AD NUMBER: AD0217056
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to US Government Agencies and their Contractors; Administrative/Operational Use; 1 May 1959. Other requests shall be referred to Headquarters Quartermaster Research and Engineering Command, Natick, MA 01760.
AUTHORITY
QMREC ltr dtd 8 Apr 1965

AD 217056

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR MICRO-CARD CONTROL ONLY

1 OF 2

BEST

AVAILABLE

COPY

HEADQUARTERS

QUARTERMASTER RESEARCH & ENGINEERING COMMAND

U S ARMY

TEXTILE SERIES REPORT

NO. 106

A SURVEY OF 18-OUNCE BLENDED SERGE FABRICS: MANUFACTURING AND PHYSICAL PROPERTIES

QUARTERMASTER RESEARCH & ENGINEERING CENTER

TEXTILE, CLOTHING AND FOOTWEAR DIVISION

MAY 1959 NATICK, MASSACHUSETTS

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, U S ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

This is one of a series of three reports under the general heading "A Survey of 18 oz. Blended Serge Fabrics" which describe studies carried out as part of the Quartermaster Wool Conservation Program.

The 18 oz. serge, since it is used by the Army for trousers in the cold weather uniform and by the Air Force in its service uniform, is a military fabric of importance to both services. An indication of this is the fact that during World War II, a large part of the domestic wool clip was needed to fulfill the Quartermaster and Air Force requirements for this one fabric alone. Because of the interest of both services in the fabric, this study was funded in part by the Air Force. The support given this program by the Air Force since 1953 has enabled the Quartermaster to approach the problem of conservation on a broader basis than would have been possible with Quartermaster Corps funds alone.

This report describes the work carried out under contract with Collins and Aikman Corporation, New York City, and covers the manufacturing phase of 20 experimental fabrics and a standard control. The results indicate that most of the wool-synthetic blends included in this study can be processed on the modified Bradford system for producing worsted fabrics, using conventional equipment, with no greater difficulty than is experienced in manufacturing the all wool control. Physical properties of the fabrics necessary for specification requirements are included for information purposes and for use in preparing specifications.

Laboratory evaluations of the fabrics in terms of appearance, comfort, wear and protective properties will form the basis for a separate report.

Sincerely,

C. G. Calloway
C. G. CALLOWAY
Major General, USA
Commanding

1 Incl
TS-106

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

TEXTILE, CLOTHING & FOOTWEAR DIVISION

Textile Series
Report No. 106

A SURVEY OF 18-OUNCE BLENDED SERGE FABRICS: MANUFACTURING AND PHYSICAL PROPERTIES

Constantin J. Monego

TEXTILE ENGINEERING BRANCH

Project Reference:
93-18-020A

May 1959

FOREWORD

One of the major technical problems confronting the Quartermaster Corps during World War II was the possibility of insufficient wool being available to supply wool-type clothing to the troops. As a consequence, a wool conservation program was instituted shortly after the outbreak of the war to determine ways in which requirements for wool could be minimized. Due to a fortunate combination of factors no shortage of wool occurred during the war, but there was no assurance that in a future emergency a similar favorable combination would exist which would enable the domestic wool supply to be augmented by imports of foreign wool. Accordingly, wool continued to be considered a potentially critical material in times of national emergency.

After World War II, and in accordance with a Wool Conservation Program, the Quartermaster Corps explored the use of possible alternates for wool in a study which was made on the commercial man-made fibers then available and which evaluated their utilization either alone or in blends with wool. Subsequent to the time at which this early study was made, the textile and chemical industries developed new and improved man-made fibers. Since these appeared to offer considerable promise, it was evident that study of the newer fibers was required to evaluate their possible use in wool-blended alternates for standard all-wool fabrics. Accordingly, in 1951, the Quartermaster Corps, acting on recommendations from industry and on the advice of the National Research Council, initiated two studies covering the 18-oz. serge.

The 18-oz. serge fabric was chosen because of its importance as a military fabric as indicated by the facts that it is used for the trousers of the Army cold-weather field uniform and for the Air Force service uniform, and that, during World War II, production of this fabric alone consumed one-fifth of the total domestic production of wool.

Of the two studies initiated in 1951, one included only fabrics containing acrylic fibers, while the other included fabrics containing other man-made fibers as well as the acrylics. The results of these studies were presented in Textile Series Report No. 98, "Blends of Wool Type Fabrics".

FOREWORD (Con't)

From 1951 on, the chemical and textile industries continued their research and development efforts in the fiber field with the result that several new fibers became commercially available and existing man-made fibers underwent considerable modification and improvement. Thus again, a new evaluation of serge fabrics was required in order that the Quartermaster Corps might keep abreast of industry and take full advantage of the most recent advances in textile technology.

The present report describes a recent study conducted jointly by the Quartermaster Corps and the Air Force and covers the manufacture of twenty experimental serge fabrics containing new man-made fibers and one control fabric, the 18-oz. all-wool serge. In order to insure comparability, all fabrics in each of two wool grade series were made from a common lot of wool. The wool top was dyed, blended, spun, woven and finished by one manufacturer by conventional procedures used in the manufacture of the 18-oz. serge. The results show that experimental fabrics of this type can be produced using a modified Bradford yarn-spinning system and with no more difficulty in yarn and fabric manufacture than is encountered in processing the all-wool control. Complete processing details for manufacturing the 18-oz. serge are given in the report. Also included in the report are a number of the physical characteristics of yarns and fabrics.

The laboratory evaluation of the fabrics in terms of appearance, comfort, and wear will be covered in a separate report.

Special appreciation should be given to the following who have co-operated in this investigation: Mr. Arthur F. McNally, Mr. Fulton M. Farrel, Mr. Edward F. Menard, and Mr. Phillip T. Bodell, all of Collins and Aikman Corporation.

The author wishes to express his appreciation for the support and encouragement given to this program by Dr. S. J. Kennedy and Mr. Louis I. Weiner of Quartermaster Research & Engineering Command, and by Mr. C. A. Willis of Wright Air Development Center, and Mr. William Corry of The Landers Corporation, Toledo, Ohio

S. J. KENNEDY
Chief
Textile, Clothing & Footwear Division

Approved:

CARL L. WHITNEY, Lt. Col., QMC
Commanding Officer
QM R and E Center Laboratories

J. FRED OESTERLING, Ph.D.
Acting Scientific Director
Quartermaster Research & Engineering Command

ABSTRACT

are described

This report describes the manufacturing and physical properties of 20 experimental serge fabrics which will be evaluated as alternate fabrics for the 18-ounce, all-wool serge now used by the Army and Air Force. These experimental fabrics are blends of wool with such synthetic fibers as have shown promise of being good "wool-supply extenders" as well as wear and appearance improvers.

During the manufacture of these fabrics, the modified Bradford worsted system was found to be satisfactory and no greater production difficulty was encountered than is normally met with in processing the all-wool standard fabric.

All of the blends met the specification requirements for weight and strength. Each of the fiber types, however, when blended with wool, will require modification of the specification in terms of ends and picks per inch.

Although dyeing all-wool fabrics to match Air Force Shade Blue 84 is possible, dyeing of the blends was only partially successful, therefore greater experience must be gained by the mills in dyeing these fabrics before the specification requirements for shade can be consistently met on a full production basis.

Data on the evaluation of these fabrics in the laboratory and by means of accelerated wear and service acceptability tests will be published in later reports.

SUMMARY

Twenty experimental 18-ounce serge blends of wool with 15 and 30 percent levels of Acrilan, Dacron, Orlon, dynel, nylon, and viscose, plus an all-wool standard control fabric, have been manufactured without undue difficulty on equipment commonly in use in the wool industry. While all the yarns produced somewhat exceeded the normal operating tolerances for average and maximum evenness, this appeared to be due more to the small size of the lots than to any spinning difficulty and thus evenness would probably improve with careful test- and quality-control measures.

The blended fabrics all exceeded the specifications for strength, apparently due more to the blends used than to factors such as weave. Yarns in which high-strength fibers such as nylon and Dacron were blended showed more strength than all-wool yarns and the strength increased proportionately with the increase in synthetic fiber content. The coarse fibers such as 56's wool, when spun to the same count as 60's wool, tended to yield yarns low in breaking strength, not because of any difference in the strength of the fibers themselves, but rather because their coarseness cut down their number in cross section and their interlocking and resistance to compacting offered greater possibility of fiber slippage.

Most of the fabrics were close to the 56-inch specification for width, with only four fabrics below the requirement and then by not more than one-quarter of an inch.

There was a spread of about 2 ounces per linear yard in the weight of the fabrics. Only two fabrics fell below the specified minimum of 18 ounces. The median weight for all the fabrics was 18.6 ounces.

The minimum warp specification of 68 ends per inch was met by all but two of the finished fabrics; however, the filling requirement of 54 picks per inch was met by only four of the finished fabrics. These differences demonstrate that the blends, although set to the same loom width, did not respond uniformly to shrinkage in fulling; they also demonstrate the need for further study on texture requirements for specific blends, in terms of ends and picks per inch.

Only nine of the fabrics were acceptable for color. The shade was influenced both by the dyeing of the raw stock and by the surface characteristics of the fabrics. More experience will be needed in shade-matching blends of nylon, Dacron, and acrylic fibers with wool and of blended twill, satin, and crowfoot weaves.

The pertinent yarn and fabric data have been summarized in Table I.

TABLE I

SUMMARY OF CHARACTERISTICS OF EXPERIMENTAL YARNS AND FABRICS

	Yarn Characteristics				Fabric Characteristics					
	Evenness		Breaking Strength	Elongation	Weight	Width	Texture		Breaking Strength	Shade
	Av. Dev. (%)	Max. Dev. (%)	(oz)	(%)	(oz/lin yd)	(in)	E/in (no.)	P/in (no.)	(lb)	
Specification MIL-C-823: (minimum)	-	-	-	-	18	56	68	54	110x100	USAF-84
100% 60^s wool	57.7	83.6	18.7	8.9	18.8	57-1/8	68	52	176x136	OK
70/30 60^s wool/3d.visc:										
2 x 2 twill weave	39.6	69.1	23.0	8.7	19.6	57-1/8	68	54	157x121	thin blue
gabardine weave	39.6	69.1	23.0	8.7	19.6	55-7/8	68	52	170x121	OK
crowfoot weave	39.6	69.1	23.0	8.7	19.2	56-5/8	69	54	156x121	thin red green
mayo twill weave	39.6	69.1	23.0	8.7	19.7	56-1/4	68	52	144x116	OK
satin weave	39.6	69.1	23.0	8.7	19.3	56-1/8	70	53	155x117	thin red
100% 56^s wool	45.8	78.0	17.9	14.0	17.9	57-1/4	67	53	147x122	OK
70/30 56^s wool/3d.visc	49.4	75.8	21.4	11.6	18.6	57-1/8	68	56	145x111	OK
70/30 56^s wool/5.5d.visc	57.1	83.9	17.8	16.1	18.5	57	69	54	142x111	OK
85/15 wool/viscose	51.5	82.7	23.9	9.4	18.6	56-3/8	70	52	140x106	OK
85/15 wool/nylon	49.7	85.4	27.8	23.0	18.9	56-3/4	70	55	221x173	OK
70/30 wool/nylon	51.9	84.6	29.6	21.3	19.2	55-3/4	66	55	304x251	within tolerance
85/15 wool/Dacron	61.5	89.8	20.6	17.2	18.9	56-1/2	69	55	204x157	thin green flat
70/30 wool/Dacron	49.6	68.4	30.8	29.1	19.2	55-3/4	70	52	236x188	thin red frosty
85/15 wool/dynel	48.3	81.7	23.0	23.9	18.8	55-3/4	70	55	186x151	thin red
70/30 wool/dynel	49.6	83.1	25.9	25.8	19.6	56-7/8	69	55	215x169	thin red
85/15 wool/Orlon	35.1	64.2	19.4	16.5	17.6	56	69	54	161x124	red violet
70/30 wool/Orlon	54.6	83.4	24.6	18.4	18.0	56-1/8	70	52	180x138	thin red
70/20/10 wool/visc/nylon	52.2	77.7	23.4	17.0	18.2	56-1/2	70	55	175x139	OK
85/15 wool/Acrilan	43.4	60.0	22.2	17.6	19.2	56-1/4	70	55	177x131	thin red
70/30 wool/Acrilan	44.3	60.0	25.2	23.2	18.9	56-1/8	70	50	190x145	thin red

NOTE: Unless otherwise stated, the blends are of 60^s wool and 3-denier synthetic fibers.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

A SURVEY OF 18-OUNCE BLENDED SERGE FABRICS
Manufacturing and Physical Properties

A. Introduction

This is the first report of a study of 20 wool blends that have been developed by the Quartermaster Corps as possible alternates for the standard 18-ounce all-wool serge used in the cold weather combat uniforms of the Army and in the service uniforms of the Air Force. This part describes in detail the manufacturing processes by which these fabrics were produced and compares the resultant physical properties with specification requirements for the standard fabric. Part II will contain a critical evaluation of laboratory data on appearance, comfort, wear, protective qualities, sewability, shrinkage, crease retention and crease resistance of these fabrics. Part III will present final Quartermaster Corps field and Air Force acceptability test data and will summarize laboratory findings.

Toward the close of the Korean War the critical domestic supply of wool (data on which are given in Appendix I), plus unsettled market conditions, intensified the need of all the Armed Forces for a low-cost alternate for wool and prompted a combined Quartermaster Corps-Air Force attack on the problem.

The Quartermaster Corps had earlier developed two wool blends, a wool/nylon and a wool/viscose 18-ounce serge. While satisfactory as temporary alternates, neither fabric was satisfactory as a permanent replacement for all wool. The wool/nylon, while more durable than the all wool, presented problems in sewing and tailoring. The wool/viscose was not completely satisfactory from the points of view of durability and appearance. Neither of these fabrics was ever produced in the Air Force Blue approved by the Quartermaster Corps Technical Committee in September 1948. The combined Quartermaster Corps-Air Force approach has made possible the production and dyeing, in Air Force Shade Blue 84, of these two fabrics, also the production and dyeing of a ternary blend combining wool with both nylon and viscose, and a 100% wool control, in lots (400 yards each) sufficient for Air Force acceptability trials (Table II, A). Viscose is inexpensive and available in adequate quantity and the wool/viscose blend

---

Manuscript released by author 5 January 1959 for publication as a WADC Technical Report.

TABLE II

EXPERIMENTAL FABRICS GROUPED ACCORDING TO VARIABLES

A. Initial alternates and ternary blend*

100% wool (control)
70/30 wool/viscose
85/15 wool/nylon
70/20/10 wool/viscose/nylon

B. Viscose blends varying in weave

**100% wool (control), 2x2 twill	60's wool grade	
**70/30 wool/viscose (c), 2x2 twill	" " "	3-denier viscose
70/30 wool/viscose, gabardine	" " "	" " "
70/30 wool/viscose, crowfoot	" " "	" " "
70/30 wool/viscose, Mayo twill	" " "	" " "
70/30 wool/viscose, satin	" " "	" " "

C. Fabrics varying in fiber coarseness

**100% wool (control), 2x2 twill	60's wool grade	
100% wool, 2x2 twill	56's wool grade	
**70/30 wool/viscose (c), 2x2 twill	60's wool grade.	3-denier viscose
70/30 wool/viscose, 2x2 twill	56's wool grade.	" " "
70/30 wool/viscose, 2x2 twill	" " "	5.5-denier viscose

D. Blends using different types and levels of synthetic fibers*

**100% wool (control)
**70/30 wool/viscose
85/15 wool/viscose
70/30 wool/nylon
**85/15 wool/nylon
70/30 wool/dynel
85/15 wool/dynel
70/30 wool/Dacron
85/15 wool/Dacron
70/30 wool/Orlon
85/15 wool/Orlon
70/30 wool/Acrilan
85/15 wool/Acrilan

* 2x2 twill weave; 60's wool grade; if a blend, 3-denier synthetic
** Listed in other sections of this table
c = control

had been found to be easily manufactured.

A second and a third group of fabrics was produced for this study in order to determine whether durability could be increased by a change in weave or by the use of a coarser fiber. Four of the fabrics were constructed in various weaves for comparison with an all-wool and a wool/viscose twill (Table II, B). Then three fabrics were constructed using the coarser 56's wool: a 100% wool and two wool/viscose blends, one with 3-denier viscose and one with 5.5-denier viscose. These were compared with the standard 60's wool and a 3-denier viscose/wool blend (Table II, C). Two hundred yards of each of these fabrics were produced for both the Quartermaster Corps and Air Force tests.

A fourth group with 10 additional experimental fabrics was constructed to permit study of the effect of combining various types and percentages of synthetic* fibers with wool (Table II, D). One hundred yards of each were produced.

All 20 experimental fabrics were evaluated not only for meeting specification requirements but also for ease of processing and manufacturing.

In addition to its value in explaining the performance of the fabrics, especially as related to manufacturing variables, this information is offered to enable manufacturers to compare methods for making 18-ounce wool-blended serge with methods for making all-wool serge that have been in use and will probably continue to be in use in the future. It should help any mill which now experiences difficulty in producing a wool blend to meet the requirements of Specification MIL-C-823b, to analyze the causes of the difficulty, and to attain closer conformity to Army standards.

In designing the fabrics, the specifications for most blends were first checked by producing only enough yarn to weave and finish from 10 to 25 yards of fabric. These trial runs are referred to in the report as "preproduction". Only after the preproduction samples were examined, evaluated, and approved, did the contractors proceed with full production.

All the wool in the experimental fabrics, including that in the 100% wool control, was taken from the same combined lots of shorn wool for the 60's grade and shorn and pulled wools for the 56's grade. Data on the relative availability of shorn and pulled wool of 60's and 56's grades are included in Appendix I, together with statistics

* The term "synthetic" will refer to non-cellulosic as well as cellulosic fibers in this report.

on U. S. production and consumption of wool and other fibers.

