon fibers in the fabric picked up some rust from the wash wheel parts. A sample of each fabric is contained in Plate 3, (Appendix C). In combination with a light colored fabric, this discoloration could be detramental to the appearance of the garment in the interfaced areas.

SUMMARY AND CONCLUSIONS

Two fusible and two nonfusible nylon and polyester blend nonwoven interfacing fabrics available commercially were laundered one, five and ten times. The changes in fabric characteristics and physical properties were measured according to standard ASTM and AATCC test methods. The changes in the physical properties were determined by an analysis of dimensional change, thickness, over-all flexural rigidity, bursting strength, breaking load, elongation, flat abrasion resistance and flex abrasion resistance both before and after the various laundry cycles. The weight measurements were determined to be invalid because the polyamide particles broke off the fusible fabrics and because the fabrics demonstrated a great deal of pilling.

The acceptance or rejection of the research hypotheses are described in the following paragraphs.

Hypothesis One

1. There will be no significant differences between the two fusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength, (f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

There were significant differences in the dimensional change in both the machine and cross machine direction between the two fusible fabrics with

Fabric A showing the greatest change. The dimensional changes were in each case higher in the machine direction than in the cross machine direction. The dimensional change in both directions was the lowest in Fabric B.

The thickness results showed Fabric B to be significantly thicker than Fabric A as averaged over the laundry cycles. Both fabrics decreased in thickness after ten launderings. Fabric B was the thickest both before and after laundering.

Each fabric exhibited a significant reduction in over-all flexural rigidity at each level of treatment. There was a significant difference in the mean over-all flexural rigidity between Fabric A and B with Fabric B being stiffer than Fabric A both before and after ten laundry cycles. The greatest change due to laundering was seen in Fabric B.

The statistical analysis of the bursting strength measurements showed a significant difference between Fabrics A and B with Fabric A having a higher bursting strength than Fabric B. Both fabrics increased in bursting strength; however, these increases were not significant. Fabric A had the highest bursting strength both before and after treatment.

Fabric A had a significantly higher strength than Fabric B as measured by the breaking load in the machine direction. Fabric A, which initially had a higher strength, exhibited a reduction in strength after ten launderings. Fabric B increased in strength due to the treatment but was still weaker than Fabric A.

The statistical analysis showed the difference in apparent elongation between Fabrics A and B to be non-significant at a .05 level of significance. A comparison of the means ranked Fabric A highest in apparent elongation both before and after treatment. Both fabrics increased in elongation after ten launderings but this increase was not significant.

Fabric B was significantly more resistant to flat abrasion than Fabric A and initially showed a higher number of cycles. In addition, Fabric B decreased in abrasion resistance while Fabric A increased after ten laundry cycles.

The same relationship as reported in the flat abrasion results was apparent in the flexing and abrasion resistance measurements in the machine direction. Fabric B again was significantly higher in abrasion resistance than Fabric A. Both fabrics increased in abrasion resistance after ten washings with Fabric B ranking highest in each instance.

Fabric B exhibited a better over-all performance than Fabric A in all of the parameters that were tested except the strength measurements in which Fabric A performed better. There were significant differences in the physical properties between the two fusible fabrics as measured by the following parameters: dimensional change, thickness, over-all flexural rigidity, bursting strength, breaking load, flat abrasion resistance and flex abrasion resistance.

Therefore, at a .05 level of significance, the null hypothesis was rejected for the above mentioned physical properties. There was insufficient evidence to reject the hypothesis at the stated significance level for the weight and apparent elongation measurements.

Hypothesis Two

2. There will be no significant differences between the two non-fusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength,

(f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

There were significant differences between the two nonfusible fabrics with the greatest amount of dimensional change exhibited by Fabric D in the machine direction and by Fabric C in the cross-machine direction.

