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AIR FORCE MATERIALS LABORATORY

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FOREWORD

This report was prepared by Prodesco, Inc., under USAF Contract No. AF 33(657)-12257, in conjunction with Mr. J. H. Ross and Joyce C. McGrath of the Fibrous Materials Branch, Nonmetallic Materials Division, Air Force Materials Laboratory. The contract was initiated under Project No. 5708, "Retardation of Nuclear Weapons," and administered under the direction of the Parachute Branch, Directorate of Crew and AGE Subsystems Engineering with Mr. H. Engel acting as Project Engineer. Mr. J. H. Ross of the Fibrous Materials Branch, Nonmetallic Materials Division, AF Materials Laboratory and Mr. S. Metres of the Recovery and Crew Station Branch, AF Flight Dynamics Laboratory acted as co-project engineers.

This report covers work from 1 January 1964 to 1 July 1964.

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This technical report has been reviewed and is approved.

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ABSTRACT

The objective of this program was to develop a woven mesh material using MIL-C-5040, Type I cord and commercial grade, high tenacity nylon yarn in order to achieve a 1000-1200 lb./in. breaking strength in the warp and filling directions and a geometric porosity of 35%, or a permeability of 800-900 cu.ft./sq.ft./min. Binder yarns from 30 denier to 200 denier were evaluated in order to achieve the strongest possible bond between warp and filling cords. Various constructions, ranging from 7 ends and picks of cord to 9 ends and picks of cord, were evaluated to achieve the optimum combination of breaking strength and air permeability.

Unusual problems were encountered in weaving the cord because of its bulk and stiffness. Considerable yardage would have to be manufactured in order to determine the commercial practicality of the manufacturing technique.

This study demonstrated the feasibility of designing and weaving a fabric using a 100 lb. breaking strength cord in a crimpless weave for use in special types of parachute applications.

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ILLUSTRATIONS

I. INTRODUCTION

The purpose of this program was the development of a fabric which would exhibit properties of air permeability in the range of 800-900 cu.ft./sq.ft./min., along with a breaking strength of 1000-1200 lbs./inch in both warp and filling directions. A leno weave was to be used utilizing nylon for the binder yarn to tie warp and filling cords together. A fabric was developed to meet, as nearly as possible, the requirements as specified. Details as to problems involved with weaving and the physical properties of the fabric are discussed. Ultimately a fabric was developed using a 200 denier nylon in the structure for the binder. Utilization of such a high strength raw material as the cord, required several major deviations from normal standard textile manufacturing techniques. A crimpless weave (Figure 1) was required to achieve the air permeability, and tensile strength. As recommended in the contract, 30 denier nylon was tried as a binder and was found to be unsatisfactory.

A specially designed shuttle, extra large eye leno heddles, a high percent air space reed, and a roll-off type filling bobbin had to be fabricated. Unique weaving techniques which included rocker beam weighting for the binder warp, hand weaving, and hand wound filling, were used.

After the physical problems of weaving the fabric were overcome and the first sample was tested for air permeability and strength, it became apparent that the number of ends and picks in the warp and filling had to be changed to reach the specified air permeability. Several trials finally netted the result that was actually a compromise in fabric strength and air permeability.

The final yardage was executed with the use of hand winding techniques for winding the filling quills and hand weaving techniques for the actual weaving of the fabric. Further study will have to be conducted to determine the feasibility of weaving any production-type yardage of this particular fabric.

II. TECHNICAL DISCUSSION

A. WARPING.

A total of three warps were made under this phase of the contract, one being a 24 yard long warp containing 252 ends of the MIL-C-5040, Type I Nylon cord. The other two warps, to be used as the tie down yarns, were (1) 30 denier, 10 filament Type 330 nylon with 12 turns per inch of Z twist and (2) 200 denier, 100 filament Type 680 nylon with 5 turns of Z twist.

The warp of MIL-C-5040, Type I cord was made long enough to supply the required 15 yards at the end of the development which was anticipated to be two or three samples. The cord warp was made on Prodesco's modified silk warper directly from the 28 spools which were supplied by the Government. The warping and beaming of this particular warp created several problems. The large diameter of the cord caused it to build up upon itself and resulted in unevenness across the surface of the warp. This condition caused uneven tensions in the weaving which had to be compensated for by adding individual weights to several ends in order to keep them tight in the weaving operation.

A 30 denier nylon was the original binder warp as proposed by the Air Force and was made 50 yards long. This warp, along with the cord,were both made at 9 ends per inch because there was to be one binder yarn for every cord in the fabric length.

When the 30 denier yarn caused breakage problems in the initial weaving, it was decided to replace this with a stronger nylon of a heavier denier. Utilizing yarn Prodesco had on hand, a warp was made from 200 denier Type 680 nylon yarn with 5 turns per inch of Z twist. This yarn proved to be satisfactory in its abrasion resistance in the weaving. Because contract funds did not cover the additional costs of adding twist to this heavier denier nylon, the possibility of increasing the air permeability by increasing the twist in the binder yarn was not evaluated.

