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**DEVELOPMENT OF COTTON AND NYLON, KNITTED CLOTH  
WITH ELASTIC STRETCH CHARACTERISTICS**

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## FOREWORD

This report has been prepared by Prodesco, Inc., and covers the work accomplished during the contract period from June 1962 to September 1963 under Air Force contract AF 33(657)-9510, Project 6314, "Air Force Uniforms," Task 631403, "Materials Clothing." The work was administered by Air Force Systems Command, Aeronautical Systems Division,\* Wright-Patterson Air Force Base, Ohio. Mr. Roy Harlan, Clothing Division, Systems Engineering Group, was the contract monitor. This report is the final report and concludes the work on Contract AF 33(657)-9510.

\*Now under direction of Systems Engineering Group, Research and Technology Division.

ABSTRACT

Blends of cotton and synthetic fibers were studied (nylon, polyester). These were knitted into fabrics to evaluate their elastic elongation, gripping characteristics, as well as non-yellowing properties in the case of white. Data are presented on the yarns and fabrics employed. The fabric was designed to provide a clean, snug fitting glove which has good gripping characteristics equal to all cotton.

This technical documentary report has been reviewed and is approved.

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## INTRODUCTION

The purpose of this development was to provide an improved dress glove fabric for general use of military personnel. The fabric was to conform with as many as possible of the desirable characteristics of the cotton Simplex glove fabric of Specification MIL-C-40004, Cloth, Cotton, Knitted, Simplex. The glove fabric should have sufficient elastic elongation to permit the use of a single glove directly over the hand or the hand and standard MIL-C-835 glove inserts, Wool-M-1949 and to provide, in either case, a clean, snug fitting, wrinkle-free appearance. The cloth was to be non-yellowing and provide a gripping characteristic equal to or better than the standard MIL-C-40004 cloth to permit safe handling of military vehicles and rifles. The manufacturing techniques applied in this work had to conform to and be compatible with standard commercial practices, and industrially available equipment to assure commercial reproducibility of the finished end product. The selection of raw materials, the preparation of the yarns, warping, knitting, and finishing operations did not present any critical problems, except in scheduling. The project was terminated with a successful product and an assurance that the fabric could be reproduced at a reasonable price by any of the known manufacturers of these specific yarns and fabrics.

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## A. YARNS.

Screening of the commercial market for available yarn types which would offer the specific advantages of elasticity in the base fabric was already undertaken at the time of the contract award. It was determined that three (3) types of fibers would be examined for their potential use as the elastic component for the glove fabric. Prodesco's experience in weaving elastic yarns enabled the company to minimize the yarn screening program and thus save considerable time and money. The following yarns were utilized in the initial screening program.

1. 40/8/RO2 - Type 55 Dacron polyester
2. 30/10/.5 Z - Type 680 Nylon
3. 40/7/.5 Z - Type 280 Nylon

It should be noted that a prime requisite of the stretch yarn raw materials was the coarse denier per filament required to achieve the high powered stretch. Examination of existing stretch fabrics being used in the commercial market revealed that the highest power was achieved through the use of coarse denier/filament yarns. The large diameter filament reacts much like a coil spring in its power to recover from compression or elongation.

Selection of the total denier sizes was determined by the limitation of the simplex knitting machine which was to be used. These yarns, of course, are made into a 2-ply structure so that a zero torque yarn will result after manufacturing. We are describing on the following page, some of the characteristics of the stretch yarn system utilized for this program.

The Whitin ARCT machine manufacturers a false twist type stretch yarn similar to that made via the Flufilon, Superloft, and Helenca SPZ machines. The false twist type stretch yarns are similar to the conventional type stretch yarns in that both will stretch up to approximately 50% in fine deniers and will bulk up to 300% when relaxed. The conventional false twist stretch yarn involves a multi-stage process and is normally referred to as the Helenca process. The Whitin ARCT, like the Flufilon and Superloft, utilizes a one process operation where the yarn travels from the raw material package through a spindle which imparts a high twist, and onto a takeup package. If, as in this case, a torque-free yarn is desired, yarn from two banks of spindles or from two separate machines are combined, S and Z together, to form a 2-ply yarn with zero torque.

The selection of the ARCT was intended to present the highest degree of uniformity of texture and dye affinity possible in false twist type stretch yarns. The continuity of the process is excellent, and can be varied to suit the end use desired. By using a high twist for example, a highly elastic yarn can be produced, or by using a low twist, the resultant yarn has low stretch and imparts a soft, nubby surface. The false twist-type stretch yarns are used extensively in a wide

variety of stretch-to-fit knit fabrics and garments. Several throwsters were consulted and the consensus of opinion was that the ARCT machine would impart the greatest degree of elasticity for our purposes. The Madison Throwing Company of Madison, N. C. assisted by manufacturing the false twist stretch yarns which were utilized. They were most cooperative; however, we experienced several lengthy delays because of their scheduling problems.

