

Submitted for recognition as an American National Standard

## ENVIRONMENTAL DEGRADATION OF TEXTILES

ENTIRE DOCUMENT REVISED

### INTRODUCTION:

The intent of this technical report is to make available information concerning the environmental degradation of textiles as used in unit load device (ULD) equipment common to the air cargo community.

#### 1. SCOPE AND FIELD OF APPLICATION:

Since the ULD device containing textiles should have a predictable service life, there should be data available so that predictions can be made. This technical report compiles available information on textiles of the types used in air cargo ULD devices and reviews the degradation characteristics of each.

Textiles are used primarily in cargo restraint nets on air cargo pallets and non structural containers, restraint nets installed in cargo aircraft, and similar applications.

#### 2. REFERENCES:

AS1131B, Air and Air/Surface (Platform) Cargo Pallet Nets  
AS1492A, Interline Air Cargo Pallet Nets  
ISO 4115, Air Cargo Equipment - Air/Land Pallet Nets  
ISO 4170, Air Cargo Equipment - Interline Pallet Nets  
IATA, Unit Load Devices (ULD) Technical Manual

SAE Technical Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

### 3. TYPES OF DEGRADATION:

Many factors can contribute to the degradation process. They are:

- a. The natural environment factors of light and heat including ultraviolet exposure.
- b. The atmospheric pollution from industrial emissions.
- c. Exposure to various destructive chemicals.
- d. Washing powders and immersion in salt water.

### 4. FACTORS INFLUENCING DEGRADATION:

Natural and man-made fibers can be degraded by exposure to sunlight or to light rays from other sources. Industrial fiber products such as rope and webbing degrade at a much slower rate than fibers in yarn form; nevertheless, prolonged exposure can cause a loss in breaking strength, breaking elongation, and toughness. These properties are especially important in industrial fiber products.

- 4.1 Influence of Wave Length: Test conducted by Du Pont as well as experience show the primary cause for light degradation of fibers is ultraviolet rays with wave lengths between 290 and 400 millimicrons. Radiation of shorter wave lengths, including gamma rays, damages fibers; however, this radiation is seldom encountered by fiber products. Radiation of longer wave lengths (that is, the visible and infrared rays), also damages some fibers, but this damage is minor compared to that from ultraviolet rays. Such radiation could, however, cause an increase in fiber temperature, which might result either in heat degradation or in accelerated ultraviolet degradation of the fiber.

The spectral distribution of the energy of the sun's radiation reaching the earth is about 5% in the ultraviolet region, 40% in the visible, and 55% in the infrared. These percentages vary with the seasons, time of day, atmospheric conditions, latitude, and altitude.

- 4.2 Influence of Other Factors: The deterioration of a fiber by sunlight or other radiation depends on a number of factors. A brief discussion of some of these factors follows:

- 4.2.1 Geographical Location of Exposure: Sunlight deterioration of fibers is more rapid at certain geographical locations than at others. This is due to differences in the duration and intensity of radiation in the particular wave lengths that damage fibers.
- 4.2.2 Time of Year When Exposed: The rate of sunlight deterioration of fibers also varies with the time of year of exposure. At most locations, deterioration is considerably more rapid in summer than in winter because of the relatively higher amount of ultraviolet radiation during the summer months.

- 4.2.3 Type of Exposure: Window glass filters out part of the ultraviolet rays from the sun; thus, the deterioration of fibers exposed behind glass is generally less rapid than that of fibers exposed outdoors. Fluorescent lamps having appreciable radiation in the ultraviolet range of wave lengths can cause deterioration of fibers, especially when unprotected fiber products are stored in close proximity to such lamps for long periods of time. Accelerated light deterioration tests are often made by exposing fiber products to radiation from carbon-arc lamps. When interpreting the results of such tests it should be recognized that (a) critical wave lengths differ for different fibers, and (b) the spectral distribution, temperature, and moisture conditions are likely to be quite different from those encountered in actual use of fiber products.
- 4.2.4 Size or Thickness of Fiber Structure: The light resistance of a single filament or single fiber increases with denier because less of the damaging radiation penetrates into the interior of the filament or fiber. This same principle applies to most cords and ropes since the outer fibers protect the inner fibers.
- 4.2.5 Materials Added in Fiber Manufacture: The amount of delustrant present in a fiber may greatly increase the rate of light deterioration. Bright fibers usually have better light resistance than semi-dull fibers which, in turn, usually have better resistance than dull fibers. Other pigments and additives incorporated in the polymer can be quite effective in improving the light resistance of fibers.
- 4.2.6 Effect of Dyes, Finishes and Other Agents: The effect of agents (coatings, dyes, finishes, etc.) applied to a fiber was not evaluated in the later Florida outdoor-exposure test; however, this effect is significant enough to warrant comment in the Du Pont report (see 12.4).

