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TENT PRESERVATION PROJECT DEMONSTRATION/VALIDATION FOR REPLACEMENT OF AQUEOUS COPPER 8 QUINOLINOLATE TREATMENT OF COTTON WEBBING WITH RO-59-WP

by
Suzanne E. Bosselman

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Final Report
November 2006 – September 2007

Approved for public release; distribution is unlimited

U.S. Army Natick Soldier Research, Development and Engineering Center
Natick, Massachusetts 01760-5020

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14. ABSTRACT

The Department of Defense (DoD) uses cotton webbing as seam reinforcement on military tents. This material is subject to degradation in both use and storage by exposure to bacteria and fungi in a moist environment. The treatment Copper 8 quinolinolate (Copper 8) is currently applied to the webbing to prevent biocorrosion. This report describes a demonstration/validation study of an alternative coating, RO-59-WP, as a potential additive to or replacement for Copper 8, which has been taken off the market several times due to environmental concerns. Tents coated with both the baseline coating (Copper 8 only) and two candidate coatings (RO-59-WP only and RO-59-WP applied over Copper 8) were exposed to three different outdoor environments in the continental United States and were subsequently destructively evaluated for comparison. Performance data were collected and analyzed to validate the effectiveness of RO-59-WP as an alternative to Copper 8. This work was performed by U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) personnel, in cooperation with Concurrent Technologies Corporation (CTC), in support of the "Commercialization of Technologies to Lower Defense Costs" (CT/LDC) Task and under the NSRDEC "Mildew Growth/Bio-Corrosion Prevention using an Antimicrobial Coating on Material Surfaces," program. These efforts were funded through the DoD Corrosion Prevention Control Program.

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ENVIRONMENTAL PROTECTION BIODETERIORATION COST REDUCTION TENTS WEATHERING TEXTILES ANTIMICROBAL AGENTS MOISTUREPROOFING QUINOLINES COPPER FINISHES COATINGS TECHNOLOGY TRANSFER TENSILE STRENGTH TEMPERATURE WEBBING FUNGICIDES HUMIDITY

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PREFACE

This report documents testing to evaluate the performance of three coating combinations to protect against material degradation of cotton webbing used in military tents. The work was performed under the Natick Soldier Research, Development and Engineering Center (NSRDEC) ”Materials Degradation Corrosion Prevention and Control Project Plan--Mildew Growth/Bio-Corrosion Prevention Using an Antimicrobial Coating on Material Surface” program, under program element number 423000, during the period November 2006 – September 2007. The work was performed by the NSRDEC Warfighter Science, Technology & Applied Research Directorate, Molecular Sciences and Engineering Team, in cooperation with Concurrent Technologies Corporation (CTC), in support of Contract Task 403, “Commercialization of Technologies to Lower Defense Costs” (CT/LDC), funded through the Department of Defense Corrosion Prevention Control Program. Task 403 is administered by the National Defense Center for Environmental Excellence (NDCEE), which is operated by CTC.

The three coating combinations were (1) the aqueous Copper 8 quinolinolate (Copper 8) treatment currently used to protect the cotton webbing used in military tents, (2) an environmentally benign alternative RO-59-WP, and (3) RO-59-WP applied over Copper 8. The purpose of the testing was to determine the viability of an alternative to the stand-alone use of Copper 8, which requires periodic recoatings that have adverse environmental consequences. Each combination was applied to webbing of each of three tents located at three different sites that were exposed to high levels of precipitation, a wide range of temperatures, high relative humidity, high levels of ultraviolet radiation, and wind gusts. The performance of the treatments was monitored for six months at each site.

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TENT PRESERVATION PROJECT - DEMONSTRATION/VALIDATION STUDY FOR REPLACEMENT OF AQUEOUS COPPER 8 QUINOLIN-OLATE WITH RO-59-WP FOR TREATMENT OF COTTON WEBBING

1. INTRODUCTION

This report documents a demonstration/validation study of a protective coating, RO-59-WP, as an alternative to the aqueous Copper 8 quinolinolate (Copper 8) treatment currently used to protect the cotton webbing used in military tents. The U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) conducted this study, in cooperation with Concurrent Technologies Corporation (CTC), under contract to the National Defense Center for Environmental Excellence (NDCEE), through the Department of Defense (DoD) Corrosion Prevention Control Program. The work was performed as outlined in the test plan "Final Demonstration/Validation Plan for Replacement for Aqueous Copper 8 Quinolinolate Treatment on Cotton Webbing with RO-59-WP."

Lowering the costs of acquisition and operation of weapon systems are major goals of DoD. The Army tasked the NDCEE, operated by CTC, to source, assess, and develop technologies having the potential to lower DoD costs. Transfer of technologies which have both military and commercial applications can effectively lower defense procurement costs by increasing supply and availability.

1.1. Background

DoD uses a variety of textile materials for individual and collective protection of personnel and equipment from the weather and from man-made conditions. Examples of textile applications include soft shelters, parachutes, clothing, and truck covers. In the case of soft shelters, cotton webbing is used for seam reinforcement between tent panels.

Cotton is composed mostly of cellulose, and can degrade in use and in storage by exposure to bacteria and fungi in a moist environment. To counter this process, materials are coated with preservatives to reduce degradation rates and extend their life. Historically, solvent-based Copper 8 was used. Due to environmental issues (e.g., release of volatile organic compounds and hazardous waste disposal), this coating was banned by the Environmental Protection Agency (EPA) and was replaced by an aqueous-based suspension. Aqueous Copper 8 is a one-component antimicrobial agent suspension, with a separate water protection component to reduce water absorption. Periodic recoating of the aqueous-based treatment is necessary to maintain the same protection level provided by the solvent-based treatment. This has caused other environmental concerns due to runoff from treated materials and soil contamination at field recoating sites.

RO-59-WP is an environmentally benign protective treatment that consists of a three-part formulation of antimicrobial agents, a water repellant shield, and an ultraviolet radiation protector. It is an aqueous emulsion that forms a protective barrier by chemically bonding to the fiber.

1.2. Objectives

The goal of this effort was to compare the effectiveness of RO-59-WP to Copper 8 for the preservation of cotton webbing. The objectives included evaluating the performance of three different treatments, namely RO-59-WP alone, RO-50-WP coated over Copper 8, and Copper 8 alone. The performance of the first two coatings was to be compared against the third. Furthermore, the plan was to evaluate the relative durability of the preservative compounds over an extended exposure to an aggressive soil burial environment for up to 12 weeks.

