AEROSPACE INFORMATION REPORT
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ENVIRONMENTAL DEGRADATION OF TEXTILES USED IN AIR CARGO RESTRAINT EQUIPMENT

1. PURPOSE

This Report determines the loss and breaking strength of nylon and polyester webbings and rope after continuous exposure to the out-of-doors environment and sunlight in Torrance, California. Also it is desired to obtain residual comparative strengths' data on nylon and polyester webbings of various colors, treatments, and weaves to be used in establishing cargo net service life and design criteria.

2. INTRODUCTION

Of concern in recent years is the degradation of textiles used in air cargo equipment. These textiles are generally in the form of webbings or rope from which restraint nets, pallet nets, and straps are made for the purpose of securing or restraining in position cargo to prevent it from becoming missile under emergency flight conditions.

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

2.1 The natural environment factors of light and heat including ultraviolet exposure.

2.2 Atmospheric pollution from industrial emissions.

2.3 Exposure to various destructive chemicals.

2.4 Washing powders and soaps and immersion in salt water.

Insufficient information exists from which to draw conclusions regarding the aging or degradation of the synthetic materials used in air cargo equipment; it now seems necessary to accumulate this data in order to establish design factors and allowances which will compensate for a reasonable period or the eventual deterioration. From these design factors the goal is to establish service life and design criteria. It is hoped that the information presented will contribute to this objective.

3. DISCUSSION

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.

3.1 <u>Influence of Wave Length</u>: 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.

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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.

3.2 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:

3.2.1 Geographical location of the 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 the fibers.

3.2.2 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.

3.2.3 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.

3.2.4 Size or 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.

3.2.5 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.

3.2.6 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 of 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 1/2 in. (12.7 mm) 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.

4. OUTDOOR EXPOSURE TEST

4.1 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.

4.2 Exposure Conditions:

4.2.1 Geographical location: United States of America, Torrance, California.

4.2.2 Season of year: May 22, 1975 to August 22, 1976 (15 months).

4.2.3 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.

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

4.2.5 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 AM. About 4% of the days experienced rain. And about 7% of the days were mostly or completely overcast.

5. TEST CONDITION

5.1 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.

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

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

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

6. 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 8 through 17.

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

6.2 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.

6.3 Material: Generally, the polyesters retained their strength far better than nylon. The exception was the 4,000 lb capacity nylon rope.

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

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

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

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

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

NOTE: Except for Item D, for which there is no test data available, the conducted tests support the conclusions listed above.

PREPARED BY:

SAE COMMITTEE AGE-2, CIVIL AIRCRAFT GROUND SUPPORT EQUIPMENT

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

TABLE I

Webbing Description	Color	Control Sample Strength lb (kg)	Strength in lb (kg) after 450 Days Exposure	% Retention
Type 25 nylon resin treated	White	4,540 (2,064)	2,000 (909)	44
Type 25 nylon resin treated	Olive Drab	5,120 (2,327)	2,800 (1,273)	54
Type 25 nylon resin treated	Blue	5,320 (2,418)	2,400 (1,091)	45
Type 25 nylon resin treated	Red	5,100 (2,318)	1,960 (891)	38
Type 25 nylon resin treated	Black	4,940 (2,245)	2,690 (1,223)	54
Polyester Type 25 resin treated	Blue	4,700 (2,136)	2,860 (1,300)	60
Polyester Type 25 resin treated	White	4,700 (2,136)	2,500 (1,136)	53
Polyester Type 25 resin treated	Olive Drab	4,500 (2,045)	3,080 (1,400)	68
Type 17 nylon resin treated	White	3,600 (1,636)	1,180 (536)	32
Type 17 nylon resin treated	Olive Drab	3,600 (1,636)	1,940 (882)	54
Type 17 nylon resin treated	Red	3,130 (1,423)	1,230 (559)	39
Type 17 nylon resin treated	Black	3,300 (1,500)	1,220 (555)	37
Type 17 nylon resin treated	Blue	3,560 (1,618)	1,060 (482)	29
Polyester resin treated (spec)	White	3,260 (1,482)	1,240 (564)	38
Polyester resin treated (spec)	Blue	2,760 (1,255)	1,940 (882)	70
Polyester resin treated (spec)	Pink	2,920 (1,327)	1,600 (727)	55
Nylon Type 18 resin treated	Olive Drab	7,040 (3,200)	3,300 (1,500)	47
Nylon Type 18 resin treated	White	7,000 (3,182)	2,000 (909)	28

