

PARACHUTE HARNESS WEBBINGS

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The parachute harness, as you all know, consists of a series of interlocking straps prepared from woven webbings, and connecting snaps, adjusters and links. The principal parts of the harness are the body attaching straps, such as the cross and horizontal back straps, the chest straps and the leg straps, and the supporting straps, such as the lift webs, the risers and the sling, which link the body to the canopy.

Earlier harnesses were manufactured from high-grade linen webbings equivalent to Type VII of cancelled Air Force-Navy Specification AN-W-16 for webbing, linen, linen-hemp or linen-ramie. The principal physical properties of the webbing were as follows:

Thickness	- 0.14 to 0.17 inches
Weight	- 4.80 ounces per yard (maximum)
Breaking Strength	- 2800 pounds full width - 1-3/4 inches

Although very hard, stiff and uncomfortable, this webbing was satisfactorily used for quite a few years when airplane speeds were low and flights were limited in duration. However, with the advent of faster aircraft of greater cruising range, a webbing of higher strength capable of withstanding the increased parachute opening impact due to bail-out at higher speeds and a softer construction to reduce pilot discomfort and fatigue were required. Investigation resulted in the development of the Type X linen webbing of Specification AN-W-16, the principal physical properties of which were:

Thickness	- 0.14 to 0.17 inches
Weight	- 4.80 ounces per yard (maximum)
Breaking Strength	- 5000 pounds full width

It is to be noted that while the thickness and weight requirements of the Type X webbing were no greater than those for Type VII, the strength was almost double. The difference was due primarily to a change in weave, ends and pickage. In comparison with the Type VII webbing, the Type X was fairly soft and flexible.

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During all this time, cotton was being investigated but was not acceptable since the strength - weight - thickness ratio obtainable with linen, due to its longer fiber, was higher.

With the advent of the war, a shortage of linen entailed. Belgium, France, and the Slav countries were overrun. The Irish production was low and, of course, no linen could be obtained from either Germany or Austria. The flax domestically grown was raised more for seed than for fiber. More and more parachutes were required, not only for pilot and crew members, but also for a rapidly growing paratroop force. A frantic search for a replacement was initiated. Fortunately, about this time the heat treatment of cotton yarns was developed and the problem was partially solved. For Navy use, Specification NAF W-49 was issued setting forth for Type X webbing the following requirements:

Thickness	- 0.140 to 0.175 inches
Weight	- 4.60 ounces per yard (maximum)
Breaking Strength	- 4650 pounds

It is to be noted that the weight and thickness of the webbing is approximately that of Type X linen and that the strength is about 350 pounds lower. The weave was identical to that of the linen webbing. This webbing was very soft and flexible. However, service difficulties were encountered in that when damp or wet, the webbing swelled and it became very difficult to adjust the harness for size, sometimes requiring the use of tools. This unsatisfactory condition was finally eliminated by the use of nylon filling yarns in lieu of cotton. Through refinement, the specification finally developed into the current Military Specification MIL-W-5665 for webbing cotton with requirements for Type X webbing as follows:

Thickness	- 0.125 to 0.135 inches
Weight	- 3.35 ounces per yard (maximum)
Breaking Strength	- 5000 pounds (minimum)

It is to be noted that the thickness and weight of the material is lower than that of Type X linen webbing while the strength is equivalent. Unfortunately, the number of warp ends required has been deleted from the specification and this has led to sleazy material being furnished under contracts.

Meanwhile, airplane speeds and cruising range continued to increase. Means of reducing the opening impacts of parachutes, or their effect on the human body, were being studied. It was considered by Air Force-Navy

personnel that the human system could safely withstand the shock of opening impacts up to 25g. The criteria for a personnel parachute was set at a maximum opening shock of 16g at 600 MPH at altitudes up to 50,000 feet. The parachute panel accepted that the present parachute was safe to use with a 200 pound load at speeds up to 250 MPH and that the ejection seat should be used for bail-outs at speeds from 250 to 500 MPH. It was further considered that the parachute should be capable of withstanding loads developed during a jump at 350 MPH with one second delay in the parachute opening. With these parameters set, the search for a more suitable harness webbing continued.

At this time, it was considered that the replacement material must be superior to Type X cotton webbing in the following respects:

- a. Its strength must be greater.
- b. Its thickness must be no greater.
- c. Its weight must be no greater.
- d. It must have better shock absorbing characteristics.
- e. Its aging qualities must be equal or superior.
- f. It must be as tough or tougher.
- g. It must be durable and wear as well.
- h. It must be as available.

Glass, saponified acetate and Vinyon were stronger than cottons but were inferior to elongation, toughness and weight. Nylon, alone, appeared to be a satisfactory replacement material. After a study of the dynamic load-stretch and stretch-energy data of several nylon webbings in comparison with similar data for cotton webbing by the National Bureau of Standards, the rib weave nylon webbing was decided upon.