1.3. Tasks/Personnel

The major tasks were:

- Preparation of test samples and procurement of tents
- Identification of tent test sites and tent set up
- Field observations of tents including photography and weather conditions
- Laboratory tensile testing of recovered tent webbing
- Analysis of results

The names and contact information of personnel involved in the effort are:

Name	Role / Organization	Phone / Email
Scott McPherson	CT/LDC Technology Evaluator, CTC Corp, Johnstown, PA	(904) 486-4003 mcpherso@ctc.com
Lawrence Gintert	CT/LDC Project Mgr. (NDCEE Task 435) CTC Corp, Largo, FL	(727) 549-7092 GintertL@ctc.com
Allan W. Butler, PE, CEM, SSBB	Senior Engineer CTC Corp, Bremerton, WA	butler@ctc.com (360)782-5554
Dr. Margaret Roylance	Division Chief, U.S. Army NSRDEC	(508) 233-5510 margaret.roylance@us.army.mil
Ms. Kris Senecal	Research Biologist, Molecular Sciences and Engineering Team, U.S. Army NSRDEC	(508) 233-5510 kris.senecal@us.army.mil
Ms. Suzanne Bosselman	Research Engineer, Molecular Sciences and Engineering Team, U.S. Army NSRDEC	(508)-233-6969 suzanne.bosselman@us.army.mil
Mr. Ronnie Bender	President, RO-59 Inc.	(781) 341-1222 ro59inc@aol.com

2. MATERIALS/METHODS

The demonstration/validation evaluated the performance of three coating combinations for cotton webbing used in military tents, namely, RO-59-WP, RO-59-WP applied over Copper 8, and Copper 8. A field study was conducted where tents were fabricated with webbing material that was coated with the three preservatives, exposed to outdoor environments for six months, and subsequently destructively evaluated for comparison. The demonstration/validation was conducted at three test sites in the continental United States having harsh environmental conditions. The tensile strength of the exposed samples of the treated cotton webbing was subsequently determined through testing at the U.S. Army NSRDEC, in Natick, Massachusetts. To complement the study, previously collected laboratory data were included in which the treated cotton webbing materials were subjected to soil burial and tensile tested.

2.1. Sample Preparation

Prior to the start of the study, representatives of CTC coordinated with cotton webbing supplier and tent supplier Outdoor Venture Corporation (OVC) to prepare and procure three identical tents.

Leedon Webbing Company, Inc. produced tent webbing (MIL-W-530) for each experimental group. Samples were produced on the same manufacture date and material source, reducing variability associated with webbing material production. The cotton webbing was treated with the baseline Copper 8 treatment, the baseline Copper 8 treatment with a subsequent application of RO-59-WP (to represent previously coated materials that had been fielded, but then subsequently treated with RO-59-WP), and the RO-59-WP treatment alone.

OVC constructed three identical five-man Arctic tents. A schematic of the tent design, which uses a center pole to support the weight of the tent through a grommet at the tent peak, is shown in Figure 1. All three treatment compound combinations were used within each tent. Each of the candidate coated webbing materials contained a distinct uniquely colored tracer yarn in the core of the webbing. The locations and compound type are shown in Figure 2.

Inconsistencies were identified between the documented configuration and the as-built tents. Most notable was that the tent lugs were not treated with the preservative compounds as indicated in the schematic. However, the type and locations of the treated webbing were consistent between the tents.

2.2. Tent Site Selection and Setup

The three designated test sites were NSRDEC in Natick, Massachusetts, Fort Lewis, Washington, and the Army National Guard (ANG) site in St. Petersburg, Florida. An essential site selection criterion was climate that provides a high level of environmental stress on the tent materials. Each location experiences a very high level of precipitation, a wide range of temperatures, high relative humidity, high levels of ultraviolet radiation, and wind gusts. Figure 3 shows the total annual precipitation for the continental United

States, obtained from the National Atmospheric Deposition Program. Each test site is in a region where the annual precipitation ranges from 160 cm to 180 cm (63 to 70 in).

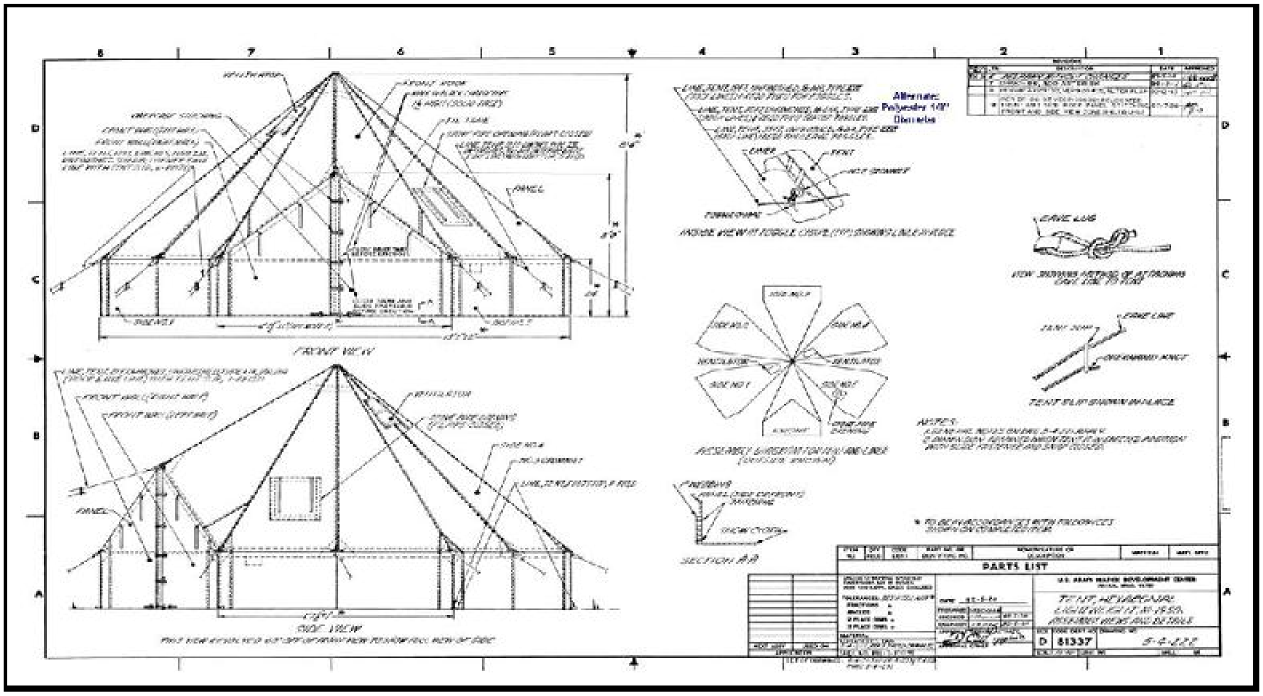

Figure 1. Schematic of five-man Arctic tent utilized in field tests.

