HT-1 FIBROUS STRUCTURES

by

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During the past decade the tremendous upward trends in speed, range, and ceiling of aircraft and missiles has accentuated the limitations of current fibrous materials. The nuclear type weapon has revolutionized many traditional concepts of strategic, tactical, and defensive warfare. This revolution has changed the fundamental approach toward the development of many existing, and new fibrous materials for military use.

Quantitative superiority of materials won the last war. This method was expensive; however, it did save the United States and her allies from an ignominious defeat. Neither quantity of weapons or personnel can assure this nation's survival in any future war. However to match man for man, weapon for weapon, equipment for equipment with other countries would ruin the United States economically. Economic defeat could be as disastrous as defeat through failure at arms, especially air arms.

Today's weapons and materials of superior quality are an absolute necessity for the Air Force. Not only must we have qualitative superiority, but we must maintain this qualitative superiority for an indefinite period of time.

Under these prevailing conditions the following responsibilities were given to the Air Force System Command:

a. To attain and maintain qualitative superiority of materials.
b. To conduct or supervise the scientific and technical research required for the accomplishment of the Air Force mission.
c. To seek new basic knowledge from which improved aeronautical equipment, materials, weapons, and techniques can be developed.
d. To undertake the development and recommend the adoption of new and improved materials, devices, and systems.

Under the Air Force System Command, the Fibrous Materials Branch of the Nonmetallic Materials Laboratory in the Directorate of Materials and Processes (Materials Central) has the responsibility of conducting research on fibrous materials which are capable of functioning satisfactorily in aerodynamic decelerators, in expandable, and in rigidized structures.

A quick look at the state-of-the-art in Fiber Technology reveals commercially available synthetic fibers and materials which have already become marginal, due principally to the rigorous environments encountered by Air Force usage. A temporary solution to this problem may be accomplished by refinements to these synthetic materials; however, these materials are still limited by their own physical and chemical properties which are melting point, strength at elevated temperature, etc.

To attain the maximum design and performance of a fabricated article requires familiarity with the characteristics and properties of the materials employed. There is keen appreciation of these facts evidenced by new and improved materials and processes throughout the industry. As long as fibrous materials are used as structural members they must necessarily be subjected to the same careful scrutiny as other structural materials with regard to their design and performance.

The performance of fibrous materials, when subjected to stresses and strains depends on many factors. Prior to the development of a successful decelerator (or other application), the characteristics and chemical and physical properties of the materials should be known. A specific requirement for a material that will be used under certain conditions could lead to the development of a new material or the development of a new fiber, and could on the other hand suggest a new goal to the end-item designer. The question of suitability of a fibrous material for use in connection with personnel and equipment is limited not only by the consideration of utility and performance but also by the quantity available and the source of supply. This fact was forced on us during the early stages of World War II when our supply of silk for parachutes was no longer available and new substitute materials or sources had to be found.

Due to the efforts of Mr. Charles Cleary, formerly of the Materials Laboratory and now deceased, a then new synthetic fiber, called nylon, developed by E. I. du Pont de Nemours & Company, Inc., was brought into use for personnel and equipment items. From these early stages in the development of nylon for Air Force use (when specifications were single page documents) nylon has been the main stay of fibrous materials. However, we have increased our knowledge and capabilities for the use of it, and the use of other synthetic fibers. Again, not war, but the rapid advances in technology have necessitated requirements for materials that are much too strenuous for nylon, especially in high temperature areas.

Industry has been long aware of the need for an industrial fiber with good high temperature characteristics. Since 1933 when nylon got its name, three more fibers have been produced from the same du Pont Laboratory in which in 1928 Dr. Wallace H. Carrothers learned why certain molecules unite to form "giant" molecules or polymers which could be synthesized into thin strands or fibers having many properties of textiles. These fibers are known as Orlan acrylic, Dacron polyester, and HT-1. It is the latter, HT-1 which interests us in this paper, because of its outstanding characteristics to perform some of the jobs that nylon can no longer perform due to its physical and chemical limitations.