The statistical analysis determined that there were significant differences between the mean thickness measurements for Fabrics C and D. Fabric C was significantly thicker initially and remained the thickest after treatment. There were no significant differences between the thickness measurements for either fabric at each treatment level. Fabric C decreased in thickness after ten launderings while Fabric D increased in thickness.

Both nonfusible fabrics showed a decrease in over-all flexural rigidity at each treatment level. Fabric D measured the highest in over-all flexural rigidity before laundering; however, Fabric C was stiffest after ten launderings. The statistical analysis showed Fabric C to be significantly higher in over-all flexural rigidity than Fabric D.

The statistical analysis of the bursting strength means showed a significant difference between the two nonfusible fabrics with Fabric D ranking higher than Fabric C in bursting strength. Fabric D was stronger both before and after laundering even though Fabric D decreased in strength after treatment.

Fabric D was significantly stronger than Fabric C as measured by the breaking load in the machine direction. Fabric D was stronger both before and after laundering even though Fabric D exhibited the greatest amount of change after ten washings.

The statistical anaylsis showed no significant difference between Fabrics

C and D in apparent elongation. Fabric C increased in apparent elongation after ten launderings while Fabric D decreased slightly. Fabric C was higher than Fabric D in this test.

Of the two nonfusible fabrics, Fabric C was significantly more resistant to flat abrasion than Fabric D. The means were higher for Fabric C at every level of treatment. Fabric C increased in abrasion resistance while Fabric D decreased after ten laundry cycles.

Fabric D was significantly more resistant to flexing and abrasion than Fabric C which is opposite of the relationship shown in the flat abrasion results. A comparison of the means showed that the cycles for both fabrics increased with Fabric D increasing the most thereby resulting in greater flex abrasion resistance.

The results of the machine direction dimensional change, thickness, over-all flexural rigidity and flat abrasion resistance tests ranked Fabric C higher than Fabric D. Fabric D performed better than Fabric C in the strength and flex abrasion resistance tests. There were significant differences in the physical properties between the two nonfusible fabrics for the following parameters: dimensional change, thickness, over-all flexural rigidity, bursting strength, breaking load, flat abrasion resistance and flex abrasion resistance.

Therefore, at a .05 level of significance, the null hypothesis was rejected for these physical properties. There was insufficient evidence to reject the hypothesis at the stated significance level for the weight and apparent elongation measurements.

Hypothesis Three

3. There will be no significant differences between the two fusible

and two nonfusible nonwoven interfacing fabrics after one, five and ten launderings for the following physical properties: (a) dimensional change, (b) thickness, (c) weight, (d) over-all flexural rigidity, (e) bursting strength, (f) breaking load, (g) elongation, (h) flat abrasion resistance and (i) flex abrasion resistance.

In each case, there was a significant difference between the dimensional change in the machine and cross machine directions with the nonfusible fabrics having a greater over-all amount of dimensional change.

There was a significant difference between the thickness measurements both before and after treatment. The fusibles were thicker than the nonfusible fabrics.

The over-all flexural rigidity measurements showed a significant difference between the types of fabrics with the fusibles being stiffer than the nonfusibles.

The statistical analysis showed the nonfusibles to have a significantly higher bursting strength than the fusibles. One washing significantly increased the bursting strength of the fusibles while the differences between each treatment level for the nonfusibles was not significant.

The nonfusibles had a significantly greater strength than the fusibles as measured by the breaking load and apparent elongation experiments.

The statistical analysis showed a significant difference between the types of fabrics with the fusibles showing higher resistance to flat abrasion than the nonfusibles.

The difference between the fusible and nonfusible fabrics as measured by flexing and abrasion resistance was not significant at a .05 level of significance.

Over-all, the fusibles performed better than the nonfusibles in the dimensional change, thickness, over-all flexural rigidity and flat abrasion resistance analysis. The nonfusibles were the highest in the strength and elongation measurements. There were significant differences in the physical properties of the two types of fabrics in the following parameters: dimensional change, thickness, over-all flexural rigidity, bursting strength, breaking load, elongation, and flat abrasion resistance.

