A Study of Waterproof and Water-Repellent Fabrics used in Active Outdoor Wear

An Honors Thesis (ID 499)

by

Linda Hartman

Thesis Advisor
Dr. Lois Gotwals

Lois M. Gotwals

Ball State University

Muncie, Indiana

May 1991

Expected date of graduation: December 1991

The fabrics studied were Gore-Tex and Ultrex, which are fabrics with microporous membranes, and a nylon fabric. Gore-Tex, Ultrex, and nylon are used in active outdoor wear like jogging suits, ski clothes, sleeping bags, gloves, boots, and more. Gore-Tex is also used in artificial blood vessels, artificial ligaments, astronauts' space suits, and industrial filters. Gore-Tex and Ultrex were chosen, because they are readily available to the consumer through mail order catalogs. Research was done on the development and qualities of the fabrics. This paper contains more background information on Gore-Tex than Ultrex. Gore-Tex was developed earlier, so there is more information to be found on Gore-Tex. The fabrics were also tested; the water resistance, strength, soil resistance, appearance, and seam smoothness of the fabrics were tested.

Gore-Tex Fabric

Gore-Tex is made from polytetrafluoroethylene (PTFE). PTFE was first discovered by a DuPont researcher in 1938 and is most commonly known by its tradename, Teflon. (Tanner, 65) The same material that keeps your eggs from sticking to the frying pan in the morning will also keep you dry when you are out in the rain. Joe Tanner, an associate at W. L. Gore Inc., describes Gore-Tex in the following:

> PTFE's molecular structure is that of a long carbon backbone totally protected by tightly bonded

fluorine atoms, which gives it a broad range of properties unlike any other material. PTFE is hydrophobic - that is, "water-hating" - chemically inert, flexible over a broad range of temperatures, and a good electrical insulator.

In 1969, W. L. Gore and his son, Robert, were working on expanding PTFE. Their plan was to stretch the material into a thin membrane that could be used to insulate wire (Vanderhoff 342). They took rods of the PTFE and softened them by heating them to various temperatures. Next, they carefully and slowly tried to stretch the PTFE; the material stretched only a little and then snapped. "Late one night in the fall of 1969 after repeated failures to slowly stretch the Teflon, Robert in frustration yanked at it violently. It didn't snap." (Ward 68) After stretching it, they discovered it had pores too small for water drops to pass through but large enough for water vapor to pass through (Vanderhoff 342).

Gore-Tex is waterproof and windproof because of the small size of the pores in the membrane. According to the W. L. Gore company, the Gore-Tex membrane has nine billion pores per square inch, and they are .000008 of an inch in diameter. Each pore is 20,000 times smaller than a drop of water and 700 times larger than a water vapor molecule. Also, Gore-Tex fabric will withstand at least 90 pounds of water per square inch before leaking.

Gore-Tex fabric is made by laminating the Gore-Tex membrane to a fabric. According to Gore-Tex's Retailer's Guide to Gore-Tex Fabric, Gore-Tex fabric was first introduced in 1976 and is now known as first generation Gore-Tex. This fabric could become contaminated with oil, body oils, oil vapor from frying food, and even natural oils found in some wool sweaters and stop working as it should. When contamination occurred, the fabric could be sponged with alcohol and then rinsed with water to return the fabric to its waterproof and breathable state. (Berger 108) In 1978, according to Gore-Tex's Retailer's guide to Gore-Tex Fabric, a new and improved Gore-Tex fabric was introduced. The membrane was made to be oleophobic, so oils would not enter the membrane and contaminate the fabric. This new and improved fabric is known as second generation Gore-Tex fabric.

<u>Patent information on Gore-Tex</u>

PTFE is patented by DuPont. The expanded form of PTFE is patented by W. L. Gore and Associates Inc. They began to apply for a patent in 1969, and they did not get an application accepted until 1979. The first three applications Gore submitted to the United States patent office failed. In 1984 Garlock Inc. and W. L. Gore and Associates Inc. were involved in a law suit. Gore won and was able to keep their patent. Garlock had attempted to convince the court that Sumitomo Electric Industries' 1967 Japanese patent and W. L. Gore and Associates' 1979

United States patent were not distinguishable. If this could be shown, Gore's patent would be invalid.

