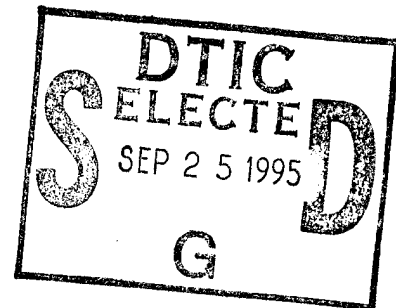


# Improved Marine Corps Lightweight Rainsuit



Navy Clothing and Textile Research Facility  
Natick, Massachusetts

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Technical Report No.  
NCTRF #209

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# REPORT DOCUMENTATION PAGE

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## MATERIALS EVALUATION REPORT

Project Title:: Improved Marine Corps Lightweight Rainsuit

Technical Objective: To provide baseline water resistance - hydrostatic pressure and moisture vapor transmission rate data on USMC proposed commercial and experimental rainsuits, before and after shipboard laundering. In addition, two experimental prototypes were to be tested following a four month user evaluation. Data obtained from this effort was intended to provide the Marine Corps with potential product variation information for comparison with data obtained from a similar evaluation being conducted concurrently by the U. S. Army Natick Research, Development, and Engineering Center (NRDEC). (It should be noted that the experimental rainsuits were never intended for laundering, while the commercial rainsuits are marketed as being launderable.)

### Test Garment Descriptions:

1) Experimental Prototype (new): Manufactured by Barrier Wear Inc. (DAAK60-92-C-0071); constructed with a waterproof/moisture vapor permeable, 2.8 ounces per square yard plain weave, 100% nylon woodland camouflage printed cloth. The back of the cloth (unprinted side) was coated with a breathable polyurethane and the face of the cloth (printed side) was treated with a Quarpel water repellent. Four sets of sample garments, consisting of trousers and parkas, were provided by NRDEC.

2) Experimental Prototype (worn): The same rainsuit described above following a four month user evaluation in Okinawa, Japan. The user evaluation was conducted by the USMC. The treatment of the garments throughout this evaluation, with respect to care and use, was not provided to this Facility. Two sets of sample garments, consisting of trousers and parkas, were provided by USMC Quantico.

3) Commercial Rainsuit (new): "Dritex Rainwear" manufactured by Reliable Outfitters; constructed with polyurethane coated, 220 grams per square meter, warp knitted 100% nylon. The coated fabric contains a mildew resistant treatment. Two sets of sample garments, consisting of trousers and parkas, were provided by USMC Quantico.

Test Methods:

All three test garment types were measured for (I) water resistance - hydrostatic pressure; and (II) moisture vapor transmission rate (MVTR), in accordance with the following plan, as approved by the USMC:

- I. Water Resistance - Hydrostatic Pressure, TM 5516, FED-STD-191A
  - a. Experimental Prototype (new)
    1. Initial
    2. After 5 shipboard laundering cycles, Formula III
    3. After 10 shipboard laundering cycles, Formula III
  - b. Experimental Prototype (worn)
    1. After 4 month user evaluation
  - c. Commercial rainsuit (new)
    1. Initial
    2. After 5 shipboard laundering cycles, Formula III
    3. After 10 shipboard laundering cycles, Formula III
  
- II. Moisture Vapor Transmission Rate, ASTM E96-93: Procedure B and BW
  - a. Experimental Prototype (new)
    1. Initial
    2. After 5 shipboard laundering cycles, Formula III
    3. After 10 shipboard laundering cycles, Formula III
  - b. Experimental Prototype (worn)
    1. After 4 month user evaluation
  - c. Commercial rainsuit (new)
    1. Initial
    2. After 5 shipboard laundering cycles, Formula III
    3. After 10 shipboard laundering cycles, Formula III

The water resistance - hydrostatic pressure test was conducted in accordance with Test Method 5516 of FED-STD-191A. This test determines the water permeability of cloth under low hydrostatic pressure. In conducting the test, each parka, with the exception of the Commercial rainsuit, was tested in 5 sample areas: one unseamed fabric area, and four seamed areas as identified in Table I. The Commercial Rainsuit was not tested at the Corner Left Sleeve Pocket because this garment did not have a pocket in this location. These areas are the same areas which were being tested by NRDEC on other garments. NOTE: NRDEC used Test Method 5512 of FED-STD-191A, Water Resistance of Coated Cloth; High Range, Hydrostatic Pressure which determines the resistance of coated cloth to the passage of water under high pressure.

After test samples were subjected to a three minute, 50 cm hydrostatic head pressure exposure, samples were observed for water droplet break through. Three drops constituted a failure. Results are reported as Pass/Fail.

The worn experimental prototype parkas were only tested once, following the four month wear test period, and were not subjected to any controlled laundering cycles. Samples of new parkas, four experimental prototypes and two commercial items, were tested three times: initially, after 5 shipboard launderings, and again after 10 shipboard launderings.