The synthetic fibers were selected on the basis of their availability. The 15% level was chosen because experience had shown that this amount could be incorporated without detracting from the functional properties of all wool. The 30% level was chosen because it would conserve more wool and also because it had been indicated that this level would not materially affect the performance of the fabric. One of the purposes of this report is to seek to confirm the suitability of this 30% level of synthetic fiber content.

B. The Production of Experimentally Blended Wool Serges

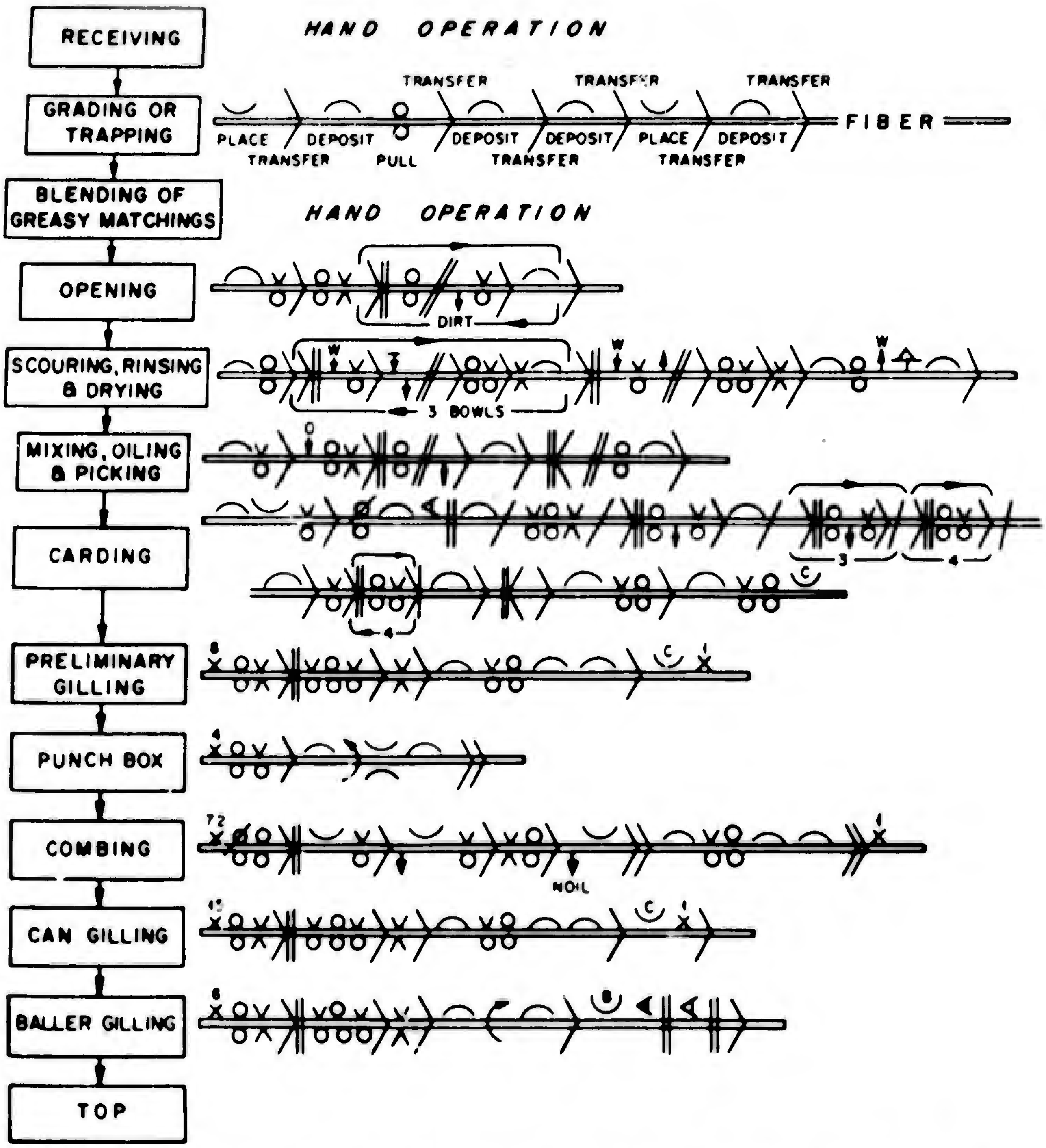
Until 1947, most of the standard serges that were delivered to the Army were manufactured on the Bradford or modified Bradford spinning system. Williamson* shows that of the 24 spinning plants in the United States after World War II, 20 used the Bradford system and, of these, 11 used cap spinning exclusively and 6 used a combination of cap and ring spinning. This study is confined to the "modified" Bradford system (using cap spinning exclusively) around which the specifications for these serges were drawn; this is done to provide producers with a reference to the techniques used in making serge fabrics and to show how these techniques can be adapted to the manufacturing of wool blends.

Production has been broken down into: the processing of raw materials into a combed strand of fibers known as "top"; dyeing and blending operations; drafting, spinning, and twisting of the fibers to form a strong and uniform yarn; weaving of the yarns; and finishing of the material into a form ready for tailoring.

1. Processing - Wool stock to top

Raw wool stock consists of the fleece as it is shorn from the sheep. Regardless of its grade, raw wool may contain 50% or more of its weight in impurities that must be removed before the wool can be processed for clothing. The methods used to remove the impurities and to convert the raw stock used in this study, with its fibers arranged at random, to a clean top with fibers parallel, are outlined in the accompanying flow chart (Fig. 1). In addition, standard engineering action symbols are included. A glossary of these symbols (proposed by Dr. E. R. Schwarz of the Massachusetts Institute of Technology)

* Williamson, William T, "Report on Survey of Various Manufacturing Methods in Use by Worsted Industry for Production of Cloth, Serge, OD, 18-ounce." QM R&D Textile Series Report No. 27, 27 February 1947.



MEANING OF ACTION SYMBOLS IS GIVEN BELOW THE FIRST PROCESS. SYMBOLS ONLY ARE GIVEN FOR SUBSEQUENT PROCESSES. EXPLANATION OF SYMBOLS MAY BE FOUND IN APPENDIX II

Figure 1. Wool Top Manufacture Flow Chart

is in Appendix II. These symbols may help the reader to visualize what happens to fibers during the process of manufacturing. They may aid the textile technologist and machinery manufacturer in their thinking about textile equipment which can be used for a greater variety of fibers than is presently possible.

a. Receiving

Raw wool, or wool "in the grease", is delivered to the mill in bales. These are opened and the wool is removed in the form of rolls, each representing an entire fleece as shorn from the sheep. Strings holding the rolls are cut, and the fleece is opened and placed on a conveyor belt.

b. Grading or trapping

Men stationed along the conveyor belt, strip out by hand the stained and defective wools. Then the fleece is dropped into storage bins according to source and grade. This operation is termed grading or trapping.

c. Blending of greasy matchings

In this study, blends of bright and territory wools* were made for each of the grades tested, namely 60's as required by the specification, and the coarser grade of 56's, called for by the experiment.

In each instance, maximum use of the United States wool supply was insured by following the accepted commercial practice of blending wools from different geographical areas of the country as available. For the 60's wools, the blends consisted of shorn "territory" and "bright" wools. For the 56's, the blends consisted of pulled** wools as well as shorn wools since, in this grade, an abundance of pulled wool is available.

d. Opening

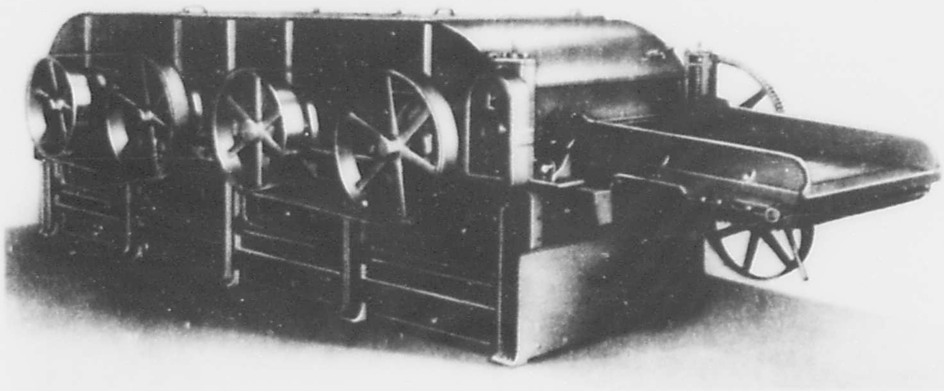
The blend of fibers in the grease is then passed through an opener which, by means of a spiked rotating cylinder, separates the locks of fleece into smaller fiber bundles. The mechanical action involved in opening also loosens up sand and other dirt so that it may be

---

* Wools produced east of the Mississippi River are known as "bright", "fleece", or in a limited sense, "domestic" wool. Wools produced west of the Mississippi River are called "territory" wools.

** Wool taken from the hides of slaughtered sheep is termed "pulled".

more easily removed by the scouring process which follows. Figure 2 shows a 4-cylinder opener.

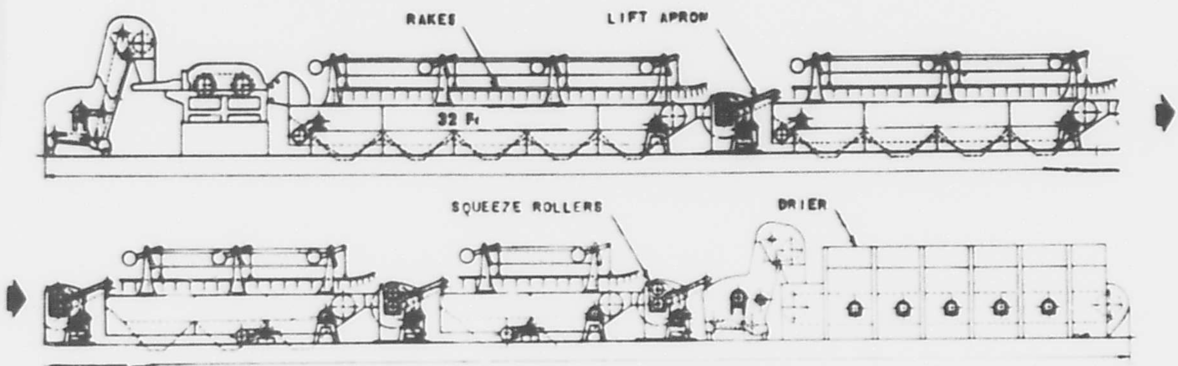


Courtesy of C. G. Sargent's Sons Corp.

Figure 2. Four-Cylinder Opener

e. Scouring, rinsing, and drying

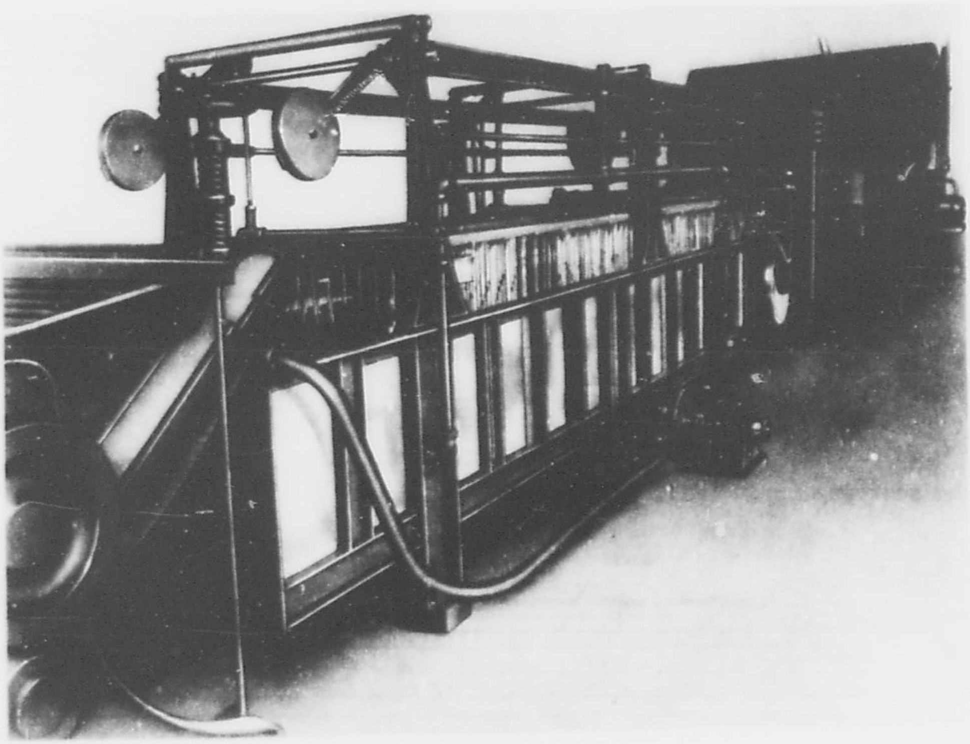
A mechanized feeder further opens the wool and feeds it to the scouring train (Fig. 3).



Courtesy of C. G. Sargent's Sons Corp.

Figure 3. Four-Bowl Scouring Train (165 feet, 3 inches)

There are four bowls in the scouring train. The first three hold the scouring liquor--a soap, detergent, or alkali solution--at a low temperature. The fourth bowl (Fig. 4) is reserved for rinsing. Impurities in the wool, such as wool grease, perspiration salts, and dirt, are removed by the scouring action. The wool is transported through the bowls by a series of rakes and a lift apron which draws the wool from one bowl and passes it between squeeze rollers to the next bowl. On leaving the scouring train, the wool is passed through a drier. The drier reduces the moisture content of the wool to from 16 to 18%. (Wool can retain up to 30% of water by weight before feeling wet.)



Courtesy of C. G. Sargent's Sons Corp.

Figure 4. Fourth Bowl in Scouring Train

f. Mixing, oiling, and picking

This operation mixes and opens the stock even further so that it may be delivered to the cards in the most suitable condition possible.

The mixing picker (diagrammatic view is shown in Figure 5) consists of a feeding apron, two pair of fluted feed rollers, spring-loaded to provide sufficient pressure to hold the stock and to insure its separation, and a large rotating cylinder. This cylinder is provided with hooks or strong spikes bent in the direction in which the cylinder rotates. These hooks pull the stock from the feed rollers and tumble it. This pulling and tumbling action opens up the locks of wool so that smaller fiber bundles will be presented to the cards.

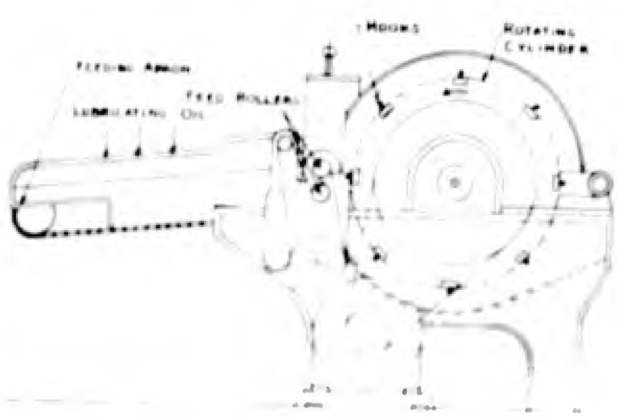


Figure 5. Mixing Picker

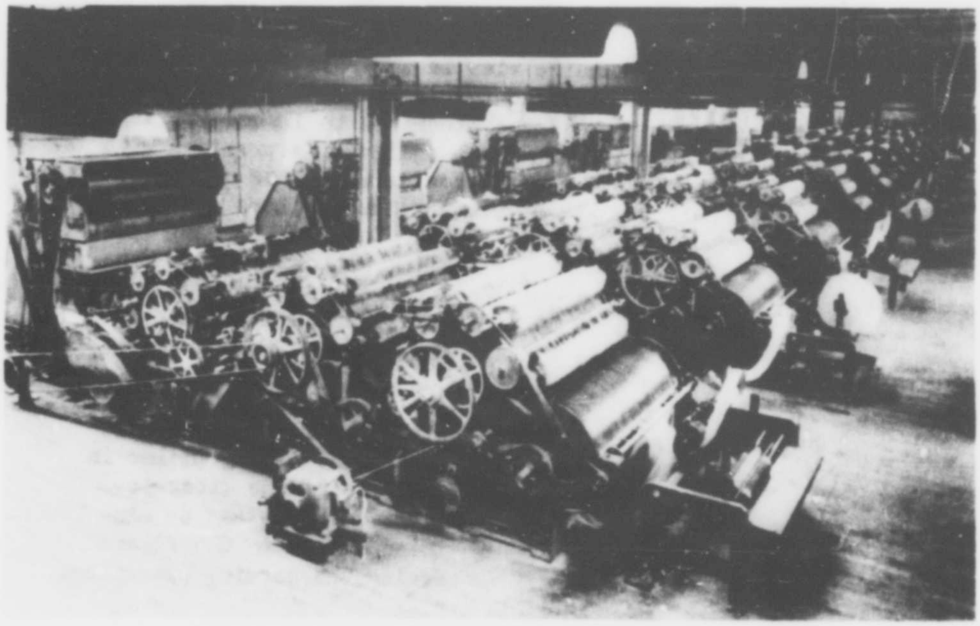
The stock is lubricated with an oil emulsion as it enters the mixing picker in order to reduce fiber-to-fiber friction and to minimize damage to the fibers during the carding operation.

g. Carding

After the stock has been thoroughly picked, mixed, and oiled, the individual fibers in the stock must be straightened. The first straightening operation is the carding process, which: 1) untangles the locks or bunches of fibers and starts to straighten them; 2) removes impurities vegetable matter, burs, dust, and dirt; 3) further mixes the stock; and 4) delivers the fibers in a convenient form for the next operation.