The first HT-1 experimental yarn samples for military evaluation were supplied to Wright Air Development Center in March 1958. The general properties of HT-1 fiber are : (1) its color is a creamy white to silver white with a high luster, (2) its tenacity is 5.8 to 5.9 grams/denier, (3) its elongation at rupture is 12 to 16 per cent, (4) its initial modulus is 158 grams/denier, (5) its chemical resistance to common acids and solvents is greater than nylon and Dacron, (6) its ignition is slow when placed in direct flame, and it is self-extinguishable upon removal from the flame, (7) it will not drip, melt or fuse together, (8) and lastly but most important, it retains over 50 per cent of its original room temperature tenacity at 550°F after 16 hours of oven aging.

Higher operational temperatures are closely associated with the advances in aeronautics and astronautics; therefore, HT-1 is rapidly gaining importance due to the severity of thermal environments and as the capabilities of other conventional synthetic fibrous materials are surpassed. To fill this critical materials' gap, research was conducted on HT-1 for its characteristics and behavior under environmental conditions similar to those anticipated in the earth's atmosphere and in space.

The greatest limitation of materials is the ability to function properly with reliability after heat soaking for extended periods of time. Figures 1 and 2 indicate some of the principal advantages of HT-1 over other natural and synthetic fibers like cotton and nylon. Oven-aging the fiber HT-1 for 8 and 16 hours at 400°F reveals that it lost very little strength, 4 and 13 per cent respectively. Evaluation while at 400°F shows HT-1 retained 71 per cent of its original room tenacity. At 600°F for 8 and 16 hours, the aged fiber loses 41 and 63 per cent of its room tenacity. Breaking HT-1 while at the elevated temperature of 600°F shows that it retains 43 per cent of its original strength. The temperature range of 500-575°F should be remembered as the point where HT-1's strength falls below 50 per cent when it is not protected by a coating of some type.

The degree of damage done by ultraviolet radiation is shown on figures 3 and 4. Two time increments only are shown between 0 and 50 hours exposure. For the first 8 hours the fiber can be expected to degrade at a rate of 1 per cent per exposure hour; thereafter, it will lose strength at the rate of 3/4 per cent per exposure hour up to 50 hours exposure.

Information is also needed on combinations of environments expected in the earth's atmosphere. Figures 1 through 4 present research data on various environmental conditions and listed below are generalized conclusions from this data:

1. Exposure of HT-1 to gamma radiation at room temperature does not effect its tenacity.
2. Subsequent heating of HT-1 after exposure to gamma radiation at room temperature indicated that combining the two conditions may improve its overall tenacity.
3. Proper cross-linking of the molecules by heat and gamma radiation simultaneously, will enhance HT-1 resistance to temperature degradation.
4. Subsequent heating after exposure to ultraviolet radiation, and evaluation at room or elevated temperatures increases the amount of degradation.

We have learned much about the evaluation of synthetic materials in the twenty odd years since the development of nylon and its initial uses in Air Force personnel and equipment items, and this knowledge is useful when evaluating a new fibrous material. Before a new material can be completely evaluated, the yarns or fibers have to be woven into structures such as fabric, tapes and webbings, and these structures in turn fabricated into experimental end items to prove their acceptability and reliability. One of the many phases of evaluation of a new material is the characterization of strength retention or amount of degradation that the material can withstand after exposure to various environments.

Concurrent with the HT-1 fiber investigation, structures (fabrics, webbings and tapes) were woven so that they might also be evaluated. We will not attempt to present data on all of these materials, however, the data presented will be representative. In all, four fabrics, three cords and twelve webbings, ribbons, and tapes were evaluated. For the purpose of this paper, two fabrics, one cord and two tapes will be discussed. All materials were subjected to outdoor weathering, accelerated aging and thermal exposure of 400°F, 500°F and 600°F.