Laundering was performed in accordance with Formula III, NAVEDTRA 10176/Jul 90 (see Appendix A). Following laundering, samples were tumble dried in a commercial stack drier at 140-170°F for 30-45 minutes. Formula III was selected because (a) the USMC had requested that a Navy shipboard procedure be used, (b) it was the lowest temperature shipboard procedure and (c) it closely simulated field laundry Formula VIII of FM 10-280. The major differences between Navy Formula III and Army Formula VIII are the capacity levels, extraction speeds, and chemicals.

The moisture vapor transmission rate test was conducted in accordance with ASTM E96-93, using both Procedure B and Procedure BW, by the Defense Personnel Support Center (DPSC) Analytical Testing Laboratory. This test determines vapor permeability of cloth as it relates to the ability of the fabric to allow moisture from sweat to dissipate through the fabric. Both Procedure B and BW are water methods which determine the rate of vapor movement through the test specimen from the water to the controlled atmosphere. Results are presented as the amount of water passing thru the fabric over a 24 hour period. Procedure B uses a dish of distilled water, filled to a level  $3/4 \pm 1/4$  inch from the test specimen, and simulates the air gap created by wearing loosely fitted clothing. For Procedure BW, the water dish is inverted, bringing the water in direct contact with the test specimen, and simulating direct contact between clothing and body sweat.

Fabric swatch samples for this test were obtained from the knee and seat areas of the test trousers. On advice from NRDEC personnel, the black areas of the colored camouflage were not sampled because of a different dye type which generated variability in test data. The same swatches were used for the Procedure B and BW tests. Results for both procedures are reported as the average of three test samples.

### Results/Discussion:

Results of the Water resistance - Hydrostatic pressure and Moisture Vapor Transmission Rate (MVTR) tests are reported in Tables I and II, respectively.

TABLE I. WATER RESISTANCE - HYDROSTATIC PRESSURE  
TM 5516, FED-STD-191A

	<u>Before Laundering</u>	<u>After 5 Shipboard Laundering Cycles</u>	<u>After 10 Shipboard Laundering Cycles</u>
<u>a. Experimental Prototype (new)</u>			
<u>Parka #1</u>			
<b>Fabric</b>	Pass	Pass	Fail
Hood Seam	Pass	Pass	Pass
Hood/Neck Seam	Pass	Pass	Pass
Corner Left Sleeve Pkt	Pass	Pass	Pass
Torso Seam	Pass	Pass	Pass
<u>Parka #2</u>			
<b>Fabric</b>	Pass	Pass	Fail
Hood Seam	Pass	Fail	Fail
Hood/Neck Seam	Pass	Pass	Pass
Corner Left Sleeve Pkt	Pass	Pass	Pass
Torso Seam	Pass	Pass	Fail
<u>Parka #3</u>			
<b>Fabric</b>	Pass	Pass	Fail
Hood Seam	Pass	Pass	Fail
Hood/Neck Seam	Pass	Pass	Fail
Corner Left Sleeve Pkt	Pass	Pass	Fail
Torso Seam	Pass	Fail	Fail
<u>Parka #4</u>			
<b>Fabric</b>	Pass	Pass	Fail
Hood Seam	Pass	Fail	Fail
Hood/Neck Seam	Pass	Fail	Fail
Corner Left Sleeve Pkt	Pass	Pass	Fail
Torso Seam	Pass	Pass	Fail

b. Experimental Prototype (worn)

After 4 month user evaluation

<u>Parka #1</u>	
<b>Fabric</b>	Pass
Hood Seam	Pass
Hood/Neck Seam	Pass
Corner Left Sleeve Pkt	Fail
Torso Seam	Fail
<u>Parka #2</u>	
<b>Fabric</b>	Pass
Hood Seam	Pass
Hood/Neck Seam	Pass
Corner Left Sleeve Pkt	Fail
Torso Seam	Fail

TABLE I. WATER RESISTANCE - HYDROSTATIC PRESSURE (cont'd)  
 TM 5516, FED-STD-191A

	<u>Before Laundering</u>	<u>After 5 Shipboard Laundering Cycles</u>	<u>After 10 Shipboard Laundering Cycles</u>
<u>c. Commercial Rainsuit (new)</u>			
<u>Parka #1</u>			
<b>Fabric</b>	Pass	Pass	Pass
Hood Seam	Pass	Pass	Pass
Hood/Neck Seam	Pass	Fail	Pass
Corner Left Sleeve Pkt	N/A*	N/A	N/A
Torso Seam	Pass	Pass	Pass
<u>Parka #2</u>			
<b>Fabric</b>	Pass	Pass	Pass
Hood Seam	Pass	Pass	Pass
Hood/Neck Seam	Pass	Fail	Pass
Corner Left Sleeve Pkt	N/A	N/A	N/A
Torso Seam	Pass	Pass	Pass

\* N/A - Commercial suit had no left sleeve pocket.