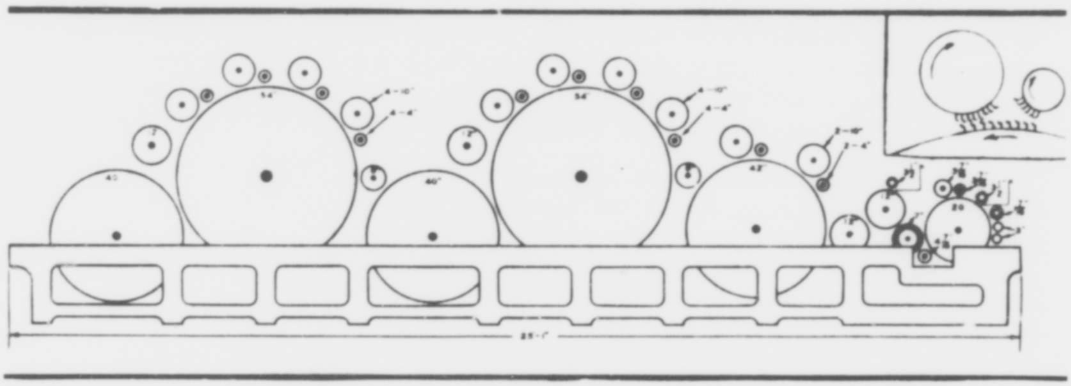
A 2-cylinder worsted card is shown in Figure 6. It consists of a feeding device which controls the amount of wool fed to the card and a series of cylinders which may be seen in the diagrammatic sketch, Figure 7. Each cylinder is covered with wire teeth resembling a brush. These teeth vary in shape and size depending on the particular stock to be carded. In this study, the teeth were bent as shown in the insert of Figure 7.

The manner in which the card opens the wool locks and alines the fibers can best be explained by describing the action of three of the rolls: the main cylinder, the worker, and the stripper. The wool is carried on the teeth of the main cylinder, which travels at high speed,



Courtesy of Proctor & Schwartz, Inc.

Figure 6. Two-Cylinder Worsted Card



Courtesy of Davis & Furber Machine Co.

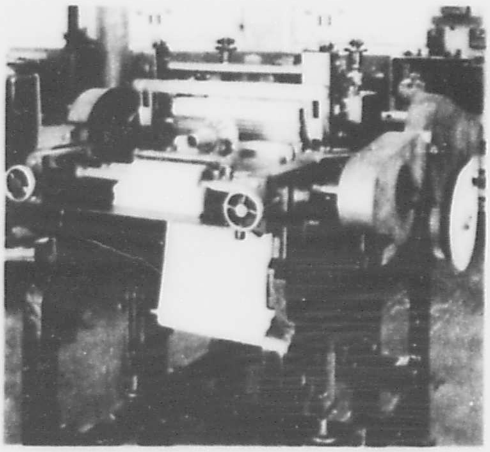
Figure 7. Two-Cylinder Worsted Card

until it comes in contact with the slower moving worker, to which small loads of fibers are transferred a bit at a time by point-to-point action of the teeth. The stripper is the smallest cylinder and it also has a higher surface speed than the worker. The points of the stripper teeth come in contact with the back of the worker teeth, which remove the wool without further combing action. As the wool on the stripper comes close to the main cylinder, which travels at an even higher speed than the stripper, it is removed by another point-to-back action without further combing. This striking and pulling action by the workers, removing the fibers through restraint and transferring them through the stripper to the main cylinder, is repeated eight times in a 2-cylinder worsted card, not counting the feeding mechanism at the start or the doffer at the end.

The doffing action differs from the actions previously described in that the teeth of the doffer cylinder, pointing back-to-back against those of the main cylinder, raise the wool to the tops of the wires of the main cylinder and remove it in a uniform web. This web is removed from the doffer by a doffer comb. It then passes through a funnel to rolls which draw it off. The fibers of the web, while in better alinement than in the scoured wool, are still oriented more or less at random. Also, along its length the card sliver is rarely uniform in weight.

h. Preliminary gilling

(1) First Operation: The next step in straightening and making the fibers parallel as well as producing a more uniform weight of sliver is the preliminary gilling operation. A gill box (Fig. 8) is made up of two front (feed) and two back (delivery) rolls with a set of 16 traveling combs with steel pins following one another between the rolls. Eight continuous strands of sliver are fed to the giller through the slow-moving feed rolls. The steel teeth of the moving combs pierce the wool and comb it out by traveling in the same direction as the wool but at a higher speed. As the combs approach the delivery roll they drop down and are returned to the feed rolls for another pass forward. The delivery rolls pull the wool through the combs, further straightening the fibers. These rolls have a



Courtesy of Atkinson, Haserick & Co., Inc.

Figure 8. Gill Box

surface speed 8 times that of the feed rolls, which in turn exceed that of the combs. A speed ratio of 1 to 8 means that for every 1 inch of sliver fed to the machine, 8 inches are removed. Therefore, with 8 card slivers feeding into the giller, a single sliver emerges equal in size and weight to a single card sliver but with better alinement of fibers and greater uniformity of weight.

(2) Second Operation: The gilling operation is repeated using six ends and a speed ratio of 1 to 6 for further making the fibers parallel before combing.

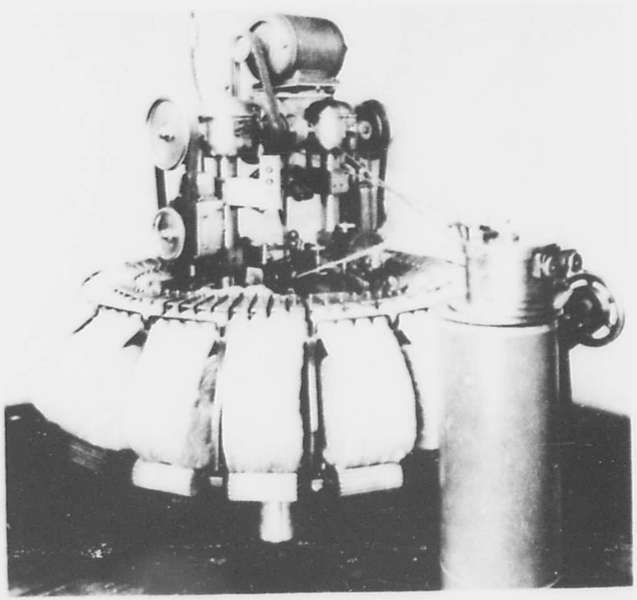
i. Punch box

The punch box consists of a driving roll that rotates a spindle by friction contact. The punch box winds the wool sliver from the gill into suitable packages to fit the Noble comb. Four slivers are wound side by side on the spindle. Each completely wound spindle or punch roll contains 20 pounds of wool. Eighteen packages are required to load one comb.

j. Combing

Combing is the operation that separates the long fibers from the short and presents them in a parallel alinement in the form of a sliver. In this study the Noble comb (Fig. 9) was used, since it is an integral part of the Bradford system. Eighteen punch rolls (balls of wool), each containing four slivers, were loaded around the comb.

The combing action can best be described by referring to Figure 10, which shows diagrammatically the movement of the sliver and the component parts of the comb. The main parts consist of one large circular comb (horizontal circle) containing eight rows of vertical pins, and two smaller circular combs (horizontal circles) with five rows of vertical pins. All the combs rotate about their own axes in a clockwise direction. Two high-speed dabbing brushes drive the fibers into the pins of the large and small circles at their point of convergence. The wool fibers separate as the two circles diverge. The longer fibers protrude inside the large circle and outside the small circle. The star wheel flips the extending fringe of wool fibers into the path of the take-off mechanism: rollers for the small circle, drawing-off rollers and apron for the large circle. The long fibers from both small and large circles are combined into a single strand at the rollers. The strands from both sides of the machine leave through the funnel and take-off rollers as a



Courtesy of James Smith & Son, Inc.

Figure 9. Noble Comb

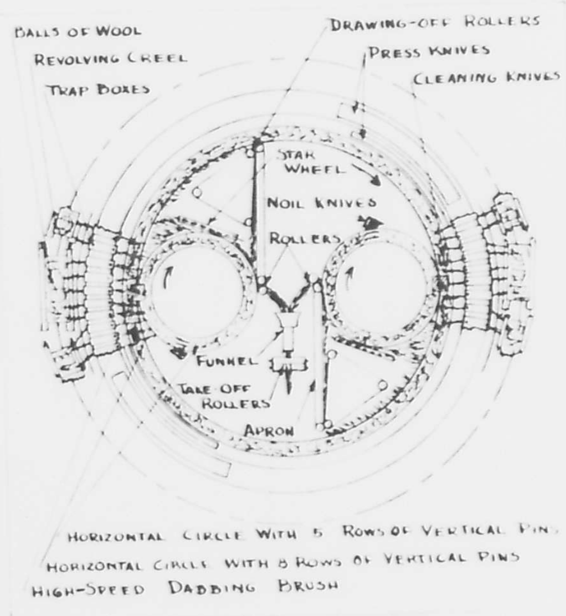


Figure 10. Noble Comb

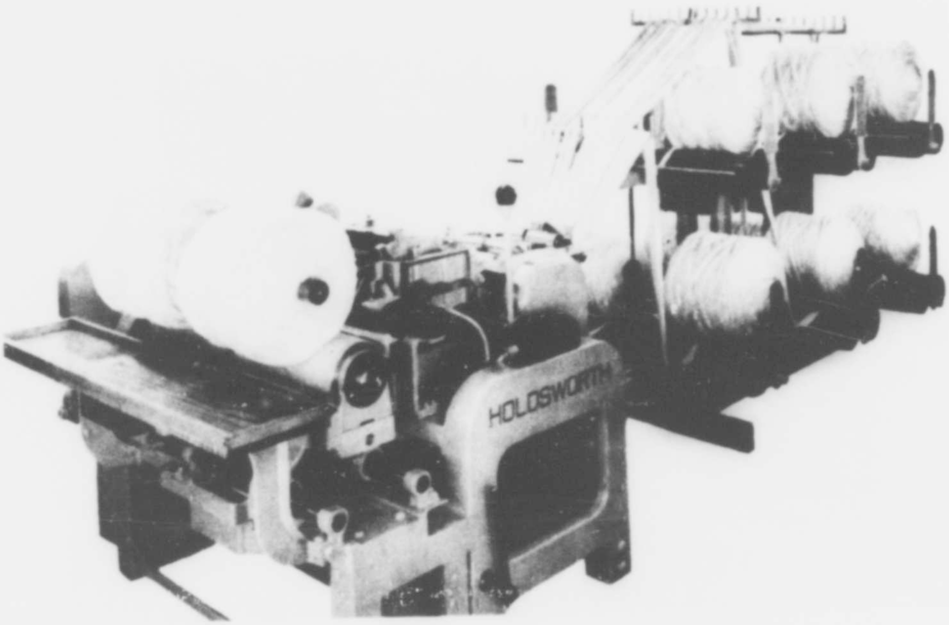
single sliver or top. The short fibers, neps, and noils remain in the small circle to be removed by noil and cleaning knives. The small circle, now cleared of fibers, is ready for another charge as it converges with the large circle, which has as an integral part of its mechanism the trap boxes, revolving creel, and the balls of wool.

k. Can gilling

The sliver, as it comes from the comb, is still not sufficiently uniform in diameter and weight, yard for yard. Therefore, several slivers are combined and passed through another gilling operation to produce more uniform strands and to further make the fibers parallel.

l. Baller gilling (or finisher gilling)

Another gilling operation follows in order to deliver a uniform top with a specified unit-weight per yard for the grade and quality of the stock, in this case 262 grains per yard. This gill (Fig. 11) prepares the top in a ball shape for commercial packaging.



Courtesy of Atkinson, Haserick & Co., Inc.

Figure 11. Baller Gill

m. Evaluating the wool top

The wool top, in the form of balls, was purchased by the contractor, who submitted samples to the Quartermaster laboratories for approval. The Philadelphia Quartermaster Depot evaluated the wool by test methods described in the U. S. Department of Agriculture pamphlet, "Method of Test for Grade of Wool Top", December 1954. Although test methods for both 60's and 56's top were the same, tolerance standards differed. The 60's was compared to the standard then in effect for the Quartermaster Corps (but since superseded by a 60's USDA standard). The 56's top was evaluated by a 56's USDA standard.

It will be seen by Table III that both the 60's and 56's met their respective requirements for average diameter and fineness.

TABLE III

WOOL TOP - FINENESS RANGE AND FIBER PERCENT

Grade	56's		60's	
	USDA Standard	Experimental Top	QMC Standard	Experimental Top
Fineness range, microns				
Average diameter, min.	27.1	—	25.0	—
Average diameter, max.	28.5	27.5	27.0	25.5
Fibers, percent				
10-20 microns, min.	—	—	17.0	18.5
10-30 microns, min.	62.0	69.2	75.0	80.3
30.1 microns and over, max.	38.0	30.8	—	—
30-50 microns, max.	—	—	24.0	19.6
40-50 microns, max.	—	—	4.0	2.9
50.1 microns and over, max.	1.0	0.6	1.0	0.1

2. Processing of Synthetic Fibers

Synthetic fibers are produced in various diameters (deniers) and lengths. For this study, those fiber diameters and lengths were selected that would give maximum yarn evenness and strength and minimum manufacturing difficulties when blended with 60's wool, based on information already gathered by the trade. In order to benefit from practical knowledge of this type, the Quartermaster Corps selected contractors with broad experience in blending synthetic fibers with wool. As a result, the Quartermaster Corps decided upon fibers in the following deniers and staple lengths:

	Denier	Staple Length (inches)
Acrilan	3	3-5
Dacron	3	3-5
Dynel	3	4-6
Nylon	3	3 1/2-5
Orlon	3	3-5
Viscose	3	4-6
Viscose	5 1/2	4-6

Synthetic fibers may be purchased in staple or continuous filament, or tow, form. Acrilan, Dacron, dynel, nylon, and Orlon were purchased in staple form, and were then opened and carded into a continuous sliver, then gilled, combed, and can and baller gilled, as shown in Figure 1, to make a top of a specific unit-weight per yard before blending. The viscose was purchased in the form of tow and was processed according to Figure 12.

The viscose tow was converted on a Pacific Converter (Figs. 13 and 14)*, which stretched and broke the continuous filaments into fibers of a specified length. Mechanical crimp was introduced at this stage in order to facilitate further processing. After it was converted, the continuous strand was gilled to provide a more uniform sliver and then pin-drafted (Figure 15) and balled to a definite weight-per-yard.

3. Dyeing and Blending of Colors

The colors selected for matching Air Force Blue 84 were discussed at an American Association of Textile Chemists and Colorists meeting in

* The diagram shows a pre-stretching and heating device which was not used with these fibers.

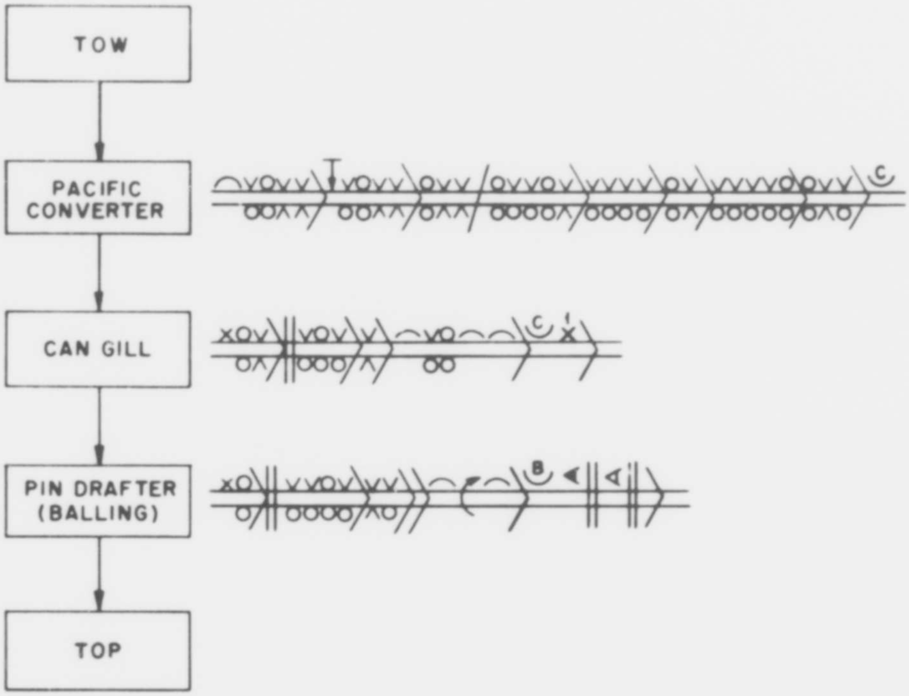
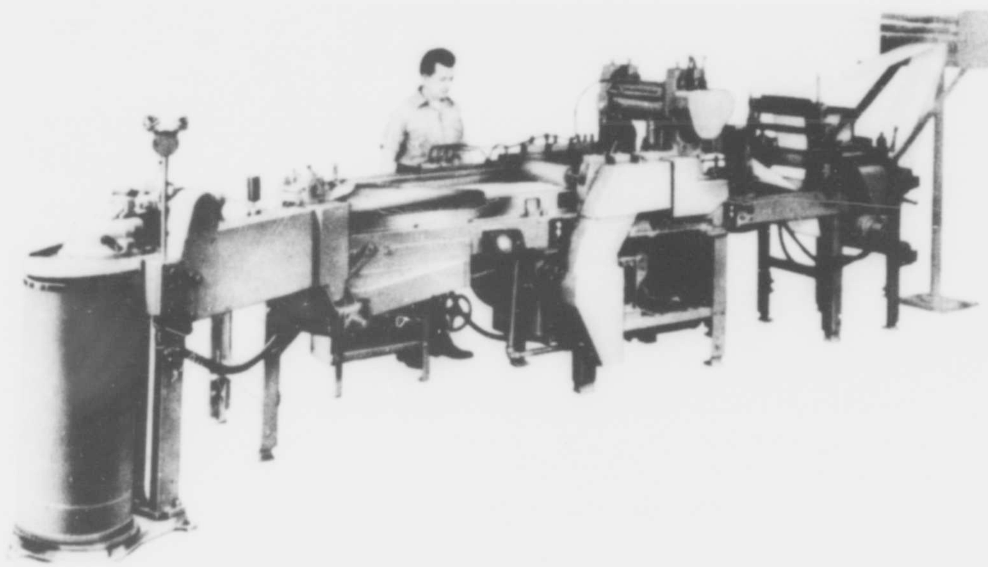
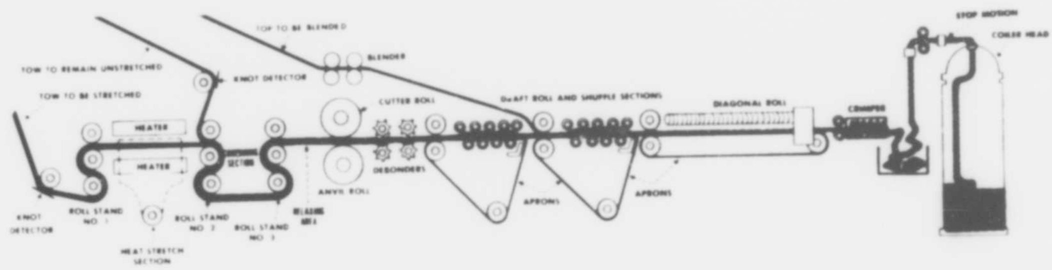


