TECHNICAL REPORT

ISO/TR 8647

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1990-07-15

Environmental degradation of textiles used in air cargo restraint equipment

Dégradation en environnement des textiles utilisés dans les équipements de retenue du fret aérien

Reference number
ISO 8647 : 1990 (E)

Foreword

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— type 2, when the subject is still under technical development requiring wider exposure;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

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ISO/TR 8647, which is a technical report of type 3, was prepared by Technical Committee ISO/TC 20, *Aircarft and space vehicles.*

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INTRODUCTION

The lack of assembled information regarding deterioration of textiles used in air cargo equipment has become a matter of some concern. Typically, webbings or rope are used in pallet restraint nets, crash barrier net internal in aircraft, cargo retention straps, and other applications.

These textile products have a service life based on environmental factors. Knowledge of their susceptibility to environmental deterioration is essential. Data on the subject has been fragmented and not specifically applicable.

Cognizant Society of Engineers Committee AGE-2A, Aircraft Cargo Handling, sponsored a test program intended to provide more usable information directed to specific interests of the air cargo technical community. The first efforts have been expanded by others to include tests on newer materials coming into use.

Results of these tests are published along with abstracts and bibliographies of previously published data.

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Environmental degradation of textiles used in air cargo restraint equipment

1. SCOPE

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.

Since the ULD device containing textiles should have a predictable service life, there should be data available from which the 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

ISO 4115, Air cargo equipment - Air/land pallet nets.
ISO 4170, Air cargo equipment - Interline pallet nets.
IATA, Unit Load Devices (ULD) Technical Manual, available from: IATA, 2000 Peel St., Montreal, Canada H3A 2R4.

3. TYPES OF DEGRADATION

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

- The natural environment factors of light and heat including ultraviolet exposure.
- The atmospheric pollution from industrial emissions.
- Exposure to various destructive chemicals.
- 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

Du Pont tests and 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, (i.e., 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 of Thickness of Fiber Structure

The light resistance of a single filament or single fiber increases with denier, probably 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 semidull 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 (such as 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.

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 13mm (0.5 inch) 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, California

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, California, 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 hours 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 CONDITIONS

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 26,700 daN (60,000 lb.) 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 on Pages 11 through 17.

7.1 Color

Generally, the most weather resistant webbings were those which were dyed with darker colors such as olive drab.

7.2 Weave

Webbings 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 1779 daN (4,000 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 and/or British 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 occuring 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 indicates 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 Hitherto, polypropylene has been regarded as having a poor resistance to weathering, but recent advances in manufacturing technology have allowed the production of high tenacity and improvements in U.V. stability.

10.3 Unlike polyester or nylon, so far 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 Figure 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 Kevlar synthetic fabric or webbing has been promoted for use in various aircraft structures 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 wover from 380 denier year 3mm (0.11 inches) thick retained 51 percent strength after 5 weeks exposure to Florida sunlight.

11.2.2 Three strand rope, 13mm (0.50 inches) diameter retained 69 percent strength after 24 months exposure to Florida sunlight.

11.2.3 Since Kevlar is not dyeable, consideration should be given to a U.V. 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.

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

TABLE I

Description	Color	Control Sample Strength daN (lb)	Strength, daN(lb) after 450 Days Exposure	% Retention
Type 25 nylon, resin treated.	White	2,019 (4,540)	890 (2,000)	44
Type 25 nylon, resin treated.	Olive Drab	2,277 (5,120)	1,246 (2,800)	54
Type 25 nylon, resin treated.	Blue	2,366 (5,320)	1,068 (2,400)	45
Type 25 nylon, resin treated.	Red	2,269 (5,100)	872 (1,960)	38
Type 25 nylon, resin treated.	Black	2,197 (4,940)	1,197 (2,690)	54
Polyester Type 25 resin treated.	Blue	2,091 (4,700)	1,272 (2,860)	60
Polyester Type 25, resin treated.	White	2,091 (4,700)	1,112 (2,500)	53
Polyester Type 25, resin treated.	Olive Drab	2,002 (4,500)	1,370 (3,080)	68
Type 17 nylon, resin treated.	White	1,601 (3,600)	525 (1,180)	32
Type 17 nylon, resin treated.	Olive Drab	1,601 (3,600)	863 (1,940)	54
Type 17 nylon, resin treated.	Red	1,392 (3,130)	547 (1,230)	39
Type 17 nylon, resin treated.	Black	1,468 (3,300)	543 (1,220)	37
Type 17 nylon, resin treated.	Blue	1,584 (3,560)	472 (1,060)	29
Polyester, resin treated(spec)	White	1,450 (3,260)	552 (1,240)	38
Polyester, resin treated(spec)	Blue	1,228 (2,760)	863 (1,940)	70
Polyester, resin treated(spec)	Pink	1,299 (2,920)	712 (1,600)	55
Nylon Type 18, resin treated.	Olive Drab	3,132 (7,040)	1,468 (3,300)	47
Nylon Type 18, resin treated.	White	3,114 (7,000)	890 (2,000)	28