Outdoor weathering exposures were made at the Naval Auxiliary Air Station, El Centro, California during the months of January and February 1962. The samples were exposed for periods of one, two, three, four, five and six weeks on racks placed at an approximate 45 degree angle on the roof of a flat (roofed) building. Figure 5 shows the amount of strength retained after each exposure period. (Fabrics were woven to meet general requirements of specifications Mil-C-7350, Type I and Mil-C-8021, Type I). The Mil-C-8021 fabric, woven of 200 denier yarns, broke down at a much slower rate than did the Mil-C-7350, Type I, which is woven of 100 denier yarns, and at the end of the six weeks exposure period retained approximately 60% of its original strength. The Mil-C-7350, Type I fabric retained approximately 30% of its original strength. Figure 6 indicates that both the tapes, Mil-T-5038, 1-inch and Mil-T-5625, 9/16-inch and the Mil-C-5040, Type III cord, all retain a high percentage of strength. Since these exposures were made during the winter months, a second series of HT-1 fabric and the equivalent nylon fabric were exposed in July and August 1962 in order to determine how much variation there would be for the two exposure periods and also for the purpose of comparing the degree of ultraviolet degradation of HT-1 with nylon. This data is not yet available, however it is anticipated that there will be a much greater rate of breakdown for the samples exposed during the summer months, since the average number of langleys ($gms/cal/cm^2$) per day is approximately 600 for summer exposures and 300 for winter exposures. (Complete data will be presented in a future ASD Technical Documentary Report).

Accelerated aging exposures were made for periods of twenty, forty, sixty, eighty, one hundred, and one hundred and fifty hours in an accelerated weathering unit, Type X1A using sunshine carbon arcs and no water spray. Figures 7 and 8 show the degree of breakdown for all the samples. Here again, the two tapes and the cord retain a high percentage of strength while the strength retained by the fabrics after 150 hours is about the same as after 6 weeks outdoor exposure. Figures 9 and 10 show a comparison of strength retention after outdoor exposure and accelerated weathering of Types 300 and 330 nylon against the HT-1 fabrics. It should be noted that the 330 type nylon is an ultraviolet resistant type nylon. The nylons were woven in accordance with Mil-C-7020, Type I and the outdoor exposures were made in July and August 1959.

The third series of exposures was to heat. Exposures were made in controlled high temperature ovens at temperatures of 400°F, 500°F and 600°F for periods of 1 1/2, 3, 6, 12 and 24 hours. Data are for fabrics only. Figures 11 and 12 show these results.

Figure 13 gives a comparison of fiber, fabric and tape strength retention after weatherometer exposure (up to 60 hrs). The pattern of breakdown for the fabric and fiber indicates a fairly definite trend in that there is a rapid and steady loss of strength, while the tape which is a thicker and heavier material breaks down at a much slower rate. In comparing fabrics and fiber after exposure to elevated temperatures (Fig. 14) it should be noted that there is little or no correlation in per cent strength retained after exposure to 400°F up until the 24 hour period when they seem to reach a common grouping. There is no explanation that can be given at this time for the high percentage of strength loss for the Mil-C-8021, Type I fabric, after exposure to 600°F.

It would appear that some of the results just presented are erratic, however, in HT-1 this seems to be the normal rather than the unusual, and until further evaluation has been completed no conclusions will be made. There has been little attempt to do more than offer general information regarding the effects of varying exposure conditions on HT-1 or to offer requirements for use and application. The evaluation of HT-1 materials in the future will include impact studies of tapes and webbings, and air permeability data for fabrics over a range of pressures. There is nothing particularly involved about evaluating HT-1, either fiber or structure, and the design of end items can be accomplished providing sufficient study and effort are made. A knowledge of the basic fiber, design of woven structures, laboratory control, and evaluation of specific end items under field conditions are all essential parts of proving the capability of a new fibrous material. From the standpoint of satisfactory performance, it is necessary that we have considerable knowledge of all these and that we continue to improve fibrous materials in order to keep abreast of the ever-changing technology and more stringent requirements of the future.