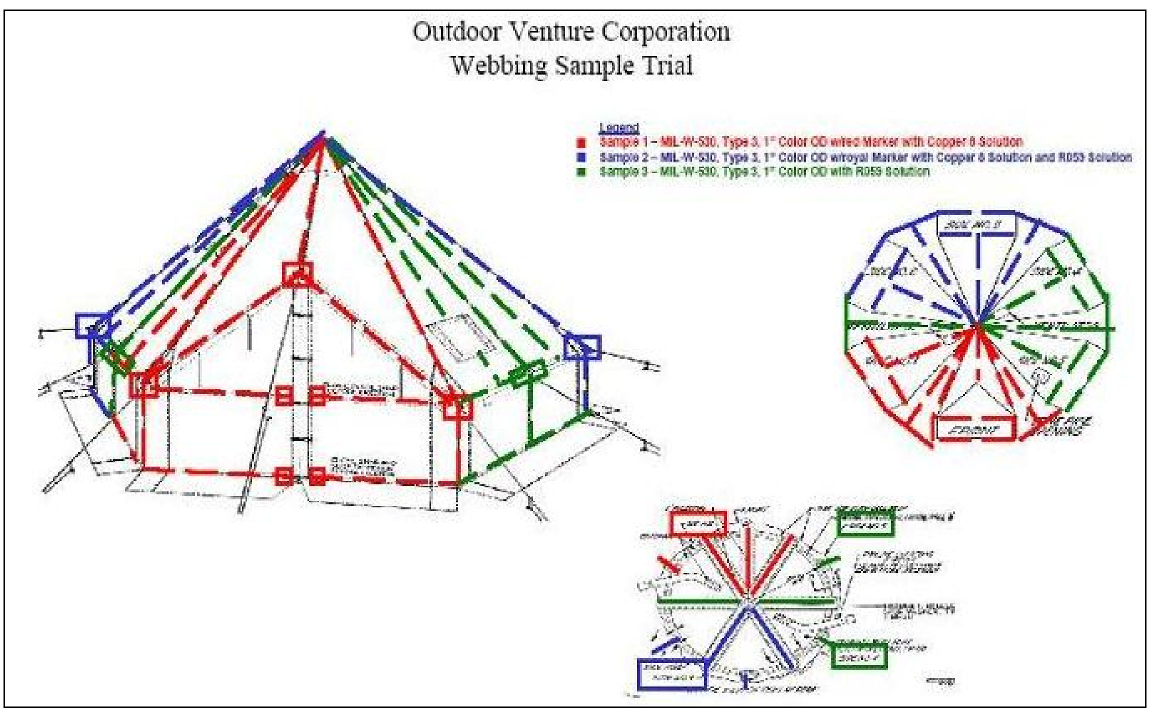

Figure 2. Arctic tent depicting locations and treatment type of cotton webbing reinforcements.

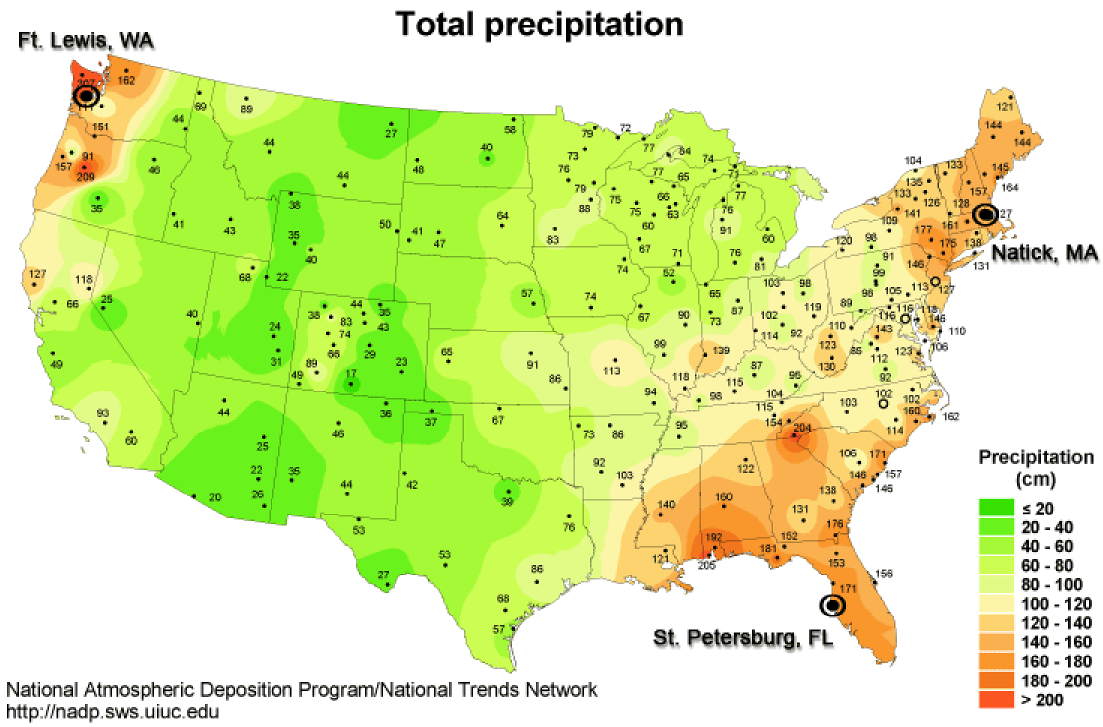

Figure 3. Total annual precipitation during calendar year 2006.

The Natick, MA tent (shown in Figure 4) was erected first, oriented with the door opening to the north. The same orientation was used for the Fort Lewis, WA and St. Petersburg, FL tents (shown in Figures 5 and 6, respectively), using a compass to confirm the proper direction.

Figure 4. Initial tent set-up in Natick, MA.

Figure 5. Initial tent set-up in Ft. Lewis, WA.

Figure 6. Initial tent set-up in St. Petersburg, FL.