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

TABLE II

Webbing Description	Color	Control Sample Strength lb (kg)	Strength in lb (kg) after 450 Days Exposure	% Retention
Type 13 nylon resin treated	Red	7,800 (3,545)	2,700 (1,227)	34
Type 13 nylon not treated	White	8,440 (3,836)	2,220 (1,009)	26
Type 13 nylon resin treated	Blue	8,120 (3,691)	3,340 (1,518)	41
Type 13 nylon resin treated	Olive Drab	8,360 (3,800)	4,200 (1,909)	50
Polyester 6,500 lb. not treated rating	Red	6,730 (3,059)	4,620 (2,100)	68
Type 19 nylon resin treated	White	11,240 (5,109)	5,900 (2,682)	52
Type 19 nylon resin treated	Olive Drab	11,600 (5,273)	6,800 (3,091)	58
Type 26 nylon not treated	White	15,500 (7,045)	5,400 (2,455)	35
X-581 nylon not treated	White	18,700 (8,500)	8,040 (3,655)	43
Polyester, type 5 not treated	White	10,640 (4,836)	7,500 (3,409)	70
Polyester, Type 6 Not treated	White	18,600 (8,455)	12,500 (5,682)	67
Bridport Gundry Nylon braided rope	Yellow	2,600 (1,182)	1,500 (682)	58
Bridport Gundry Nylon braided rope	Yellow	4,000 (1,818)	3,000 (1,364)	75

ULTRAVIOLET AND CORROSIVE ATMOSPHERE TESTS

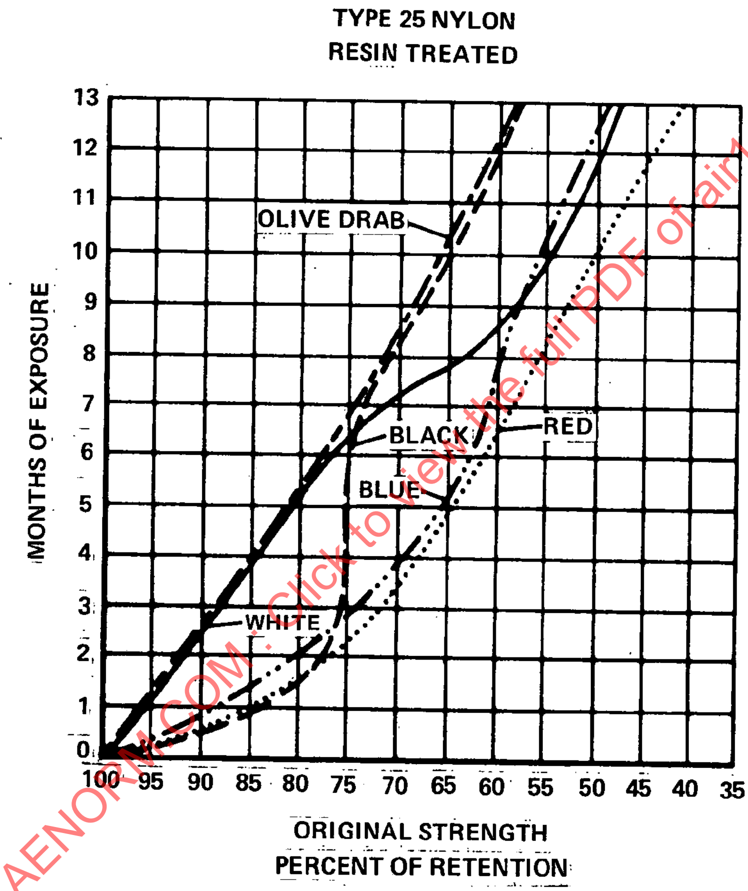
TABLE III
THREAD TESTS

Description of Thread	Color	Control Sample Strength lb (kg) 1	Strength in lb (kg) after 450 Days Exposure 1		% Retention
Number 3 cord nylon	White	3,390 (1,541)	1,560 (709)	2	46
Number 3 cord nylon	Olive Drab	3,790 (1,723)	2,160 (982)	3	57
Number 3 cord polyester	White	3,160 (1,436)	1,920 (873)	3	60