EFFECTS OF GAMMA RADIATION ON HT-1 AT 400°F

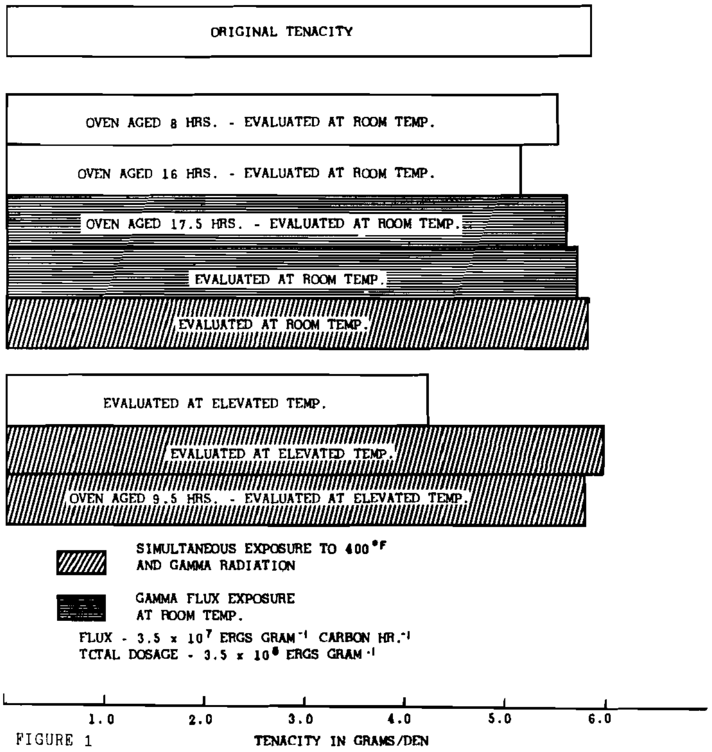

FIGURE 1

EFFECTS OF GAMMA RADIATION ON HT-1 AT 600°F

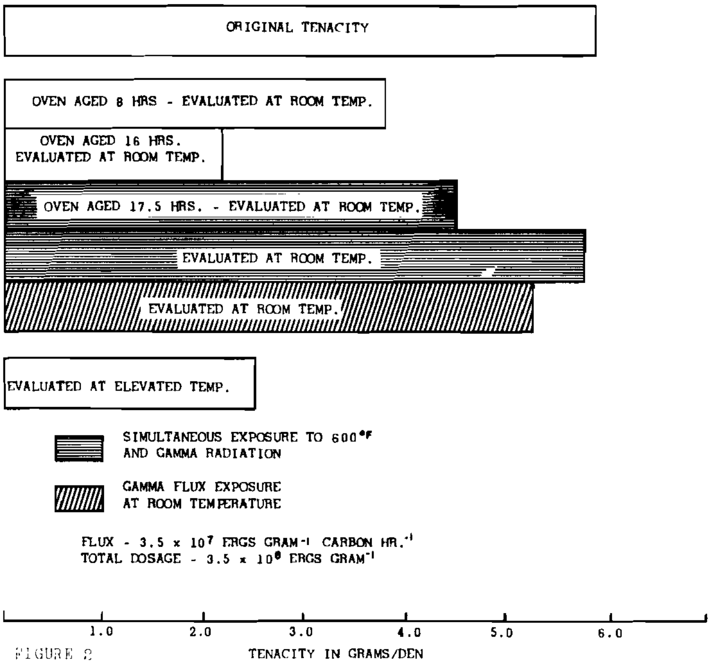

FIGURE 2

DEGRADATION OF HT-1 AFTER EXPOSURE TO ULTRA VIOLET RADIATION AND ELEVATED TEMPERATURES

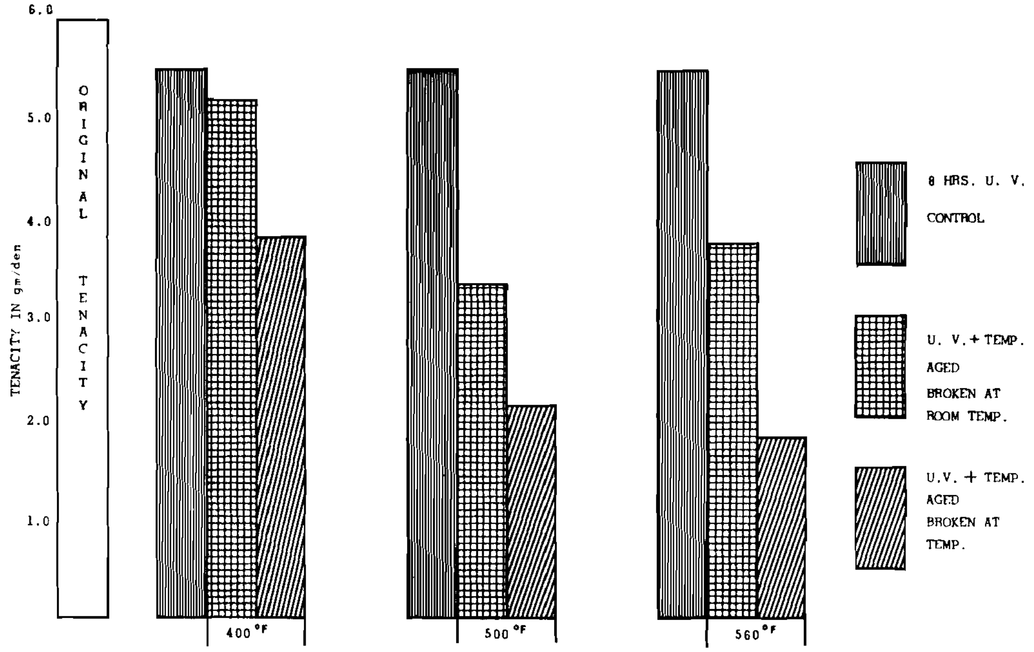