2.3. Data Collection

2.3.1 <u>Meteorological Readings</u>

The following meteorological data were collected daily for each test site via existing internet sources (www.wunderground.com) by CTC personnel:

- Temperature, humidity, dew point temperature, pressure (minimum, maximum, and mean)
- Wind speed, visibility (maximum, mean)
- Wind gusts (maximum)

- Ultraviolet radiation
- Precipitation (type and amount)

2.3.2 Observations and Photographs

Visual observations were made and photographs were taken at the initial set-up and at intervals of two months, with a final visual assessment made at NSRDEC following the demonstrations for any signs of damage due to exposure. Photographs included the following:

- Overall tent site
- Tent door (with compass for reference direction/orientation)*
- Interior webbing at ground (counterclockwise from door)
- Interior webbing at top of wall (counterclockwise from door)
- Interior webbing at vent openings
- Exterior ground webbing
- 12 Tent lugs

* During initial setup of WA and FL tents

The data for the Natick, MA site were collected by NSRDEC personnel. The data for the Fort Lewis, WA, and St. Petersburg, FL sites were collected by CTC personnel.

2.3.3 Tensile Testing of Experimental Tents

At the end of six months of exposure, the Fort Lewis, WA and St. Petersburg, FL tents were dismantled and shipped to NSRDEC for extraction, visual assessment, and strength testing of the webbing materials. Experimental tensile strength testing of treated tent materials from each tent was performed in accordance with the American Society for Testing and Materials (ASTM) Test Method ASTM D 5035-95, Standard Test Method for Breaking Force and Elongation of Textile Fabrics - Strip Method. The coated webbing was extracted from each of the three tents, at several locations from the roof down to the ground seams, and cut to six-inch long strips.

2.4. Soil Burial and Testing of Webbing

The same webbing type (MIL-W-530) as used in the experimental tents was tested at NSRDEC. The webbing was coated with the three different treatments. Samples were buried in soil in accordance with American Association of Textile Chemists and Colorists (AATCC) Test Method 30-1999 - Antifungal Activity, Assessment on Textile Materials: Mildew and Rot Resistance of Textile Materials. Those samples were then tested for tensile strength in accordance with ASTM Test Method D 5035-95.

Soil burial and tensile testing was also performed on cotton webbing (MIL-W-5665) treated with one and two coats of RO-59-WP.

3. RESULTS

3.1. Meteorological Data

The local ambient temperatures at the three test sites during the test period are shown in Figure 7. The temperatures ranged widely between the test sites. The variation of the average daily relative humidity at the three test sites is shown in Figure 8. The total monthly precipitation for the three sites is shown in Figure 9. All of the data compiled can be found in full length report “Demonstration/Validation and Cost Benefit Analysis Report for Replacement of Aqueous Copper 8 Quinolinolate Treatment of Cotton Webbing with RO-59-WP,” prepared by CTC.

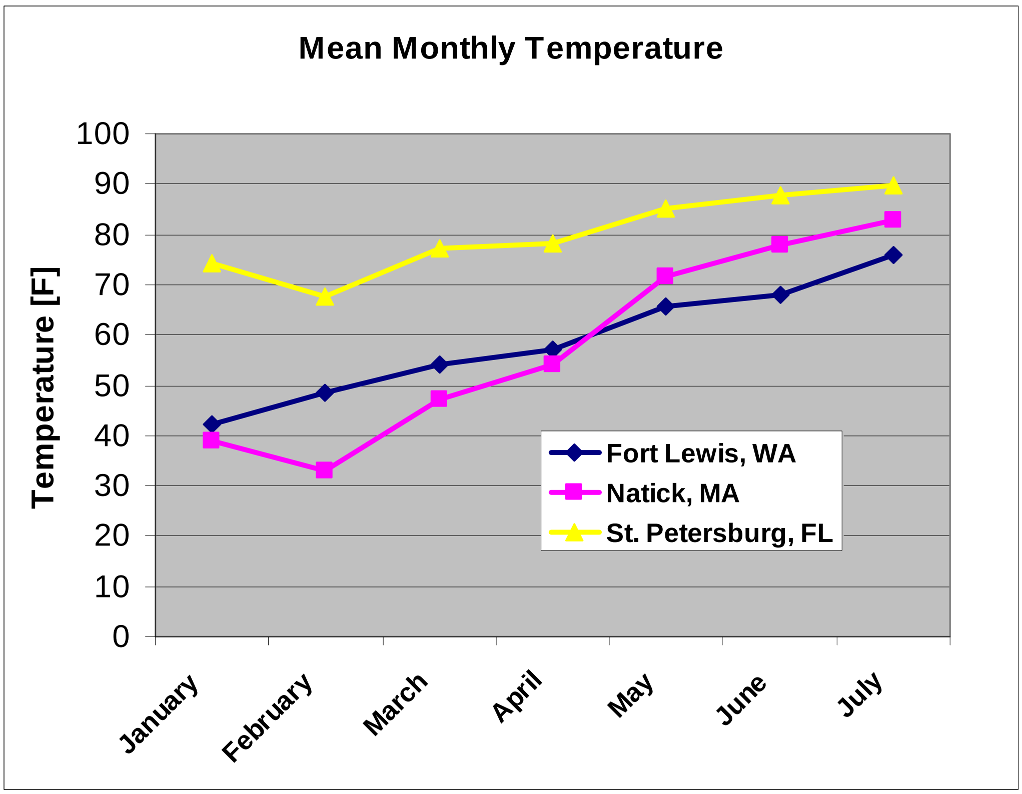

Figure 7. Variation in mean monthly temperatures during the test period.