It has been noted in previous work (Ref. 1) that an increase in yarn twist results in a higher permeability for the same construction and weave.

B. WEAVING TRIALS.

The first attempt at weaving utilized a warp construction of 9 cord ends and 9 binder ends. The binder was 30 denier nylon, and had 9 picks per inch. Leno weaving involves more yarn bending in the weaving operation because the heddles are of particular construction. On the first attempt, the cord was drawn through the eye of the leno heddle. A second draw with the cord through the legs of the leno heddle was successful and was the final method of drawing the cord through.

The bending which the cord had to do was the first problem that presented itself in the weaving operation and the warp had to be re-drawn through the leno heddles after they had been moved further away from the reed in the loom. This cut the angle of the bend to an acceptable degree but problems still arose in the opening of the shed through which the shuttle must pass, and the 30 denier binder warp getting caught on the braid itself and on the leno heddle shoulders.

An extra pick motion was added to the loom in order to help the yarns vibrate themselves apart. An empty box on the loom was utilized so that every other pick would not have a shuttle going across the fabric. This helped to open up the shed and eliminated a lot of the nylon hanging on the cord yarn.

With the making of the 200 denier warp, both warps were then re-drawn moving the leno harness to different positions in the loom in relationship to the reed. The nylon yarn was drawn through controlling harness which were placed 16 harness spaces behind the leno to give the longest possible distance from the leno to the controlling harnesses. It is Prodesco's experience that when difficulty arrives in bending yarns or moving yarns that the smaller the angle of the bend the better the possibility of allowing these to work themselves free.

A "jazz" bar was installed behind the last harness in the loom. This bar runs across the width of the warp and is spring loaded to remove any slack from the yarns in the weaving operation. Figures 1 and 2 show the "jazz" bar set up behind the harness. Figure 2 shows the cord warp in the lowered position and it is in this position where the shuttle passes through. Figure 1 shows the cord warp in the raised position, that is on the open pick.

This draw still had the cord passing through the eye of the leno heddle and this was found to be one of the major causes of difficulty in the weaving.

A new draw was made utilizing the same harness placings but re-drawing the cord through the legs of the leno harness. Placing the nylon binder warps through the eye of the heddle and allowing it to move back and forth by virtue of the "rocker" type weighting system, the cord remains straight and the binder warp wrapped around it.

By moving this warp to another loom which had a larger opening for the shuttle, acceptable fabric was then made. At no time during the weaving of samples or production was it possible to use power in weaving.

C. MODIFICATIONS.

Several modifications were made to machinery and procedures to produce a satisfactory fabric. Because of the fact that the MIL-C-5040, Type I Cord is roughly one hundred times the diameter of a normal weaving yarn, problems arose in bending, winding, and manipulating the cord. To get the cord to act as close to a textile yarn as possible, the following modifications had to be made to procedures and equipment. A shuttle was modified to accept a specially made spool in place of a normal quill. The yarn path was changed so that the cord would come out the side of the shuttle rather than through the eye and tensioning device. Figure 3 shows a comparison of a standard shuttle in the background to the modified shuttle in the foreground with bobbin inserted. Additional modifications to the shuttle, including a guiding eye for the cord and a tensioning device for the bobbin, would be necessary in order to make an attempt at weaving this fabric under power.

Winding of the special bobbin for filling necessitated a hand operation. Figure 4 shows the bobbin set up in a hand crank apparatus with the cord being wound onto it. This cord was guided on by hand by the operator who while guiding it also tensioned the cord going onto the bobbin. Figure 5 shows a full bobbin completely wound ready to be taken to the loom and placed in the shuttle. All filling was wound in this manner.

Along with hand winding of the filling, hand weaving of the actual fabric also was necessary, not only because of the modifications to the shuttle, but because of the extreme difficulty which was encountered in keeping a satisfactory yarn motion in the weaving. In the hand weaving operation, the weaver had to pull off a certain amount of cord and then hand throw the shuttle through the shed. Figure 6 shows the weaver about to throw the shuttle across the loom. He is holding the cord in his left hand.

As referred to in the previous section, a "jazz" bar was installed in the back of the loom in order to keep the slackness out of the yarn and the raising and lowering of the harness controlling the cord. This "jazz" bar can be seen in Figures 1 and 2. A double pick motion was also incorporated into the loom. This is an unusual operation in that every other pick does not have a shuttle going across the face or the width of the fabric. Figure 7 illustrates the method of throwing the shuttle while Figure 8 shows the shuttle half way across the shed, with the cord in the lowered position and the binder warp in the raised position. The rocker weighting device as used on the binder warp is not uncommon, but was necessary for this particular operation. These changes illustrate the possibility in weaving this fabric; however, the feasibility of doing it on a production basis, will require further investigation. Figures 9 and 10 are sketches of top and side views of the fabric.