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

TABLE II

Webbing Description	Color	Control Sample Strength daN (lb)	Strength, daN(lb) after 450 Days Exposure	% Retention
Type 13 nylon, resin treated.	Red	3,470 (7,800)	1,201 (2,700)	34
Type 13 nylon, not treated.	White	3,754 (8,440)	979 (2,200)	26
Type 13 nylon, resin treated.	Blue	3,612 (8,120)	1,486 (3,340)	41
Type 13 nylon, resin treated.	Olive Drab	3,719 (8,360)	1,868 (4,200)	50
Polyester,untreat-ed 2,900 daN rating	Red	2,994 (6,730	2,055 (4,620)	68
Type 19 nylon, resin treated.	White	5,000 (11,240)	2,624 (5,900)	52
Type 19 nylon, resin treated.	Olive Drab	5,160 (11,600)	3,025 (6,800)	58
Type 26 nylon, not treated.	White	6,895 (15,500)	2,402 (5,400)	35
X-581 nylon, not treated.	White	8,318 (18,700)	3,576 (8,040)	43
Polyester, Type 5, not treated.	White	4,733 (10,640)	3,336 (7,500)	70
Polyester, Type 6, not treated.	White	8,274 (18,600)	5,560 (12,500	67
Bridport Gundry nylon braided rope.	Yellow	1,157 (2,600)	667 (1,500)	58
Bridport Gundry nylon braided rope	Yellow	1,779 (4,000)	1,334 (3,000)	75

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

TABLE III

THREAD TESTS

Description Of Thread	Color	Control Sample Strength [1] daN(lb)	Strength in daN(lb) after 450 Days [1] Exposure	% Retention
Number 3 cord, nylon.	White	1,508 (3,390)	694 (1,560) [2]	46
Number 3 cord, nylon.	Olive Drab	1,673 (3,760)	961 (2,160) [3]	57
Number 3 cord, polyester.	White	1,406 (3,160)	854 (1,920) [3]	60

NOTE:

[1] 72 stitch sewing pattern, 19mm (0.75 in.) square.