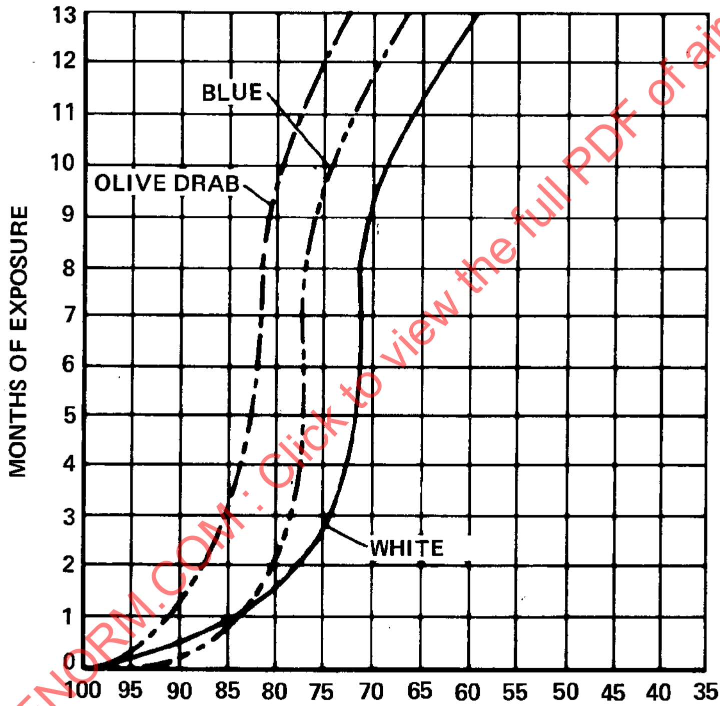
1 NOTE: 72 stitch sewing pattern
3/4 in. (19 mm) square