Therefore, at a .05 level of significance, the null hypothesis was rejected for the above named physical properties. There was insufficient evidence to reject the hypothesis for the weight and flex abrasion resistance measurements.

Conclusions

The experimental fabrics were commercial products manufactured by three different companies. Many of the differences between the fabrics may be attributed to the varying specifications of the manufacturers. The fabrics were chosen to be similar in weight as labeled by the manufacturer; however, the weight per unit area was different for each fabric.

Some of the results may be attributed to the uni-directional web formation of these fabrics. The flexural rigidity results in each case showed greater stiffness in the machine direction. A greater dimensional change was exhibited in the machine direction of the fabrics. The breaking load and flex abrasion resistance in the cross machine direction could not be measured because of the inherent weakness of the fabrics in that direction.

The results of this research indicated that the qualities desired of an interfacing fabric should be evaluated and the most suitable fabric chosen for that application. An important consideration is that the fusible fabrics will be permanently attached to another fabric which could minimize some of the deficiencies exhibited by the fabric in the unfused state.

Recommendations for Further Research

The recommendations for further research are as follows:

1. Analysis of fiber and fabric deterioration after repeated laundering using a scanning electron microscope.

2. Testing of the bond strength of a fusible nonwoven interfacing fabric after it has been washed at least once before fusing.

3. Analysis of the properties and changes due to laundering after the interfacing fabric has been fused to another fabric.

4. Development of standard test procedures for applying and evaluating fusible interfacings.

5. Development of standard performance requirements for stitched-in and fused nonwoven interfacings.

LITERATURE CITED

1. AAss, T., T. Clay abd Graham Morrison. "Fusibles: Section 1: Interlinings, Part 1," Bobbin, 15:168-169, 172, 176, 180, September 1973.

2. Aass, T., T. Clay and Graham Morrison. "Fusibles: Section 1: Interlinings, Part 2," Bobbin, 15:114, 116-117, October, 1973.

3. Allewelt, Arthur L. and Jackson Bauer, eds. Handbook on Bonded and Laminated Fabrics, American Association of Textile Chemists and Colorists, 1974.

4. American Association of Textile Chemists and Colorists, Technical Manual, Vol. 51, 1975.

5. American Society for Testing and Materials. 1976 Book of ASTM Standards, part 32, Philadelphia: ASTM, 1976.

6. Baxter, Fred J. "What Are Fusibles?" Apparel Manufacturer, 53:36, March, 1970.

7. Coke, C. Eugene. "Nonwoven Fabrics," Advances in Textile Processing, 1:1-37, 1961.

8. Cusick, G. E. "Materials and Methods Used in the Production and Application of Fusible Interlinings," Textile Institute and Industry, 9(3): 67-68, March, 1971.

9. Cusick, G. E. and L. J. Cook. "Factors Concerning the Use of Fusible Interlinings in Garment Construction," Proceedings of the Fourth International Wool Textile Research Conference, Part II, Applied Polymer Symposia, No. 18, New York: John Wiley & Sons, 1971.

10. Depoe, R. L. "Nonwoven Interlinings," Masculines, 18(6): 24-26, 1974.

11. El-Behery, Hassan M. Study of Mechanical and Physical Properties of Commercially Available Adhesively and Mechanically Bonded Nonwoven Fabrics, Clemson University, April, 1972.

12. Griswold, Hector W. "Selection and Use of Fusible Interlinings in Knit Garments," Knit Shrinkage: Cause, Effect and Control, AATCC Symposium #13, 1973.

13. Gross, David. "Pellon's Klothe sees fusibles gaining in domestic market," Knitting Times, 42:70-71, March 5, 1973.

14. Jones, P. E. "Fusible Interlinings," Guild of Cleaners and Launderers Journal, Winter 1970, pp. 3-10.

15. Kamat, V. "The Role of Thermoplastic Resins in Fusible Interlinings," Textile Chemist and Colorist, 5(7):125-127, July, 1973.