In May 1990 Gore and Impra, a medical prosthetics company in Tennessee, were involved in a law suit. In their defense, Impra commissioned a team of materials scientists to produce material following the Japanese patent exactly. The result was a plastic indistinguishable from Gore-Tex when comparing them using the specifications in W. L. Gore's patent. The United States Federal Court in Phoenix ruled that Gore's patent "failed to define a unique material," so their claim of infringement on their patent by Impra was rejected. Gore claims that the Japanese patent is vague, and they are planning to appeal the decision. (Concar 126)

Other Breathable Membrane Fabrics

Ultrex is made by Burlington Mills. It is made of a nylon fabric with a microporous coating and a durable water-repellent finish. According to Burlington, a coating is better than a laminate, since a coating goes into the surface of a fabric and a laminate is only adhered to the surface of a fabric. This can be observed by looking at the fabric through an electron microscope. The face fabric of Ultrex is made of either Supplex or Tactel which are nylon fabrics made by Burlington Mills. According to Burlington, Ultrex will withstand a force of 25 to 40 pounds of water per a square inch before leaking.

Bion II is a continuous polyurethane film through which perspiration diffuses to evaporate on the outside surface, and the film is laminated directly to the cloth (Trachtenberg 174). Bion II is made by Biotex Industries which is a subsidiary of Thoratec, a biomedical products firm. They developed a waterproof and breathable wound dressing in 1983, and later adapted the process for use in fabrics for outdoor wear. (Lunzer 126)

Bukflex II, Helly-Tech, Sympatex, and Dermoflex are also fabrics with microporous membranes. Bukflex II is made by coating Dacron with microporous polyurethane (Berger 109). Helly-Tech, made by the Helly-Hansen company, also has a polyurethane coating. The coating is made by the parent company in Norway, and it is applied to fabric in the United States. Sympatex has a membrane made of polyester and is made by the Enka company in the Netherlands and laminated at Shawmut Mills in Massachusetts. Dermoflex also has a microporous membrane and is made by Consoltex in Canada. (Trachtenberg 174)

Sewing Information

Pattern pieces should not be pinned to fabrics with microporous membranes; weights should be used. Pinning the fabric will create holes large enough for water drops to pass through, so the fabric would no longer be waterproof. According to Burlington's Technical Bulletin on Ultrex, a ball point needle should be used to sew the fabric. When the seams of the garment or article are sewn, the needle will, of course, create holes in the fabric large enough for water drops to pass through. Since it is difficult to avoid using a needle when sewing a garment, the seams will need to be sealed. Seam sealer can be purchased and applied to the seams. The sealer usually comes in a tube and has a glue-like consistency. A thin even coating should be applied to the seam on the inside of the garment. If a garment or article is purchased ready made, the seams may already be sealed with seam tape. The Gore-Tex seam tape consists of a layer of hot melt adhesive, Gore-Tex membrane, and a fabric like tricot knit. The tape is then sealed to the seam using a sealing machine. According to Gore-Tex's Retailer's Guide to Gore-Tex, ready made Gore-Tex garments that have this seam tape carry a gold Gore-Tex hangtag. Gore also recommends a fabric that wicks moisture or nylon mesh should be used to line garments. It does not make sense to have a water absorbing fabric inside rainwear, because it will retain body moisture close to the skin.

<u>Care Information</u>

Burlington recommends that Ultrex be machine washed on the wash and wear cycle with warm water and low phosphate detergent and rinsed twice with cold water. It should be tumble dried on the permanent press setting, and the fabric can be steam ironed with a medium setting on the face side only. The fabric should not be dry cleaned or commercially laundered. Bleach should not be used, fabric softeners should be avoided, and the garment should not be stored until completely dry. Gore recommends that the Gore-Tex fabric be washed with powdered detergent in cold water and that it be tumble dried at a low setting or dripped dry.