FIGURE 3

DEGRADATION OF HT-1 AFTER EXPOSURE TO ULTRA VIOLET RADIATION AND ELEVATED TEMPERATURES

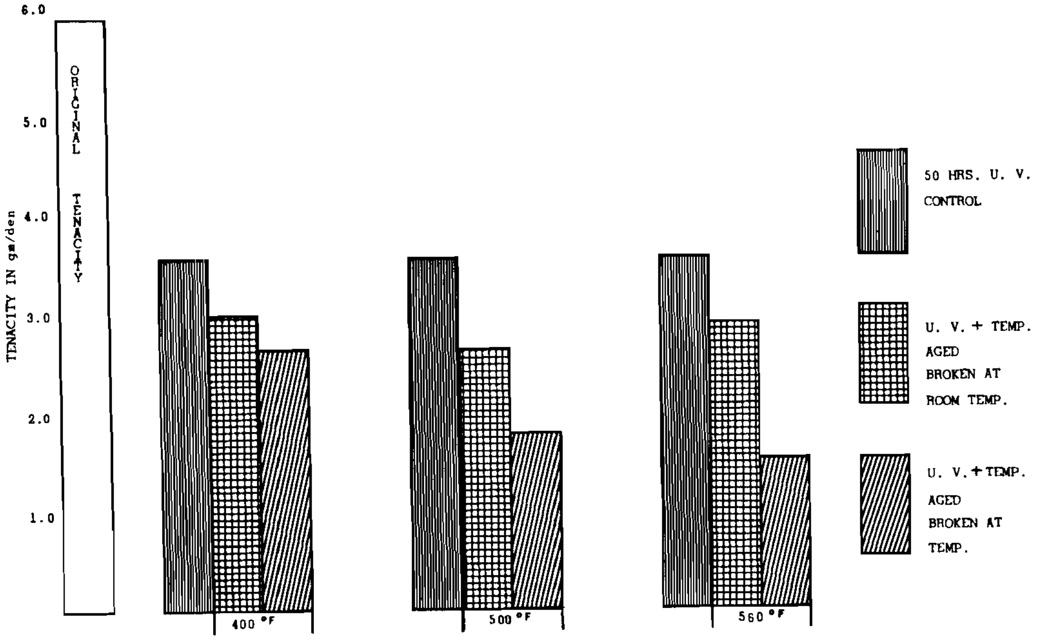

FIGURE 4

STRENGTH RETAINED AFTER OUT DOOR EXPOSURE

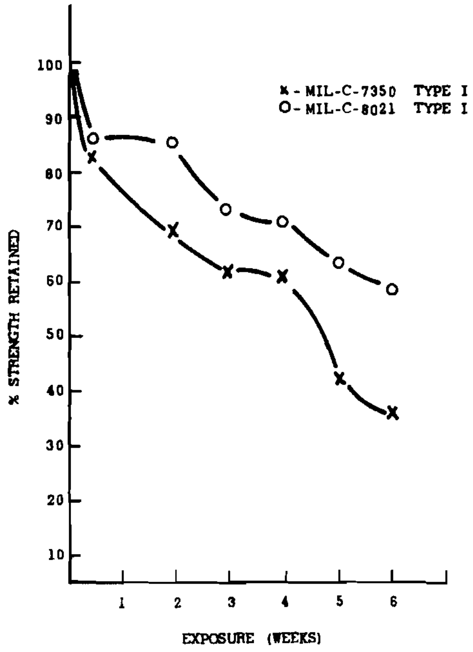

FIGURE 5

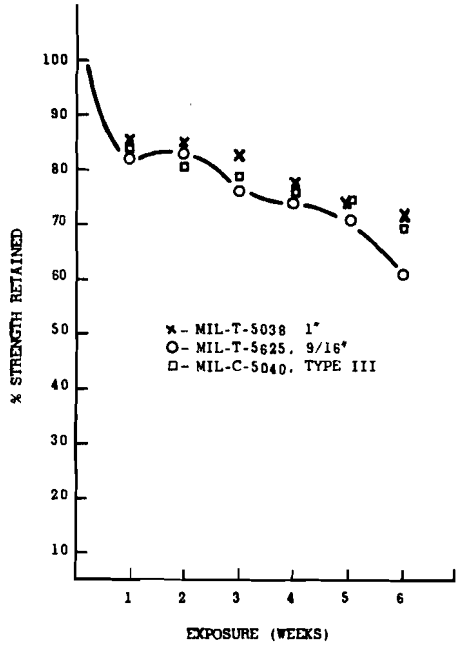