D. TESTS.

All physical testing as required by the contract was conducted at the facilities of the Fabric Research Laboratories, Inc., in Dedham, Mass. These tests included ravel strip breaking strength, both warp and filling direction, and air permeability.

After the weaving problems had been resolved to a certain extent and it was possible to weave a sample for testing, the first sample was woven and submitted to Fabric Research Laboratories for tests. This sample was woven at 9 picks per inch and 9 ends per inch, tied down with the 200 denier binder warp. This sample is identified as Sample #5 and exhibited air permeability of 500 cu.ft./sq.ft./minute, with a breaking strength of 1090 lbs./in. in the warp and 1080 lbs./in. in the filling. These results were forwarded to AFML and it was concluded that the air permeability was not up to the expected standard and the breaking strength could be sacrificed somewhat so it was decided to re-reed and weave another sample.

Sample #6 was woven at 8 ends and 8 picks per inch and exhibited air permeability of 697 cu.ft. with a break in strength of 1045 lbs./in. in the warp and 1080 lbs./in. in the filling. This meant that the air permeability was still below the expected result with not much drop in breaking strength. This breaking strength retention could be attributed to a change in test procedures.

An additional Sample #7 was woven at 7 ends and 7 picks and submitted to Fabric Research Laboratories for testing. The air permeability on this fabric was 894 cu.ft. with breaking strength in both directions of 966 lbs. With the results of this sample, the Air Force authorized Prodesco to weave the final fabric at a construction of 7-1/4 ends and 7-1/4 picks per inch. (Table No. I gives a listing of the test results conducted on this phase of the contract). Physical Property data for Sample #7 are as follows:

TABLE I

SAMPLE	ENDS PER INCH	PICKS PER INCH	PERMEABILITY TO AIR CU FT/MIN/SQ FT	BREAK STRENGTH/LBS/IN.	
				WARP	FILLING
#5	9	9	570	1090	1080
#6	8	8	697	1045	1080
#7	7	7	894	966	966
#8	7-1/4	7-1/4	800	1000	1000

III. CONCLUSIONS

As a result of the fabric development and loom modification it has been shown that:

1. It is possible to weave a limited amount of fabric with the equipment modifications as noted in this report.
2. The original fabric construction of 9 ends & 9 picks/inch was too closely woven to give the desired permeability, and had to be opened up to 7-1/4 x 7-1/4 ends and picks.
3. The binder warp has to be made from at least 200 denier nylon or stronger.

IV. RECOMMENDATIONS

As a result of the data obtained from this development it is recommended:

1. That an additional study be conducted to determine the feasibility of weaving larger quantities of this fabric.

2. That consideration be given to the possibility of substituting another material in place of the MIL-C-5040 Cord, possibly a plied high tenacity nylon or a more tightly braided super tenacity nylon or Dacron yarn.

Reference: Brockman, H., Development of Nomex Mesh Materials, ML-TDR-64-208, September 1964.