[2] Thread failure

[3] Webbing failure at stitching

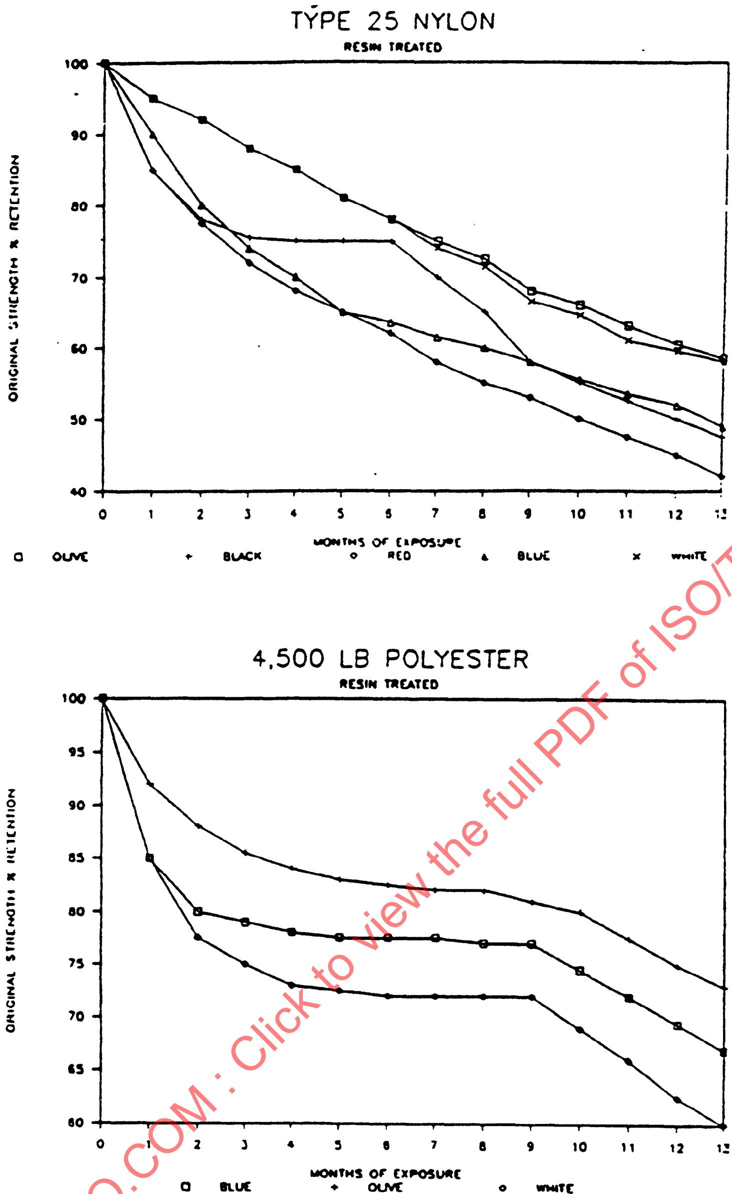
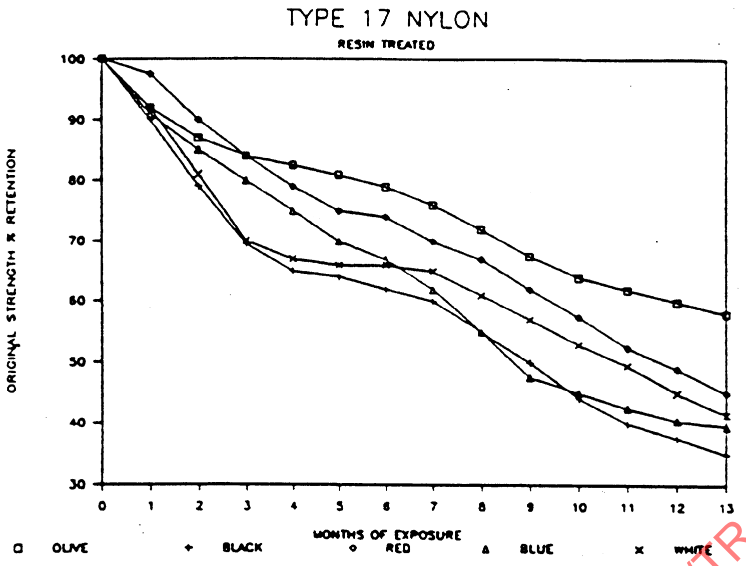
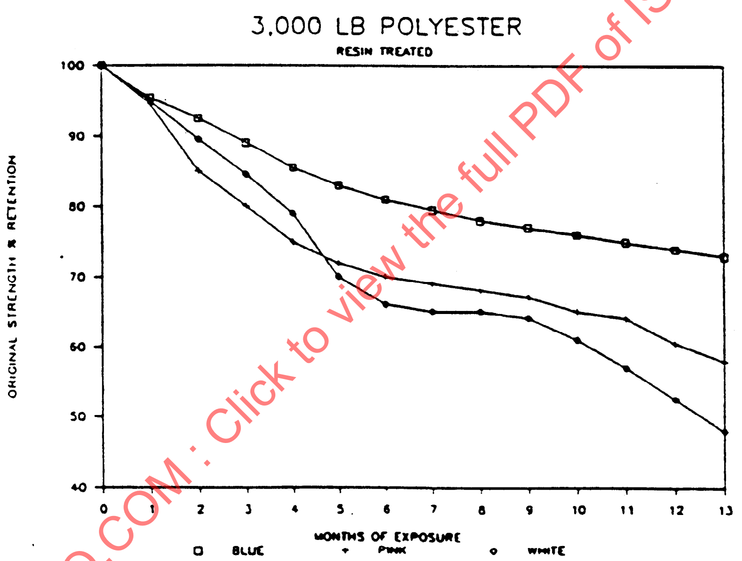

TYPE 25 NYLON
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
90
80
70
60
50
40
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
OLIVE
BLACK
RED
BLUE
WHITE
4,500 LB POLYESTER
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
95
90
85
80
75
70
65
60
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
BLUE
OLIVE
WHITE

Figure 1.