Table II - Moisture Vapor Transmission Rate (g/m<sup>2</sup>/24 hours)  
ASTM E-96

	Experimental Prototype (new)				Experimental Prototype (worm)	
	Procedure B		Procedure BW		Procedure B	Procedure BW
	Before Laundering	After 5 Launderings	After 10 Launderings	Before Laundering	After 5 Launderings	After 10 Launderings
Sample #1	512.00	500.90	523.00	5649.40	5432.90	6068.20
Sample #2	523.20	526.80	514.80	5216.10	5718.40	5945.10
Sample #3	463.10	516.70	521.80	5488.20	5641.40	5728.70
Average	499.43	514.80	519.87	5451.23	5597.57	5914.00
Std Dev	31.96	13.05	4.43	219.00	147.71	171.87
						After 4 month user evaluation
						492.20
						5056.40
						492.60
						5680.60
						482.70
						5037.40
						489.17
						5258.13
						5.60
						365.99

	Commercial Rainsuit (new)		
	Procedure B		Procedure BW
	Before Laundering	After 5 Launderings	After 10 Launderings
Sample #1	120.60	137.40	131.70
Sample #2	124.50	141.50	148.60
Sample #3	124.50	141.80	122.60
Average	123.20	140.23	134.30
Std Dev	2.25	2.46	13.19
			Before Laundering
			121.90
			134.10
			131.10
			129.03
			6.36
			After 5 Laundering
			131.90
			178.70
			161.20
			157.27
			23.65
			After 10 Laundering
			296.90
			216.10
			118.10
			210.37
			89.54

Water Resistance - Hydrostatic Pressure:

a. Experimental prototype (new): There were no failures on new garments before laundering. Failures began to occur after the parkas were subjected to five shipboard launderings. These failures occurred in three parkas, located in sporadic seamed areas. After 10 shipboard cycles, all four parkas exhibited failures in the unseamed fabric areas, as well as in the majority of the seamed areas.

b. Experimental prototype (worn): Although the unseamed fabric areas displayed no failures, failures occurred in 50% of the seamed areas.

c. Commercial rainsuit (new): With the exception of the failures exhibited at the hood/neck seam area after five shipboard launderings, the commercial garments displayed no failures. No explanation can be offered as to why hood/neck seam failures were not evident after 10 launderings.

Moisture Vapor Transmission Rates (MVTR):

MVTR was evaluated against a USMC requirement of 400 and 5000 for Procedures B and BW, respectively. (See Appendix B for further material requirements).

a. Experimental prototype (new): All samples exceeded the requirements for both procedures (B and BW), before and after laundering.

b. Experimental prototype (worn): All samples exceeded the requirements for both procedures (B and BW), before and after laundering.

c. Commercial rainsuit (new): All samples failed to meet the requirements for both procedures (B and BW), before and after laundering. These samples fall within the category of "impermeable."

Conclusions:

Experimental Prototypes, when new, passed water resistance - hydrostatic pressure tests. However, multiple launderings, or wear in the field, had an adverse effect on the garments. Multiple launderings caused failure of both fabric and seams. Wear in the field resulted in some seam failures. With respect to moisture vapor transmission, these garments passed minimum requirements when new, after multiple launderings, and after wear in the field.

Based on the limited amount of data collected, the Commercial Rainsuit, appears to possess durable water resistance after multiple launderings; the only exception to this was the failure in the hood/neck seam area evident after 5 launderings but not after 10. However, these garments exhibited essentially no vapor permeability.

Recommendations:

Based on our testing, it is recommended that laundering of the experimental prototype garment be either prohibited or kept to a minimum in order to maintain water resistance. If the commercial rainsuit is considered further, additional laboratory testing is recommended to investigate water resistance, since the number of sample garments tested under this project was very small. The disadvantage of the commercial suit is its impermeability to moisture vapor. While this impermeability may be fine for short duration use, with longer duration use it may cause heat stress. Physiological evaluations should be conducted to assess the extent of this potential heat stress if the commercial garments are to be considered. Additionally, the effects of field use would still need to be assessed for these garments.

APPENDIX - A

NAVY WASH FORMULA III  
 LOW TEMPERATURE FORMULA  
CLASSIFICATION: WOOLENS, SYNTHETIC, COTTON BLENDS, AND NONFAST COLORS

Step	Operation	Cycle Time (Minutes)	Water Temperature (Degrees Fahrenheit)	Water Level (Inches)	Supplies (100-lb Basis)	Notes
1	Break/suds	5	100 to 120	9	14 to 16 oz detergent oxygen bleach	A
2	Drain	1				
3	Flush/suds	5	100	9	4 oz detergent if required	
4	Drain	1				
5	Spin	1				
6	Rinse	3	90	9		
7	Drain	1				
8	Rinse	3	90	8		
9	Drain	1				
10	Sour	4	90	8	1.0 oz sour	
11	Drain	1				
12	Final Spin	4				

A. Detergent/bleach may be added to the wash wheel once the water level has been reached. Detergent amounts are based on a 100-lb basis and must be adjusted according to the size of the washer extractor used.

FOR SEAWATER WASHING

1. Use seawater in steps 1 and 3. Detergent bleach should be increased to 20 oz.
2. Use fresh water in steps 6, 8, and 10.