The rate of deterioration of fibers may be affected appreciably by the presence of dyes; hence, this effect should be investigated whenever light durability is important. Some dyes adversely affect the light resistance to fibers. Others, including many of the "Capracyl" dyes and some of the "Pontamine" dyes, are very effective in increasing the light resistance of nylon 6-6. For instance, a 12.7 mm (1/2 in) diameter rope of Du Pont nylon dyed with 5% "Capracyl" yellow NW retained 80% of its original strength after 18 months of direct exposure to Florida sunlight and weather, while the same rope in the undyed state retained only 50% of its strength during exposure under exactly the same conditions.

## 5. OUTDOOR EXPOSURE TEST - 1975-1976:

- 5.1 The samples of webbing and thread used in the tests were representative samples of materials used in the construction of cargo nets, tie down straps and barrier nets.

## 5.2 Exposure Conditions:

5.2.1 Geographical Location: United States of America, Torrance, CA.

5.2.2 Season of Year: May 22, 1975 to August 22, 1976 (15 months).

5.2.3 Type of Exposure: Out-of-doors in direct sunlight. No attempt was made to measure radiation. Torrance, CA, is a light industrial complex which emits an indeterminate amount of pollutants into the atmosphere. Although near the Los Angeles County smog area, Torrance is relatively free from noticeable smog because of prevailing sea breezes.

5.2.4 Exposure Period: Continuous exposure 24 h per day for a period of 15 months. One rope exposure test was, however, for 12 months.

5.2.5 Weather Conditions: A stochastic analysis of the weather conditions was made from U.S. Department of Commerce weather summaries for the Los Angeles-Long Beach area.

About 95% of the days were overcast in the mornings until approximately 11:00 a.m. About 4% of the days experienced rain, and about 7% of the days were mostly or completely overcast.

## 6. TEST CONDITION:

6.1 A broad sampling of commercially available webbing and thread were used in this test. A total of 29 different webbings and 3 thread samples were included. All specimens were suspended vertically and faced due north when mounted on the exposure stand.

6.2 No weights were attached to the ends of each specimen.

6.3 Breaking strength of the specimens was determined at 21°C (70°F) 65% R.H. using a 27 272 kg (60 000 lbf) tensile tester.

6.4 Percent strength retained after exposure was calculated from the breaking strength of the unexposed specimens.

## 7. ANALYSIS OF TEST RESULTS:

The percent of original breaking strength retained by the specimens after exposure is a measure of the outdoor durability of the test items.

Data for percent strength retained is tabulated in Tables I, II, and III. The progressive rates of strength loss are shown in graphs in Figs. 1-5.

7.1 Color: Generally, the most weather resistant webbings are those dyed with darker colors such as olive drab.

7.2 Weave: Webbing and the rope in the heavier strength ranges were also much more weather resistant. This can be explained by the webbing weave patterns, which hide many fibers from direct exposure. As an example, some heavy webbings have a stiffer weave with parallel strength members buried under a top and bottom warp. This type of weave weakens less than a plain weave where strength members weave from top to bottom and are directly exposed to sunlight.

7.3 Material: Generally, the polyesters retained their strength far better than nylon. The exception was the 4000 lb capacity nylon rope.

8. CONCLUSIONS BY THE WRIGHT AIR DEVELOPMENT CENTER ON "SUNLIGHT EXPOSURE TEST OF NYLON WEBBING" - TEST CONDUCTED DECEMBER 1954:

8.1 Olive drab color webbing has better ultraviolet resistance than natural colored webbing.

8.2 Strength retention of olive drab resin-treated webbing was superior to that of olive drab untreated webbing.

8.3 Resin-treated natural color webbing and natural color untreated webbing lost approximately the same amount of strength.