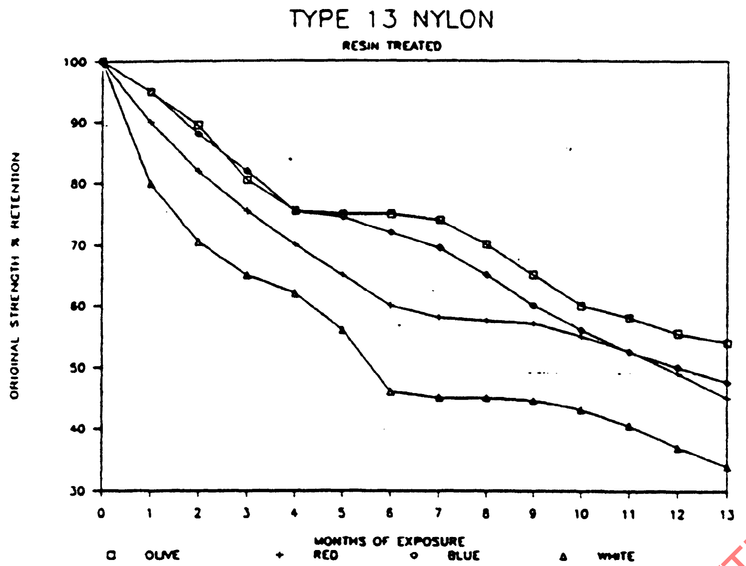


TYPE 17 NYLON
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
90
80
70
60
50
40
30
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
OLIVE
BLACK
RED
BLUE
WHITE



3,000 LB POLYESTER
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
90
80
70
60
50
40
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
BLUE
PINK
WHITE

Figure 2.


TYPE 13 NYLON
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
90
80
70
60
50
40
30
0
1
2
3
4
5
6
7
8
9
10
11
12
13
MONTHS OF EXPOSURE
OLIVE
RED
BLUE
WHITE

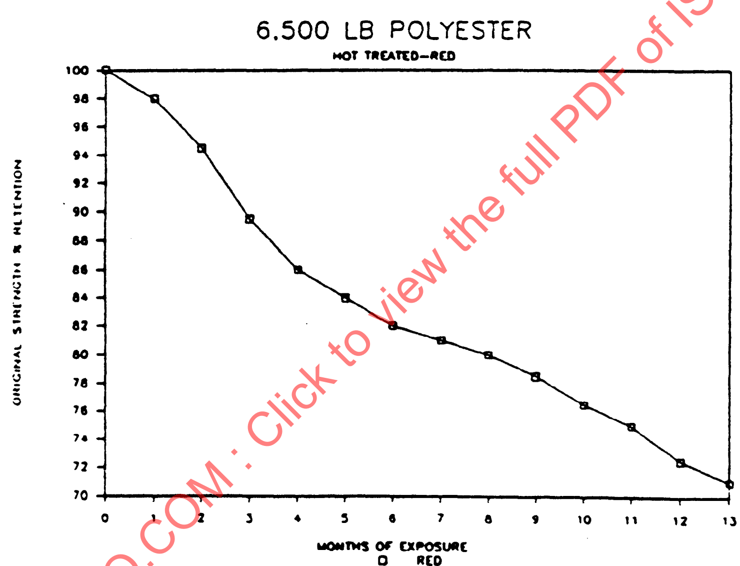

6.500 LB POLYESTER
HOT TREATED–RED
ORIGINAL STRENGTH % RETENTION
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
0
1
2
3
4
5
6
7
8
9
10
11
12
13
MONTHS OF EXPOSURE
RED

Figure 3.