APPENDIX - B

INCH POUND

FQSE/PD 95-05  
20 June 1995

## PURCHASE DESCRIPTION

### CLOTH, WATERPROOF AND MOISTURE VAPOR PERMEABLE

This purchase description is approved for use by all departments and agencies of the Department of Defense.

#### 1. SCOPE

1.1 Scope. This document covers the requirements for woodland camouflage printed cloth which is waterproof and moisture vapor permeable.

#### 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this specification, whether or not they are listed.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Defense Personnel Support Center, Clothing and Textiles Directorate, Attn: DPSC-FQSC, 2800 South 20th Street, Philadelphia, PA 19145-5099, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

FSC 8305

DISTRIBUTION STATEMENT A.

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distribution is unlimited.

2.2 Government documents

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

- O-I-503 - Insect Repellent, Clothing and Personal Application
- P-D-245 - Detergent, Laundry and Hand Dishwashing (Granular)

STANDARDS

FEDERAL

- FED-STD-101 - Test Procedures for Packaging Materials
- FED-STD-191 - Textile Test Methods

(Unless otherwise indicated, copies of Federal and military specifications, standards and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues shall be those in effect on the date of the solicitation.

DRAWINGS

U.S. ARMY NATICK RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER

2-1-1516B - Woodland Pattern - 60 inches

2.3 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN ASSOCIATION OF TEXTILE CHEMISTS AND COLORISTS (AATCC)

Evaluation Procedure 1 - Gray Scale for Color Change

Evaluation Procedure 3 - Chromatic Transference Scale

119 - Color Change Due to Flat Abrasion (Frosting):  
Screen Wire Method

135 - Dimensional Changes in Automatic Home Laundering of:  
Woven and Knit Fabrics

(Copies should be obtained from the American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709-2215.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/ASQC Z1.4 - Sampling Procedures and Tables For  
Inspection By Attributes

(Copies should be obtained from the American National Standards Institute, 11 W. 42nd Street, New York, NY 10036-8002.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

D 2582 - Puncture-Propagation Tear Resistance of Plastic  
Film and Thin Sheeting

D 3776 - Standard Test Methods for Mass Per Unit Area  
(Weight) of Woven Fabric

D 5034 - Breaking Force and Elongation of Textile Fabrics  
(Grab Test)

E 96 - Water Vapor Transmission of Materials, Procedures  
B and BW

(Copies should be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Standard sample. The basic material shall match the standard sample for shade, appearance, and texture on the face side and shall be equal to or better than the standard sample with respect to the characteristics for which the standard sample is referenced.

3.2 First article. When specified (see 6.2), a sample shall be subjected to first article inspection in accordance with 4.2.

3.3 Basic material. The basic material shall be a woodland camouflage pattern nylon fabric. The face side shall be the woodland camouflage printed side of the basic material. The back side shall be compatible and show good adhesion with commercially-available, thermally-applied, seam seal tape materials. The components of the basic material shall be approved (see 6.7). The finished basic material shall meet the requirements specified in Table I and 3.5 when tested as specified in 4.3.3; shall match the standard sample for shade, appearance, and pattern execution as specified in 3.4 and 3.6; and shall conform to the infrared reflectance requirements of 3.7 when tested as specified in 4.3.3.

TABLE I. Physical requirements

<u>Characteristic</u>	<u>Requirement</u>	
	<u>Minimum</u>	<u>Maximum</u>
Overall weight, oz/sq. yd	4.0	6.0
Breaking strength, lbs.		
Warp	135	
Filling	100	
Tearing resistance, kgf		
Warp	2.2	
Filling	2.8	
Hydrostatic resistance, psi		
Initial	90	
After strength of coating	80	
After abrasion	70	
After high humidity	80	
After diethyltoluamide	80	
Stiffness, cm		
At 70 degrees Fahrenheit		12.0
At 0 degrees Fahrenheit		13.0
Physical surface appearance	1/	
Blocking, rating		No. 2

TABLE I. Physical requirements (continued)

<u>Characteristic</u>	<u>Requirement</u>	
	<u>Minimum</u>	<u>Maximum</u>
Resistance to leakage		
Initial		No leakage
After cold flex (-25°F)		
Warp		No leakage
Filling		No leakage
After physical surface appearance		No leakage
Moisture vapor transmission rate, g/sq. m/24 hours		
Procedure B	400	
Procedure BW	5000	
Spray rating		
Initial	100,90,90	
After 3 launderings	90,90,80	
Resistance to organic liquids		2/

1/ Both sides of the sample shall be visually examined for any evidence of physical surface appearance changes after 5 laundering cycles as specified in 4.3.3.2. The physical surface appearance of the laundered sample shall show no difference when compared to the unlaundered sample.

2/ The face side of the basic material shall show no wetting by n-tetradecane, initially and after 3 launderings. Different specimens shall be used for initial and after laundering tests.

3.4 Color. The face side of the finished basic material shall match Light Green 354, Dark Green 355, Brown 356, and Black 357, each area matching the specific colors of the pattern in accordance with the applicable standard sample referenced in the contract. The color of the back side of the finished basic material shall approximate the colors of the woodland camouflage printed face side or shall be Camouflage Green 483.