Figure 12. Viscose Yarns - Tow to Top Flow Chart



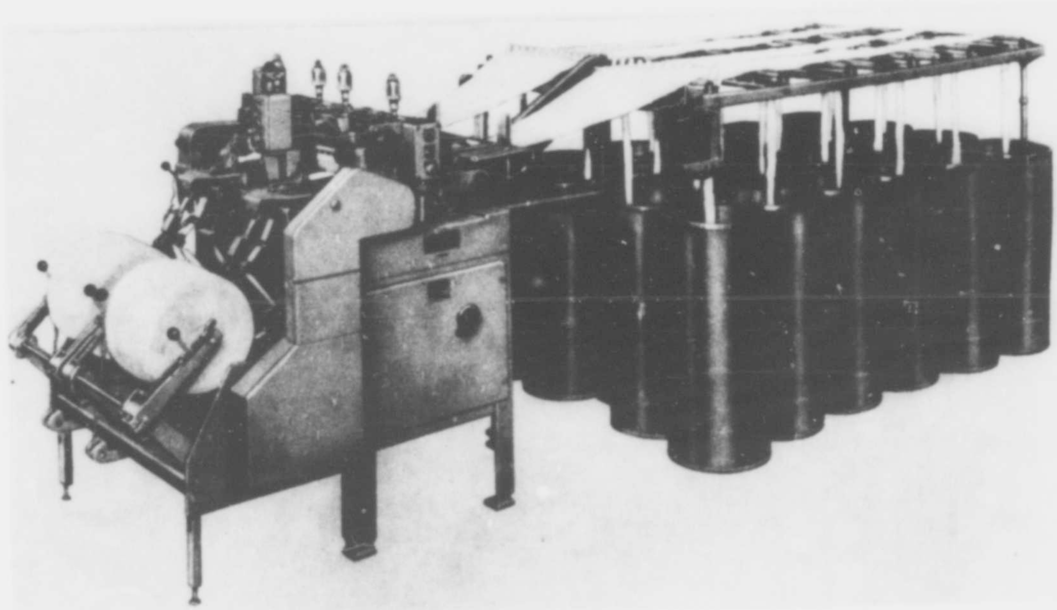
Courtesy of The Warner & Swasey Co.

Figure 13. Pacific Converter



Courtesy of The Warner & Swasey Co.

Figure 14. Pacific Converter



Courtesy of The Warner & Swasey Co.

Figure 15. Pin Drafter with Ball Delivery

New York City on 2 April 1953. At this meeting, a sub-committee (composed of members of the Industry Advisory Committee, the Textile Dyeing Laboratory Branch of the Textile, Clothing & Footwear Division, Quartermaster laboratories, and the Air Force) determined that the Blue 84 shade could be matched by using a pearl base plus a supplementary blue and red-blue. Details on the selection of dyestuffs, the matching of the colors, and the blending for final shade are given in Appendix III.

Color standards developed by the military services make provisions for color tolerance. The standard operating procedure with woolens and worsteds is to use a base color plus three supplementary colors of various hues to establish a full tolerance range. The Quartermaster Corps determined that, in addition to the base and two supplementary colors selected by the Sub-committee, a slate blue (blue with a greenish hue) was needed to establish the required range. The addition of the slate blue enabled the manufacturer to better compensate for dyeing variations in matching the AF Blue 84.

The Quartermaster laboratories (using the pearl base and the three supplementary colors) made a set of color pads* to match the Blue 84 shade--one pad for each of the 17 fiber combinations included in this program. A set of pads and a table showing the percentage of each component used was furnished the contractor as a guide. Figure 16 shows the proportion of primary colors for both preproduction and production lots.

Wool manufactured on the worsted system is dyed in the form of top, so this was done with most of the synthetic fibers, with the exception of viscose and dynel, which were spun-dyed and thus were received in a dyed form.

As is shown in Figure 17, the top from the baller or finisher gill is prepared for dyeing by rewinding it in an intersecting gill to remove any surface roughness or other defects caused by handling. As it leaves the gill box, the top is wound on a perforated dye kettle spool. This spool is hollow and flanged at both ends, which are open. One end is fitted to a special adaptor at the bottom of the dye kettle (Abbott Dye Kettle, Fig. 18). A rod extends through the spool and a metal disc

* A color pad is prepared by blending together, in a laboratory-scale card, wools of two or more colors. This operation is usually repeated three or four times to thoroughly mix the fibers. The blend is treated with a soap solution to produce a light fulling, which locks the fibers together to form a pad, the soap is rinsed out, and the pad dried. The resulting color indicates the color of the finished cloth.

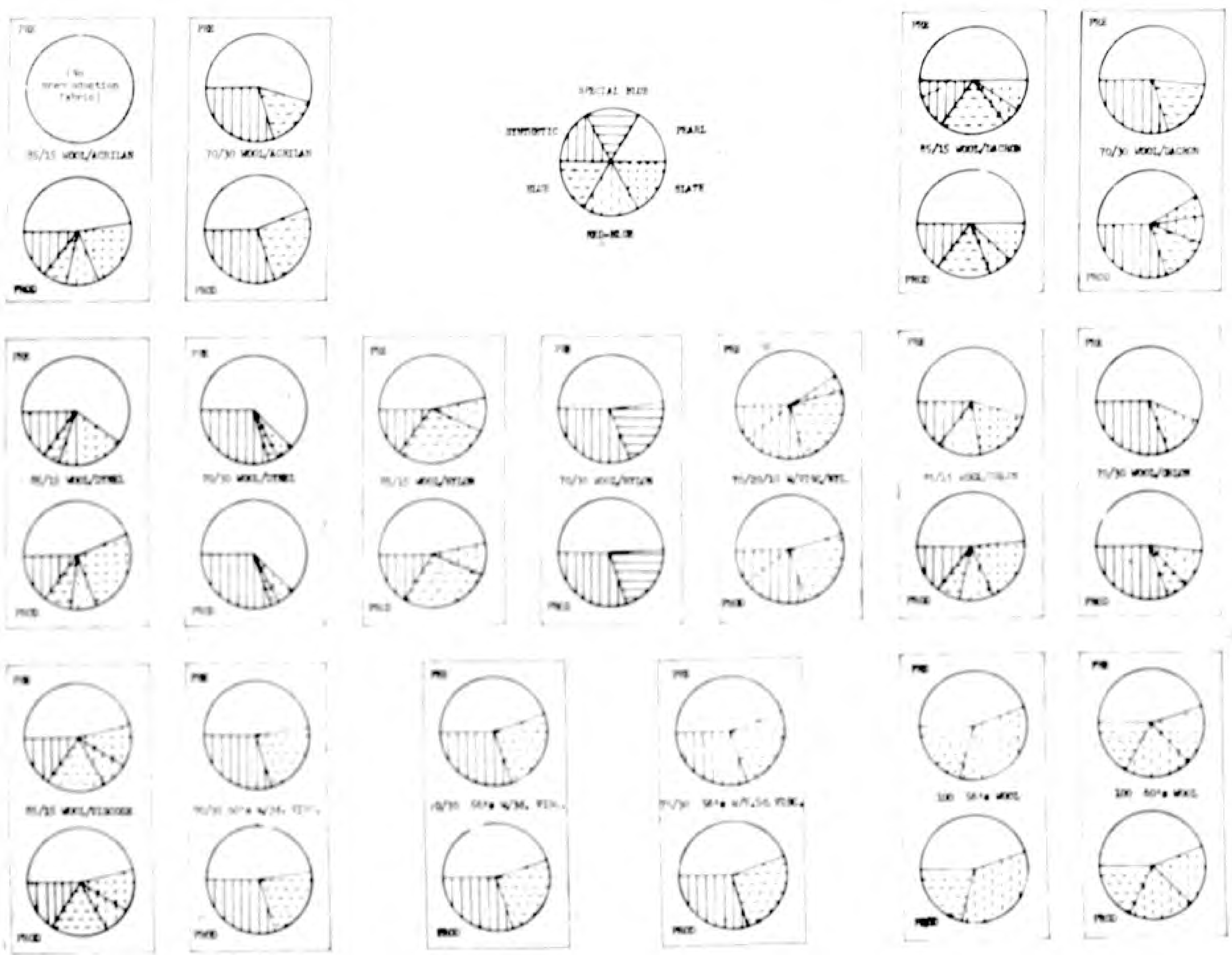


Figure 16. Color Chart

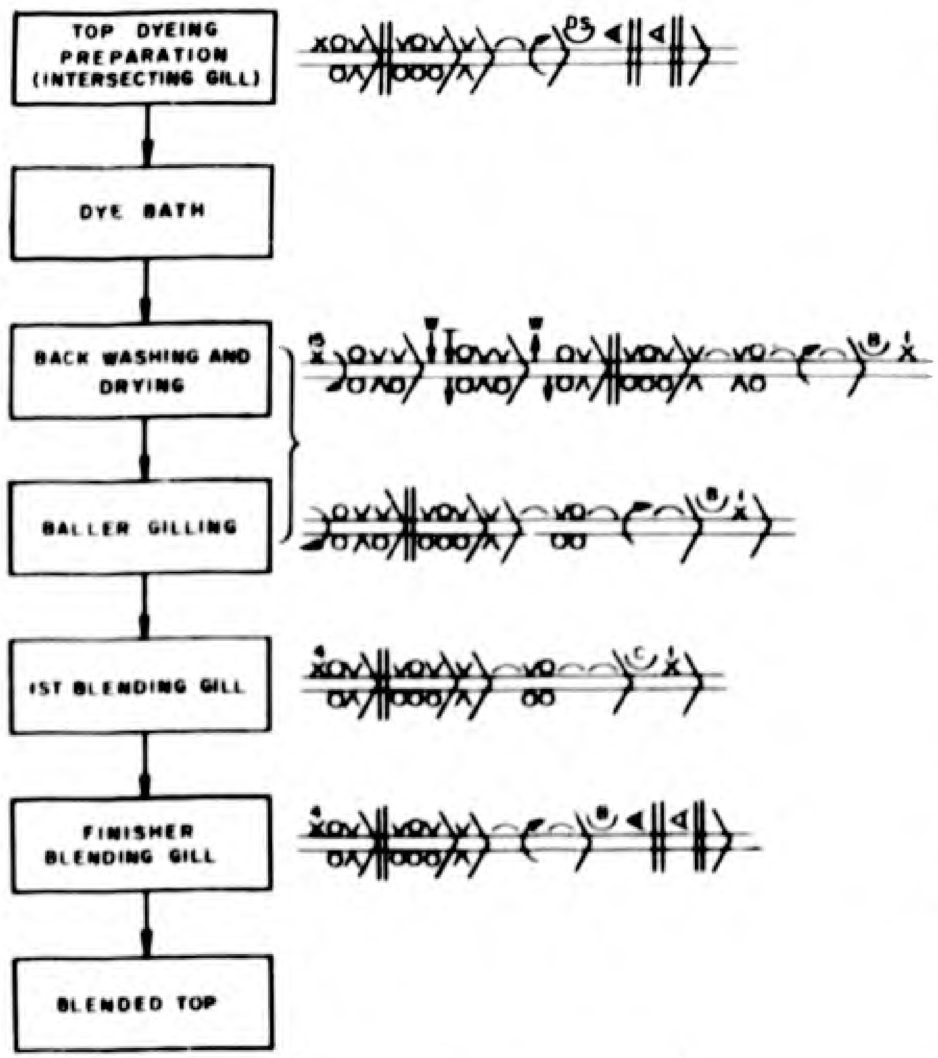
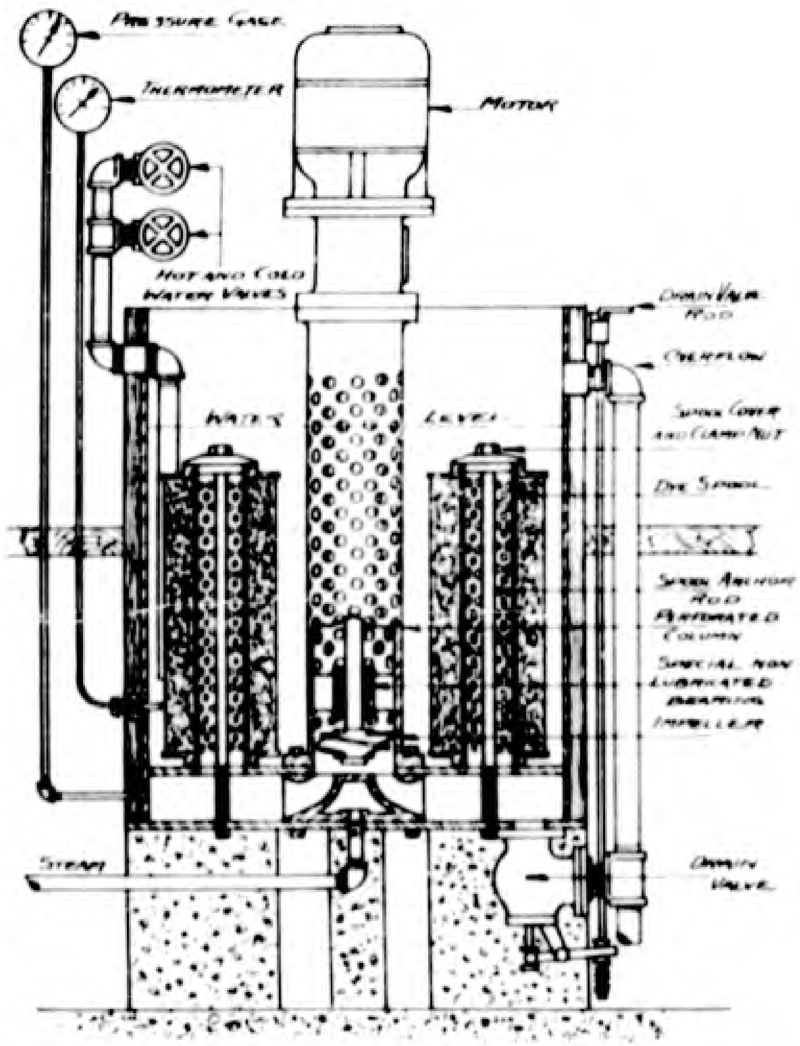


Figure 17. Dyeing and Blending Flow Chart



Courtesy of Abbott Machine Co., Inc.

Figure 18. Abbot Dye Kettle

is bolted to the other end to hold the spool in a rigid upright position. This permits the impeller to force the dye liquor up through the center of the spool, out through the perforations, and through the wool back into the dye kettle. A number of these spools are placed in the kettle at one time. The use of this equipment permits more uniform dyeing of the wool stock.

The usual dyeing cycle consists of placing the spools in the machine, preparing the liquor, wetting and dyeing the top until a color match is obtained, and rinsing. This cycle usually requires from 5 to 7 hours, and the wool is subjected to the boiling dye bath for a good portion of this time.

Groups of from 12 to 15 slivers, which possibly had been dyed in different shades, are run through a back washer (Fig. 19). This operation removes dirt, excess dye, and other impurities by means of warm water and soap in one tank and, after squeezing, a clean, warm water rinse in another tank. The stock passes through a dryer to remove excess moisture. In order to start the initial blending, four sets of slivers (12 to 15 slivers per set) are drawn and passed through a 4-head gill box and a pin control to separate, mix, straighten, and make parallel the fibers that may have become matted or felted during the dyeing operation. The weight of the sliver delivered from each head of this operation is 7 to 8 ounces per 5 yards.