The purpose of the testing was to compare the qualities and performances of some of the waterproof and water repellent fabrics available today. I compared the water resistance, strength, soil resistance, general appearance, and the smoothness of the seams of the fabrics. The fabrics tested were Gore-Tex, Ultrex and nylon. The test procedures followed as close as possible to the procedures described in the 1990 edition of the Technical Manual of the American Association of Textile Chemists and Colorists.

Water Repellency

The water repellency of the fabrics of the fabrics were tested using AATCC Test Method 22, Water Repellency: Spray Test.

Test Specimens

Three specimens (7 X 7 inches) were cut from each of the three fabrics.

Procedure

The set up for the spray testing is shown in figure 1. The fabric specimen was placed in a six inch embroidery hoop and placed at a 45 degree angle to the spray nozzle. The center of the specimen is six inches below the spray nozzle. Distilled water (250 mL.) was sprayed onto the fabric. The test method instructed that the water be 80F. The temperature of the water was not checked; it was at room temperature. After the spraying, the specimens were rated by comparing them to the AATCC Standard Spray Test Ratings Chart shown in figure 2.

Results

Each of the fabrics had a rating of 90, slight random sticking or wetting of upper surface. However, the water drops did not stick to the Gore-Tex fabric as much as they did to the Ultrex and nylon fabric.

Fabric Strength

The strengths of the fabrics were tested using a Scott Tester.

Test Specimens

The specimens were 6 by 1.5 inches, and a quarter of an inch of the yarns were raveled off along the six inch sides of the specimen. Ten of the specimens were cut with the lengthwise yarns in the long direction and ten were cut with the crosswise yarns in the long direction.

Procedure

The fabric specimen was placed in the clamps of the Scott Tester. The force was applied to the fabric when the pendulum is pulled away from its original vertical downward position. A scale at the top of the Scott Tester gives the amount of force in pounds it took to break the fabric sample. Both wet and dry strengths of the fabrics were tested. The Scott Tester is shown in figure 3.

Results

	dry	wet
nylon crosswise	65 lbs.	52.2 lbs.
nylon lengthwise	62 lbs.	59.8 lbs.
Gore-Tex crosswise	61.2 lbs.	62 lbs.
Gore-Tex lengthwise	87.8 lbs.	96.8 lbs.
Ultrex crosswise	70.8 lbs.	66 lbs.
Ultrex lengthwise	77 lbs.	68 lbs.

All the fabrics had good strength. Gore-Tex in the lengthwise direction was the strongest. It was able to withstand 87.8 pounds of force when dry and 96.8 pounds of force when wet. Ultrex in the lengthwise direction withstood 77 pounds of force when dry and 68 pounds of force when wet. Gore-Tex is also stronger wet than dry, and the Ultrex and nylon fabrics were not stronger wet than dry. It is advantageous for the fabric to be stronger wet, since it would most likely be used in wet conditions. Ultrex was stronger than the Gore-Tex in the crosswise direction. Ultrex in the crosswise direction withstood 70.8 pounds when dry and 66 pounds of force when wet. Gore-Tex withstood 61.2 pounds when dry and 62 pounds when wet. The Ultrex and Gore-Tex differed more in its lengthwise strength than in its crosswise strength. Gore-Tex varied the most in its strength; the lengthwise grain of Gore-Tex was over 20 pounds stronger than its crosswise grain. The greatest stress in an item made of Gore-Tex should be put on the lengthwise grain. The nylon was less strong than both Gore-Tex and Ultrex except in the crosswise direction when dry. The nylon withstood 65 pounds of force, and the Gore-Tex withstood 61.2 pounds of force.

Soil Release

The fabrics were tested for their ability to release oily stains during home laundering. The AATCC Test Method 130-1981, Soil Release: Oily Stain Release Method, was used.

Test Specimens

Three test specimens (15 X 15 in.) were cut from each fabric. The test method instructed that the specimens be conditioned for a minimum of four hours at 21 $\pm$ 1C(70 $\pm$ 2F) and 65 $\pm$ 2% RH, the standard temperature and humidity level, prior to application of stains. Due to available facilities, the specimens were not conditioned.