In 1945, the quick fit parachute hardware was developed. It was found that in passing through this hardware, the nylon webbings had a tendency to develop a fuzzy surface and after a number of rubs showed a decrease in strength. Tests consisting of rubbing the webbing back and forth over parachute adapters 10,000 times showed a reduction of approximately 40 percent in tensile strength. An Air Force investigation developed, however, that the condition could be alleviated, without affecting the other properties of the material except for a stiffening effect by the application of a water soluble

solution of polyvinyl butyral (Merlon BR) and a heat cure. As a result of this work, Air Force Specification 16107 (now MIL-W-4088) for webbing, nylon was developed and Type X webbing was proposed for parachutes. The principal physical properties were as follows:

Thickness	-0.125 to 0.145 inches
Weight	-3.70 ounces per yard (maximum +12 percent increase for Merlon treatment.
Breaking Strength	-as received 8700 pounds (minimum) after abrading 5000 times - 90 percent of as received
Extractable Matter	5 to 8.5 percent

It is to be noted that the thickness of this material is slightly greater than that of the Type X cotton webbing while strength is 50 percent greater.

Samples of the Type X Merlon treated webbing received by the Navy were so boardy, hard, rigid and lacking in pliability that it was believed harnesses fabricated therefrom would cause considerable pilot discomfort. In 1949, because of failures of cotton parachute harnesses during routine dummy drop tests, the Navy immediately shifted to nylon, Type X webbing in lieu of cotton, even though it was still considered that the Merlon treated nylon was too stiff and hard. It was believed that reduction of the Merlon content might result in a more pliable product. Accordingly, samples containing 4 to 6 percent Merlon BR in lieu of the specified 5 to 8.5 percent were obtained and when treated were found to be more flexible and equally resistant to abrasion as those with the higher Merlon content. The webbings were not considered to be completely satisfactory as they were still on the boardy, hard and rigid side, and the pliability as compared to that of the untreated webbing was still reduced greatly by the resin treatment.

Meanwhile, two other compounds for increasing abrasion resistance were under investigation. Silicone treated webbings abraded fast. Samples of Type X webbing treated with a water soluble solution of GRS Buna S Latex estimated to give a 4 percent pickup and cured at 270°F. was considerably softer and more pliable than the Merlon treated material. These samples showed a slight loss in breaking strength due to the impregnation material, dropping from 9000 pounds in the untreated webbing to 8400 pounds in the treated, or 300 pounds under the specified minimum value for the Merlon treated webbing. However, there was no loss in strength due to abrasion and less than 10 percent due to accelerated weathering. Harnesses manufactured from the webbing were tested at the Naval

Parachute Unit and found to be satisfactory. In the interim, however, the quality and degree of softness of the Merlon treated webbing improved to such a degree that the investigation of latex treated webbing was discontinued.

One of the primary considerations in aircraft design, or accessories, is reduction of weight to a minimum. On the basis of previous experience and the high elongation characteristics and therefore energy absorbing characteristics of nylon webbing, it was believed that the strength and, therefore, the weight of the nylon webbing could be safely reduced. In addition, it was believed a thinner webbing would result in better flexibility than the Type X webbing and afford better pilot comfort. Accordingly, the Air Force developed the Type XIII Merlon treated nylon webbing of Specification MIL-W-4088 with properties as follows:

Thickness	-0.100 to 0.120 inches
Weight	- 2.90 ounces per yard (maximum)
Breaking Strength	- 6000 pounds (minimum)

It is to be noted that this is a reduction of .025 inches in thickness, 0.80 ounces per yard in weight, and 2700 pounds in strength over the Type X webbing. The weight per harness saved will run from 14 to 20 ounces.

Although harnesses constructed from the Type XIII webbing were superior in flexibility to those made from the Type X, there was still room for considerably improvement. The webbing was still boardy and hard. A great improvement was accomplished by gradual reduction of the pickage from 30 to 26, and it is understood that a further reduction to 22 picks is contemplated.

Last year, insofar as the Navy is concerned, trouble started. Service organizations began to complain of the harness as being uncomfortable to wear, hard, stiff and difficult to adjust, especially at low temperatures. The complaints included harnesses manufactured from both the Type X and Type XIII nylon webbings. Immediate tests disclosed that the Merlon treated webbings, even when previously softened, stiffened and became rigid and board-like to such an extent, even at 0°F., as to greatly interfere with pilot comfort and proper harness adjustment. Untreated nylon webbing remained soft and flexible at the low temperatures, as low as -65°F.

Three methods of solution of the problem were outlined, namely:

1. Breakdown the bonding action of the currently used resin.

2. Develop new abrasion-resisting mediums.
3. Develop a new, untreated webbing of sufficient strength (approximately 7500 pounds) so that its strength after abrasion would be equivalent to that of Type XIII nylon webbing (6000 pounds).