3.4.1 Matching. The finished basic material shall match the standard sample when viewed under filtered tungsten lamps that approximate artificial daylight and that have a correlated color temperature of  $7500 \pm 200$  K, with illumination of  $100 \pm 20$  foot candles, and shall be a good match to the standard sample under incandescent lamplight at  $2300 \pm 200$  K.

3.5 Colorfastness. The face side of the finished basic material shall meet the following colorfastness requirements when tested in accordance with 4.3.3 for the characteristics listed below:

Colorfastness characteristics

Requirements

Fastness to laundering (after 3 launderings)	Equal to or better than a rating of "good" for color change and equal to or better than a rating of "fair" for staining of color transfer cloth.
Fastness to accelerated laundering (Black print only)	Equal to or better than "3-4" rating on AATCC Gray Scale for evaluating change in color when compared to the unlaundered sample.
Fastness to light (after 40 hours)	Equal to or better than the standard sample, or equal to or better than "fair."
Fastness to crocking	Equal to or better than the standard sample or not less than AATCC chromatic transference scale rating of 3.5. <u>1/</u>
Fastness to abrasion (Black 357 only)	Equal to or better than the standard sample or not less than "3-4" rating on AATCC Gray Scale for evaluating change in color when compared to the unabraded sample.
Fastness to high humidity	No appreciable change <u>2/</u>

1/ Except Black 357 shall show an AATCC chromatic transference scale rating of not less than 1.0.

2/ An appreciable change in color means a change that is immediately noticeable on comparison of the test specimen with the original, unexposed sample. If closer inspection or a change of angle of light is required to make apparent a slight change of color, then change is not considered appreciable.

3.6 Pattern execution. The pattern shall reproduce the standard sample in respect to design, colors, and registration of the respective areas. The pattern repeat of the dyed, printed, and finished basic material shall be 27.25 inches (+2.00 inches, -2.50 inches) in the warp direction. The various areas of the pattern shall be properly registered in relation to each other and shall present definite sharp demarcations with a minimum of feathering or spew. Each pattern area shall show solid coverage; skitteriness exceeding that shown by the standard sample in any of the printed areas shall not be acceptable. When the standard sample is not referenced for pattern execution or design, a pattern drawing shall be provided, and the pattern on the finished basic material shall match that of drawing 2-1-1516B.

3.7 Infrared reflectance. The infrared reflectance of the colors in the four-color, camouflage-printed, finished basic material shall conform to the requirements specified in Table II when tested as specified in 4.3.3.4.

TABLE II. Spectral reflectance requirements

Wavelength, Nanometers (nm)	<u>Reflectance values (percent)</u>					
	<u>Black 357</u>		<u>Light Green 354</u>		<u>Dark Green 355 and Brown 356</u>	
	<u>min</u>	<u>max</u>	<u>min</u>	<u>max</u>	<u>min</u>	<u>max</u>
600	-	-	8	20	3	13
620	-	-	8	20	3	13
640	-	-	8	20	3	13
660	-	-	8	22	3	13
680	-	-	8	36	3	22
700	-	20	14	60	8	46
720	-	30	26	78	20	66
740	-	33	40	90	30	80
760	-	33	50	92	32	88
780	-	34	55	92	32	90
800	-	34	55	92	32	90
820	-	35	55	92	32	90
840	-	35	55	92	32	90
860	-	35	55	92	32	90

3.8 Water repellency. The basic material shall conform to the water-repellency requirements of this document. If necessary, to meet the water-repellency requirements the basic material may be given an approved, durable, water-repellent treatment on the face side. The use of materials other than approved water repellents is prohibited (see 6.3).

3.9 Odor. The finished basic material shall be free from any objectionable odor.

#### 4. VERIFICATION

4.1 Classification of inspection. The inspection requirements specified herein are classified as follows:

1. First article inspection (see 4.2)
2. Quality conformance inspection (see 4.3)

4.2 First article inspection. The first article, submitted in accordance with 3.2, shall be inspected as specified in 4.3.2 through 4.3.3.4 for compliance with design, construction, workmanship and dimensional requirements.

4.3 Quality conformance inspection. Sampling for inspection shall be performed in accordance with ANSI/ASQC Z1.4, except where otherwise indicated.

4.3.1 Component and material inspection. In accordance with 4.1 above, components and materials shall be tested in accordance with all the requirements of referenced specifications, drawings, and standards unless otherwise excluded, amended, modified, or qualified in this specification or applicable procurement documents.