Procedure

The specimens were stained with mineral oil. Five drops, using a medicine dropper, of the oil were placed on each specimen. A five pound weight was left on the stain for one minute. The specimens were washed with AATCC Standard Detergent 124 in 105F water, and they were left in the dryer until dry. A Maytag washer and dryer were used. Then the residual stains were rated by a panel of three people. The stains were compared to the stains in the stain release photographic replicas.

Results

The stains' ratings are on a scale of one to five (one being the worst stain release and 5 being the best stain release). The ratings for the nylon, Gore-Tex and Ultrex were 1.9, 3.8 and 3.9 respectively. All of the fabrics had an extremely poor soil release rating. The nylon had the best soil release rating. The nylon's better rating may have been due to its darker color. The nylon fabric was royal blue and the Ultrex and Gore-Tex were turquoise. The darker color may have hid some of the soil.

Fabric Appearance

The general appearance of the fabrics after repeated home laundering was evaluated using AATCC Test Method 124-1989, Appearance of Fabrics after Repeated Home Laundering.

Test Specimens

Three specimens (15 X 15 inches) were cut from each of the fabrics.

Procedure

The fabrics were washed on the wash and wear cycle with warm water, AATCC Standard Detergent 124, and a cold rinse; they were dried on the damp dry cycle. A Maytag washer and dryer were used. The fabrics were wash and dried a total of five times. Next, the appearance of the fabrics were evaluated by a panel of three observers. The appearance of the fabrics were compared to the appearance of the 3-D Smoothness Appearance replicas. The specimens were not conditioned at the standard temperature and humidity level prior to evaluation as the test method instructed.

Results

The appearance of the fabrics were rated on a scale of 1-5 (1 being the worst appearance and 5 being the best appearance). The nylon had a rating of 1.9, The Gore-Tex had a rating of 3.8, and the Ultrex had a rating of 3.9. The Gore-Tex and Ultrex fabrics both had a fairly good appearance after repeated laundering. Ultrex had the best rating but only by one tenth of a rating unit. The nylon had a rather poor appearance rating. The face fabric of the Ultrex is made of texturized nylon yarns, and the face fabric of the Gore-Tex appears to be made of texturized nylon yarns. The yarns in the nylon fabric are not texturized. The more texturized surfaces of the Ultrex and Gore-Tex could mask some of the wrinkles in the general appearance of the fabrics.

Seam Smoothness

The smoothness appearance of seams in the fabrics after repeated home laundering were evaluated using AATCC Test

Method 88B-1989, Smoothness of Seams in Fabrics after Repeated Home Laundering.

Test Specimens

The seamed specimens were 15 X 4 inches with the seam running parallel to the 15 inch sides. A Singer brand size 14 ball point needle and Molnlycke polyester thread were used to sew the seams. Single needle and double needle seams running in the crosswise and lengthwise direction were evaluated. Three specimens of each type were evaluated.

Procedure

The specimens were washed in a Maytag washer using the wash and wear cycle, warm water, AATCC Standard Detergent 124 and cold water rinse; they were dried using the damp dry cycle on the Maytag dryer. The washing and drying procedures were completed a total of five times. The test specimens were not conditioned at the standard temperature and relative humidity after washing and drying as the test method instructed. The smoothness of the seams were then evaluated by a panel of three observers. They compared the seams to the standard seam smoothness photographic replicas. The center of the board that the specimens and replicas were mounted on was approximately 5 feet above the floor, and the observers stood about four feet from the board.

Results

The seams were rated on a scale of one to five (one being the least smooth and 5 being the smoothest seam appearance).

	single needle seams	double needle seams
nylon crosswise	2	1.3
nylon lengthwise	2	1.4
Gore-Tex crosswise	3.9	4
Gore-Tex lengthwise	3.2	2.2
Ultrex crosswise	3.3	3.6
Ultrex lengthwise	2.7	3

The Gore-Tex had the smoothest seams except for the flat felled seams in the lengthwise direction. The Ultrex and Gore-Tex had fairly close ratings, and they both had smoother seams in the crosswise direction than in the lengthwise. The nylon had the poorest ratings. As in the appearance of the fabric, the poorer appearance of the seams in the nylon fabric may be due to its untexturized yarns.