On the first method of attack, mechanical means of softening and breaking down the resin treated webbings were investigated. It was found that running the webbing by hand action around rollers or a series of sharp bends would cause it to become as soft and flexible as needed, but when webbing so treated was exposed to low temperatures, it resumed its former hard, stiff state. The webbing was exposed at approximately -40°F. until it became rigid, which required a short period of time. While still exposed at the low temperature, it was subjected to the same breaking action which softened it. The softened webbing when exposed to room temperature and again to -40°F., remained soft. Although this process is considered impracticable for commercial manufacturing purposes, it is being further investigated.

On the second and third methods of attack, interested webbing manufacturers were contacted and informed of the unsatisfactory performance of the Merlon treated webbing. These manufacturers were requested to suggest changes to eliminate the defect or to submit samples of improved webbing for study.

Along the lines of the second method of attack, one manufacturer submitted samples of Type XIII nylon webbing treated with liquid latex. The material was not as soft and as flexible as the untreated Type XIII nylon webbing, but was considered to be entirely satisfactory. At -65°F., the latex treated webbing retained its softness and flexibility. After abrasion, the loss in strength amounted to approximately 300 pounds, less than 5 percent loss. The strength of the material after aging was greater than the strength of the aged untreated webbing. The weight was less than the maximum permitted for resin treated webbing. It did not absorb or retain water within the fabric when wet and consequently dried more rapidly than untreated nylon material. The liquid latex treatment does have a tendency to increase flame sizes when loose ends are ignited but on the other hand, the droppings of molten nylon are decreased. On exposure of flat surfaces, there is apparently no difference in ignition of the webbing either treated with Merlon or liquid latex or if untreated. The test values obtained were as follows:

	<u>Sample</u>	<u>Type XIII Nylon</u>
Thickness, inches	0.094 to 0.104	0.100 to 0.120
Weight, ounces per yard		2.90 + 12%
Breaking Strength, pounds		
As Received	6700	6000
After Abrasion	6700	90%
Elongation at Rupture	32%	33%

Although the slightly increased flamability is not considered serious, the supplier of the webbing has been asked to investigate the possibility of adding flame retardants.

The third method of attack of the problem was the development of new untreated webbings. Attacking the problem from this angle, one manufacturer submitted samples of untreated webbing woven from high twist yarns and a modified weave. The material was extremely soft and flexible and retained these qualities even when exposed at -65°F. It lost 2 percent strength when abraded 5000 times. The weight was slightly less than that of Type XIII nylon and the thickness slightly greater. The elongation value at rupture was higher. The values were as follows:

	<u>Sample</u>	<u>Type XIII Webbing</u>
Thickness, inches	0.127 to 0.137	0.100 to 0.120
Weight, ounces per yard (max.)	2.80	2.90 + 12%
Breaking Strength, pounds		
As Received	6000 +	6000 +
After Abrasion	90%	90%
Warp Twist per inch	20 to 22	Normal
Elongation at Rupture	41%	33%

Harnesses manufactured from the webbing proved as comfortable as those made from cotton webbing. They were easy to adjust at all temperatures. Parachute drop tests conducted were satisfactory. It is our opinion that the webbing is more desirable than the Type XIII resin treated webbing because of its softness at normal and reduced temperatures, thereby reducing pilot discomfort and fatigue. Because of the high twist, the cost per yard is increased by about 10 percent above that of the Merlon treated webbing. The increased cost, however, and the fact that some properties have been adversely affected must be considered minor, in view of the major achievement of increasing pilot comfort. Action has been initiated to

purchase a number of harnesses to be fabricated from this webbing.

In May 1948, the Air Force reported in Technical Report 5699 that the test of Type VIII nylon webbing manufactured from 240 denier, 12 filament yarn with normal twist tested 3627 pounds in the as-received state and 3578 pounds after being abraded 5000 strokes, a loss of 1 percent. Unfortunately, Du Pont stopped the manufacture of this yarn.

Investigation of webbings for parachute harnesses and, in fact, other aeronautical usage, is not stopping with the foregoing. Other webbings, other yarns will be given consideration as fast as they are developed. As an example, recently an interested manufacturer has been experimenting with untreated webbing of 260 denier, 17 filament yarn spun with normal twist. He reports a loss of 14 percent due to abrasion. If the material proves satisfactory, and samples are being submitted for tests, it will result in a further reduction in weight and price, since the cost of both high twisting and resin treating will be eliminated.

Orlon, dacron and X-36 have been studied for parachute webbings but have been deemed inferior to nylon in one respect or another. Dacron, because of certain advantageous properties, is being investigated for other uses.

Finally, in the search for more suitable parachute harness webbings, the following factors must be given consideration:

- a. Pilot comfort.
- b. Cost.
- c. High strength at high, normal and low temperatures.
- d. A minimum of weight.
- e. Good elongation with very little decrease at low temperatures or increase at high temperatures.
- f. Good flexibility and pliability at all temperatures. Very little, if any, change will be tolerated.
- g. Good elastic recovery at all temperatures.
- h. Low permanent set.
- i. Low impact transmission or high shock absorbing qualities.
- j. Toughness.
- k. Good durability.
- l. Good aging qualities.
- m. Good resistance to abrasion.
- n. Good mildew and fungus resistance.