8.4 Latex-treated, olive drab color webbing lost more breaking strength at most exposure times than resin-treated olive drab color webbing.

9. OUTDOOR EXPOSURE TESTS - 1978-1980:

9.1 More recent tests, or trials, than those previously reported, were conducted in south England to compare the "weathering" of nylon and polyester braids and webbing.

9.1.1 Braid and webbing was manufactured by Bridport to their own or British, or both, specifications. Some MIL-W-4088 webbing was used in the tests.

9.1.2 The test samples were treated with different finishes to establish the amount of degradation occurring against the original strength of the material, and also to establish the efficiency of selected stitch patterns under the same conditions.

9.2 Test results indicate the natural or anti-abrasive treated polyester braid retains a greater proportion of its strength than its nylon equivalent (Fig. 6). Although dyeing of the braids causes an initial loss of strength to the nylon, both materials show a similar degradation after 30 months indicating that the dyeing of braid is more effective on nylon than on polyester in reducing the effect of UV degradation.

9.2.1 The amount of degradation appears to have a direct relation to the cross-section of the braid. Those braids with a larger cross-section retain less strength than the smaller braids of similar material.

- 9.2.2 Tests on webbing give similar results to those on braids. That is, the nylon degrades quicker than polyester. A direct comparison between two samples of webbing of different material with similar width and minimum breaking force and with an identical finish, showed an appreciable percentage strength increase in favor of the polyester sample over the test period.
- 9.2.3 Tests to establish the effects of stitching on the webbing confirm that the current stitch patterns and threads are satisfactory, and, although there is an expected loss of strength due to stitching, the loss differential remained constant throughout the tests.
10. TESTS TO ACCESS THE ENVIRONMENTAL DEGRADATION OF POLYPROPYLENE BRAID - 1986:
- 10.1 Twelve-month interim results from "weathering" trial in southern England of untreated polypropylene braid indicate a strength retention in excess of 80%. This is an improvement over the performance of both nylon and polyester braids of similar construction.
- 10.2 Polypropylene has been regarded as having a poor resistance to weathering, but recent advances in manufacturing technology have allowed the production of high tenacity yarns and improvements in UV stability.
- 10.3 Unlike polyester or nylon, there does not appear to be any correlation between braid cross-section (or initial strength) and retained strength.
- 10.4 Trials will continue to complete a 30-month test period in order to obtain a broader spectrum of "weathering."
- 10.5 Fig. 7 shows average percentage retained strengths for the four constructions tested over the interim trial period.
11. ENVIRONMENTAL CHARACTERISTICS OF KEVLAR (REGISTERED TRADEMARK):
- 11.1 Synthetic fabric or webbing marketed by Du Pont under the name "Kevlar" has been promoted for use in various aircraft structure applications where high strength-low yield characteristics are desired. It has been considered as an aircraft cargo container material and for certain netting applications, particularly barrier nets.
- 11.2 General conclusions from Du Pont published data.
- 11.2.1 Fabric woven from 380-denier yarn, 3 mm (0.11 in) thick, retained 51% strength after five weeks' exposure to Florida sunlight.
- 11.2.2 Three-strand rope, 13 mm (0.50 in) diameter, retained 69% strength after 24 months' exposure to Florida sunlight.
- 11.2.3 Since Kevlar is not dyeable, consideration should be given to a UV barrier integrated with the design application.
- 11.2.4 A comprehensive discussion of Kevlar's reaction to heat and various chemicals found in aircraft environment is generally favorable.