16. Kartun, Derek. "Interlinings," Textiles, 3(3):68-72, October, 1974.

17. "Kyron Non-Woven Interfacing," American Fabrics and Fashions, No. 104, Summer 1975, pp. 40-41.

18. "New Fusible Nonwovens Developed," Daily News Record, No. 169, August 29, 1962, p. 17.

19. Schaaf, Siegfried. "Copolymeric Nylon Powdeers for Fusing Textiles." American Dyestuff Reporter, 61(11): 31, 34, 36, 38-40, November, 1972.

20. Schofield, N. "Hot Melts and Fusibles," Flexible Textile Composites, ed. Peter Lennox-Kerr, Manchester, England: The Textile Trade Press, 1973.

21. Shiloh, Miriam. "The Wrinkling and Bending of Fusible Interlinings," Journal of the Textile Institute, 63(10): 533-543, October, 1972.

22. Smith, Delmont K. "Fusible Systems for Bonding," Textile Chemist and Colorist, 1(27):619-626, December 31, 1969.

23. Starr, A. E. "Fusibles: Their Uses, Advantages, Problems and the Future." Clothing Institute Journal, 17:205-212, May/June, 1969.

24. Stukenbrock, K. H. "Chemical Bases of Adhesives for Fusible Interlinings," Clothing Institute Journal, 19(3): 183-192.

25. Zisk, M. H. "Fusibles and Fusing," Masculines, 18(6):20-23, 1974.

APPENDIX

THIS BOOK CONTAINS NUMEROUS PAGES THAT CONTAIN SWATCHES OF FABRIC THAT ARE ILLEGIBLE DUE TO INABILITY TO SCAN THE TEXTURE OF THE FABRIC.

THIS IS AS RECEIVED FROM THE CUSTOMER.

APPENDIX A

Plate 1. Unlaundered Experimental Test Fabrics.