2 Thread failure

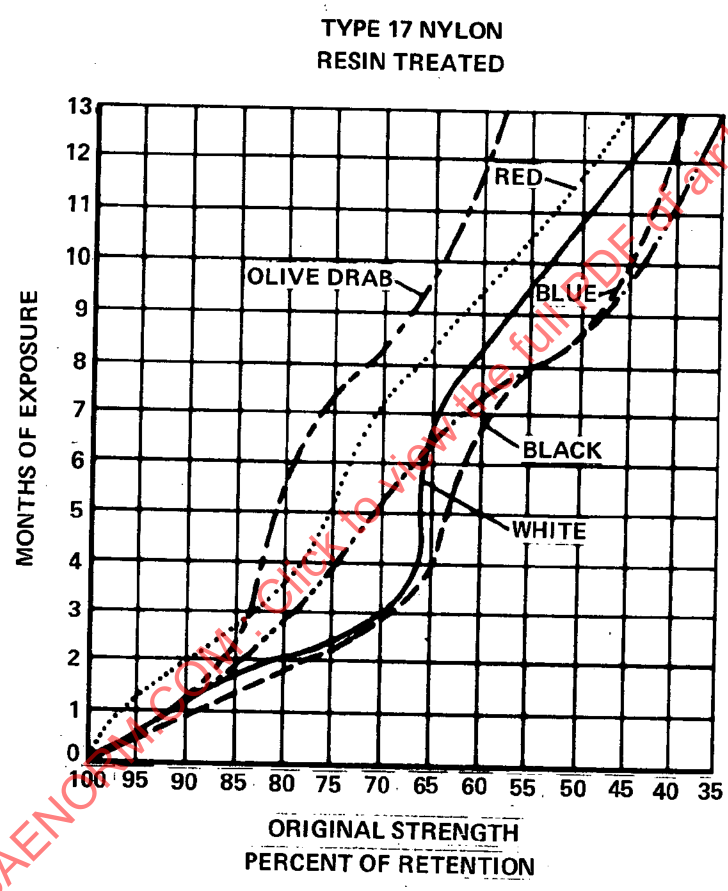
3 Webbing failure at stitching

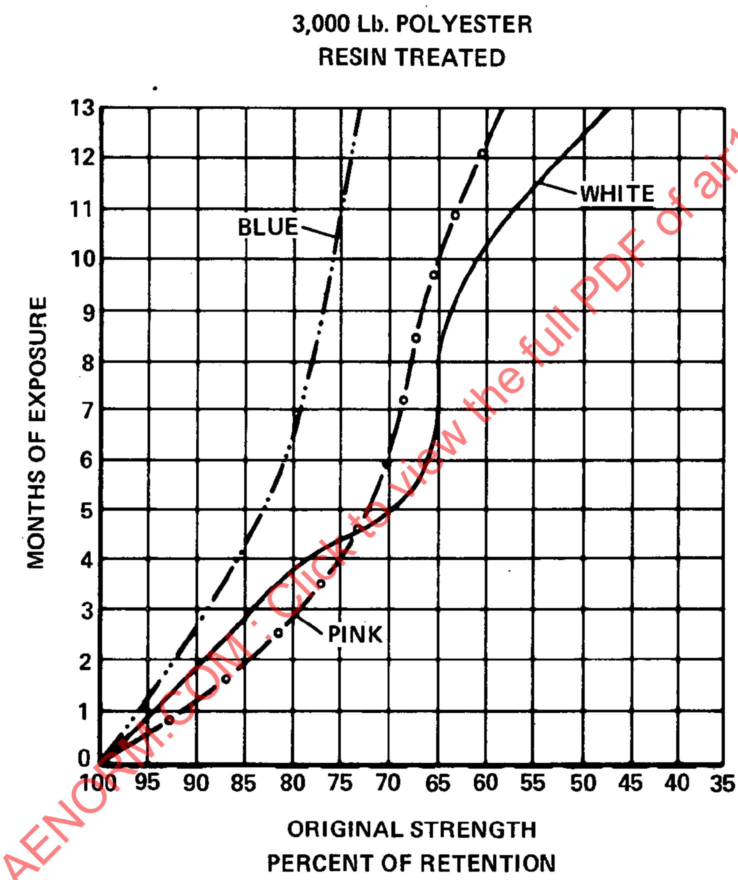

TYPE 25 NYLON
RESIN TREATED
MONTHS OF EXPOSURE
13
12
11
10
9
8
7
6
5
4
3
2
1
0
OLIVE DRAB
BLACK
RED
BLUE
WHITE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
ORIGINAL STRENGTH
PERCENT OF RETENTION

4,500 Lb. POLYESTER
RESIN TREATED



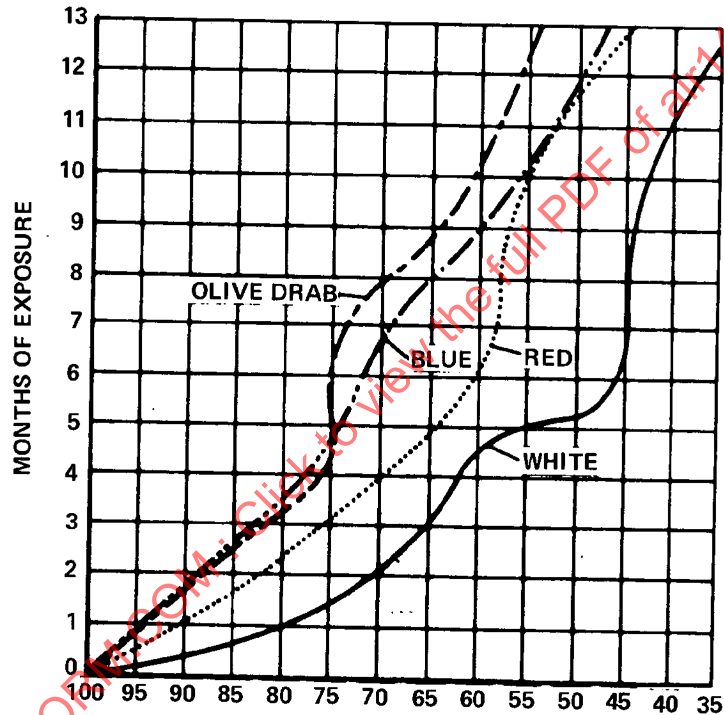
ORIGINAL STRENGTH
PERCENT OF RETENTION


TYPE 17 NYLON
RESIN TREATED
MONTHS OF EXPOSURE
13
12
11
10
9
8
7
6
5
4
3
2
1
0
RED
OLIVE DRAB
BLUE
BLACK
WHITE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
ORIGINAL STRENGTH
PERCENT OF RETENTION