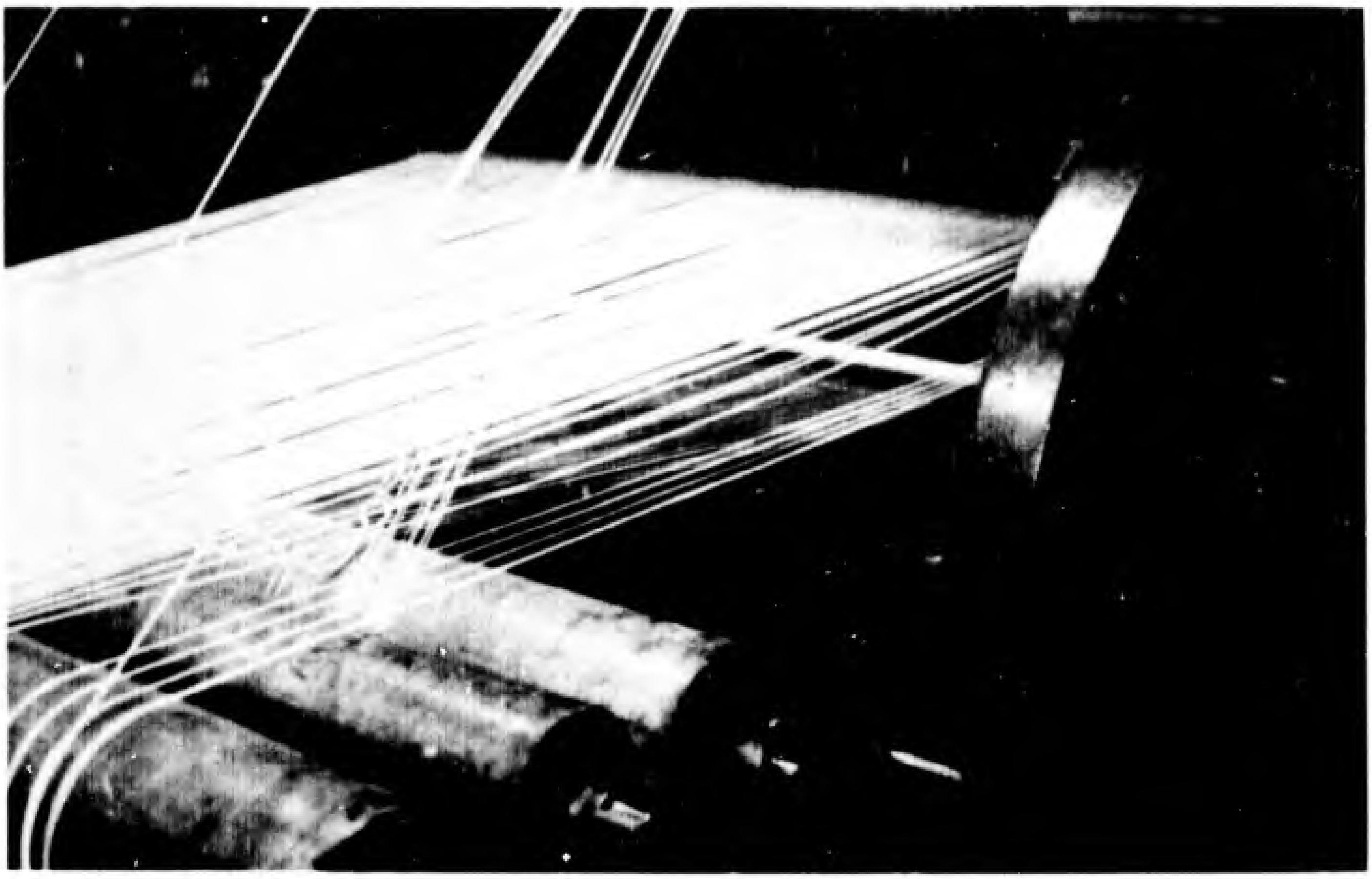

Figure 1. Back of Loom, Cord Raised

Figure 2. Back of Loom, Cord Down

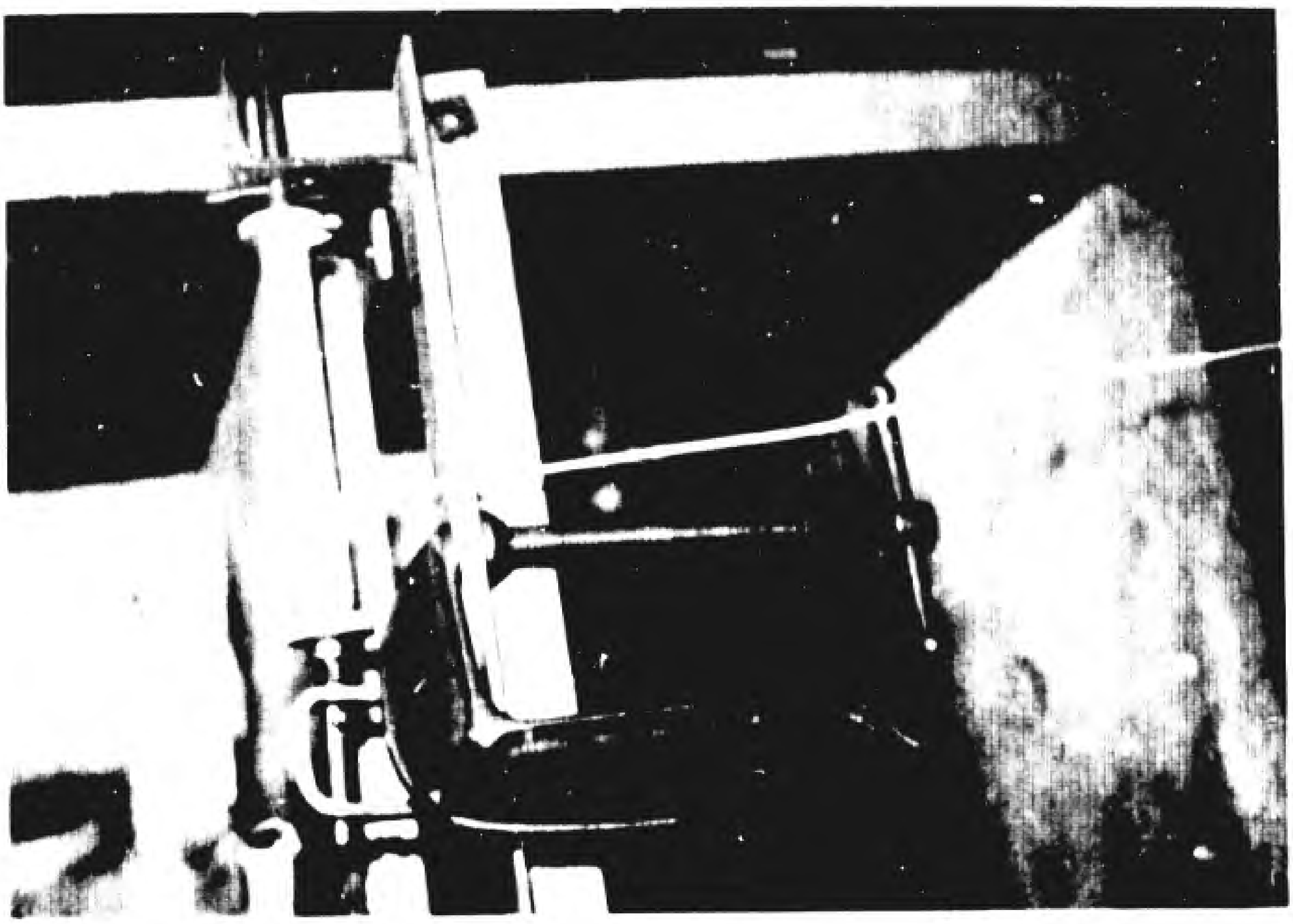

Figure 4. Winding Cordonte Filament [illegible]