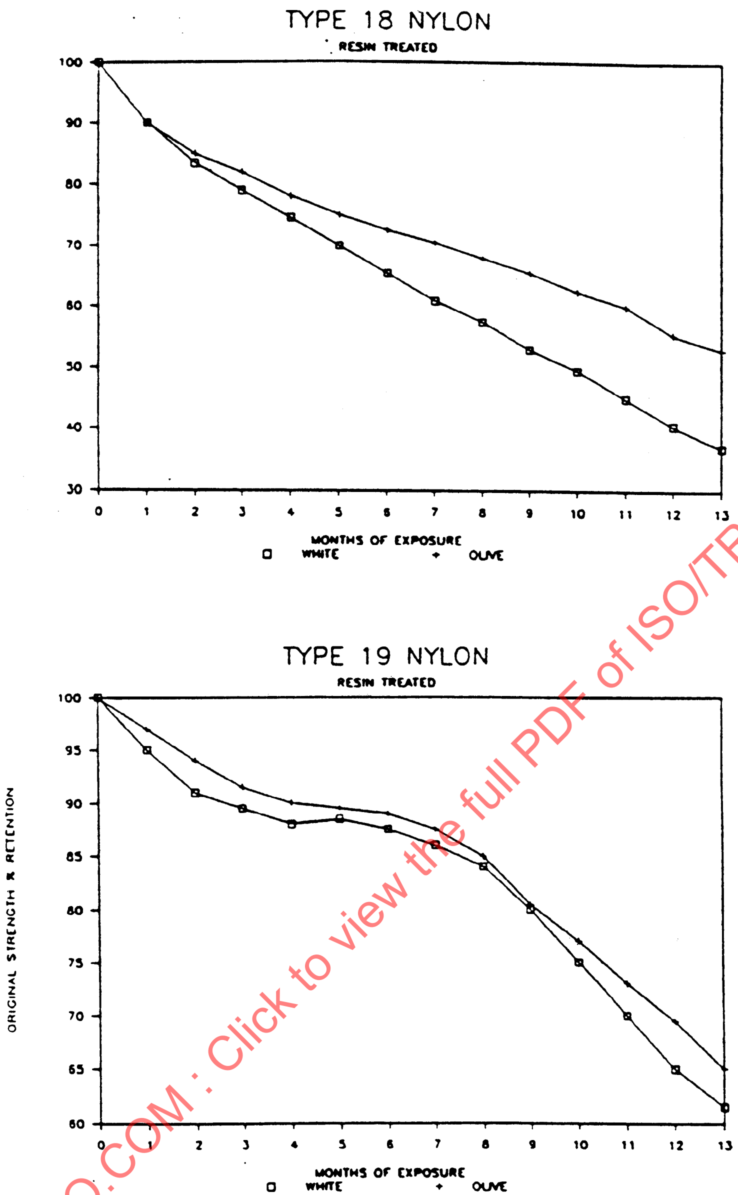
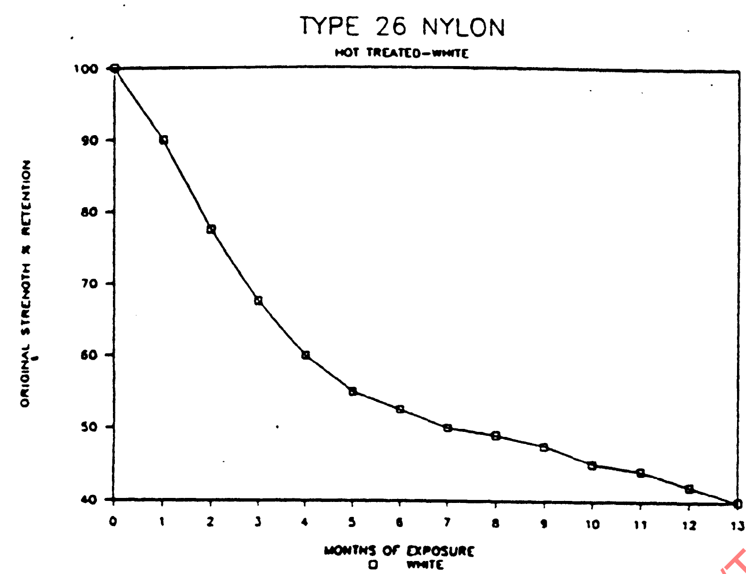

TYPE 18 NYLON
RESIN TREATED
100
90
80
70
60
50
40
30
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
WHITE
OLIVE
TYPE 19 NYLON
RESIN TREATED
ORIGINAL STRENGTH % RETENTION
100
95
90
85
80
75
70
65
60
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
WHITE
OLIVE

Figure 4.