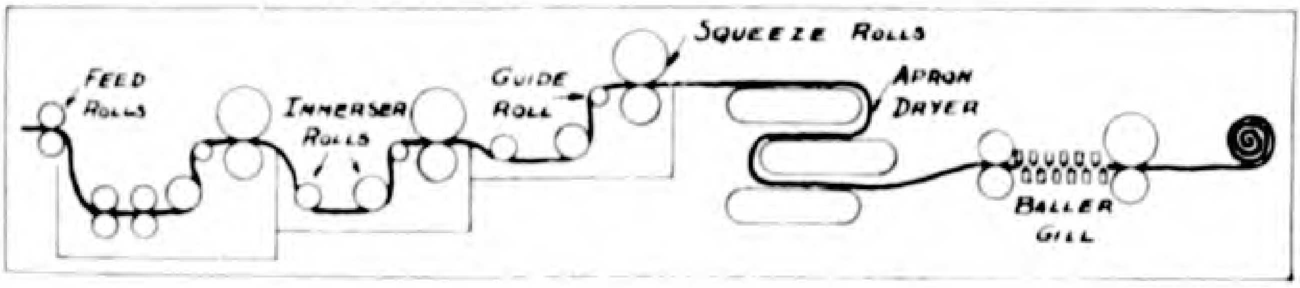


Figure 19. Back Washer

Four doublings from the back washer gill are drawn by means of another gilling operation to a delivered weight of 5 ounces per 5 yards.

Four doublings from the previous blending operation are passed through a finisher gill for better intermingling of the colored stocks and to present a more thorough mixture of component parts to the drawing operation. A 3-ounce per 5-yard sliver is made in this operation.

A tabulation showing the mechanism of color blending after dyeing follows:

DYEING AND BLENDING LAYOUT

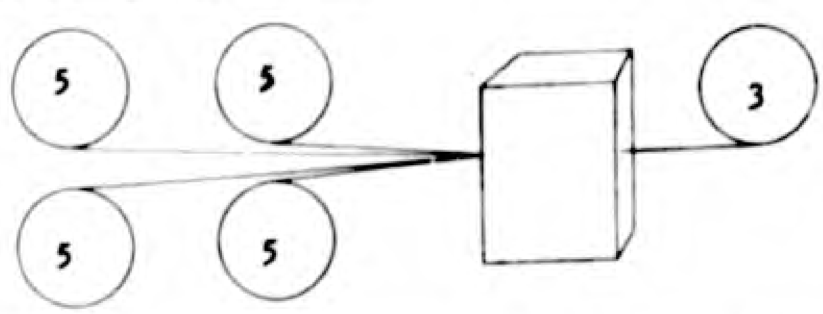
(Weight fed - 3-oz/5-yd sliver)

Gill Operation	Doublings (no.)	Draft*	Weight Delivered (oz/5 yd)
Back washer	12-15	5.2-5.6	7-8
First blending	4	5.61	5
Finisher blending	4	6.67	3

*Ratio of surface speeds of feed and delivery rolls.

The data given above show the reduction in the weight per yard as the stock passes through the machine.

EXAMPLE:
(oz/5 yd)



In this example of finisher blending, 4 ends at 5 oz/5 yd were used to obtain 1 end at 3 oz/5 yd. Draft (the ratio of the surface speeds of the feed and delivery rolls) is calculated as follows:

$$\frac{\text{Weight of sliver fed x number of doublings or ends}}{\text{Weight of sliver delivered x ends}} = \text{draft}$$

OR

$$\frac{5 \text{ oz x } 4 \text{ ends}}{3 \text{ oz x } 1 \text{ end}} = 6.67 \text{ draft}$$

4. Yarn Production

Based on previous studies of serge fabrics, all yarns used in this study were spun to the counts specified for 18-ounce serge construction (2/23.5's) except the wool/Orlon and wool/Dacron blends. Mill experience had shown that yarns containing Orlon and Dacron should be spun to a finer count (2/25's) than wool; otherwise they produce boardy fabrics. All warp and filling yarns were prepared and processed on the modified Bradford system in the same way that a contractor would run a regular production lot of this count of worsted yarn. This was done to determine whether this system, with slight variations if necessary, could produce yarns efficiently and satisfactorily using the types of fibers and blends included in this study. The fiber blends were processed as one lot up to and including the spinning operation.

Reducing a 262.5 grains/yard top (see Baller Gilling, Section B, 1, L, of this report) to a 4.1 grains/yard roving necessary to spin yarn of the required count cannot be accomplished in one operation. To reduce top to a lightweight roving suitable for spinning, several sequences of doubling and stretching (drafting) are necessary if uniformity in size and weight is to be achieved. The modified Bradford system here provided five such steps: three operations of pin drafting and two roller drafting operations (see Fig. 20).

a. <u>Pin Drafting</u>

A pin drafter (Fig. 21) consists of a feed table, moving pin bars called fallers (Fig. 22), and front rolls. The amount of stock fed to the macnine is controlled by the speed of the fallers. The stock is pulled through the machine by the front rolls, which move at a higher rate of speed than the bars. The pins on the bars are arranged above and below the stock and pierce the slivers simultaneously, retarding the forward motion and maintaining the straight and parallel position of the fibers. All of the drawing occurs between the end of the pin bars and the nip of the front rolls.

In the first pin drafting, three strands of top, each weighing 262.5 grains/yard, are reduced to one strand weighing 148.8 grains/yard, using a draft or speed difference of 5.3. The second and third pin drafting operations are carried out in the same manner and reduce the weight of the slivers to 81.0 grains/yard.

After the third pin drafting, the sliver still has enough tensile strength (enough fibers per cross section of thickness) for further processing. But, as it is drawn out further, the strand must be strengthened by imparting to it a slight twist. Twisting and further drawing out are accomplished by two roller drafting operations. The first employs a

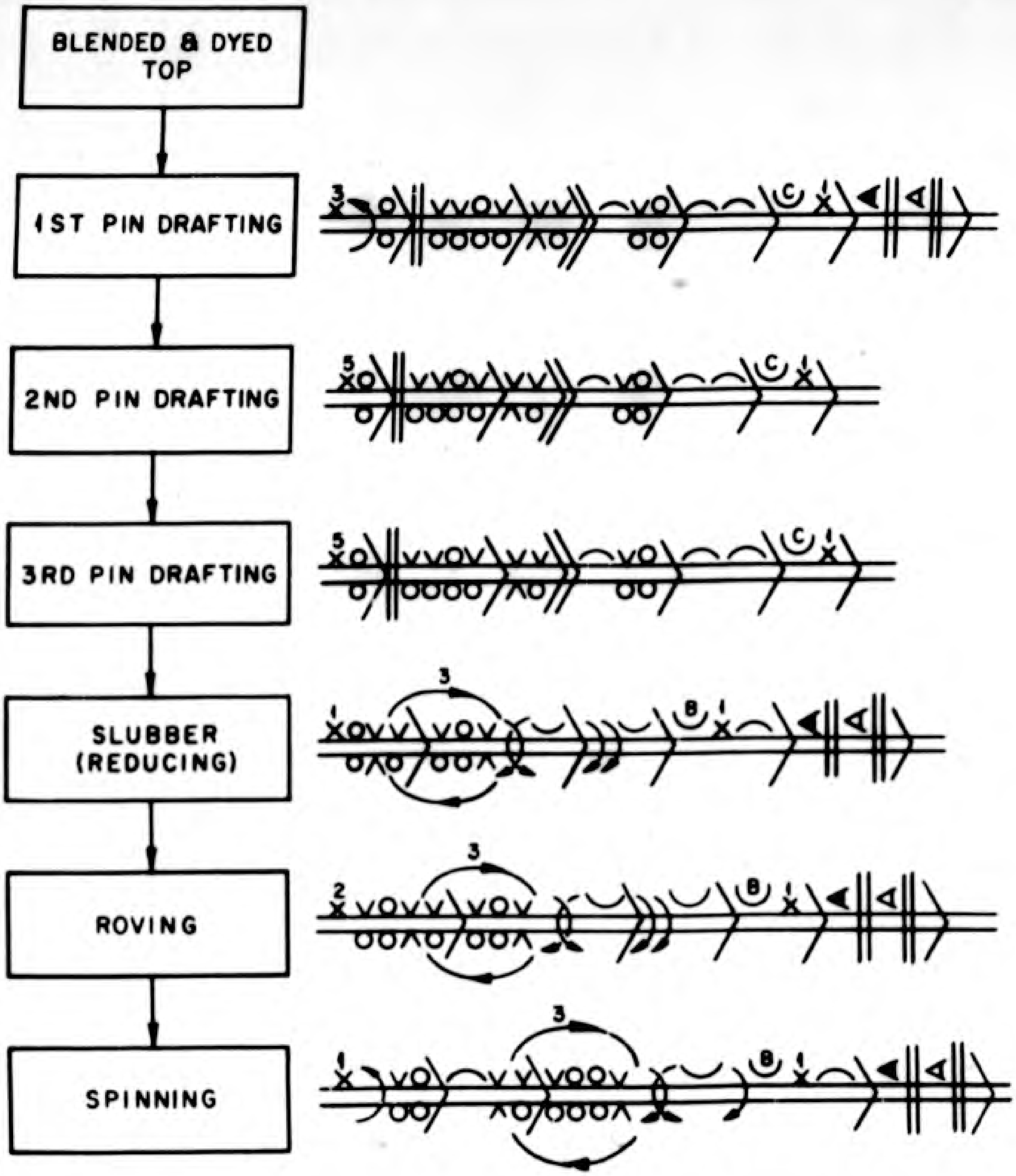
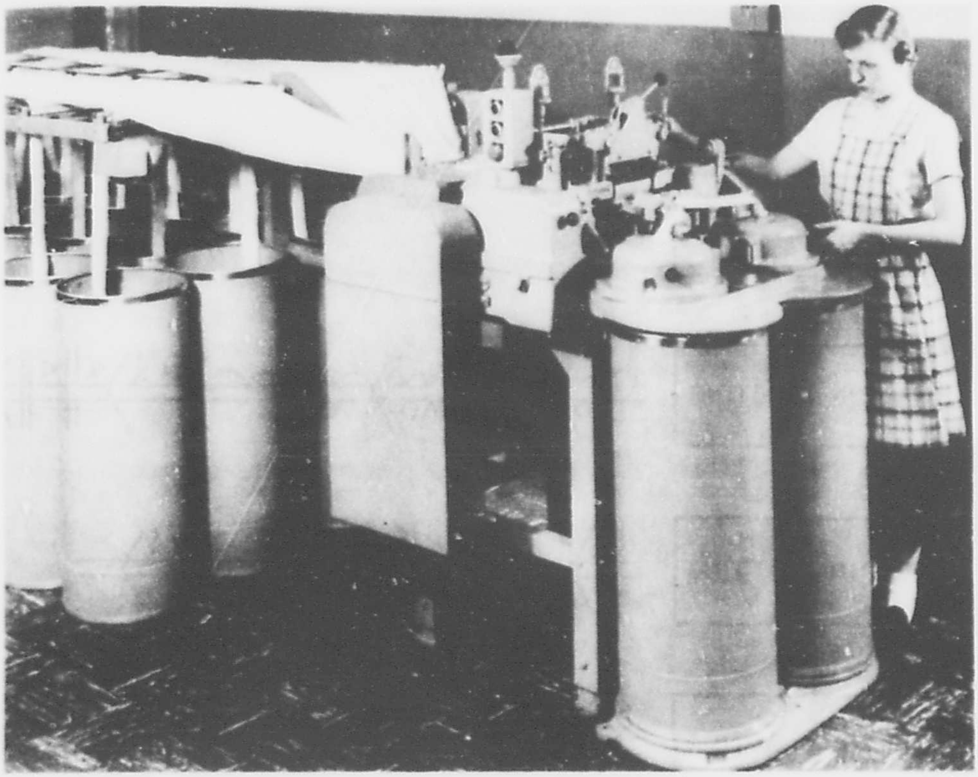
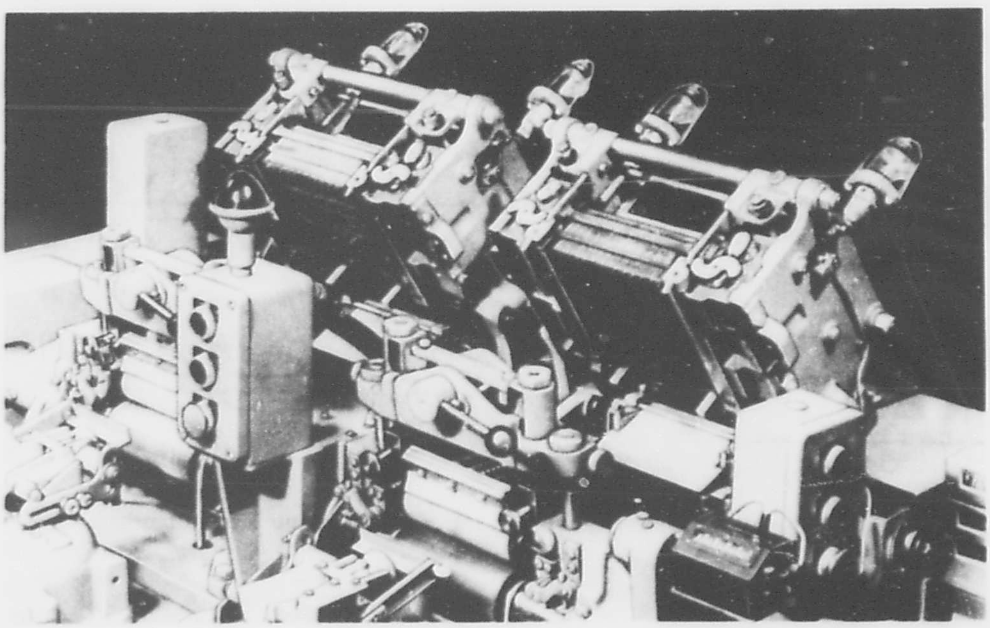


Figure 20. Yarn Preparation and Spinning Flow Chart



Courtesy of The Warner & Swasey Co.

Figure 21. Pin Drafter



Courtesy of The Warner & Swasey Co.

Figure 22. Faller Section of Pin Drafter

machine called a slubber (Fig. 23). The slubber consists of a roller drafter (Fig. 24) with regular drafting equipment consisting of feed rolls and delivery rolls plus a "flyer" arrangement that imparts a twist to the strand (now called "slubbing") as it leaves the delivery rolls and is wound onto a spool.

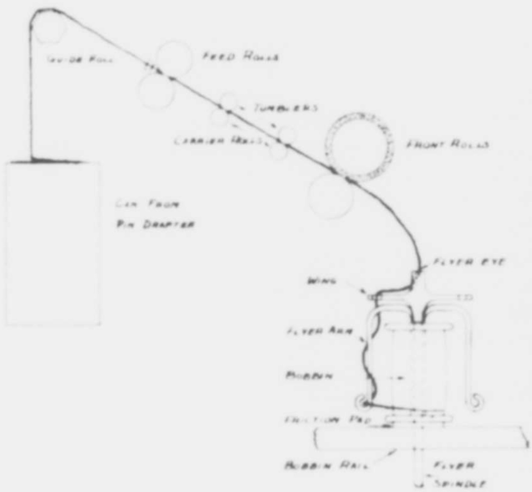
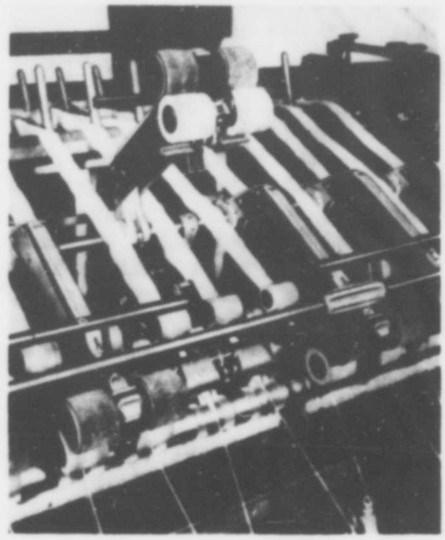


Figure 23. Slubber



Courtesy of Whitin Machine Works

Figure 24. Roller Drafter

The second roller drafting operation is carried out in a rover, Fig. 25, which is similar to the slubber but operates at a higher speed. These operations produce a final roving of the required 4.1 grains/yard, as may be seen in the following tabulation:

	Strands (no.)	Strand Weight (grains/yd)	Draft	Weight Delivered (grains/yd)
1. 1st Pin Drafting	3	262.5	5.3	148.8
2. 2nd Pin Drafting	5	148.8	7.0	106.0
3. 3rd Pin Drafting	5	106.0	6.5	81.0
4. (Slubber) Reducing	1	81.0	5.8	14.1
5. Roving	2	14.1	6.9	4.1

b. Spinning

All yarns for this project were spun on a cap spinning frame (Fig. 26). This consists of a set of drafting rolls and stationary upright spindles. The bobbins are revolved by a sleeve which fits over the spindle and rests on a bobbin rail. The bobbin rail moves the tubes up and down, allowing the yarn to wind on the bobbins guided by a stationary metal cap. The diameter of the cap can be varied. A 2 1/8-inch cap was used to spin all but the dynel blends.

The roving is fed into the machine by feed (or back) rolls, while a set of front (or drawing) rolls, traveling at a higher rate of speed, reduces the size of the roving to the desired yarn count. The distance between the back and front rolls (in this case 5 3/4 inches) is called the "ratch". As the reduced roving leaves the front rolls, it is drawn onto the bobbins revolving at 6,500 revolutions per minute. The amount of twist is controlled by the ratio between the speed of delivery and the speed of the spindle. To give the specified 13 turns of twist per inch with a spindle speed of 6,500 revolutions per minute, delivery must be at the rate of 500 inches per minute. The spindle speed was maintained at a constant rate, since this speed was found to cause the twisted strand to balloon and wind around the bobbin at the rim of the cap in a manner satisfactory for promoting spinning efficiency.