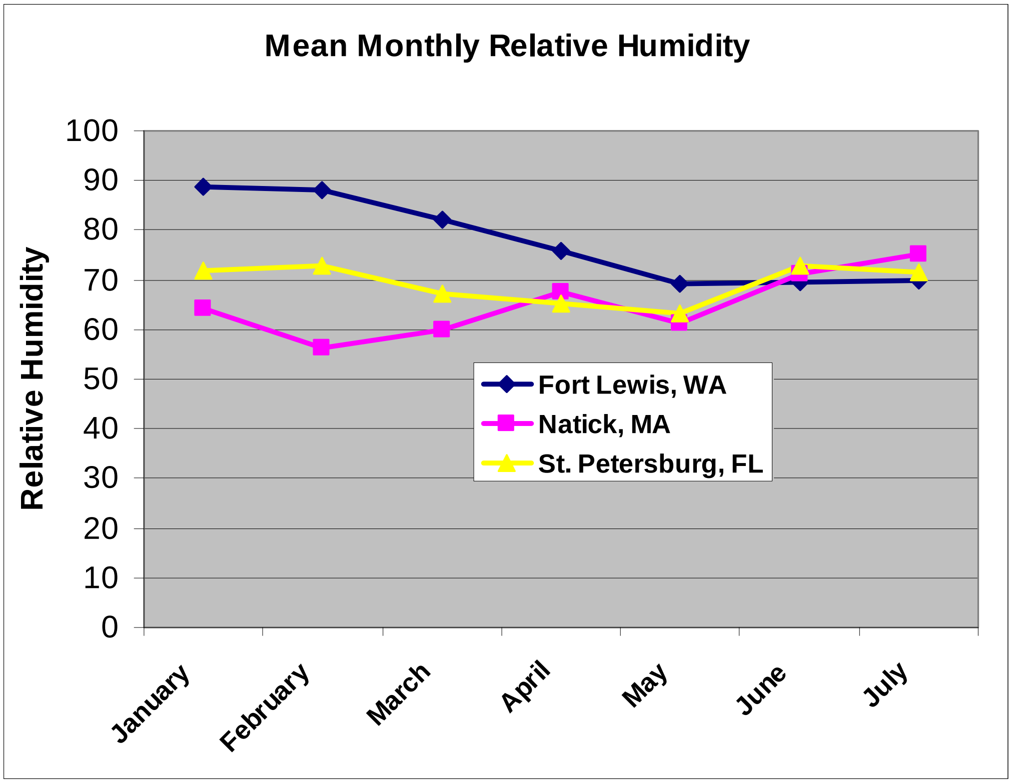

Figure 8. Variation in mean monthly relative humidity during the test period.

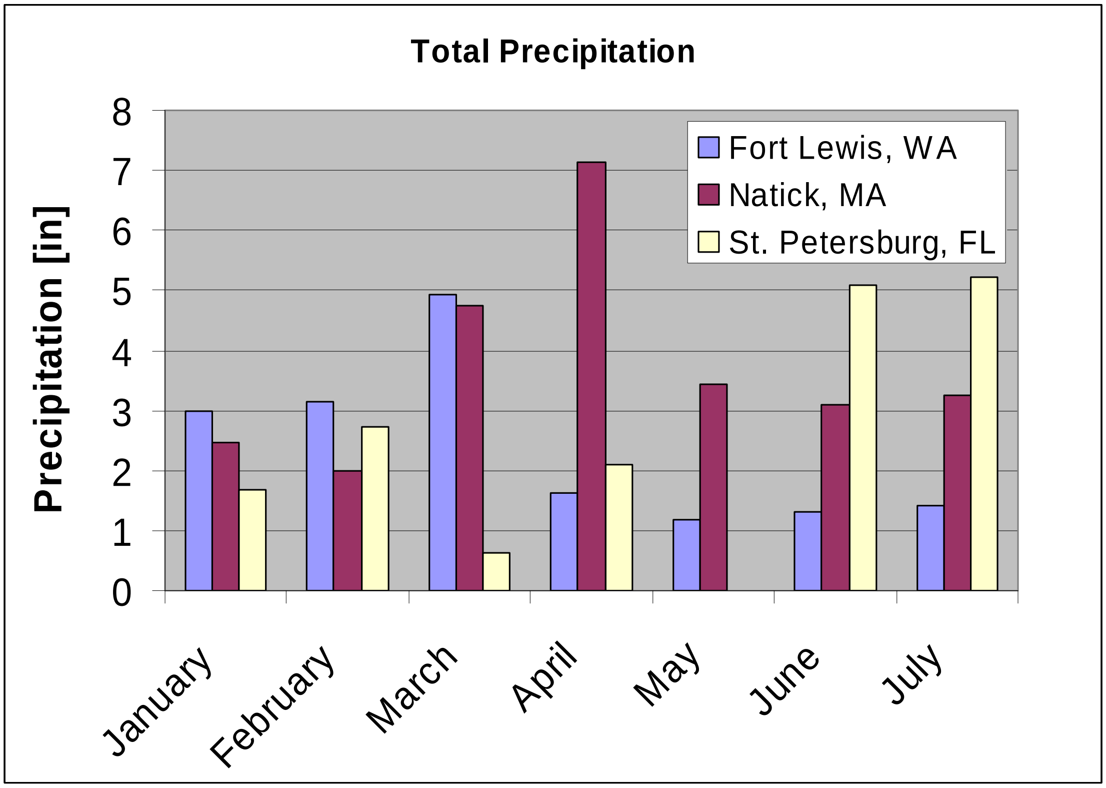

Figure 9. Total precipitation in inches over the test duration.

3.2. Photographic and Visual Observations

Each field site was visited periodically during the study. Photographs of each overall tent site were taken to document any changes to the test conditions. As described in section 2.3.2, photographs of tent webbing in specified locations were taken to document any apparent degradation of the webbing over the course of the study. These data were collected at exposure times of two, four, and six months. A summary of photographic data is listed in APPENDIX A.

Following a snow storm that occurred approximately four weeks into the study, the grommet at the peak of the Natick, MA tent failed. Initially, the failure of was attributed to the heavy snow load. Shortly thereafter, the St. Petersburg, FL and Ft Lewis, WA tents also failed in an identical manner, at the tent peak where the cotton webbing and connected tent fabric pulled loose from the grommet, with no snow load. Figures 10 and 11 show tent failure at Natick and St. Petersburg, respectively.

Upon discussion between team members and OVC representatives, it was determined that the failures were caused by altering the tent fabrication method to accommodate the combinations of webbing material needed for the experimental tents. In the standard fabrication, webbing is continuous across the peak and is joined with the grommet at the crossover point of the webbing. This type of failure would not have occurred in the typical construction.

Figure 10. Tent failure at Natick, MA site.

Figure 11. Tent failure at St. Petersburg, FL site.

To resolve the problem and continue the study, each tent was fitted with a standard plastic funnel, through which the center pole was housed. This also served to distribute the load such that the tents could be fully erected, eliminating slack in the tent sides. Figures 12, 13, and 14 show tent peak damage and funnel repair at Natick, St. Petersburg, and Ft. Lewis, respectively.

Figure 12. Tent peak damage and funnel repair at Natick, MA site.

Figure 13. Tent peak damage and funnel repair at St. Petersburg, FL site.

Figure 14. Tent peak damage and funnel repair at Ft. Lewis, WA site.

The visual assessment of the three tents, performed at NSRDEC following the six months of exposure, revealed no significant differences between the coated materials or between the individual tents.