FIGURE 6

STRENGTH RETAINED AFTER EXPOSURE IN WEATHER OMETER

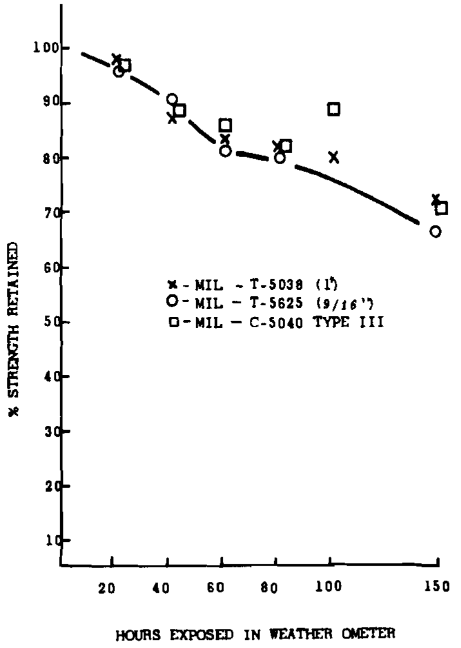

FIGURE 7

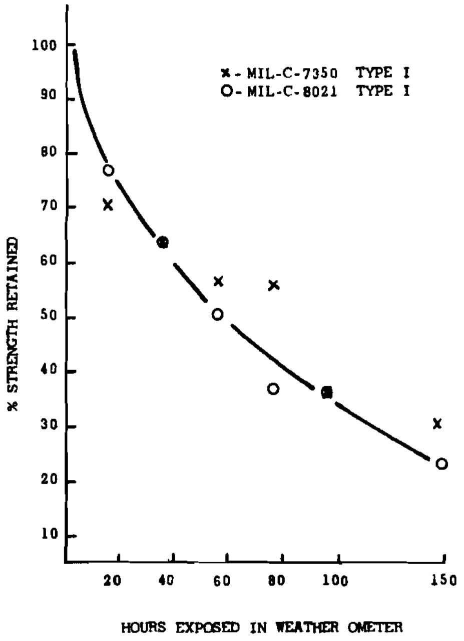

FIGURE 8

DEGRADATION OF MIL-C-8021, TYPE 1 FABRIC AFTER EXPOSURE TO ELEVATED TEMPERATURE

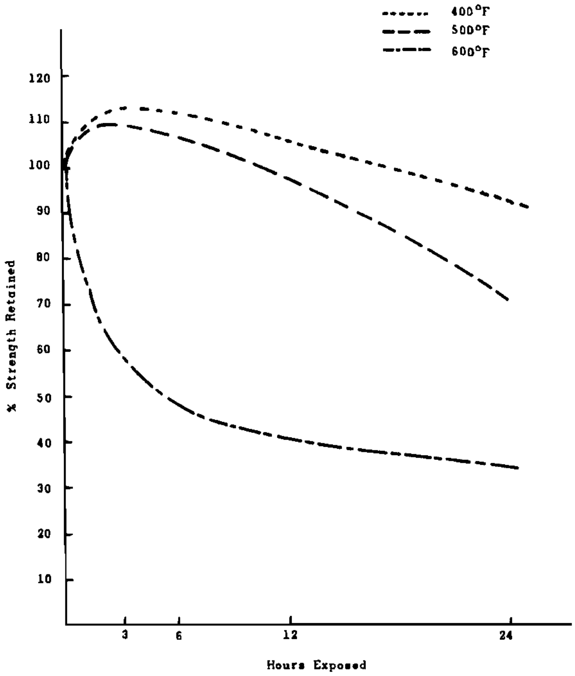

FIGURE 9