## B. KNITTING STUDY

### 1. Machine and Stitch Selection

The knitting machine normally used to manufacture the MIL-C-40004 cotton simplex fabric is a 32 ga., 2 needle bar, warp knitting machine which utilizes a 48 line Atlas pattern in that spec. For reasons of achieving better elasticity, the use of stretch yarns and the jersey stitch were made. Because of the denier of the total stretch yarn to be used, it was necessary to utilize a 30 gauge rather than a 32 gauge. Normally, simplex fabrics are made on one or the other, depending upon the ultimate weight to be achieved; however, there is a limitation on the size of yarn to be used on a 32 ga., and therefore, it was necessary to utilize the coarser gauge machine. The experience of the Blue Ridge Textile Co. indicated that the jersey or plain stitch would be preferred over the Atlas principally because the additional benefits of recovery from stretch. Use of the plain stitch also eliminated the striped effect which results from the Atlas pattern. We felt that the Atlas pattern might also tend to reveal the differences in luster between the cotton and the stretch yarn component in the proposed fabric.

Initially, one of the considerations was the use of a combination stretch yarn spun into the core of a cotton yarn. This was soon removed as a candidate because of the coarseness of the resultant yarn and the fact that it could not be knitted on the limited gauge machines available.

### 2. Experimental Fabrication

When the initial yarn selections were made, experimental quantities were secured for knitting experiments. Over thirty-five (35) experimental fabrics were manufactured and evaluated in the first phase. Care was taken to run the nylon in such a way that it would appear mostly on one side of the fabric and not 'grin' through too much. The runner lengths were adjusted so that a greater proportion of cotton was apparent on the side which would be utilized as the outside of the glove. Ten (10) of the best candidate fabrics were selected to be made into experimental gloves and evaluated by the Air Force. The ten (10) that were selected are listed in Table I with their top and bottom runner lengths noted so that one may discern the amount of cotton versus nylon or Dacron which was made. The selections were made based on elasticity, hand and appearance.

The results of this study indicated that the 30 denier nylon provided a much more supple and desirable fabric, both from the standpoint of hand and elasticity. All of the fabrics knitted with the 40 denier stretch yarns tended to be heavy and boardy, lacked stretch and had a less desirable surface appearance. The experimental gloves were submitted to an evaluation including wash tests. It was found that there was very little shrinkage in the finished glove when subjected to repeated washing and tumble drying cycles. This indicated a very high degree of fabric stability.



The Air Force noted that a slight degree of greying occurred after several washings on the experimental gloves. The exact cause was not determined; however, the addition of a small amount of household bleach in the wash water maintained a satisfactory white during the repeated washings.

Prodesco, in a further effort to improve on the experimental submissions, investigated the use of a finer count cotton yarn. Prodesco and Blue Ridge decided the best running characteristics and the best economies for long term buying would be achieved if the 90/1 cotton yarn which was used in all the experimental prototypes would be used in the final product also. Although it is common to use finer cotton yarns up to 120/1 cotton count in simplex glove fabrics, it was felt that the peculiar running characteristics of the combination cotton and stretch nylon would make it undesirable in this instance. Further experimentation in the future might reveal a better pair of yarns but the manufacture of such a limited quantity of fabric did not allow for such extensive experimentation.

All experimental and production knitting was performed with personnel and equipment of the Blue Ridge Textile Co., under the supervision and guidance of Prodesco. This company had been selected as subcontractor because of its experience in manufacturing knitted simplex fabrics for the glove industry and because the company was willing to cooperate in this development effort. The location of the Blue Ridge Textile Co., was also a distinctive advantage to the supervisory responsibility of Prodesco.

Prodesco prepared all of the experimental warps for the initial screening phase. Warping of stretch nylon is a critical operation and one over which close control is necessary to achieve the best product. Tension control is accentuated by the requirement of stretch yarn which, if allowed to run slack, provides an impossible situation for knitting. Every effort was made to produce the most uniform beams and warps for the knitting operations.

Considerable difficulty was encountered in the initial knitting experiments. It was found that unusual care had to be taken in the knitting operation to avoid entanglements of the stretch yarns with the cotton yarns during the knitting operation. Some broken filaments were encountered in the stretch nylons but it was felt that larger quantities of this yarn processed in a more commercial-like manner would probably result in fewer number of broken filaments. All defects noted during the experimental knitting were closely investigated by Prodesco and Blue Ridge personnel. The causes for these yarn and fabric defects were identified as best as possible and determined to be from factors which were easily modified. Approximately three (3) yards of experimental fabric resulted from each prototype. Some of this was lost during the finishing processes but the balance was utilized for testing and glove manufacture.