In summary, using the cap-spinning arrangement, the yarns were spun to the following specifications:

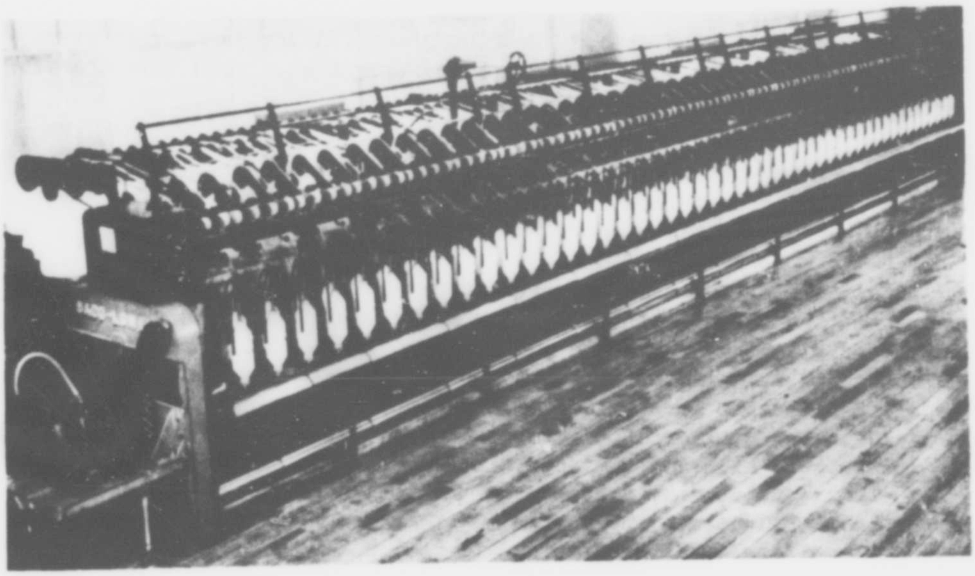
Count	1/23.5's
Twist	13 turns per inch "Z"
Spindle speed	6,500 revolutions per minute
Ratch	5 3/4 inches
Cap diameter	2 1/8 inches

c. Twisting

Spinning frames deliver singles yarns. To obtain a 2-ply yarn, two ends of single yarns must be twisted together. This is done by means of a twisting frame. The twisting frame resembles a spinning machine both in appearance and action, the only exception being the absence of the drafting or drawing mechanisms.

The yarn from the spinning room is divided into two parts, or lots, one lot for the warp and the other for the filling.

Warp and filling yarns in this study were twisted on different types of twisting frames for greater efficiency. A dolly roll twister (Fig. 27) was used for the warp yarns in order to produce as smooth a plied yarn as possible and thus to better resist abrasive action in the loom. An overend twister was used for the filling yarns for greater production and to remove



Courtesy of Saco-Lowell Shops

Figure 25. Rover

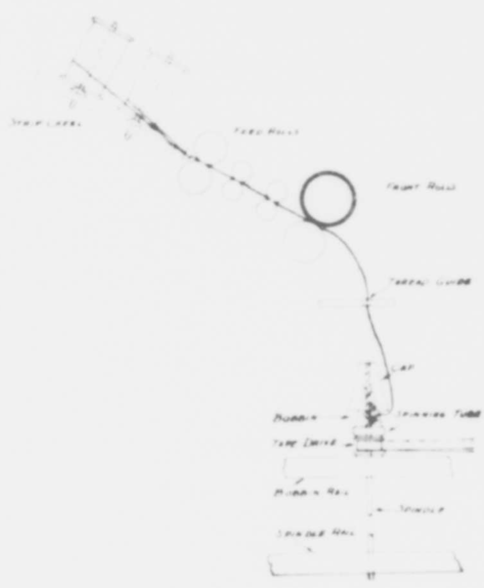


Figure 26. Cap Spinning Frame

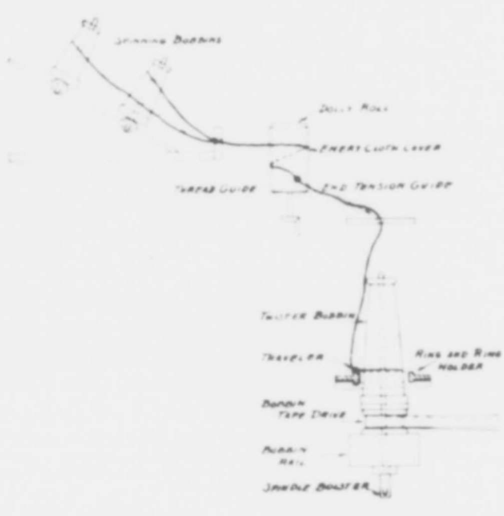


Figure 27. Dolly Roll Twister

defects by catching the slub.* Both warp and filling yarns were given 11 turns per inch "S" twist in the plying operation. Both this process and winding, which followed, are represented in Figure 28.

The characteristics of the yarn (such as percentage of spinning breaks, percentage of loss in spinning, and yarn size) are shown in Table IV for all of the blends.

Operating efficiency is evaluated by the percentage of spinning breaks and the percentage loss of raw material in spinning. A low percentage of spinning breaks and a low percentage loss of raw material indicate good spinning efficiency. It can be seen from Table IV that the spinning breaks were well within the upper tolerance limits of 10%. However, in the smaller lots (preproduction), yarn yields** were low and losses were high and variable. Losses ranged from 4.9 (wool/viscose, A6436) to an unaccountable 29.1% for the wool/Acrilan, A6434. For the larger lots (production) more yarn was processed and therefore losses were more uniform, ranging from 5.2 to 18.9 and averaging 11.6%. In large production runs, mill losses usually average between 8 and 10%. In general, yarn yields were in line with practical mill acceptances.

The data show that all blends can easily be spun to the required count using the same frame setting as for all wool. The only exception was the wool/dynel. When the cap spinning frames had been in operation about 5 minutes, the heat of friction melted the dynel fibers, weakening the yarn and causing end breaks. This was easily remedied by using a smaller cap—1 7/8 inches instead of 2 1/8 inches--without changing any other setting of the frame.

*Slub - thickening of the yarn because of extraneous fibers picked up during the spinning operation.

**Yarn yields are usually determined by dividing the weight of the yarn delivered by the weight of the dyed top before the first drafting.

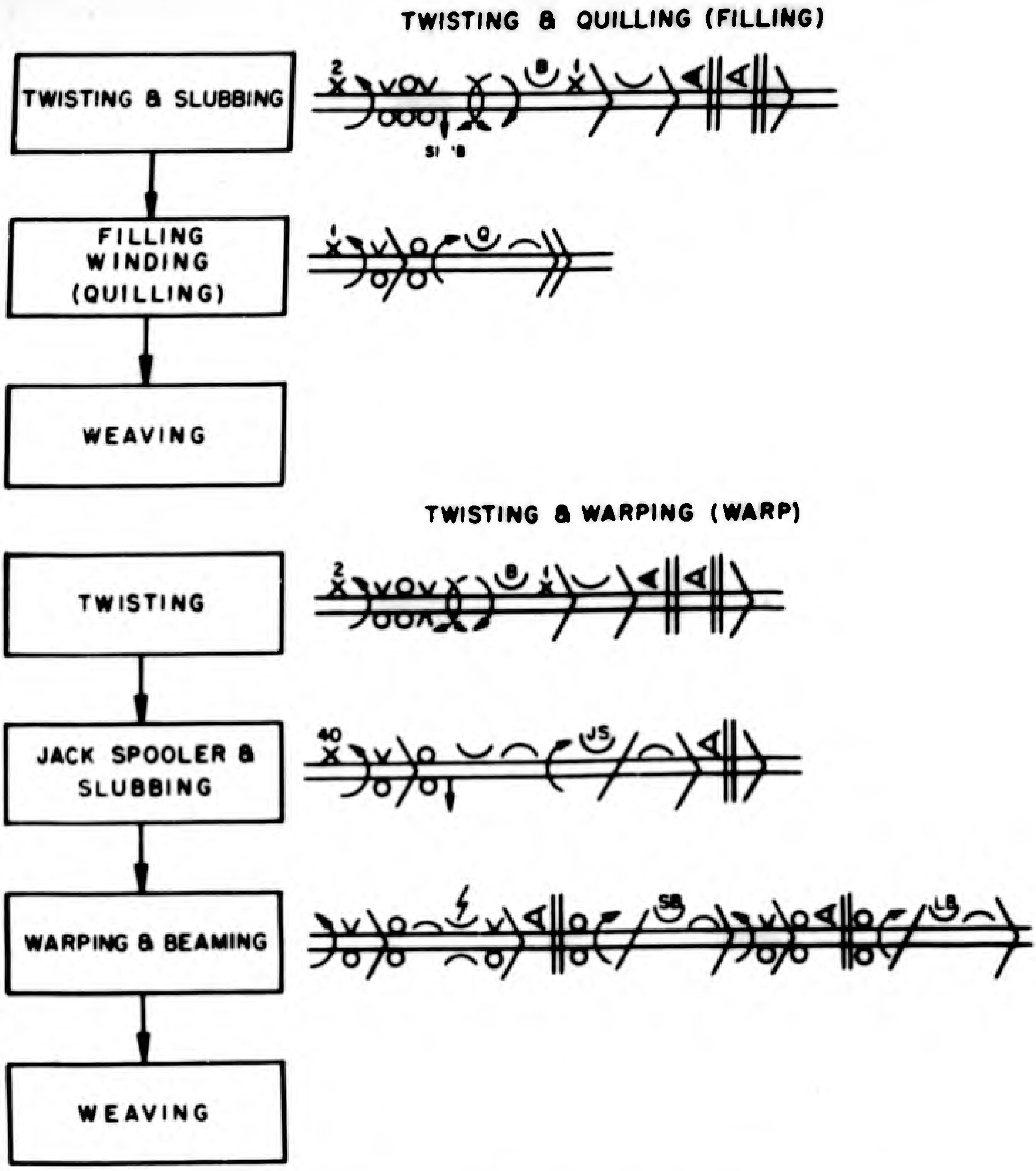


Figure 28. Yarn Preparation - Twisting, Quilling, and Warping Flow Chart

TABLE IV: SPINNING DATA

Yarn Lot & Number		Fiber Blend	Yarn Size Required	Yarn Size Produced	Spinning Breaks %	Top Used (lb)	Yarn Yield (lb)	Loss in Spinning (%)	Synthetic Staple Length (in.)
A 6421	Preprod	70/30 wool/viscose	2/23.5	2/24.2	6	148	119.0	19.6	4 to 6
	Prod				5	2535	2203.0	9.2	
A 6432	Preprod	70/30 wool/nylon	2/23.5	2/23.7	4	75	60.8	19.0	3-1/2 to 5
	Prod				4	147	130.3	11.4	
A 6426	Preprod	70/30 wool/Dacron	2/25	2/25.6	4	77	65.5	15.0	3-1/2 to 5
	Prod				4	90	73.0	18.9	
A 6428	Preprod	70/30 wool/dynel	2/23.5	2/24.0	5	73	63.8	15.0	4 to 6
	Prod				4	142	126.5	10.9	
A 6431	Preprod	70/30 wool/Orlon	2/25	2/26.1	3	74	65.0	12.2	3 to 5
	Prod				4	141	123.3	12.6	
A 6434	Preprod	70/30 wool/Acrilan	2/23.5	2/23.9	4	12	8.5	29.1	3 to 5
	Prod				4	142	124.5	12.3	
A 6429	Preprod	85/15 wool/viscose	2/23.5	2/24.2	4	75	65.5	12.7	4 to 6
	Prod				4	176	165.0	6.3	
A 6423	Preprod	85/15 wool/nylon	2/23.5	2/24.5	4	73	67.5	7.5	3-1/2 to 5
	Prod				5	1126	1024.0	9.1	
A 6425	Preprod	85/15 wool/Dacron	2/25	2/24.5	4	75	67.0	10.7	3-1/2 to 5
	Prod				3	144	125.0	13.2	
A 6427	Preprod	85/15 wool/dynel	2/23.5	2/23.8	5	76	61.5	19.1	4 to 6
	Prod				4	141	123.5	12.4	
A 6430	Preprod	85/15 wool/Orlon	2/25	2/25.7	4	75	61.0	18.7	3 to 5
	Prod				4	142	127.5	10.2	
A 6433	Preprod	85/15 wool/Acrilan	2/23.5	2/24.1		No preproduction fabric			3 to 5
	Prod				4	143	120.3	15.6	
A 6424	Preprod	100% - 60's wool	2/23.5	2/24.1	6	97	79.0	18.5	- - -
	Prod				5	1102	1021.0	17.4	
A 6435	Preprod	100% - 56's wool	2/23.5	2/24.1	6	61	49.5	18.8	- - -
	Prod				4	330	279.5	15.3	
A 6422	Preprod	70/20/10 w/visc/nyl	2/23.5	2/23.8	8	72	63.0	17.5	visc: 4 to 6
	Prod				4	1271	1174.0	7.6	nylon: 3-1/2 to 5
A 6436	Preprod	70/30 56's w/3-d visc	2/23.5	2/23.7	3	71	67.5	4.9	4 to 6
	Prod				4	324	307.3	5.2	
A 6437	Preprod	70/30 56's w/5.5-d visc	2/23.5	2/24.0	5	69	58.3	15.6	4 to 6
	Prod				4	326	191.8	10.2	

"Preproduction" represents small trial lots; "production" refers to the actual quantity of yarn finally spun.

5. Loom Preparation

a. Winding

As has been noted, a fabric consists of two systems of yarns: the lengthwise yarns (warp) and the crosswise yarns which are interlaced with the warp (filling).

The yarns for the filling must be rewound from twister spools onto shuttle bobbins. This rewinding operation is known as "quilling".

The yarns for the warp must be rewound on a loom beam. The warp of the experimental fabrics was made up of 3,900 parallel yarns, each yarn of sufficient length to weave the required yardage of fabric. The winding of a large number of yarns side by side and under uniform tension requires careful control of each individual yarn during the winding operation. In this case the warp yarn was rewound from the twister spools to the loom beam in three successive stages: (1) jack spooling, (2) section beaming, and (3) loom beaming.

(1) Jack spooling. The first stage in preparing the warp is to take individual bobbins from the twister and rewind them side by side under uniform tension on a jack spool. During the winding, the yarn is inspected and impurities are removed.

(2) Section beaming. Forty ends from a number of jack spools are measured to assure proper length and are rewound under uniform tension onto a large creel known as a section beam. Only a fraction of the warp width is measured and wound onto the beam at one time. This fraction is known as a warp section. The creel rides on steel tracks so that it can be easily moved to repeat the winding of adjacent sections until 3,900 ends of uniform length have been wound evenly side by side. The dressing normally applied to the warp at this stage, to facilitate weaving, was omitted on these fabrics because of the limited yardages involved.

(3) Loom beaming. With the warp yarns all properly arranged on the section beam, it is a simple matter to proceed to the third winding, which transfers the yarns simultaneously onto a loom beam.

b. Drawing in

A simplified cross sectional diagram of a loom is shown in Figure 29. In order to weave a fabric, successive ends of the warp must be separated by a process known as shedding to allow the shuttle to inter-

UNCLASSIFIED

AD 217056

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR
MICRO-CARD
CONTROL ONLY

2 OF 2

UNCLASSIFIED

lace the filling yarns (picking) with the warp in the desired weave or pattern. This separation of warp ends is accomplished by harnesses, the number of which vary with the weave. Harnesses consist of a system of wires (heddles) suspended from a wooden frame. Each heddle has an eyelet through which a single warp yarn is drawn by hand. The separation of warp yarns or "shed" occurs when the harnesses move in opposite directions, providing an opening through which the shuttle may pass.

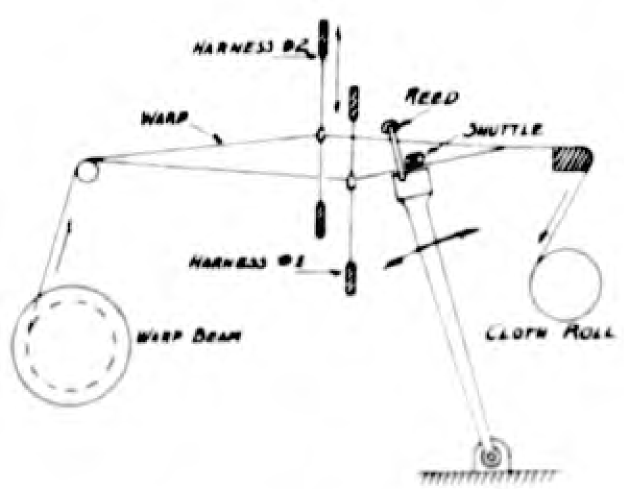


Figure 29. Loom

In addition to the shedding motion after the shuttle lays the yarn in the warp, the yarns must be pushed tightly against the preceding yarn. This is done by a forward motion of a steel comb-like device known as a reed, into which the yarn must be drawn, again by hand.

The warp yarns must be drawn through the harness and reed before the warp can be placed in the loom.

6. <u>Weaving</u>

Most of the fabrics were woven in a 2 x 2 twill weave, illustrated at the top of Figure 30. In this diagram, the filled-in squares of (a) represent a warp yarn on the face of the fabric; the blank squares represent a filling yarn or pick on the face of the fabric. The blocked-off portion represents one repeat of weave. Eight harnesses, numbered 1 to 8 in (b), were used in a straight draw. The filled-in squares of (b) represent a warp end through the harness, each harness holding 1/8 of the total number of warp ends. The raising of the harness to form a shed for the passage of the shuttle is controlled by a series of bars called a "chain". Each chain contains a roller or spacing washer in accordance with the pattern shown by the chain draft (c). The vertical line of this chain draft represents a bar; the horizontal lines set the pattern for each harness, numbered 1 to 8, and also show the order of picks. Each filled-in square of (c) represents a "roller", which means a raised harness or the warp end on the face of the cloth; the open squares represent the harness down, or a filling pick on the face of the cloth. Figure 30 also shows similar diagrams for the other weaves: gabardine, crowfoot, Mayo twill, and satin.