Figure 3. Comparison of Standard and Modified Shuttles and Quills

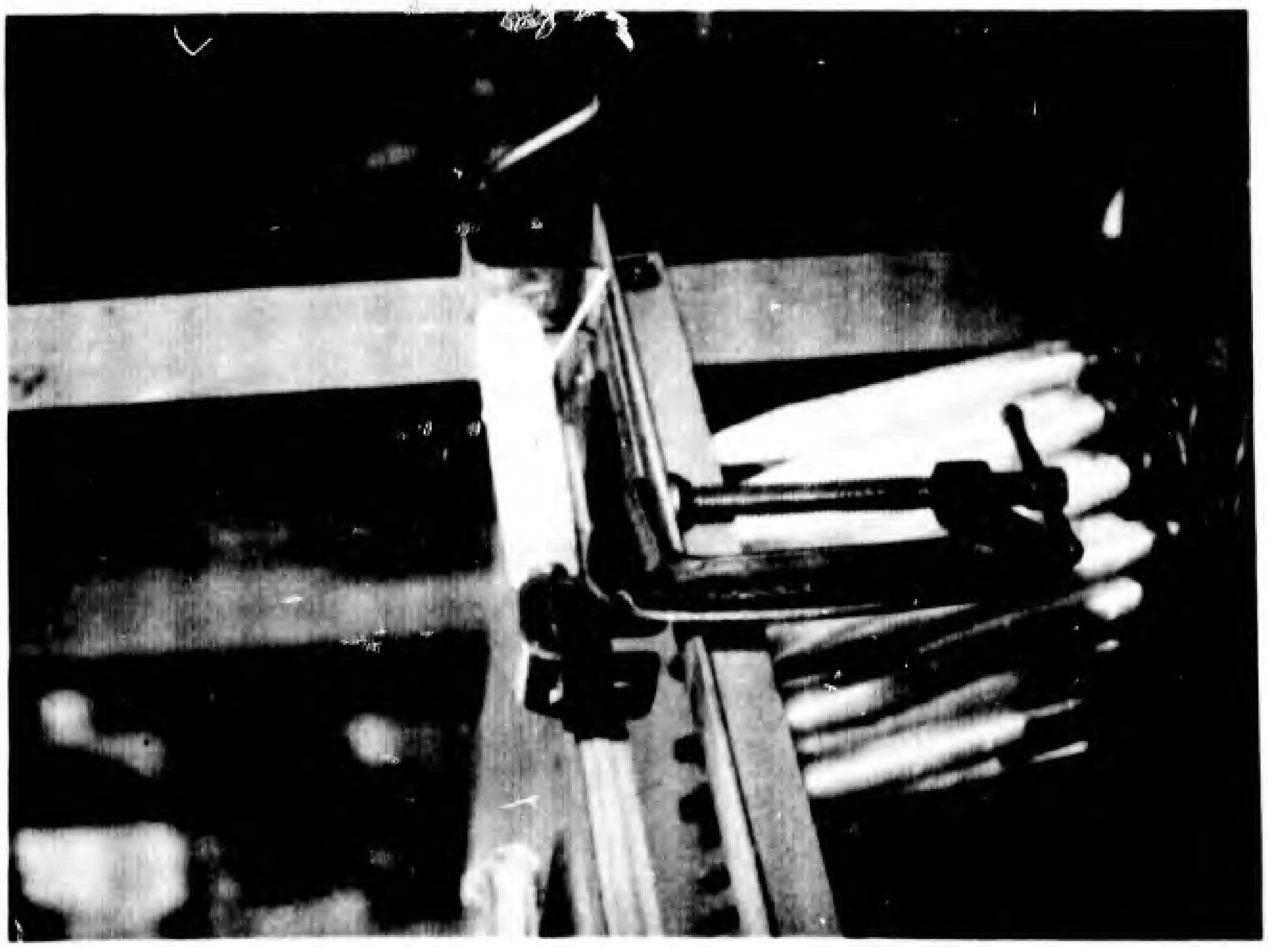

Figure 5. Full Quill Ready for Shuttle