12. BIBLIOGRAPHY:

- 12.1 Comparative Chemical Resistance of Fibers, Bulletin X-48. E.I. DuPont de Nemours & Co., Textile Fibers Department, March 1956.
- 12.2 Comparative Heat Resistance of Fibers, Bulletin X-56. E.I. DuPont de Nemours & Co., Textile Fibers Department, September 1956.
- 12.3 Tensile Stress-Strain Properties of Fibers, Bulletin X-82. E.I. DuPont de Nemours & Co., Textile Fibers Department, May 1958.
- 12.4 Light Resistance of Industrial Fiber Products, Bulletin X-189. E.I. DuPont de Nemours & Co., Textile Fibers Department, April 1964.
- 12.5 A Contribution to the Research on the Aging of Textiles, Internal Report 1B152-75/15. German Research and Testing Institution for Aeronautics and Astronautics, Plastics Section, Braunschweig, West Germany, June 25, 1975.
- 12.6 Sunlight Exposure of Nylon Webbing, Technical Note WCRT 54-249; Wright Air Development Center, ARDC, United States Air Force, Wright-Patterson AFB, Ohio, December 1954.
- 12.7 Kevlar 49 Aramid, Data catalog, E.I. DuPont de Nemours & Co., Textile Fibers Department, Wilmington, Del. USA 1977.
- 12.8 Lifing Trials to Compare the Performances of Nylon & Polyester Braids & Webbing, Report BG 067, Bridport-Gundry, Ltd., Bridport, Dorset, England, May 1981.

TABLE I - Ultraviolet and Corrosive Atmosphere Tests

Webbing Description	Color	Control Sample Strength lbf (kg)	Strength in lbf (kg) after 450 Days Exposure	% Retention
Type 25 nylon resin treated	White	4540 (2064)	2000 ( 909)	44
Type 25 nylon resin treated	Olive	5120 (2327)	2800 (1273)	54
Type 25 nylon resin treated	Drab	5320 (2418)	2400 (1091)	45
Type 25 nylon resin treated	Blue	5100 (2318)	1960 ( 891)	38
Type 25 nylon resin treated	Red	4940 (2245)	2690 (1223)	54
Polyester Type 25 resin treated	Black	4700 (2136)	2860 (1300)	60
Polyester Type 25 resin treated	Blue	4700 (2136)	2500 (1136)	53
Polyester Type 25 resin treated	White	4500 (2045)	3080 (1400)	68
Type 17 nylon resin treated	Olive	3600 (1636)	1180 ( 536)	32
Type 17 nylon resin treated	Drab	3600 (1636)	1940 ( 882)	54
Type 17 nylon resin treated	Red	3130 (1423)	1230 ( 559)	39
Type 17 nylon resin treated	Black	3300 (1500)	1220 ( 555)	37
Type 17 nylon resin treated	Blue	3560 (1618)	1060 ( 482)	29
Polyester resin treated (spec)	White	3260 (1482)	1240 ( 564)	38
Polyester resin treated (spec)	Blue	2760 (1255)	1940 ( 882)	70
Polyester resin treated (spec)	Pink	2920 (1327)	1600 ( 727)	55
Nylon Type 18 resin treated	Olive	7040 (3200)	3300 (1500)	47
Nylon Type 18 resin treated	Drab	7000 (3182)	2000 ( 909)	28
Nylon Type 18 resin treated	White			

TABLE II - Ultraviolet and Corrosive Atmosphere Tests

Webbing Description	Color	Control Sample Strength lbf (kg)	Strength in lbf (kg) after 450 Days Exposure	% Retention
Type 13 nylon resin treated	Red	7800 ( 3545)	2700 ( 1227)	34
Type 13 nylon not treated	White	8440 ( 3836)	2220 ( 1009)	26
Type 13 nylon resin treated	Blue	8120 ( 3691)	3340 ( 1518)	41
Type 13 nylon resin treated	Olive Drab	8360 ( 3800)	4200 ( 1909)	50
Polyester 6,500 lb not treated rating	Red	6730 ( 3059)	4620 ( 2100)	68
Type 19 nylon resin treated	White	11 240 ( 5109)	5900 ( 2682)	52
Type 19 nylon resin treated	Olive Drab	11 600 ( 5273)	6800 ( 3091)	58
Type 26 nylon not treated	White	15 500 ( 7045)	5400 ( 2455)	35
X-581 nylon not treated	White	18 700 ( 8500)	8040 ( 3655)	43
Polyester, type 5 not treated	White	10 640 ( 4836)	7500 ( 3409)	70
Polyester, Type 6 Not treated	White	18 600 ( 8455)	12 500 ( 5682)	67
Bridport Gundry		2600	1500	58
Nylon braided rope	Yellow	( 1182)	( 682)	
Bridport Gundry		4000	3000	75
Nylon braided rope	Yellow	( 1818)	( 1364)	