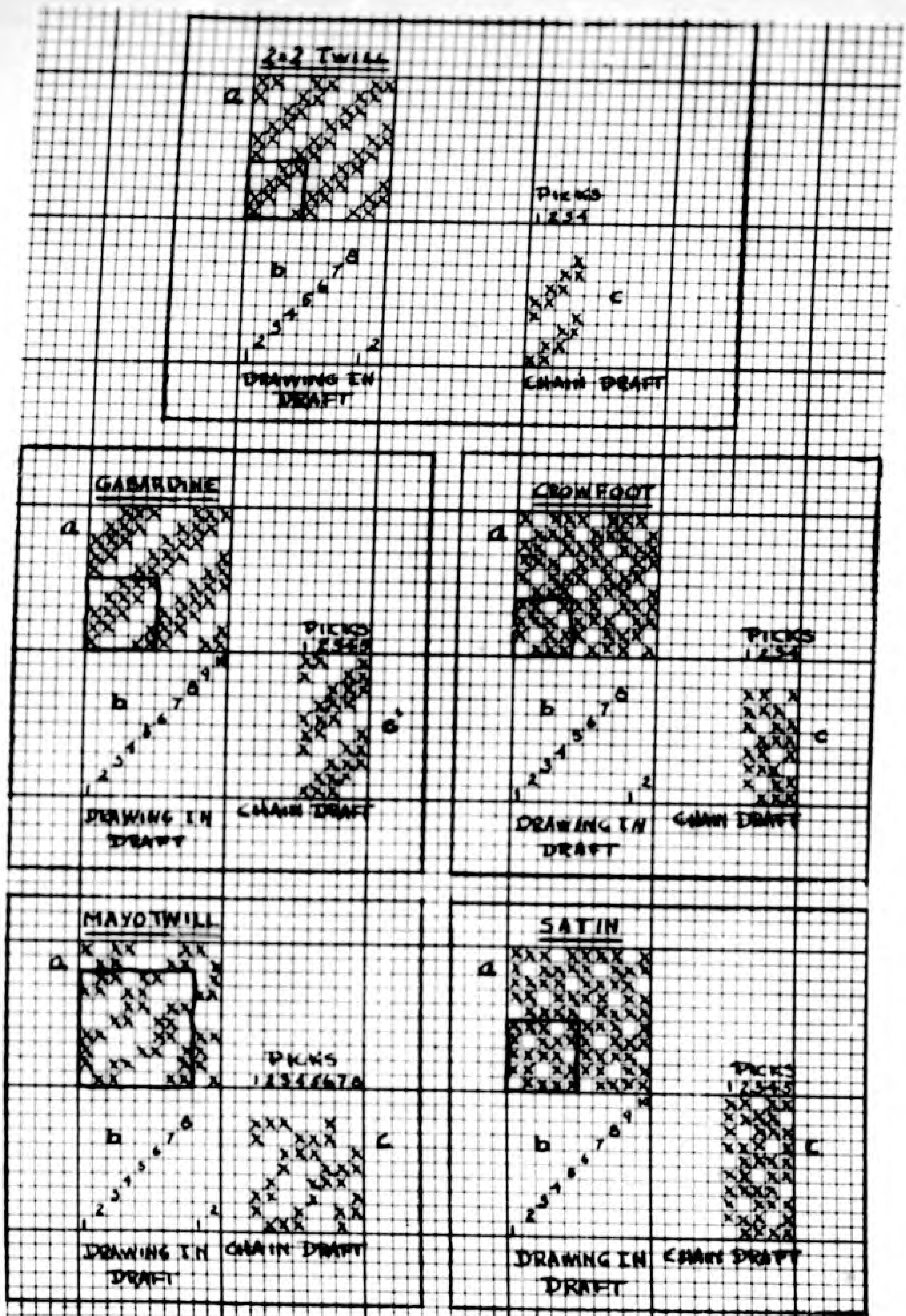


Figure 30 Weave Patterns

7. Finishing

Although weaving can be considered as a separate process, the actual loom layout, in terms of ends and picks per inch, must be considered simultaneously with the finishing procedure in order for the fabrics to meet the requirements of Specification MIL-C-823. Because of the limited amount (800 yards), it was necessary to first test the suitability of the procedures, as had been done with color matching and in the spinning of the yarns. Thus preproduction samples of 15- to 20-yard lengths were woven and finished for approval. The loom layout and finishing procedure could then be adjusted to provide a fabric that would comply with specification requirements. Uniform finishing procedures were desirable to minimize processing variables in the final performance of the fabrics and to help establish a basis for estimating cost.

The object of finishing is to clean and set the fabric in the desired width and weight; up to 20% of foreign material, such as oil and sizing, is removed at this time. The fabrics from the loom are examined, weighed, and measured and all weaving or yarn imperfections are marked along the selvage of the cloth. The cloth is then processed and defects are corrected by hand through burling and mending.

The fabric is then shrunk to the required width and weight by felting in a fulling mill. The fabric is prepared for fulling by first tacking the selvages together to form a tube, with the face of the fabric in. It is then saturated with a soap solution in the "soaper" (Fig. 31) consisting of a vat, immerser rollers holding fabric down in solution, and squeeze rollers to remove any excess solution from the piece.

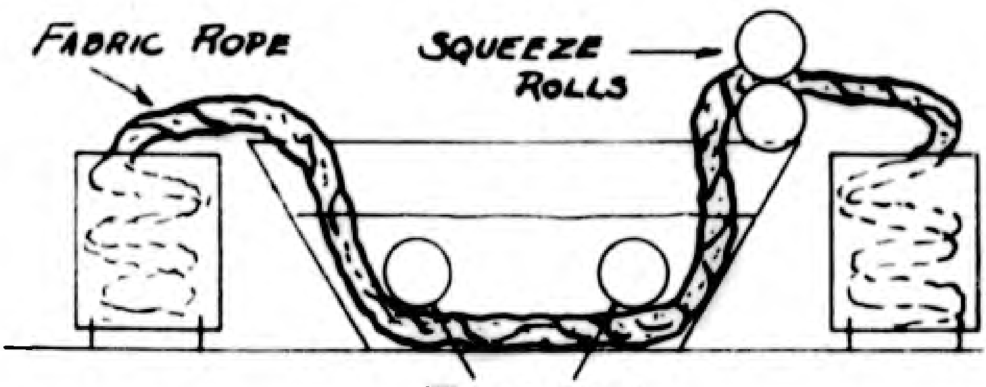
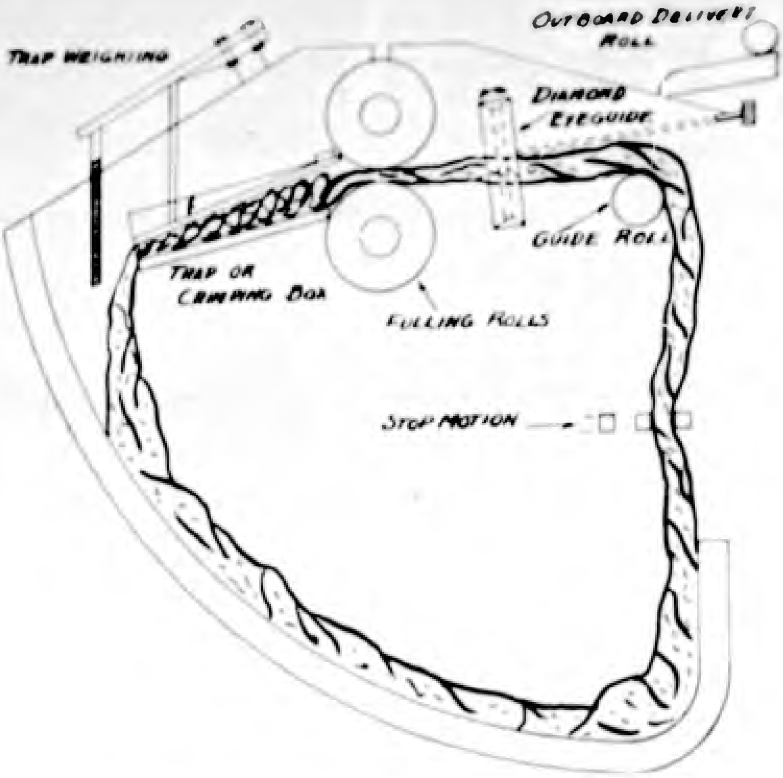


Figure 31. Soaper

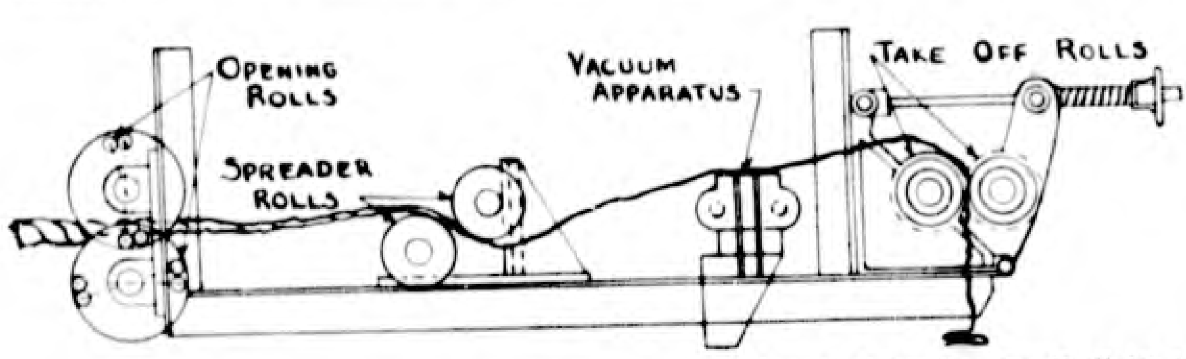


One end of the fully soaped fabric is fed into the fulling mill (Fig. 32) between fulling rolls. After it has all been admitted, the end entering the machine first is carried around to the front, where it is joined to the end entering last to form a continuous strand. The mill is now ready to operate, with the fabric passing through in an endless strip. The fulling rolls force air through the tubular construction, causing it to balloon before entering the nip of the rolls, thus preventing undesirable creasing and wrinkling during the process.

Figure 32. Fulling Mill

Widthwise fulling is accomplished by the fulling rolls; lengthwise shrinkage is brought about by a restraining channel known as a trap or crimping box. The degree of restraint placed on the forward motion is controlled by weights. The fulling mill is operated until the proper width and weight of the cloth is attained, the time depending in part on the weights placed on the trap and rolls of the machines and in part on the relation of the width in the loom to the finished width. The mechanical action involved in fulling also serves to soften the fabric and give it a more desirable hand.

When the fabric has attained its desired width and weight, it is taken from the fulling mill. The tacking string is removed and the fabric is opened by mechanical means on a device known as a "skutcher" (Fig. 33). A vacuum tube on the skutcher removes excess moisture.



Rodney Hunt Machine Co. (Bulletin 44)

Figure 33. Skutcher

The cloth is then scoured, to remove oils, soap, and other undesirable matter, in a continuous open-width washer similar to that shown in Fig. 34.

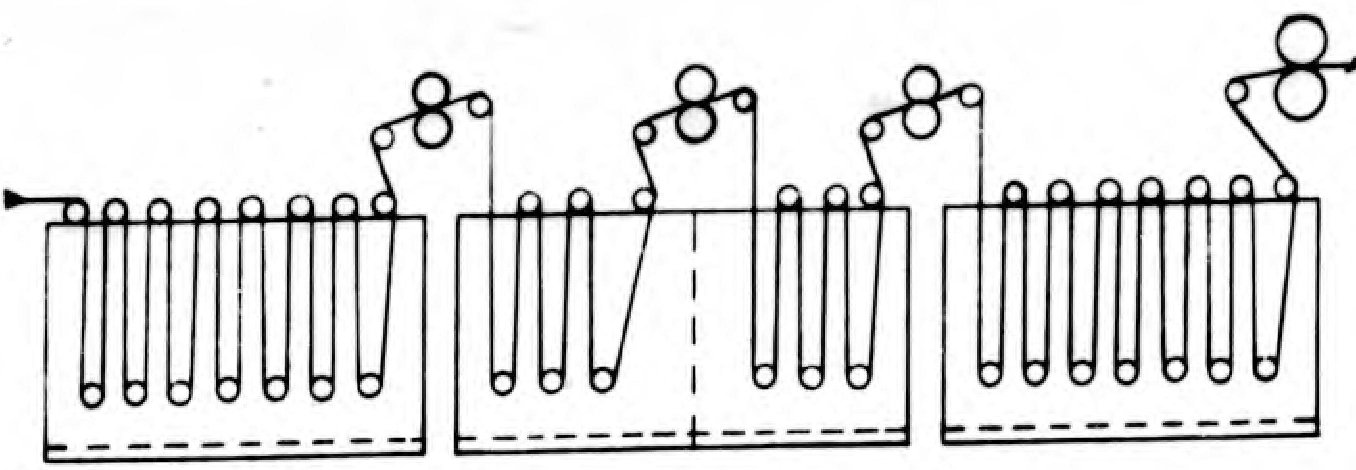
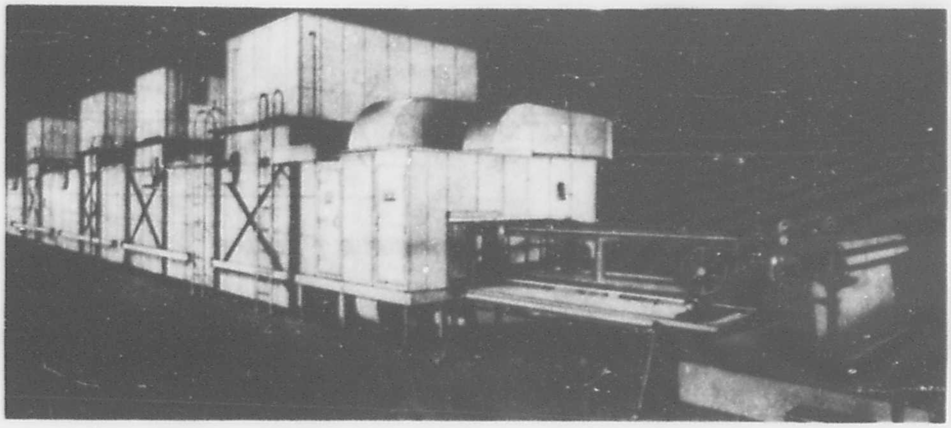


Figure 34. Open-width Washer

After the continuous washing, excess moisture is again removed by mechanical means and the fabric is dried in a conventional textile drying oven (Fig. 35). After the drying, the pieces are allowed to cool and to re-establish equilibrium with the atmosphere. Each piece is then sheared to remove loose or projecting fibers so that it will present a smooth, uniform, and clear surface. Figure 36 is a diagrammatic view of the shearing mechanism, which consists of a system of rotary knives and a stationary knife acting much like a creel lawn mower. Close control may be maintained on the depth or closeness of the cut by adjusting the distance between the table over which the cloth is drawn and the stationary blade of the shear.

The final operation is carried out in a semi-decater (Fig. 37), which imparts to the fabric a degree of dimensional stability. This is achieved by pressing the fabric between canvas aprons wrapped around a perforated steam cylinder. Steam is forced through the cylinder and the canvas aprons. The steam, in addition to the compression provided by the aprons, serves to fix the fabric in a permanent set.

After leaving the semi-decater, the fabric is considered completed and is given a final examination prior to measuring, weighing, and shipping. These processes are represented in Figure 38.



Courtesy of Andrews & Goodrich, Inc.

Figure 35. Drying Oven

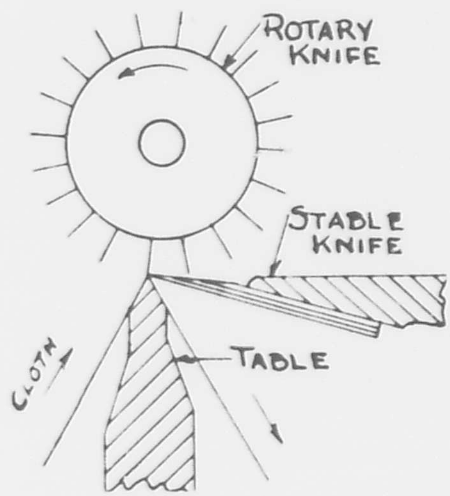
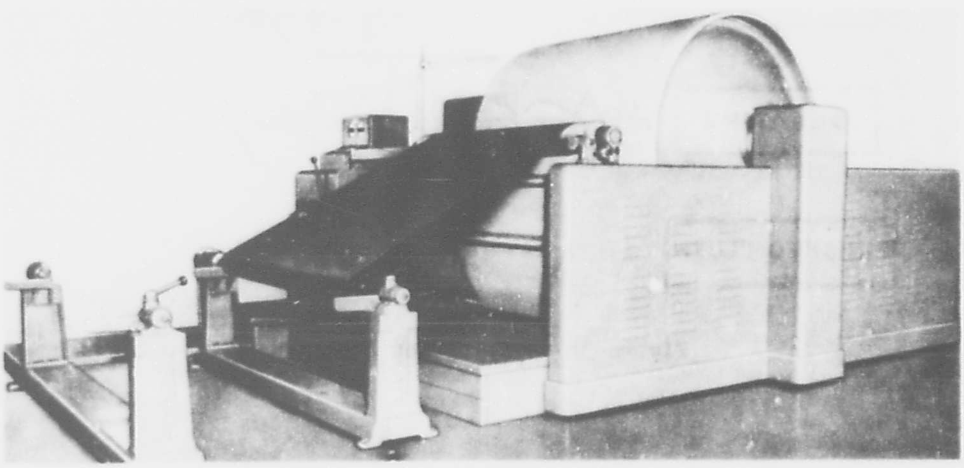


Figure 36
Shearing Mechanism



Courtesy of David Gessner Co.