Summary

The Gore-Tex and Ultrex were fairly equal in their performance of the qualities that were tested. The nylon had a lesser performance in the qualities that were tested. Some important qualities, though, like windproofness and durability were not tested. One way all three fabrics differed greatly was in price; Gore-Tex was the most expensive, and the nylon was the least expensive.

All the fabrics were fairly equal in their water repellency. The fabrics had equal water repellency ratings, but Gore-Tex had slightly better water repellency. The difference was not significant enough for a better rating though.

All the fabrics had good strength. Gore-Tex in the lengthwise direction was the strongest. Gore-Tex was the only one of the three fabric that was stronger wet than dry. The nylon was the weakest of the three fabrics.

All three of the fabrics showed stains. The nylon fabric showed the stain the least of the three fabrics, but all three had very poor soil release. The Ultrex and Gore-Tex had a stain release rating of 1, the worst possible stain release rating, and the nylon had a better rating of 1.8.

In the appearance of the fabric Gore-Tex and Ultrex both had a fairly good appearance, and the appearance of the nylon was poor. Ultrex had the best appearance rating of 3.9, and the Gore-Tex had a slightly lesser appearance rating of 3.8. The nylon had a rather poor appearance rating of 1.9.

In the seam smoothness test, Gore-Tex had the smoothest seams except the double needle seams in the lengthwise direction where Ultrex had the smoothest seams. Overall, Ultrex had the second smoothest seams; its seam smoothness ratings ranged between four tenths and eight tenths a rating unit below the Gore-Tex. The nylon fabric had the least smooth seams. Its seam smoothness ratings ranged from seven tenths to two and three tenths below the ratings of the Ultrex fabric.

Gore-Tex was stronger than the Ultrex in the lengthwise direction. Gore-Tex also had a better appearance, smoother seams, and better water repellency than the Ultrex, but these differences were small between the two fabrics. Gore-Tex and Ultrex were equal in their ability to release soil. The nylon was the weakest, had the worst appearance, and had the least smooth seams of the three fabrics. It had water repellency equal to the Ultrex, and it had a better soil release rating than both the Gore-Tex and Ultrex. Ultrex is probably a better buy than the Gore-Tex, since it costs less and is nearly equal in quality to the Gore-Tex. Gore-Tex costs $14.73 per square yard, and Ultrex costs $8.40 per square yard which is about 40 percent less than the Gore-Tex. The nylon costs $3.43 per square yard which is about 40 percent less than the Ultrex fabric and 77 percent less than the Gore-Tex fabric. The nylon fabric is lesser in quality and price.