4.3.2 Examination of the end item. Examination of the end item shall be in accordance with 4.3.2.1.

4.3.2.1 Visual examination. The cloth shall be examined for the defects listed below:

General

Any cut, hole, tear, scratch, or abrasion mark  
 Abrasion resulting in a thin or weak place  
 Any pinhole  
 Any area without waterproof finish (i.e., coating or laminating film)  
 Any thin area (i.e., thinly coated area)  
 Any lump (i.e., heavily coated area)  
 Any pit, blister, tunnel, bubbles, or delamination of components  
 Any spot, stain, or streak more than 1 inch in combined directions 1/ or any foreign matter 2/  
 Any embedded foreign matter  
 Any scorch or burn  
 Crease or wrinkle resulting in doubling that cannot be corrected by manual pressure, adhesion of surfaces against each other, or any diagonal distortion of woven (face) fabric surface  
 Any solid lump, defined as a slub C or 4, or knot which exceeds level C on the respective Sears Fabric Defect Scale (see 6.6)  
 Multiple floats or skips, 1/2 inch or more in either warp or filling direction of face fabric  
 Any tackiness  
 Any odor other than that which is characteristic of the coating or laminating compound or water-repellent finish 3/  
 Not clean

Camouflage pattern (face side)

Any skitteriness of pattern exceeding that shown by the standard sample  
 Pattern design not equal to standard sample  
 Excessive feathering or spew of pattern  
 Pattern repeat not equal to the standard sample  
 Warpwise pattern repeat less than 24.75 inches or more than 29.25 inches  
 Any color off shade, not uniform, mottled, or spotted (woven/face fabric side only)

Width

Trimmed width less than minimum specified  
 Selvages not trimmed  
 Edges not straight and uniform  
 Fabric edges curled, rolled, folded, doubled, scalloped, or wavy

- 1/ Clearly visible at normal inspection distance (approximately 3 feet).
- 2/ For the back side, any spot, stain, streak, off-shade area, or discoloration that is a result of the physical distortion or a result of uneven dyeing of a backing fabric of a laminated basic material shall not be scored for this condition. Foreign matter shall be defined as waste, fly, or extraneous material that has been spun into yarn or woven or knit into fabric.
- 3/ Odors of chemicals commonly used in coating or laminating compounds or in water-repellent finishes shall not be regarded as objectionable.

4.3.3 End item testing. The finished basic material shall be tested for the characteristics listed in Table III. The sample unit shall be 6 continuous yards full width of the finished basic material. Test methods shall be in accordance with FED-STD-191 unless otherwise specified.

TABLE III. End item tests

Characteristic	Requirement paragraph	Test method
Overall weight, oz/sq. yd	3.3	ASTM D-3776 (Method C)
Breaking strength, lbs.		
Warp	3.3	ASTM D-5034
Filling	3.3	ASTM D-5034
Tearing resistance, kgf		
Warp	3.3	ASTM D-2582 <u>12/</u>
Filling	3.3	ASTM D-2582 <u>12/</u>
Hydrostatic resistance, psi		
Initial	3.3	5512 <u>1/</u>
After strength of coating	3.3	5972 <u>2/</u> & 5512 <u>1/</u>
After abrasion	3.3	5302 <u>3/</u> & 5512 <u>1/</u>
After high humidity	3.3	<u>4/</u> & 5512 <u>1/</u>
After diethyltoluamide	3.3	<u>5/</u> & 5512 <u>1/</u>
Stiffness, cm		
At 70 degrees Fahrenheit	3.3	5204
At 0 degrees Fahrenheit	3.3	5204 <u>6/</u>
Physical surface appearance	3.3	4.3.3.2
Blocking, rating	3.3	5872 <u>7/</u>
Resistance to leakage		
Initial	3.3	5516 <u>1/</u> <u>8/</u>
After cold flex	3.3	4.3.3.3 & 5516 <u>1/</u> <u>8/</u>
After physical surface appearance	3.3	4.3.3.2 & 5516 <u>1/</u> <u>8/</u>
Moisture vapor transmission rate, g/sq. m/24 hours	3.3	ASTM E-96: Proc. B <u>13/</u>
	3.3	Proc. BW <u>14/</u>
Spray rating		
Initial	3.3	5526
After 3 launderings	3.3	5552 and 5526

TABLE III. End item tests (continued) -

Characteristic	Requirement paragraph	Test method
Resistance to organic liquids		
Initial	3.3	<u>9/</u>
After 3 launderings	3.3	5552 and <u>9/</u>
Colorfastness to:		
Light	3.5	5660
Laundering (after 3 cycles)	3.5	5614 <u>10/</u>
Accelerated laundering (Black 357 only)	3.5	4.3.3.1
Crocking	3.5	5651
Abrasion (Black 357 only)	3.5	AATCC 119 <u>11/</u>
High humidity	3.5	<u>4/</u>
Infrared reflectance	3.7	4.3.3.4

1/ Water pressure shall be applied to the face side of the finished basic material.

2/ Except that the specimens shall be stretched at 20 pounds.

3/ A solid rubber diaphragm, 0.030 ± 0.010 inch thick, with a nonmetallic contact shall be used. The abradant shall be the back side of the finished basic material. The back side of the specimen shall be abraded 1000 double strokes and then tested for hydrostatic resistance with the abraded portion of the test specimen centered in the hydrostatic test area.