TABLE III - Ultraviolet and Corrosive Atmosphere Tests  
Thread Tests

Description of Thread	Color	Control Sample Strength lbf (kg) <sup>1</sup>	Strength in lbf (kg) after 450 Days Exposure <sup>1</sup>	% Retention
Number 3 cord nylon	White	3390 (1541)	1560 <sup>2</sup> ( 709)	46
Number 3 cord nylon	Olive Drab	3790 (1723)	2160 <sup>3</sup> ( 982)	57
Number 3 cord polyester	White	3160 (1436)	1920 <sup>3</sup> ( 873)	60

<sup>1</sup>72 stitch sewing pattern  
3/4 in (19 mm) square

<sup>2</sup>Thread failure

<sup>3</sup>Webbing failure at stitching

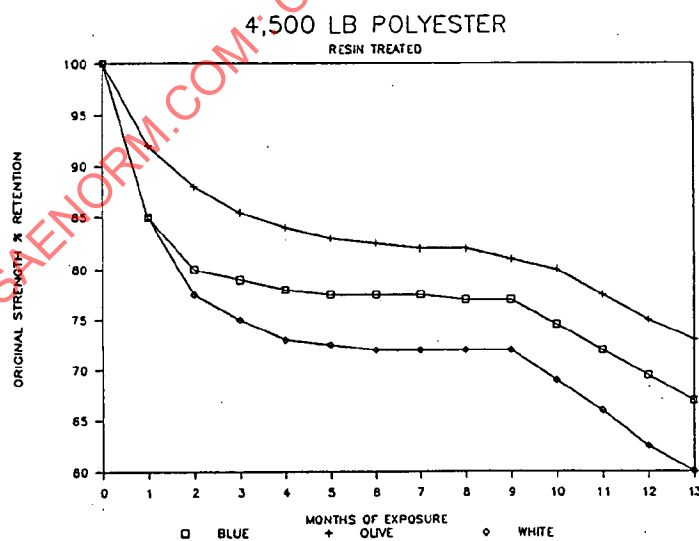
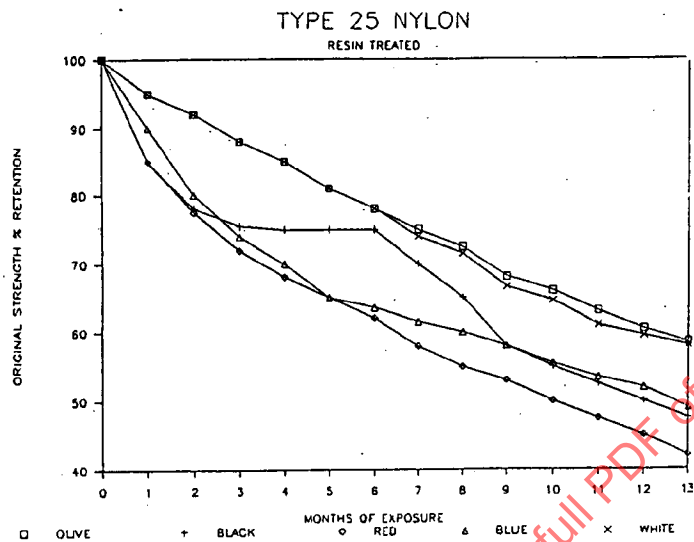