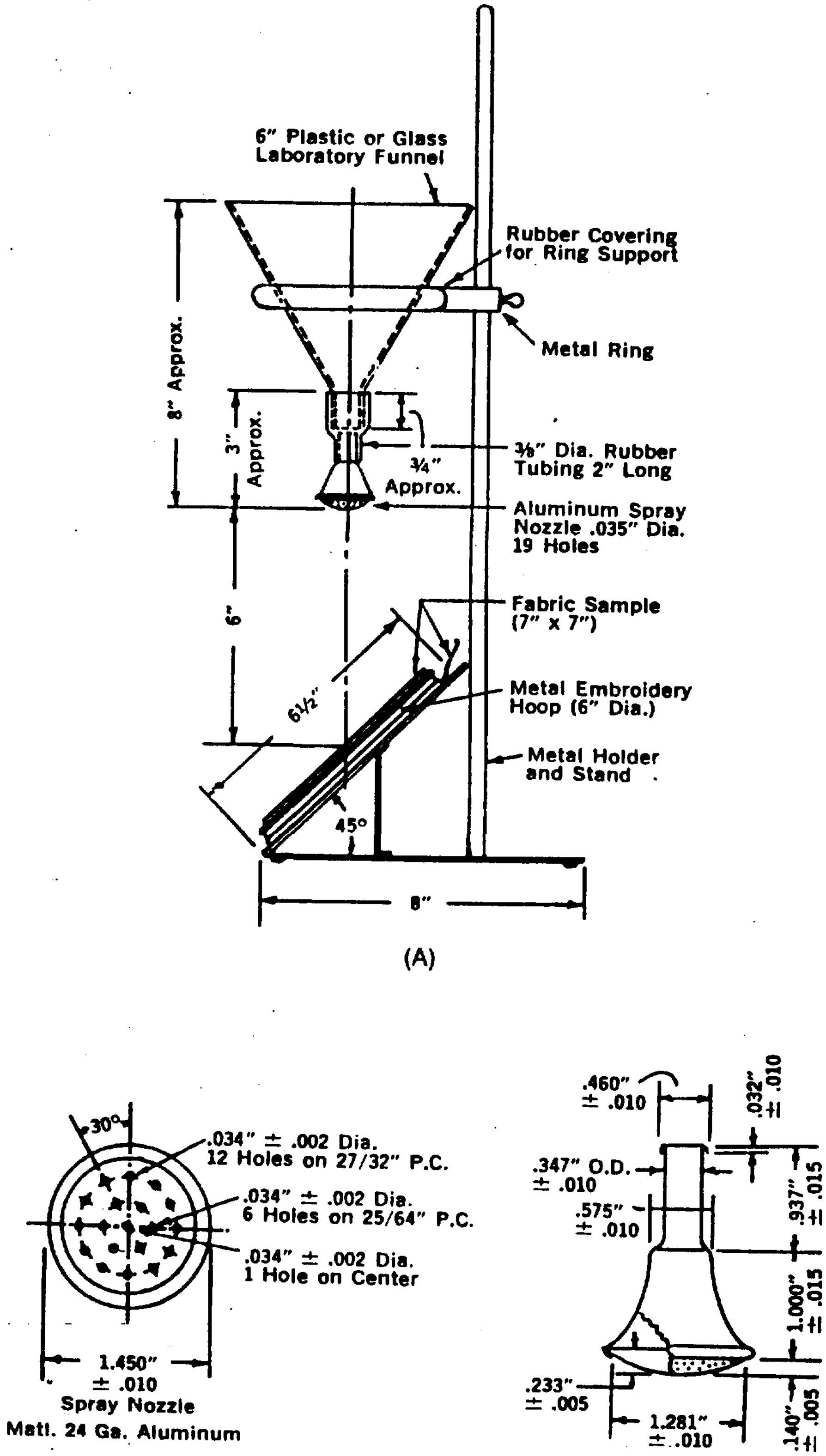
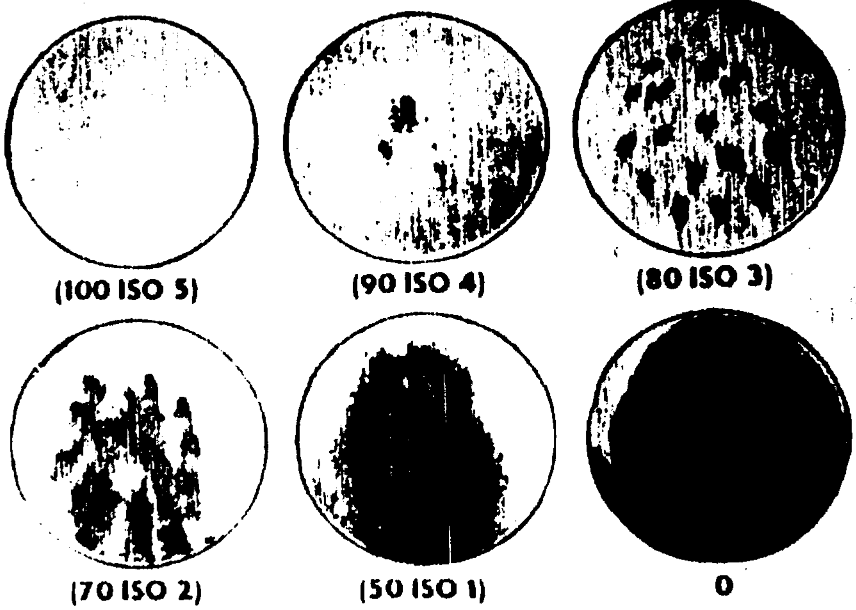