4/ Three 4 by 4 inch specimens shall be laid flat, face side up, on a supporting plate and the assembly placed in a desiccator containing water in the lower portion. The water level shall be approximately 1 inch below the specimens. The lid of the desiccator shall be put in place and the desiccator placed in a circulating air oven having a temperature of 125 ± 2 degrees F for a period of 7 days. At the end of the aging period, each specimen shall be removed from the desiccator and then immediately examined for colorfastness and tested for hydrostatic resistance.

5/ Five 4 by 4 inch specimens shall be laid flat, face side up, on a glass plate 4 by 4 inches by 1/4 inch thick. Three drops of diethyltoluamide conforming to type II, concentration A of O-I-503 shall be applied to the center of each specimen. A glass plate shall be placed on each specimen and a four pound weight placed on top. After 16 hours, the specimens shall be removed from between the glass plates and tested immediately for hydrostatic resistance.

6/ The test specimens shall be subjected to a temperature of 0 ± 2 degrees F for a minimum of 4 hours, and the test shall be performed in a still atmosphere at that temperature.

7/ Only one specimen shall be tested.

8/ The hydrostatic head shall be 50 centimeters and shall be held for 10 minutes. The report shall only include measurement of the appearance of water drops. The appearance of 1 or more water drops within the 4-1/2 inch test area shall be considered a test failure.

9/ Place a small specimen of the basic material on a smooth horizontal surface, face side up. Using a pipette or eye dropper, gently deposit one drop of n-tetradecane on the surface of the specimen. After 30 seconds, examine the specimen under light at an angle. Absence of light reflectance at the cloth/drop interface shall be taken as evidence of wetting. Three specimens (or areas) taken at various locations across the sample unit shall be tested. Evidence of wetting on one or more specimens shall be considered a test failure.

10/ Specimen size shall be 4 grams  $\pm$  0.1 gram. All colors shall be tested except for the black.

11/ Except that the number of abrasion cycles shall be 300.

12/ Five warp and five filling specimens shall be tested in accordance with section 4 of FED-STD-191. Specimen size shall be 8 inches by 8 inches. Only one tear shall be made on a single specimen. The specimen shall be positioned with the face side toward the probe and with the designated yarns of the face fabric at right angles to the direction of the tear. The test shall be conducted using the standard drop height of  $508 \pm 2$  mm. If the tear is not straight on the face side of the specimen, the result shall be considered invalid and another specimen shall be tested. The thickness of the specimen shall not be measured.

13/ The back side of the cloth shall face the water. The free stream air velocity shall be  $550 \pm 50$  FPM as measured 2 inches above the fabric specimen. The air flow shall be measured at least 2 inches from any other surface. The test shall be run for 24 hours and weight measurements shall be taken at only the start and completion of the test. At the start of the 24 hour test period, the air gap between the water surface and the back of the specimen shall be  $3/4 \pm 1/16$  inch. Five specimens shall be tested.

14/ The back side of the cloth shall face the water. The free stream air velocity shall be  $550 \pm 50$  FPM as measured 2 inches above the fabric specimen. The air flow shall be measured at least 2 inches from any other surface. The test shall be run for 2 hours and weight measurements shall be taken at only the start and completion of the test. Five specimens shall be tested. The specimens shall be sealed in any manner which prevents wicking and/or leakage of water out of the cup.

4.3.3.1 Accelerated laundering test. The test procedure shall be in accordance with FED-STD-191, test method 5614, except the following deviations shall apply: Cut five specimens containing predominantly black print, each 4-1/2 inches by 3 inches, from the basic material and then fold in half, with the face side out, to form a bag 2-1/4 inches by 3 inches in dimension. Machine stitch the open edges together (seam allowance of no more than 1/4 inch) to form a bag leaving an opening approximately one inch in length. Through the opening, add 35 stainless steel spheres. Close the bag by stapling or stitching. Place the bag in a stainless steel cylinder (one bag per cylinder) without the color transfer cloth; add 50 ml of type II P-D-245 detergent solution (0.5 percent by weight detergent solution) and 100 stainless steel spheres and close tightly. Place the stainless steel cylinder in a preheated Launder-Ometer set at a water bath temperature of  $160 \pm 5^{\circ}\text{F}$ . Agitate the cylinder for one (1) hour maintaining a constant temperature. At the end of the laundering cycle, remove the bag from the cylinder and rinse thoroughly in a beaker or in running tap water at  $100 \pm 5^{\circ}\text{F}$  for five (5) minutes with occasional stirring or hand squeezing. Remove excess water by squeezing in hand (not extracting) and then dry bag in automatic tumble dryer set on permanent press cycle,  $150\text{-}160^{\circ}\text{F}$ , for fifteen minutes (more than one bag can be dried together). If the bag breaks open to release the contained spheres at any time during the test, the test shall be considered invalid and another bag specimen shall be prepared and tested. Remove all spheres from the bag and evaluate each face of the bag without pressing or ironing the bag. Each face of the laundered bag shall be compared to the original sample (unlaundered) in accordance with AATCC evaluation procedure 1 for evaluation of Gray Scale for color change, and the rating shall be based on the portion of the black print exhibiting the most color loss. The lower of the two ratings of each bag shall be recorded as the result for the bag. Failure of any of the five bags to meet the required rating shall be considered a test failure.