DEGRADATION OF MIL-C-7350, TYPE 1 FABRIC AFTER EXPOSURE TO ELEVATED TEMPERATURE

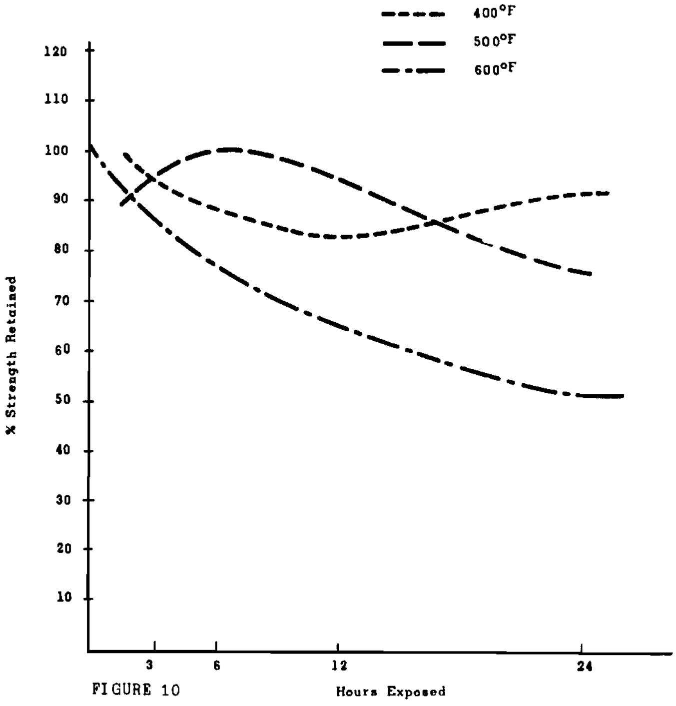

FIGURE 10

COMPARISON OF NYLON AND HT-1 FABRICS AFTER OUTDOOR EXPOSURE

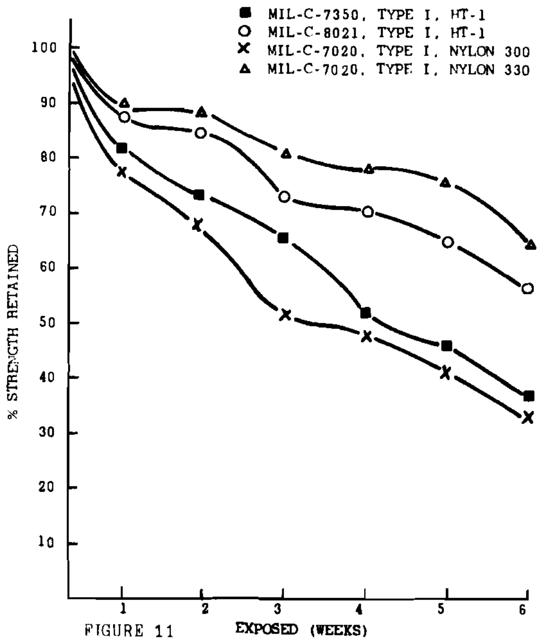

FIGURE 11

COMPARISON OF NYLON AND HT-1 FABRIC AFTER ACCELERATED WEATHERING