3.3. Tensile Test Results

3.3.1 Tensile Tests of Webbing Materials from Experimental Tents

The results of the tensile strength tests performed at NSRDEC of the materials from three experimental tests (described in section 2.3.3) are summarized in Figure 15. Approximately 100 samples were tested from each tent. Sample mean and one standard deviation are shown. Description of extraction locations and additional data are found in APPENDIX B. Results of these tensile strength tests, performed in accordance with ASTM D 5035-95, indicate that RO-59-WP when used alone performed as well as Copper 8 when used alone, and as well as RO-59-WP when used with Copper 8.

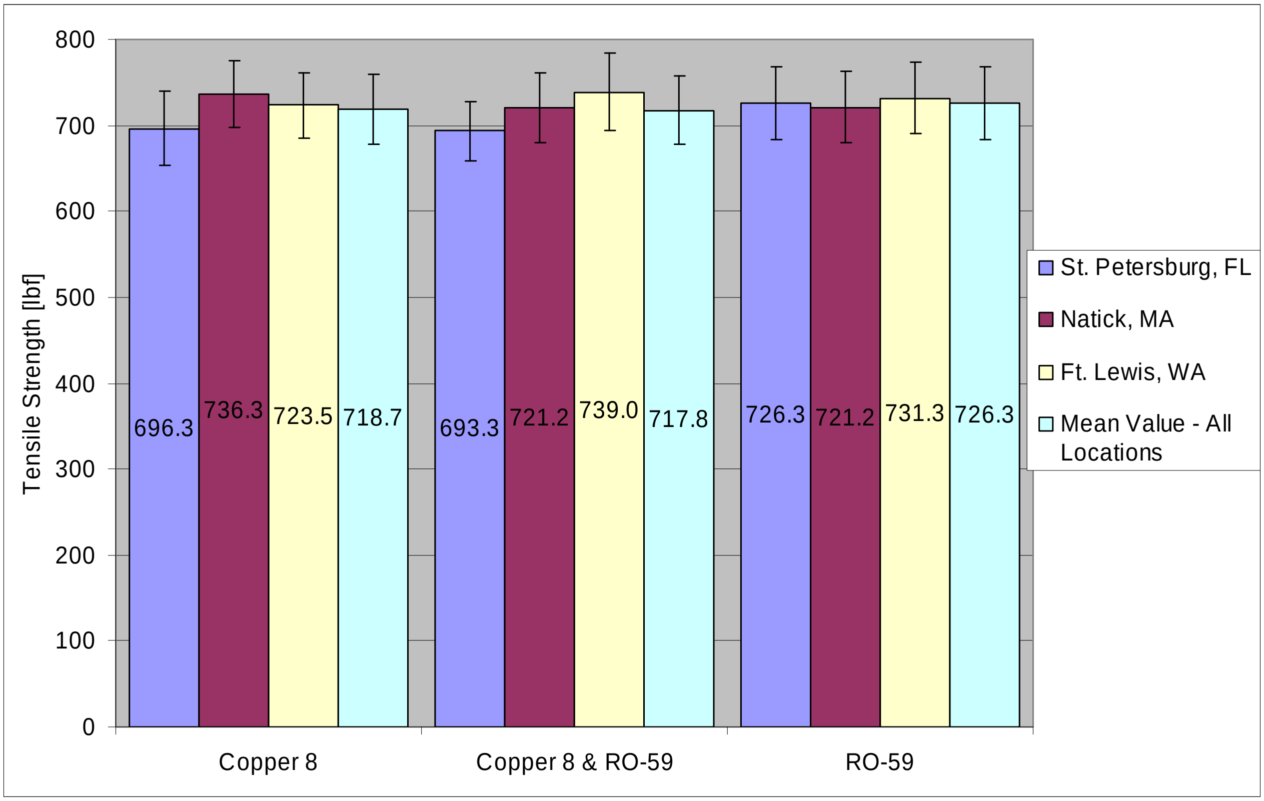

Figure 15. Mean value of tensile strength of tent webbing, measured in pounds-force.

3.3.2 Soil Burial and Tensile Tests

The results of the tensile strength testing of the MIL-W-530 webbing buried at NSRDEC (described in section 2.4) are shown in Figure 16. Each data point represents six samples, and mean values and one standard deviation are shown. Tensile test results following soil burial indicated that the strength of the cotton tent webbing samples (Mil-W-530) was similar for each coating type up to a burial duration of four weeks. After 8 weeks of burial, the strength of the Copper 8 coated samples was superior to that of the RO-59-WP coated samples, and even more so after 12 weeks of burial.