### C. DYEING AND FINISHING STUDY

The experimental fabrics were scoured, dyed white and finished by heat setting relaxed, and sueding. An outline of a typical finishing process is given in Table II. The amount of sueding can be varied considerably depending on the degree of surface smoothness that is desired. The fabric is considerably loosened and loses some of its elastic characteristics when submitted to too severe a sueding operation. Therefore, it is highly desirable to approach this operation with care and this was done so by the Blue Ridge finishing personnel. It was

agreed that some improvement in the sueding could be made after the examination of all experimental samples.

Of the ten samples submitted in glove form to the Air Force, as outlined in Table I, two were selected as having the most desirable characteristics. These were identified as PBRAF #22-4 and PBRAF #25-6. It may be noted that in both cases, the runner length on the nylon was longer than that on the cotton although the total amount of the runner length was different between the two samples. PBRAF #25-6 was a slightly heavier fabric because of the additional quantity of yarn contained therein. PBRAF #22-4 was utilized as the prototype for the production yardage.

TABLE I  
EXPERIMENTAL FABRICS FOR EVALUATION

PBRAAF #22 - 30/2 nylon top - 100/1 cotton bottom

	<u>Bottom*</u>	<u>Top*</u>
S-4	30	33
S-5	30	31

PBRAAF #25 - 30/2 nylon top - 100/1 cotton bottom

S-3	32	33
S-4	32	34
S-5	32	35
S-6	35	37

PBRAAF #26 - 40/2 Dacron top - 100/1 cotton bottom

S-2	32	33
S-5	35	37
S-6	36	38

PBRAAF #27 - 40/2 nylon top - 100/1 cotton bottom

S-1	35	37
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\* Figures shown are in inches.

## TABLE II

### TYPICAL COTTON/NYLON SIMPLEX FABRIC FINISHING

1. Scour (with detergent and caustic).
2. Bleach (with Textone).
3. Dry.
4. Suede cotton side.
5. Dye on Beck (including white).
6. Rinse (add finish if necessary).
7. Quetsch and dry.

#### D. FINAL PRODUCTION

After completion of all the experimental phases, the final product development of this improved simplex cotton/nylon fabric was undertaken by Prodesco. The necessary 30 denier nylon yarn and 90/1 cotton yarns were ordered. Madison Throwing Co. of Madison, N. C. produced the ARCT stretch yarn exactly as that item had been produced for the prototype experiments. A torque-free balanced 2-ply yarn was delivered to Prodesco for this final fabric manufacturing. The 90/1 cotton yarn was purchased from the Fitchburg Yarn Co. of Fitchburg, Mass., spinners of very fine cotton yarns. Fitchburg yarns were used because of the company's reputation in producing fine, evenly spun cotton yarns which are relatively free of excessive surface hair which would be a real problem in the knitting.

##### 1. Knitting

The warp preparation and knitting of the base cloth was performed by the Blue Ridge Textile Company. Mr. Archibold Doubleday of the subcontractor's company, supervised the entire processing of the fabric and assured Prodesco that the fabric could be manufactured in a normal manner. Inspection of the knitted fabric revealed that its quality was of highest commercial standard, free of serious imperfections. The successful knitting of this final yardage in a standard mass production fashion established that it is absolutely feasible to produce this fabric at a reasonably high efficiency and low cost and in the required high standard of quality.

##### 2. Dyeing and Finishing

The dyeing and finishing was conducted at the Blue Ridge Textile Co. under the supervision of Miss Dorothy Achey, Technical Director. A highly satisfactory fabric resulted from the dyeing and finishing. A good base white was achieved with the use of a typical commercial bleaching practice suitable for cotton and nylon combinations. Selection of dyestuffs and procedures was based on the knowledge that maintenance of a good white was critical in this application. Every effort was made to stabilize the fabric against residual shrinkage in excess of 3% so that continuous fit would be achieved in the final glove products.

E. GLOVE MANUFACTURING

The Blue Ridge Textile Co. made the arrangements for the experimental glove manufacturing. The Crescendoe Glove Co. of Johnstown, New York, manufactured the experimental gloves to the size requirements as outlined by the Air Force during that portion of the program. The pattern which they used was the standard pattern submitted by the Air Force in the form of sample gloves. A variety of sizes, in both men's and women's gloves were submitted during the course of the development program. The quality of the glove manufacturing appeared to be of the highest commercial type with attention given to the finer details in those gloves.

The comment of the glove manufacturer was that this was a very desirable fabric in its handling characteristics and they felt that there might be some commercial interest in the fabric if the cost were not too high.

TABLE III

DESCRIPTION OF YARNS AND FABRICS

YARNS:

Raw Nylon -	30 denier - 10 filament .5 Z turns - Type 680 Nylon
Stretch Nylon -	ARCT crimping method - 2-ply zero torque final yarn
Cotton -	90/1 combed long staple cotton

FABRIC:

A 635 S	
30 gauge Simplex	
Weight - oz/sq. yd	7.25
Texture:	
Wales/inch	48
Courses/inch	42
Stretch:	
Length (wales)	20.0%
Width (courses)	66.6%