FIGURE 1

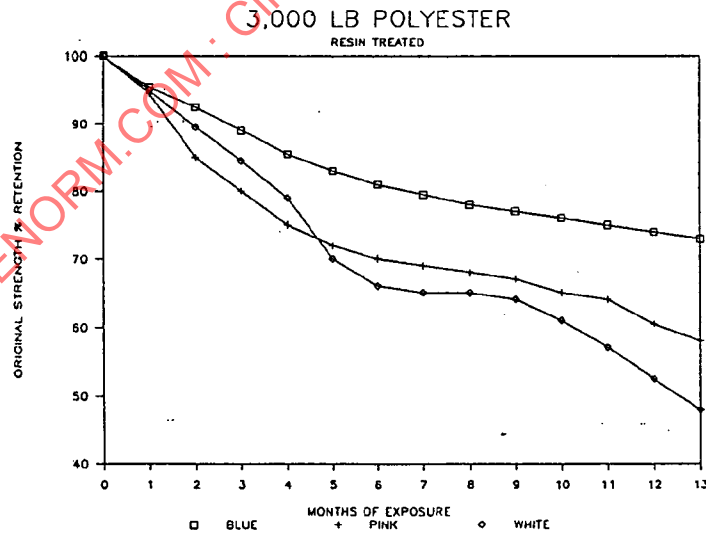
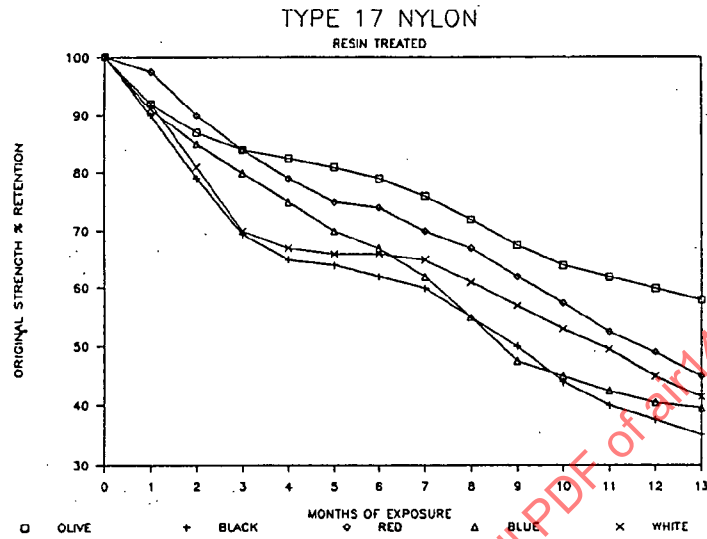


FIGURE 2

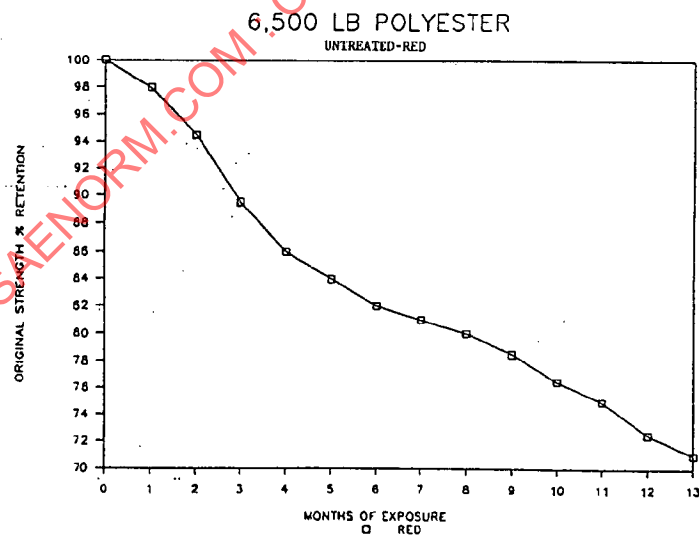
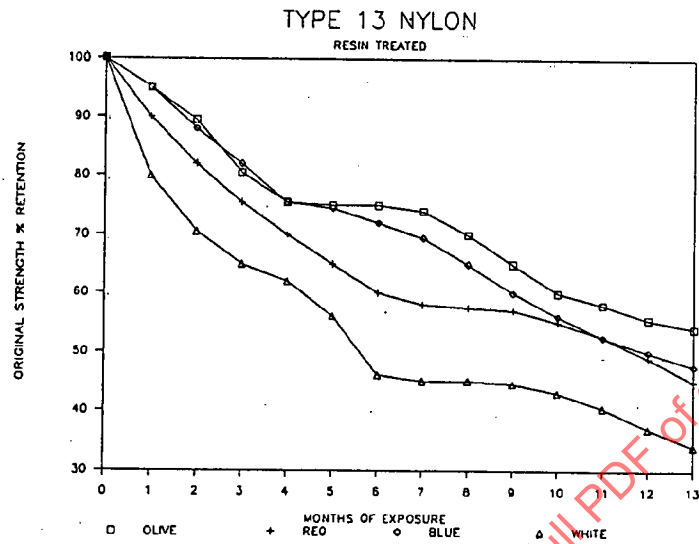


FIGURE 3