Figure 1
Source: (Merkel 316)

AATCC
STANDARD SPRAY TEST
RATINGS



100 - NO STICKING OR WETTING OF UPPER SURFACE.

90 - SLIGHT RANDOM STICKING OR WETTING OF UPPER SURFACE

80 - WETTING OF UPPER SURFACE AT SPRAY POINTS.

70 - PARTIAL WETTING OF WHOLE OF UPPER SURFACE.

50 - COMPLETE WETTING OF WHOLE OF UPPER SURFACE.

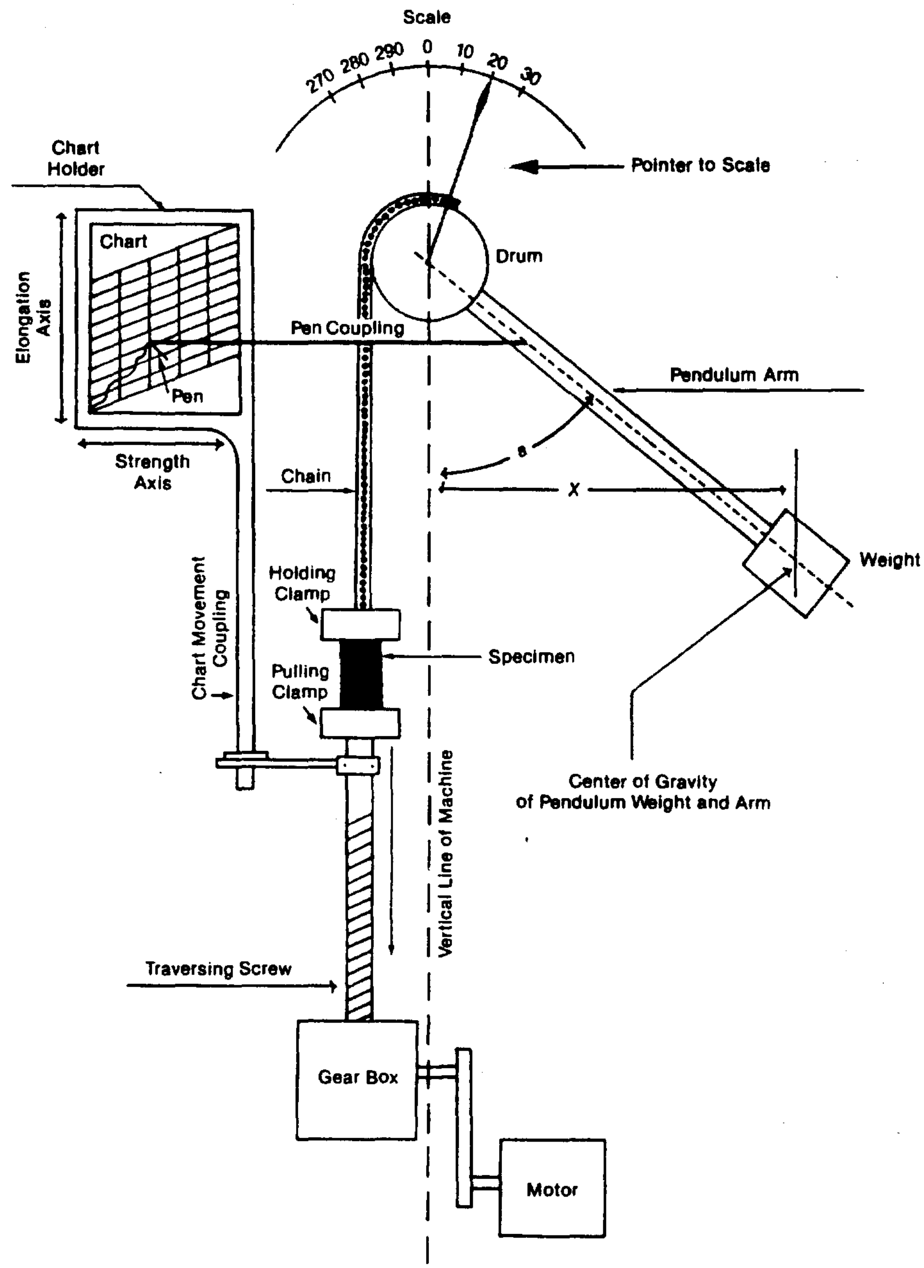
0 - COMPLETE WETTING OF WHOLE UPPER AND LOWER SURFACES.