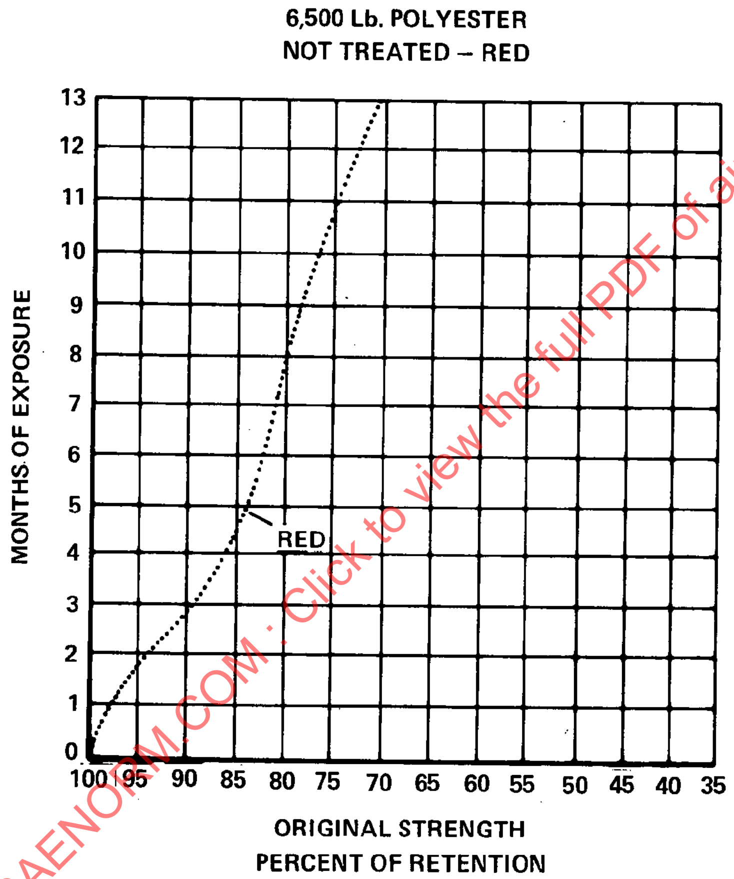


3,000 Lb. POLYESTER
RESIN TREATED
MONTHS OF EXPOSURE
13
12
11
10
9
8
7
6
5
4
3
2
1
0
BLUE
WHITE
PINK
100
95
90
85
80
75
70
65
60
55
50
45
40
35
ORIGINAL STRENGTH
PERCENT OF RETENTION

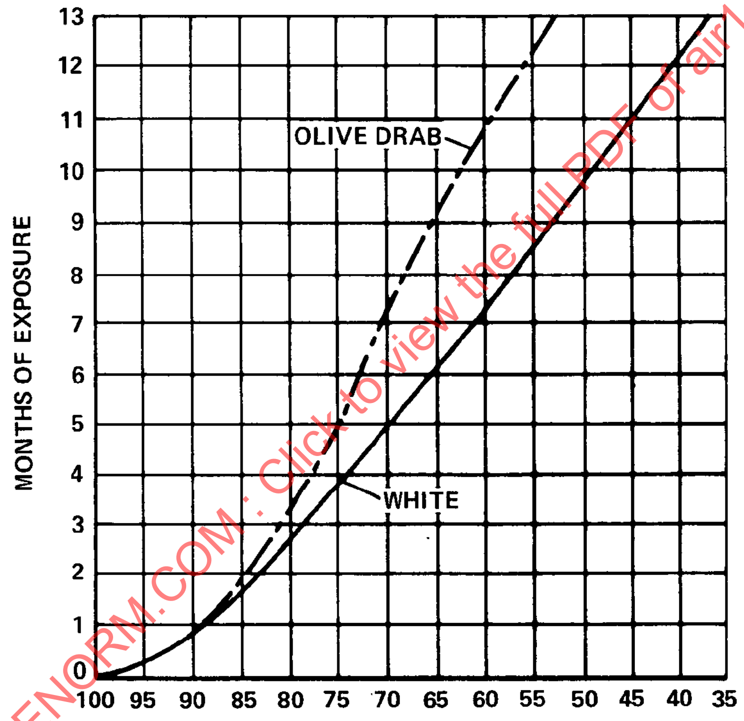
TYPE 13 NYLON
RESIN TREATED



ORIGINAL STRENGTH
PERCENT OF RETENTION


6,500 Lb. POLYESTER
NOT TREATED – RED
MONTHS OF EXPOSURE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
RED
100
95
90
85
80
75
70
65
60
55
50
45
40
35
ORIGINAL STRENGTH
PERCENT OF RETENTION

TYPE 18 NYLON
RESIN TREATED



ORIGINAL STRENGTH
PERCENT OF RETENTION