Fabric A **Fabric B**

Fusibles

Fabric C **Fabric D**

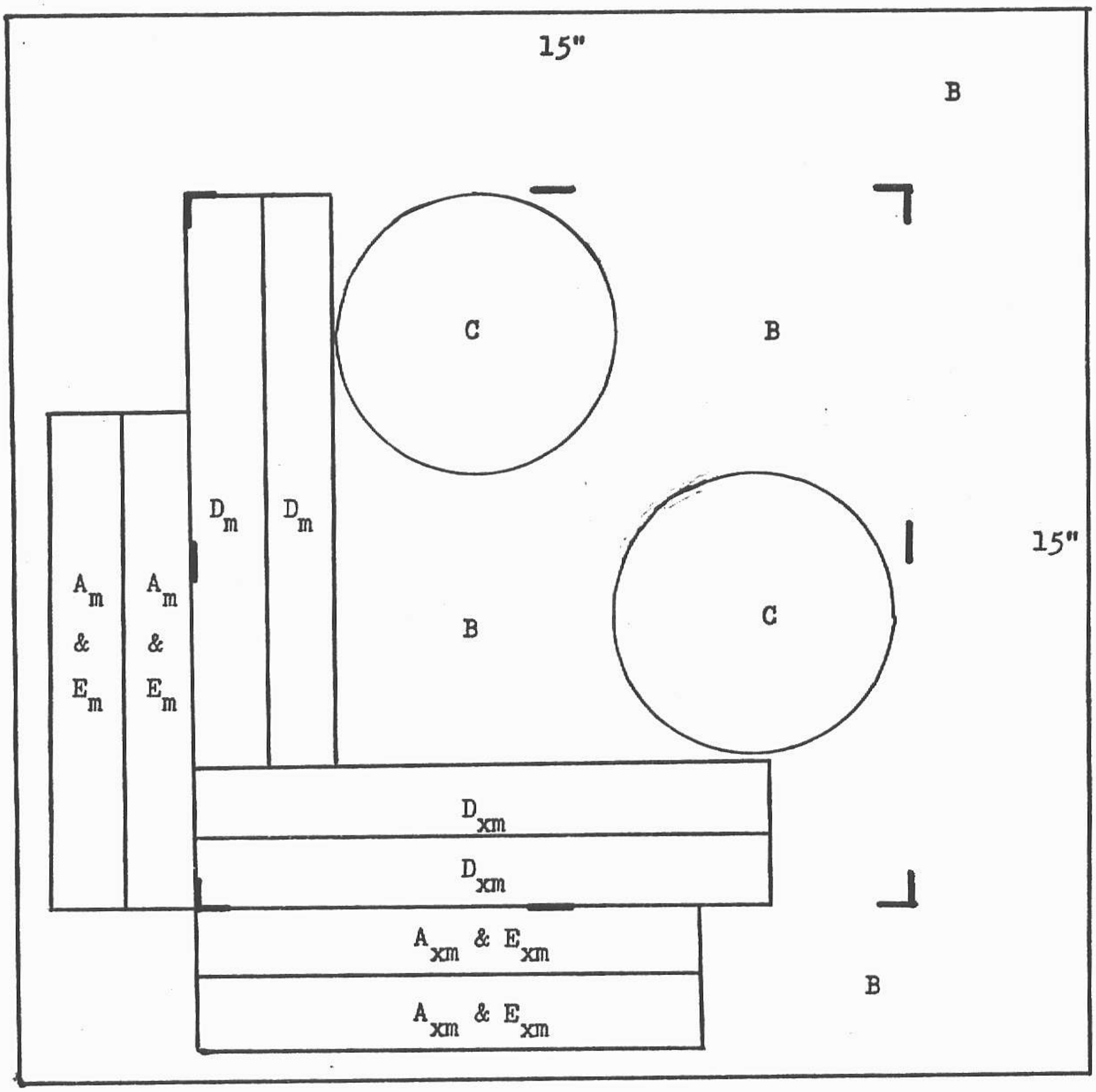
Nonfusibles

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

APPENDIX B

Plate 2. Plan For Cutting Test Specimens.

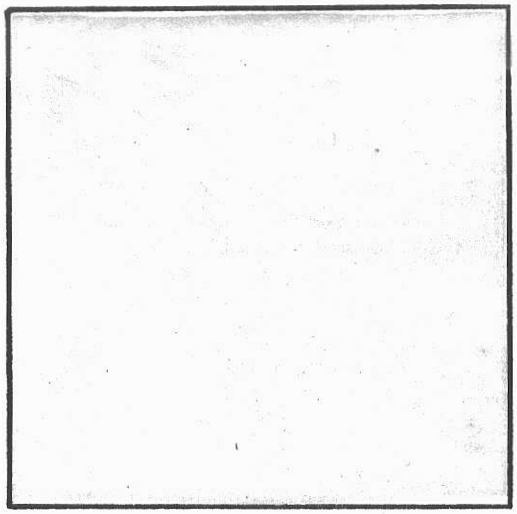


A - Breaking Load		1" x 7"
B - Bursting Strength		(Not cut from fabric)
C - Flat Abrasion Resistance		4 1/4" circle
D - Flex Abrasion Resistance		8" x 1"
E - Flexural Rigidity		1" x 7"

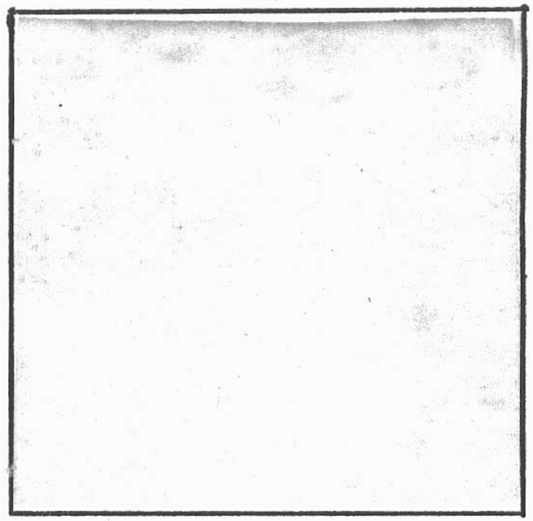
m = machine direction samples
xm = cross machine samples
▬ = indicates bench mark placement