TYPE 26 NYLON
HOT TREATED–WHITE
ORIGINAL STRENGTH % RETENTION
100
90
80
70
60
50
40
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
WHITE

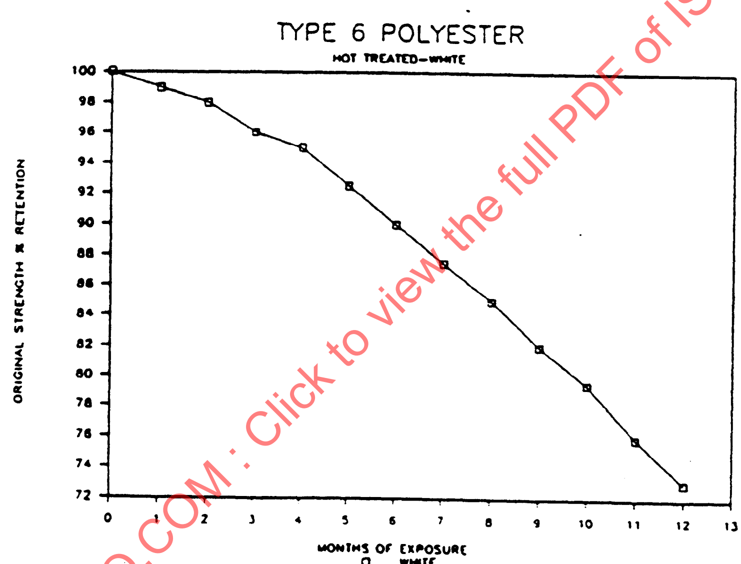
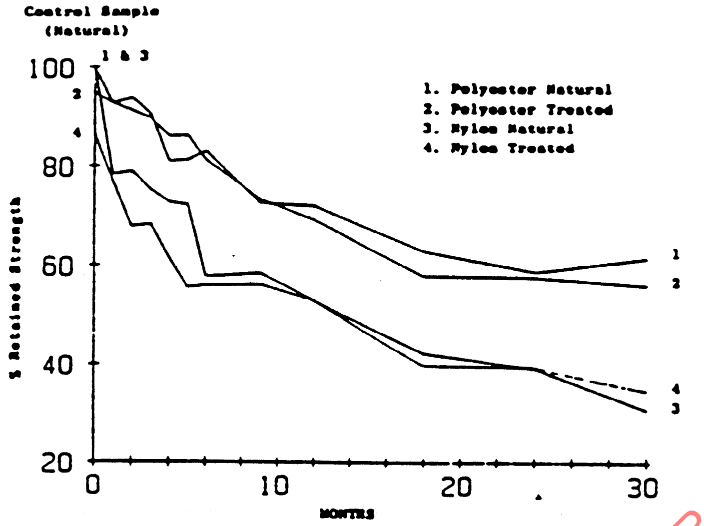

TYPE 6 POLYESTER
HOT TREATED–WHITE
ORIGINAL STRENGTH % RETENTION
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
0 1 2 3 4 5 6 7 8 9 10 11 12 13
MONTHS OF EXPOSURE
WHITE

Figure 5.


Control Sample
(Natural)
1 & 3
2
4
100
80
60
40
20
0
10
20
30
% Retained Strength
MONTHS
1. Polyester Natural
2. Polyester Treated
3. Nylon Natural
4. Nylon Treated
1
2
4
3

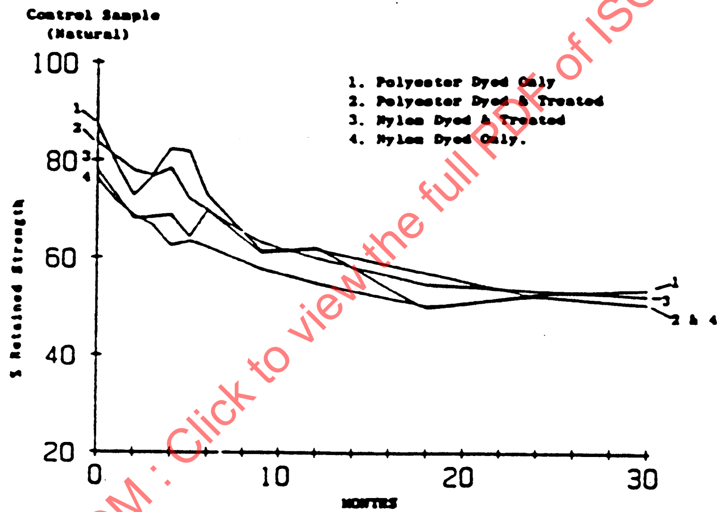

Control Sample
(Natural)
100
80
60
40
20
0
10
20
30
% Retained Strength
MONTHS
1. Polyester Dyed Only
2. Polyester Dyed & Treated
3. Nylon Dyed & Treated
4. Nylon Dyed Only.
1
2
3
4
1
3
2 & 4

Figure 6.