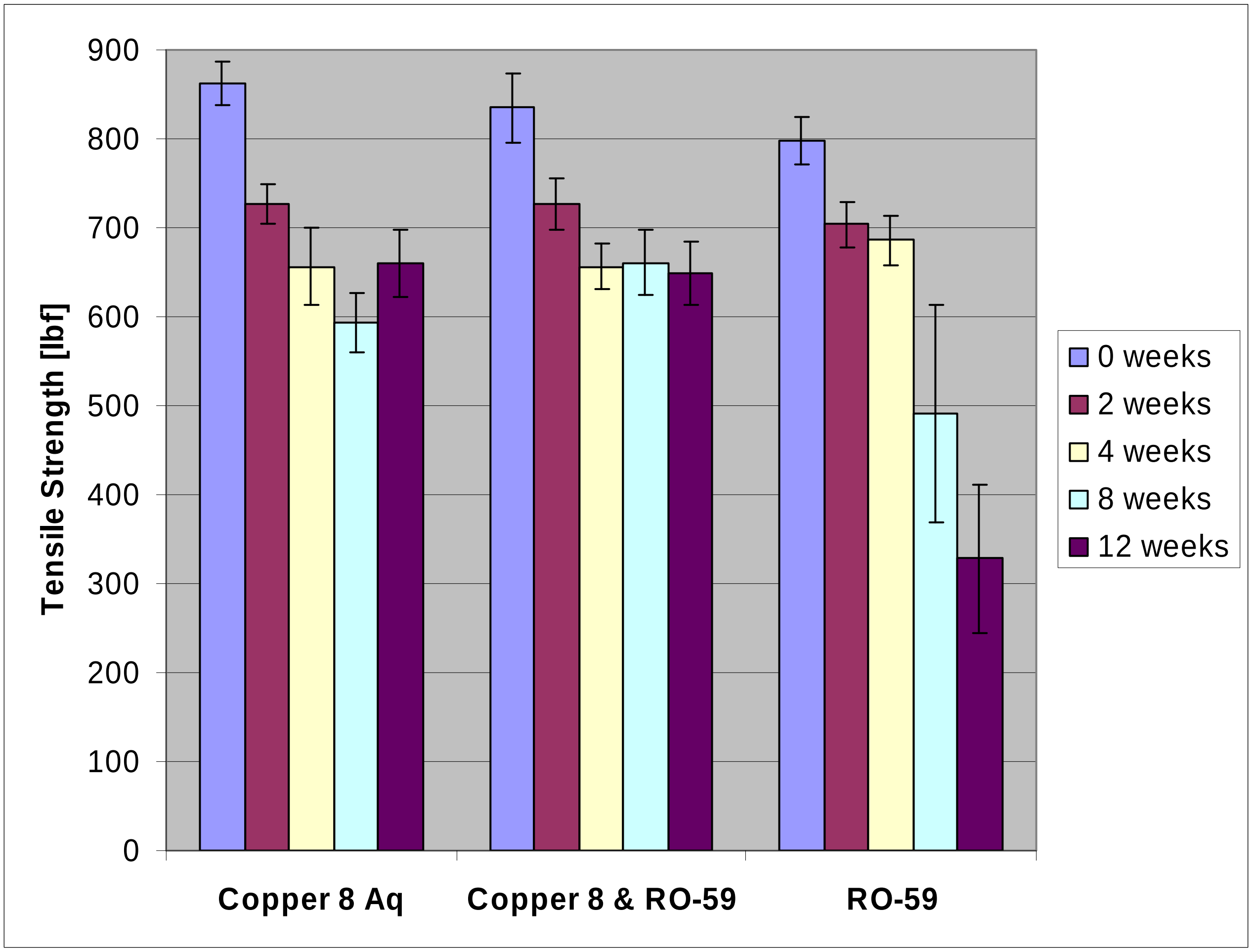

Figure 16. Mean tensile strength of MIL-W-530 webbing material following soil burial and retrieval.

The results of the soil burial and tensile testing performed on cotton webbing (MIL-W-5665) treated with one and two coats of RO-59-WP (also described in section 2.4) are shown in Figure 17. Again, each data point represents six samples, and one standard deviation is given. For each of the burial periods through 12 weeks, the measured decrease in tensile strength was found to be similar regardless of whether the webbing was treated with RO-59-WP once (one pass), or twice (two passes), during each period of performance that was observed.

It should be noted that direct soil burial is an extremely harsh test method and correlation to field exposure is unknown. It is uncertain how critical the extended (i.e., in excess of 8 weeks) exposure strength difference is to real-life use of the tents.

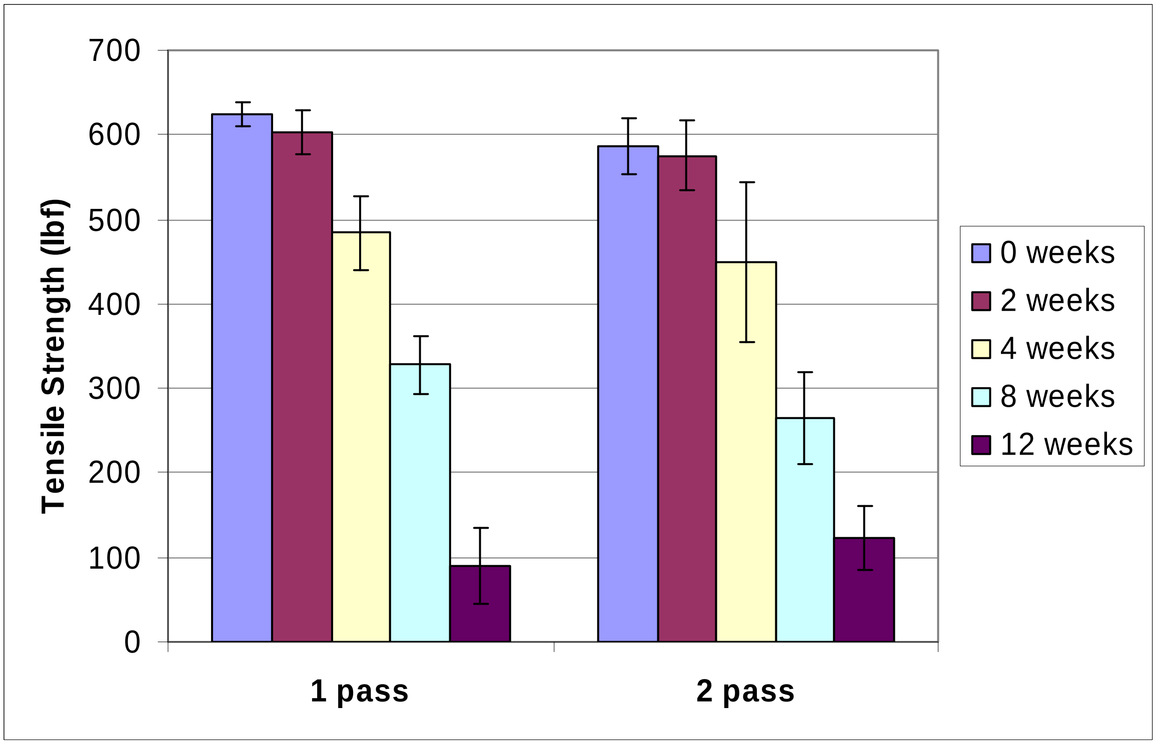

Figure 17. Mean tensile strength of MIL-W-5665 webbing material following soil burial and retrieval.

4. CONCLUSIONS

Based on a statistically significant number of tent webbing test samples, it was found that RO-59-WP when used alone performed as well as Copper 8 when used alone, and as well as RO-59-WP when used with Copper 8 for six months of outdoor exposure.

Following soil burial, strength retention of the same webbing type (Mil-W-530) as used in the experimental tents was found to be similar regardless of coating for a burial period up to four weeks, but then diverged such that the strength of the Copper 8 coated samples were superior to that of the RO-59-WP coated samples after 8 weeks of burial, and even more so after 12 weeks of burial. Furthermore, cotton webbing (Mil-W-5665) treated with one and two coats of RO-59-WP and subjected to soil burial tests demonstrated similar tensile strength retention for each of the burial periods through 12 weeks regardless of the number of treatment coats (one or two). This indicates that a single-pass coating process should be sufficient for the candidate preservative.