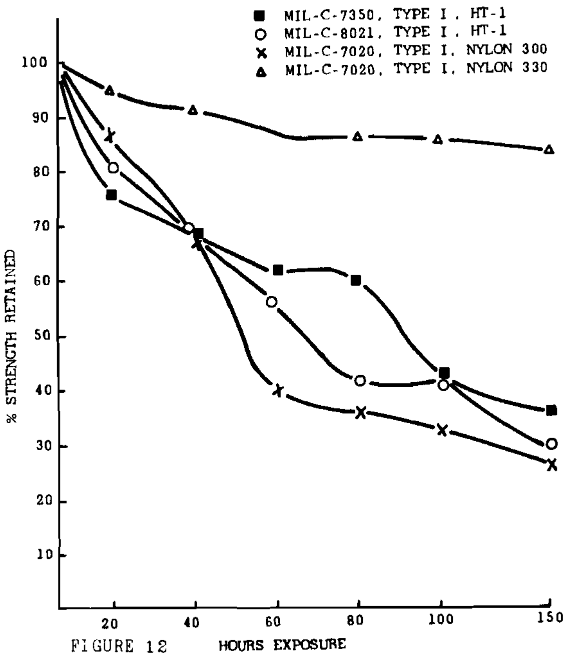

FIGURE 12

COMPARISON DATA OF HT-1 MATERIALS
(WEATHEROMETER EXPOSURE)

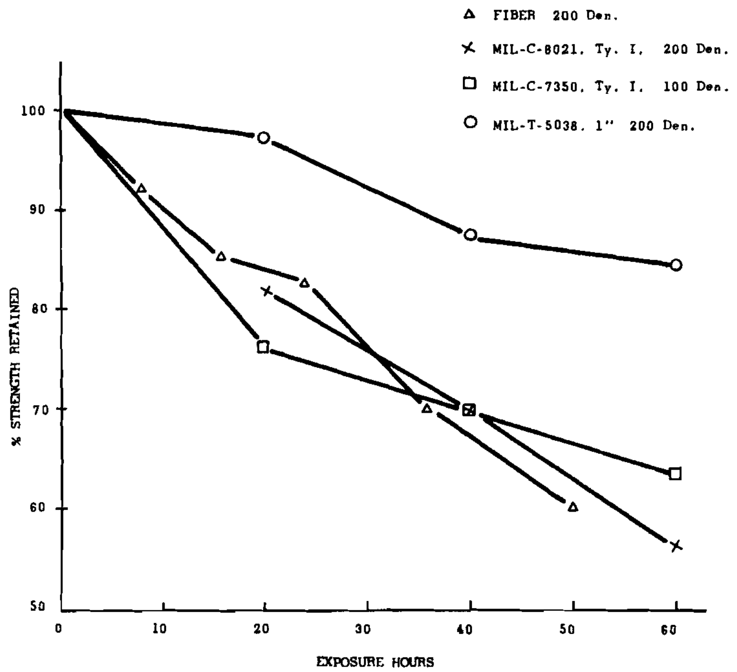

FIGURE 13

COMPARATIVE DATA OF HT-1 MATERIALS AFTER EXPOSURE TO ELEVATED TEMPERATURE

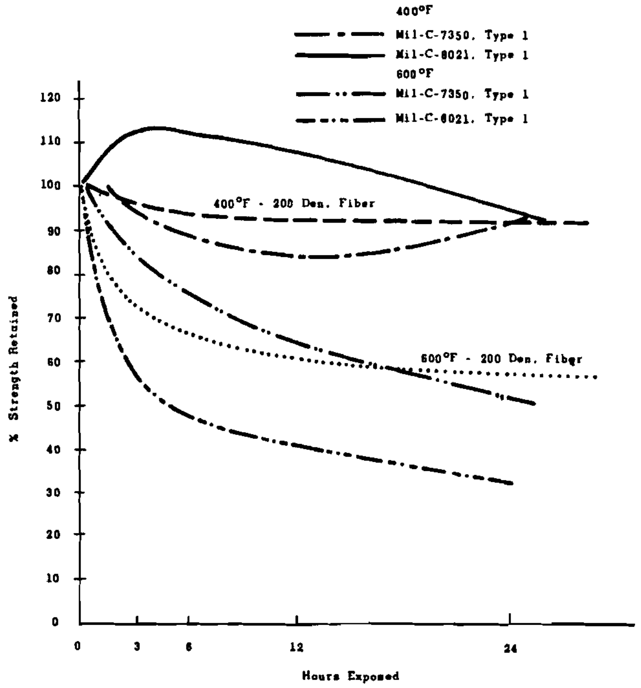

FIGURE 14