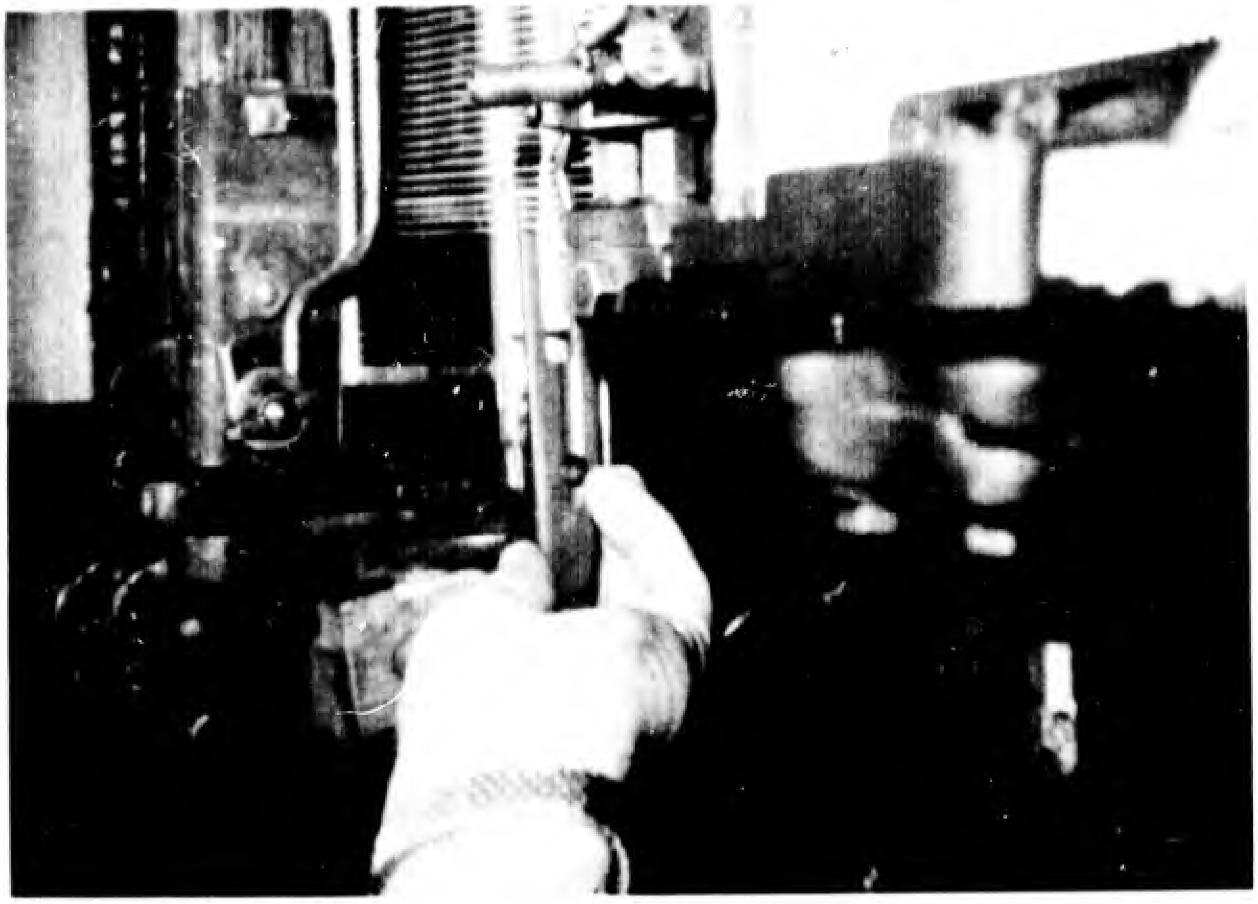

Figure 6. Inserting Shuttle by Hand

Figure 7. Throwing Shuttle Across Fabric