4.3.3.2 Physical surface appearance laundering test. Place  $2 \pm 0.2$  pounds of the finished basic material and, if needed, ballast in an automatic washing machine set on permanent press cycle, high water level, and warm ( $100 + 10^{\circ}\text{F}$ ,  $-0^{\circ}\text{F}$ ) wash temperature. Each sample unit, 48 inches in length by full width, shall be cut in half across the width of the fabric. One half of the sample unit (24 inches) shall be laundered the other half retained for final evaluation (unlaundered). Place 0.5 ounces (14 grams) of detergent conforming to type II of P-D-245 into the washer. The duration of each laundering cycle shall be  $30 \pm 5$  minutes. After laundering, place sample and ballast in an automatic tumble dryer set on permanent press cycle, high heat setting ( $150\text{-}160^{\circ}\text{F}$ ) and dry for approximately 15 minutes. Conduct 5 laundering and drying cycles. After each drying cycle, examine both sides of the cloth for changes in physical surface appearance. Sample shall show no changes in physical surface appearance when compared to the unlaundered sample. After the fifth laundering

and drying cycle, the sample shall be evaluated for resistance to leakage properties. The laundering equipment, washer and dryer, shall be in accordance with AATCC test method 135.

4.3.3.3 Resistance to leakage after cold flex (-25°F) test. One 8 inch by 12 inch area shall be cut from the sample unit with the 8 inch dimension in the indicated direction (warp or filling as applicable). The specimen shall be conditioned and flexed as specified in method 2017 of FED-STD-101 except the specimen shall not be aged, the short edges shall not be heat sealed or otherwise joined, and the specimen shall be flexed for 1500 cycles. The 8 inch by 12 inch specimen shall be mounted on the flex test apparatus, placed in a test chamber at -25°F for 1 hour, and then flexed in the test chamber at -25°F. Two 6 inch by 8 inch specimens shall be cut from the 8 inch by 12 inch flexed specimen and tested for hydrostatic resistance in accordance with method 5516 of FED-STD-191 with water pressure applied to the face side.

4.3.3.4 Infrared reflectance test. Spectral reflectance data shall be determined on the face side and shall be obtained from 600 to 860 nanometers (nm) at 20 nm intervals on a spectrophotometer (see 6.4) relative to the barium sulfate standard, the preferred white standard. Other white reference materials may be used provided they are calibrated to absolute white, e.g. magnesium oxide or vitrolite tiles (see 6.5). The spectral band width shall be less than 26 nm at 860 nm. Reflectance measurements may be made by either the monochromatic or polychromatic mode of operation. When the polychromatic mode is used, the spectrophotometer shall operate with the specimen diffusely illuminated with the full emission of a source that simulates either CIE source A or CIE source D65. The specimen shall be measured as a single layer, backed with six layers of the same fabric and shade. Measurements shall be taken on a minimum of two different areas and the data averaged. The measured areas should be at least 6 inches away from the selvage. The specimen shall be viewed at an angle no greater than 10 degrees from the normal, with the specular component included. Photometric accuracy of the spectrophotometer shall be within 1 percent and wavelength accuracy within 2 nm. The standard aperture size used in the color measurement device shall be 1.0 to 1.25 inches in diameter. Any color having spectral reflectance values falling outside the limits at four or more of the wavelengths specified shall be considered a test failure.

## 5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Department or

Defense Agency, or within the Military Department's System Command. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

## 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The cloth is intended for use in constructing the bivy cover for the modular sleeping bag (MSB). The bivy cover completely protects the sleeping bag from the ground.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number and date of this specification.
- b. Issue of DODISS to be cited in the solicitation and, if required, the specific issue of individual documents referenced (see 2.2.1 and 2.3).
- c. When first article inspection is required, (see 3.2) the item will be tested and should be a first article sample. The contracting officer should include specific instructions in acquisition documents regarding arrangement for examinations, quantity, and testing and approval.

6.3 Water repellent. Approval of components and combinations is the responsibility of U.S. Army Natick Research, Development, and Engineering Center, Natick, MA 01760-5014, and is based on extensive tests, including those for toxicity which are not set forth in this document. Because of the time necessary to conduct full evaluation (approximately six months), only those chemical treatments already approved and so listed in the invitation for bids or request for proposals shall be considered acceptable for the related procurement.

6.4 Spectrophotometer. Suitable spectrophotometers for measuring spectral reflectance in the visible/near infrared include the Diano Hardy, Diano Match Scan, Milton Roy Match Scan 2, Hunter D54P-IR, Applied Color Systems Spectro Sensor I & II, ACS CS-5, Hunter VIS/NIR Spectrocolorimeter, and the MacBeth 1500 with IR options.

6.5 White standard. Barium sulfate of suitable quality for use as a white reference standard is available from the Eastman Kodak Company. The same source has available magnesium reagent (ribbon). Suitable tiles can be obtained from the National Institute of Standards and Technology or the instrument manufacturers.



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