Based on the performance data obtained from this demonstration/validation study, the candidate coating material RO-59-WP may be considered an acceptable substitute for aqueous Copper 8 to protect cotton webbing from bio-degradation. Further testing may be required to substantiate whether or not reapplication of the compound is necessary for extended preservation of the materials. It is also recommended that the applicability of RO-59-WP for cotton webbing used in applications other than tents be investigated by conducting testing specific to those applications. This research may also be extended to consider other textile materials that require protection from bio-degradation.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 08 / 017 in a series of reports approved for publication.

APPENDIX A.
SUMMARY OF PHOTOGRAPHIC OBSERVATIONS

Tent Location	Test Duration	Number of Photos Taken (jpeg format)	Tent Items Photographed	Dates of Photos (2007)
Natick, MA	January 2007–July 2007	26	Exterior Lugs # 1-12, Bottom, Top, Front, Inside, Exterior Entire Tent, Compass, etc.	January
		32	Exterior Lugs # 1-12, Bottom, Top, Front, Inner Liner, SE Face, NE Face, Funnel/Repair, Zipper, Entire Tent, etc.	March
		28	Exterior Lugs # 1-12, Bottom, Top, Front, Inner Liner, SE Face, NE Face, Zipper, Entire Tent, etc.	May
		31	Exterior Lugs # 1-12, Bottom, Top, Front, Inner Liner, SE Face, NE Face, Zipper, Entire Tent, etc.	July
St. Petersburg, FL	February 2007 – August 2007	70	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Compass, etc.	February
		43	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, etc.	April
		50	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Funnel/Repair, etc.	June
		49	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, etc.	August
Fort Lewis, WA	January 2007 – July 2007	35	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Compass, Slack Lines/Re-set up, etc.	January
		59	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Slack Lines/Re-Set up, Sandbags Added, etc.	March/April
		53	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Slack Lines/Re-Set up, Funnel/Repair, etc.	May/June
		57	Exterior Lugs # 1-12, Inside Ground Webbing, Bottom, Top, Front, Exterior Entire Tent, Empty Site, etc.	July

APPENDIX B.
WEBBING EXTRACTION LOCATIONS AND DATA

Horizontally oriented webbing was extracted from two locations of the tents, specifically, from the base and midline, as indicated in Figure B-1.

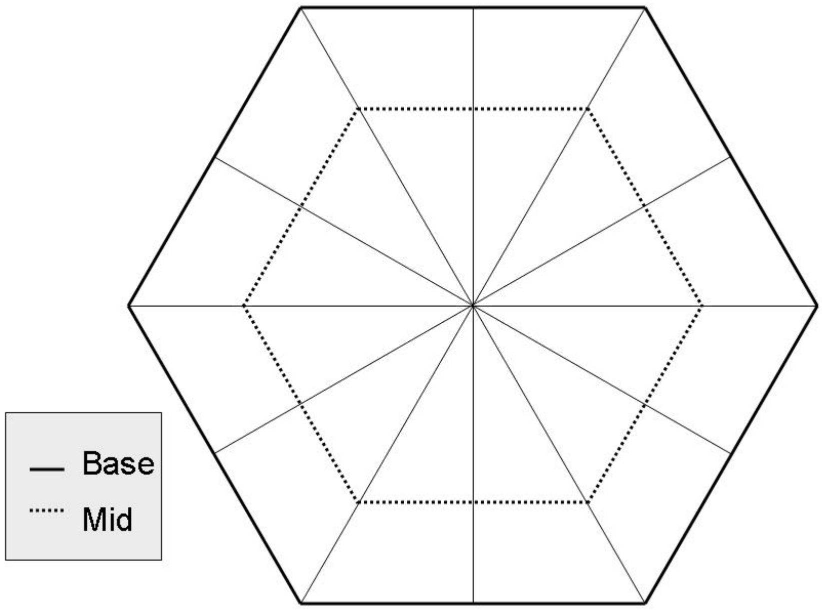

Figure B-1. Schematic of top view of experimental tents indicating webbing extraction locations.

Vertically oriented webbing was also obtained from three sections spanning from the base to the peak. Their labels and description are given below:

1) BASE/MID – material in region between base of tent and midline
2) MID/PEAK – material in region between midline and peak, closest to midline
3) PEAK – material in region between midline and peak, closest to peak

Tables B-1, B-2, and B-3 contain results of tensile tests from the experimental tents at these specific locations.

Samples were not obtained for the combination coating Copper 8 and RO-59-WP at the MID horizontal region, indicated in gray. Some samples were collected in the MID horizontal region, where the webbing was stitched onto a base layer of MIL-T-43566, indicated by an asterisk.

Table B-1. Mean tensile strength in pounds-force of webbing from St. Petersburg, FL.

Horizontal Webbing:	BASE		MID*		MID	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	720.40	24.46	719.98	36.39	746.33	42.99
Copper 8 & RO-59-WP	691.50	29.28	678.98	25.72		
RO-59-WP	708.60	81.11	734.43	43.88	730.60	27.57

Vertical Webbing:	BASE/MID		MID/PEAK		PEAK	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	661.33	53.23	681.27	18.81	697.27	38.78
Copper 8 & RO-59-WP	663.13	41.17	713.42	26.56	717.30	15.52
RO-59-WP	716.40	23.00	727.33	9.00	741.87	36.55

Table B-2. Mean tensile strength in pounds-force of webbing from Ft. Lewis, WA.

Horizontal Webbing:	BASE		MID*		MID	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	735.25	19.53	738.07	38.65	721.33	24.26
Copper 8 & RO-59-WP	714.45	38.54	746.42	25.01		
RO-59-WP	764.43	15.02	758.38	25.89	695.10	47.58
Vertical Webbing:	**BASE/MID**		**MID/PEAK**		**PEAK**	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	703.98	59.31	735.20	43.27	706.70	25.61
Copper 8 & RO-59-WP	743.24	63.51	722.83	55.53	768.77	22.02
RO-59-WP	716.15	47.21	713.28	19.58	728.45	51.50

Table B-3. Mean tensile strength in pounds-force of webbing from Natick MA.

Horizontal Webbing:	BASE		MID*		MID	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	770.7	32.0	770.5	35.1	750.1	22.0
Copper 8 & RO-59-WP	740.4	26.0	741.6	16.6		
RO-59-WP	730.5	49.3	754.4	39.0	710.5	24.2
Vertical Webbing:	**BASE/MID**		**MID/PEAK**		**PEAK**	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Copper 8	716.0	22.5	699.9	17.8	715.1	31.5
Copper 8 & RO-59-WP	734.1	11.5	684.0	68.3	708.0	22.3
RO-59-WP	714.5	24.9	689.8	48.6	724.2	41.0