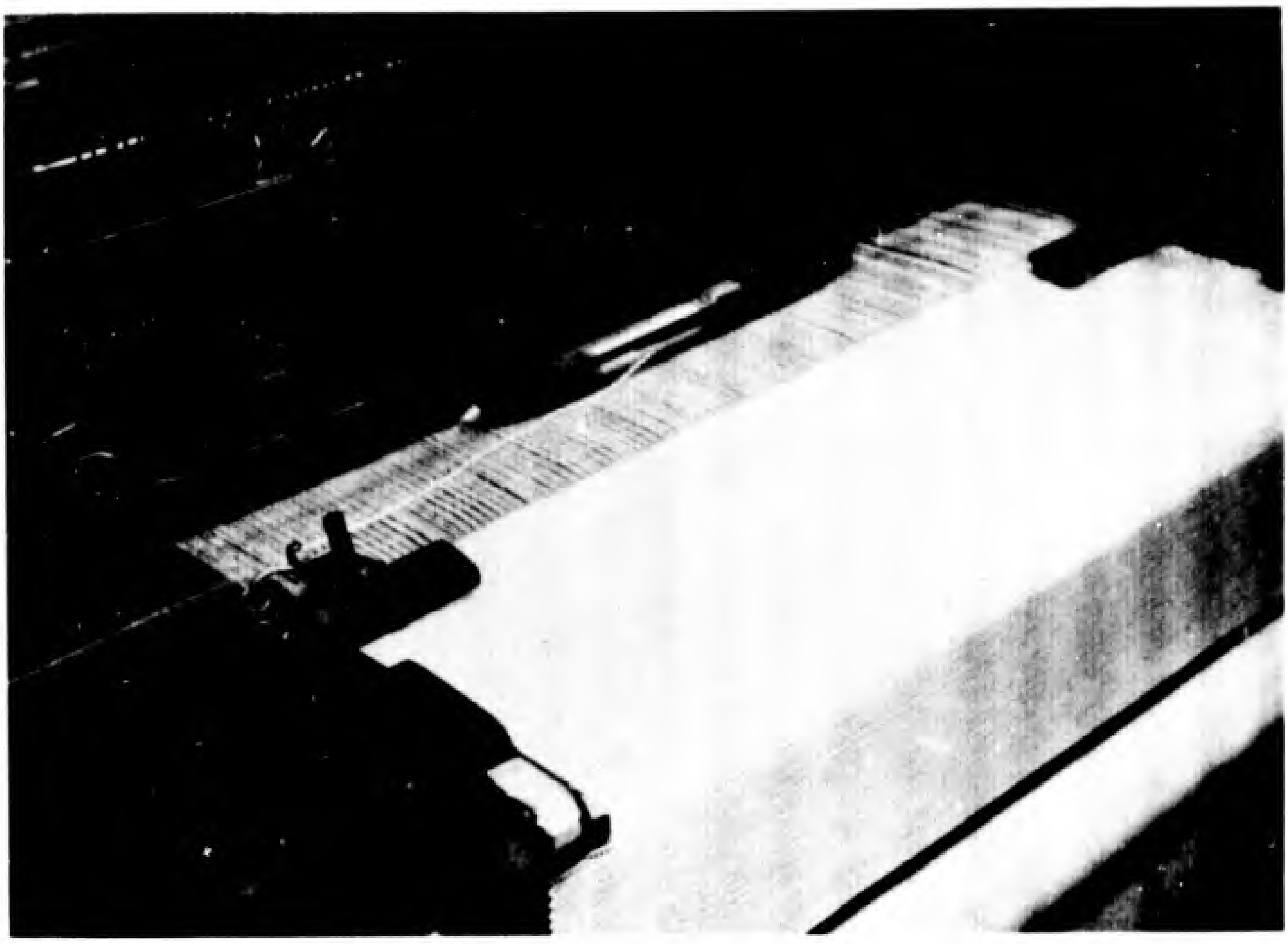

Figure 8. Shuttle Passing Through Shed, Under Binder Yarn

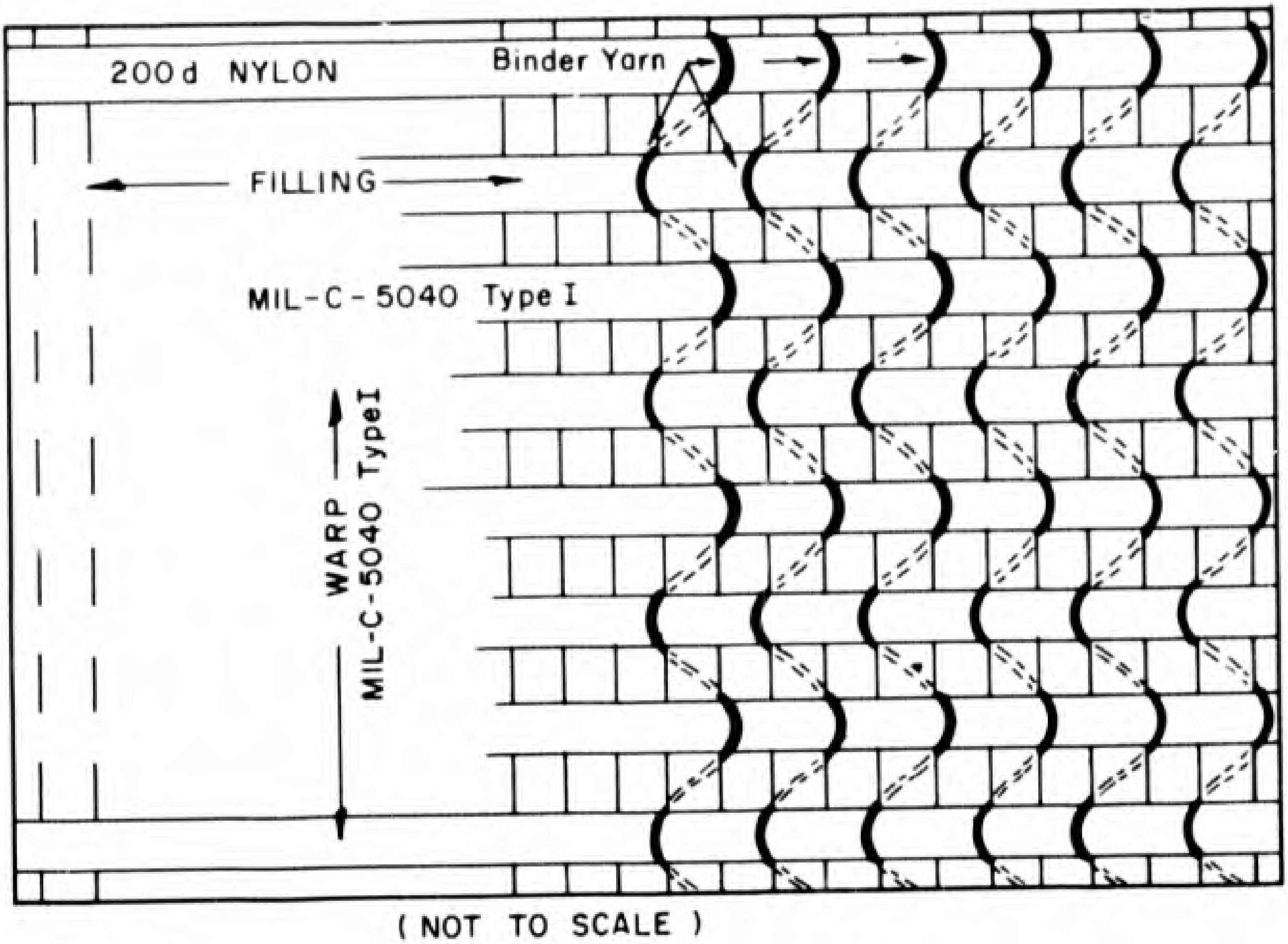