APPENDIX C

Plate 3. Experimental Test Fabrics After Ten Launderings.

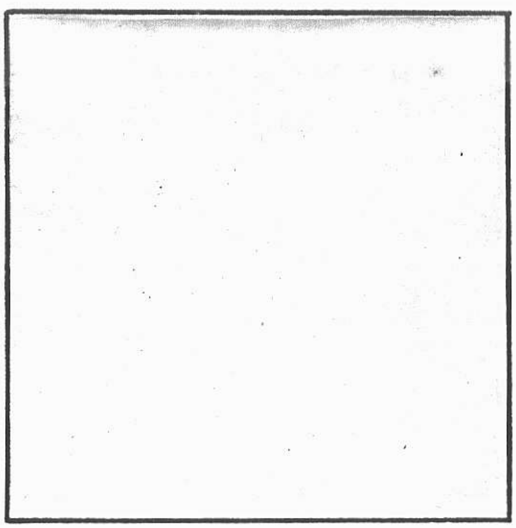


Fabric A

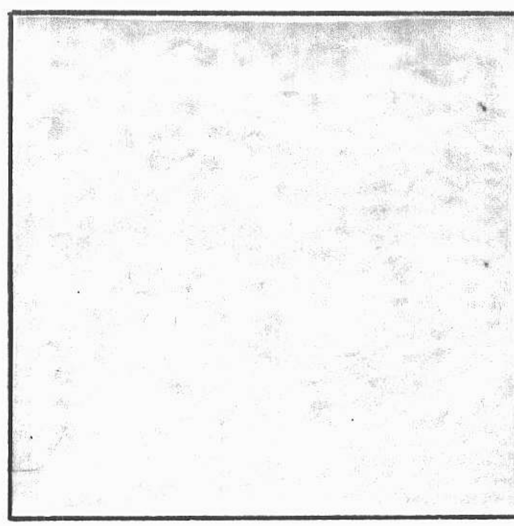


Fabric B

Fusibles



Fabric C



Fabric D

Nonfusibles

NONWOVEN INTERFACING FABRICS: A COMPARISON OF FUSIBLE AND NONFUSIBLE INTERFACING FABRICS AFTER LAUNDERING

by

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B.S., Kansas State University, 1971

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles,
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KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

Two fusible and two nonfusible nonwoven interfacing fabrics available commercially were laundered one, five and ten times. The physical properties at each laundry level were measured according to standard ASTM and AATCC test methods and compared to the physical properties of the fabric before washing. The parameters tested were dimensional change in the machine and cross machine direction, thickness, weight, over-all flexural rigidity, bursting strength, breaking load in the machine direction, elongation, flat abrasion resistance and flex abrasion resistance.

All of the fabrics appeared to be chemically bonded nonwoven fabrics constructed with a uni-directional web arrangement. Two of the fabrics were a blend of nylon and polyester and two of the fabrics were a blend of nylon, polyester and rayon. Both of the fusible fabrics contained a coating of polyamide fusing agent on the reverse side.

The results from the physical testing showed there were significant differences between the two fusible fabrics and the two nonfusible fabrics in all physical properties except apparent elongation where no significant difference could be detected. In addition, there were significant differences between the two types of fabrics in all parameters tested except in flex abrasion resistance. None of the fabrics excelled in every parameter; therefore, the qualities desired of an interfacing fabric should be evaluated and the most suitable fabric chosen for that application.