COLORED WATER USED FOR PHOTOGRAPHIC EFFECT.

AATCC. RESEARCH TRIANGLE PARK, N. C.

Source: (Merkel 317)

Figure 2



Source: (Merkel 170)

Figure 3

Summary of Test Results

Water repellency test
All three fabrics received the same rating of 90
slight random sticking or wetting of upper surface

Strength test (Scott Tester)

Nylon crosswise dry	65 lbs.	Nylon crosswise wet	52.2 lbs.
Nylon lengthwise dry	62 lbs.	Nylon lengthwise wet	59.8 lbs.
Gore-Tex crosswise dry	61.2 lbs.	Gore-Tex crosswise wet	62 lbs.
Gore-Tex lengthwise dry	87.8 lbs.	Gore-Tex lengthwise wet	96.8 lbs.
Ultrex crosswise dry	70.8 lbs.	Ultrex crosswise wet	66 lbs.
Ultrex lengthwise dry	77 lbs.	Ultrex lengthwise wet	68 lbs.

Soil release: Oily Stain Release Method
scale of 1-5 (1=worst, 5=best)

Nylon	1.8
Gore-Tex	1
Ultrex	1

Appearance of Fabrics after Repeated Home Laundering
scale of 1-5 (1=worst, 5=best)

Nylon	1.9
Gore-Tex	3.8
Ultrex	3.9

Smoothness of Seams in fabrics after Repeated Home Laundering
scale of 1-5 (1=worst, 5=best)

Single needle seams		Double needle seams	
Nylon crosswise	2	Nylon crosswise	1.3
Nylon lengthwise	2	Nylon lengthwise	1.4
Gore-Tex crosswise	3.9	Gore-Tex crosswise	4
Gore-Tex lengthwise	3.2	Gore-Tex lengthwise	2.2
Ultrex crosswise	3.3	Ultrex crosswise	3.6
Ultrex lengthwise	2.7	Ultrex lengthwise	3

Price

Nylon	$ 3.43 per square yard
Gore-Tex	$14.73 per square yard
Ultrex	$ 8.40 per square yard

Works Cited

Berger, Bob. "New Rainwear that's Full of Holes." _Mechanix Illustrated_ Dec. 1978: 108-109.

Concar, David. "Gore Weathers Storm." _Nature_ 345 (1990): 282.

Lunzer, Francesca. "Dry and cool." _Forbes_ 27 Aug. 1984: 126.

Merkel, Robert S. _Textile Product Seviceability_ New York: MacMillin Publishing Company, 1991.

Technical Manual of the American Association of Textile Chemists and Colorists. vol. 65. Research Triangle Park, NC: American Association of Textile Chemists and Colorists, 1990.

Trachtenberg, Jeffrey. "Give Them Stormy Weather." _Forbes_ 24 Mar. 1986: 174.

Vanderhoff, Margil. _Clothing: Concepts and Construction_. Englewood Cliffs, NJ: Prentice, 1988.

Ward, Alex. "An All-Weather Idea." _New York Times Magazine_ 10 Nov. 1985: 68+.