Figure 9. Sketch of Fabric (Top View)

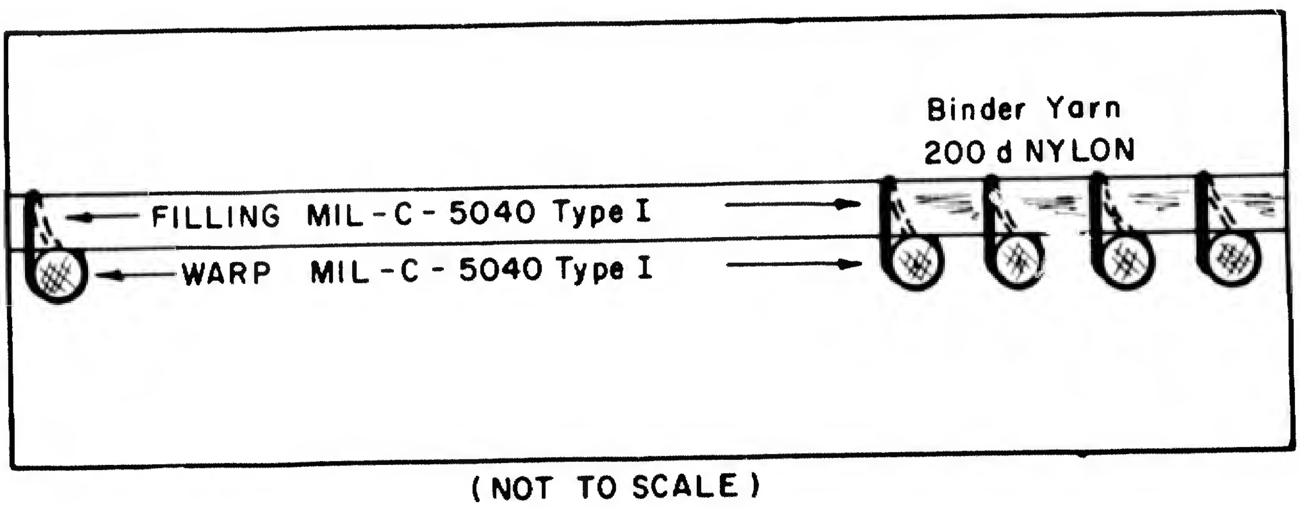

Figure 10. Sketch of Fabric (Side View)