Figure 37. Semi-decater

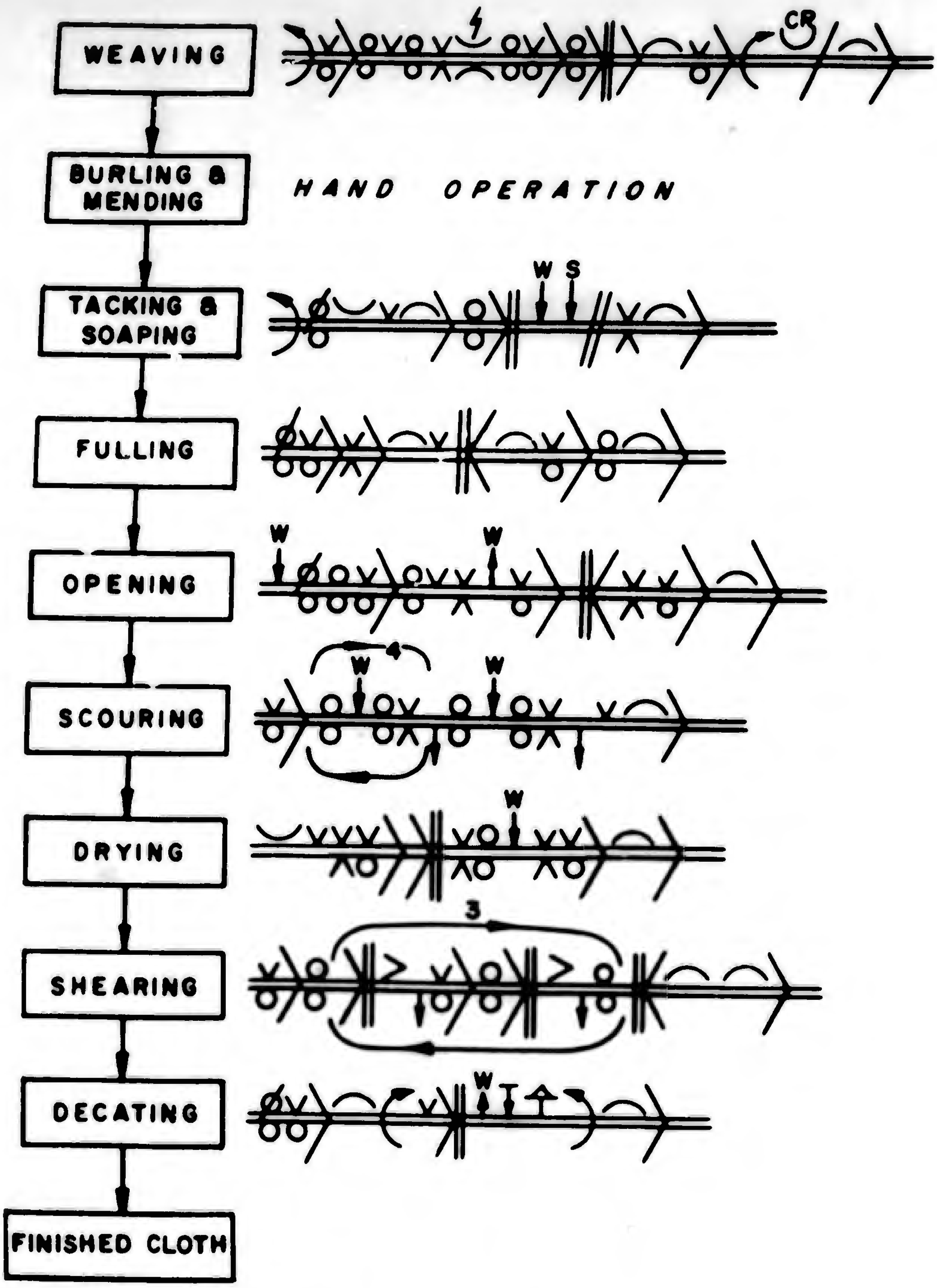


Figure 38 Weaving and Finishing Flow Chart

C. Some Physical Properties of the Experimental Yarns and Fabrics

1. Yarns

a. Evenness

Tests for yarn evenness have played an important part in worsted top and yarn manufacturing since the advent and extensive use of synthetic fibers. They have helped maintain standards of quality and uniformity in spite of the modified and short-cut systems brought about by the need for more efficient production and reduced manufacturing costs.

Among other quality-control measures, evenness standards for diameter and weight were established for these project yarns. Evenness was measured by means of the Pacific Yarn Evenness Tester. This tester measures the percentage of average and maximum deviation for any length of yarn, based on the weight or cross-sectional thickness of that particular stock.

When roving, single and plied yarns are compared, the roving yarns generally appear to be the most even (the lowest percent of deviation) and the single yarns the most uneven, while the plied yarns tend to average out any unevenness. A ply yarn with an average deviation of from 35% to 40% and a maximum deviation of from 55% to 60% is classified as "good", while an average deviation of from 55% to 60% and a maximum deviation of from 85% to 90% is considered "poor". Commercial yarn manufacturers prefer the least possible spread between average and maximum percent deviation.

Table V shows both the preproduction and production evenness figures for slubber, roving and singles and ply yarns from each blend of fibers. The evenness values for the production ply yarns are plotted in Fig. 39 with the average and maximum deviation limits for an acceptable ("good") yarn marked. While all the yarns are shown to have greater variability than the average mill production, they can nevertheless be considered somewhat better than average considering that they were spun in a single short run.

b. Breaking strength and elongation

The breaking strength of the yarns was measured by four methods:

(1) Using the Suter Tensile Tester, single strand breaks and elongation of single yarns.

(2) Using the Suter Tensile Tester, single strand breaks and elongation of 2-ply yarns.

(3) Using the Scott Tensile Tester, skein breaks of single yarns.

(4) Using the Scott Tensile Tester, skein breaks of ply yarns.

TABLE V: RESULTS OF EVENNESS TESTS OF YARNS*
(in percentage of deviation)

Item No.		Fiber Blend	Slubber Avg.	Slubber Max.	Roving Avg.	Roving Max.	Singles Yarn Avg.	Singles Yarn Max.	Ply Yarn Avg.	Ply Yarn Max.
1	Preprod	100% 60's wool	21.2	39.0	21.0	57.6	58.8	98.4	41.5	59.2
	Prod		17.7	35.5	30.8	50.8	76.2	113.2	57.7	83.6
2	Preprod	70/30 wool/viscose	14.6	34.1	27.3	42.6	57.1	82.8	36.5	52.3
	Prod		17.8	33.3	27.4	45.3	53.7	85.0	39.6	69.1
7	Preprod	100% 56's wool	28.0	37.8	40.3	67.4	88.8	135.2	65.4	96.9
	Prod		26.3	36.7	31.5	56.1	67.3	109.3	45.8	78.0
8	Preprod	70/30 56's wool/3-d visc	20.3	41.0	29.9	57.3	77.7	98.1	50.6	76.6
	Prod		19.6	39.4	30.2	55.6	76.5	97.3	49.4	75.8
9	Preprod	70/30 56's wool/5.5-d visc	19.8	36.7	34.6	63.3	81.3	101.4	47.2	74.7
	Prod		22.7	36.5	35.2	57.8	90.5	148.6	57.1	83.9
10	Preprod	85/15 wool/viscose	20.2	37.0	37.4	57.8	83.9	124.3	54.1	81.4
	Prod		21.1	34.8	33.0	56.7	87.7	138.2	51.5	82.7
11	Preprod	85/15 wool/nylon	17.9	33.2	26.1	45.8	35.1	83.9	39.2	61.4
	Prod		19.1	30.5	30.0	48.5	66.2	103.8	49.7	85.4
12	Preprod	70/30 wool/nylon	18.3	30.9	25.6	48.5	71.4	101.2	54.5	84.2
	Prod		18.8	31.7	34.7	56.4	64.6	101.3	51.9	84.6
13	Preprod	85/15 wool/Dacron	27.5	44.5	38.7	69.4	84.8	130.5	65.7	99.7
	Prod		22.4	46.3	31.8	64.6	83.9	132.6	61.5	89.8
14	Preprod	70/30 wool/Dacron	20.4	33.6	25.3	46.1	71.1	109.6	47.1	70.0
	Prod		19.7	31.3	24.7	50.1	70.3	102.3	49.6	68.4
15	Preprod	85/15 wool/dynel	20.9	35.6	26.6	43.8	70.8	114.4	50.1	79.8
	Prod		19.7	31.7	24.2	41.7	69.7	109.3	48.3	81.7
16	Preprod	70/30 wool/dynel	17.7	29.5	30.6	53.3	79.4	125.4	50.5	81.2
	Prod		15.9	28.6	29.3	51.2	74.3	122.4	49.6	83.1
17	Preprod	85/15 wool/Orlon	16.6	30.6	31.8	53.7	74.0	125.5	34.6	63.6
	Prod		17.6	29.4	33.3	54.6	74.4	124.3	35.1	64.2
18	Preprod	70/30 wool/Orlon	13.3	23.1	29.1	50.3	66.8	101.4	50.4	80.6
	Prod		14.6	21.9	26.7	48.4	70.1	104.8	54.6	83.4
19	Preprod	70/20/10 wool/viscose/nylon	13.6	32.1	25.2	46.2	54.5	94.0	37.9	68.4
	Prod		18.0	32.2	32.2	56.3	62.6	98.9	52.2	77.7
20	Preprod	85/15 wool/Acrilan	No preproduction fabric							
	Prod		20.6	30.0	28.7	44.6	70.9	104.3	43.4	60.0
21	Preprod	70/30 wool/Acrilan	No test made; yarn used for "Gam" for color approval**							
	Prod		20.3	31.3	34.7	46.8	69.3	101.6	44.3	60.0

*Evenness measured by Pacific Yarn Evenness Tester.
**"Gam" - A small 5- to 8-yard experimental piece.

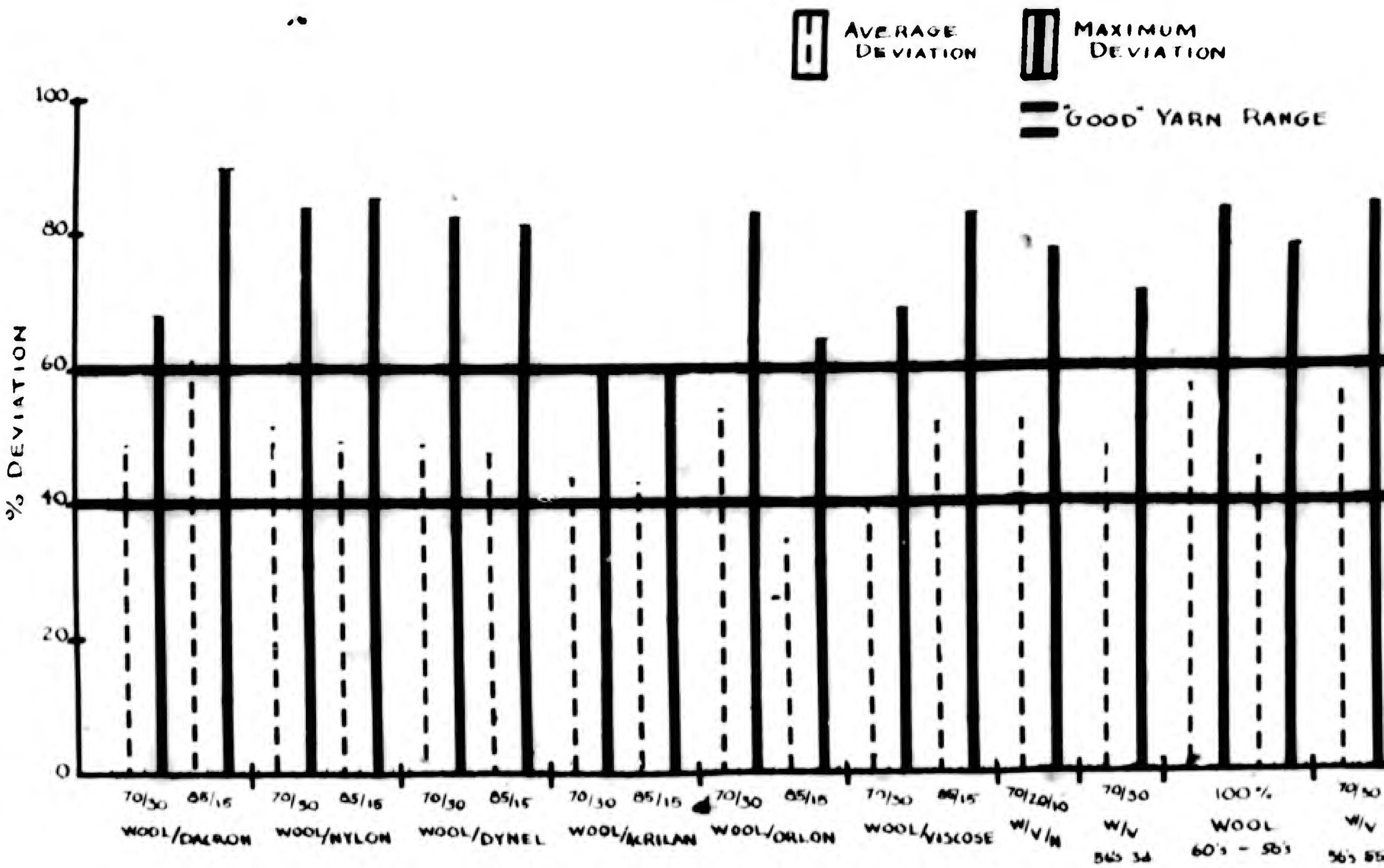


Figure 39. Yarn Evenness - Production Ply Yarns

A gage length of 10 inches was used on the Suter Tensile Tester, with a vertical scale indicating the length of jaw travel. The Scott Tensile Tester determined the breaking strength of 120-yard skeins in accordance with the ASTM Method, D404-48 paragraph 21 (a) and (b).

Table VI gives the results of breaking strength and elongation tests for both the preproduction and production series. Production lots of 100% 60's QM wool ply yarns (item 1) recorded a skein breaking strength of 167 pounds and a single strand elongation of 8.9%. The addition of 30% viscose (item 2, 3-denier, 4-6 inch staple) increased the strength of the skein yarn by 23 pounds (to 190 pounds) but slightly decreased (0.2%) its single strand elongation (to 8.7%). The addition of 15% nylon (item 11, 3-denier, 3½- to 5-inch staple) increased the strength by 49 pounds (to 216 pounds) and increased the elongation by 14.1% over all wool (to 23%). The addition of 30% nylon to the 60's wool (item 12) raised the breaking strength by 54 pounds (to 221 pounds) (an increase of 5 pounds over the 15% nylon blend) and gave an elongation increase of 12.4% (to 21.3%). The 70/30 wool/Dacron (item 14, spun to a 2/25.5's) showed a higher breaking strength and a higher percentage of elongation than the 70/30 wool/nylon (item 12). The 3-fiber blend (item 19) was intermediate between the 70/30 wool/viscose and the 85/15 wool/nylon blends both in breaking strength and in percent of elongation.

The addition of synthetic fibers to 60's wool improved the breaking strength of the yarns and skeins (Figs. 40 and 41). Nylon and Dacron showed the greatest, the acrylics an intermediate, and viscose the least gain over the breaking strength of the 100% 60's wool. In most blends of this project, decrease in breaking strength was accompanied by a decrease in elongation, as shown by the similar descending order in Figure 42. Figures 40, 41, and 42 also demonstrate that breaking strength and in most cases elongation, increase as the proportion of synthetic fiber content is increased (from 15% to 30%).

The yarns made from 56's wool were somewhat lower in breaking strength (Figs. 40 and 41) and slightly higher in elongation (Fig. 42) than equivalent yarns of 60's wool, although single fiber tests have suggested* that the average strength of 56's wool should be 8% to 10% greater than that of 60's wool. The 3-denier wool/viscose blends are stronger but less extensible than either the 100% 56's wool or the 70/30 5.5-denier viscose blend. The weakness of these coarser yarns is probably not the result of low inherent fiber strength but rather of fewer fibers per cross section and of their arrangement and possible slippage within the yarn. This is in agreement with previous studies** which have shown that coarse thick fibers tend to resist compacting and thus produce a more open yarn structure.

* Harris, M., Handbook of Textile Fibers, Harris Research Laboratories, Washington, D. C., 1st Edition, 1954, p 142.

** Bogaty, H., Hollies, N.R.S., Harris M., "Some Thermal Properties of Fabrics: The Effect of Fiber Arrangement", QM R&E Textile Engineering Laboratory Report No. 171, 1957.

TABLE VI: BREAKING STRENGTH AND ELONGATION DATA FOR YARNS AND SKEINS

Item No.	Fiber Blend	Mill Run	Single Strand: Singles Yarn Break (oz)	Single Strand: Singles Yarn Elongation (%)	Single Strand: Ply Yarn Break (oz)	Single Strand: Ply Yarn Elongation (%)	120-Yard Skein Breaking Strength: Singles Yarn (lb)	120-Yard Skein Breaking Strength: Ply Yarn (lb)
1	100% 60's wool	Preprod	6.0	3.3	17.0	12.5	54	139
		Prod	6.8	5.0	18.7	8.9	52	167
2	70/30 wool/viscose	Preprod	7.3	6.0	22.5	7.5	63	175
		Prod	10.7	9.7	23.0	8.7	73	190
7	100% 56's wool	Preprod	6.8	5.2	18.7	9.0	49	153
		Prod	7.9	9.6	17.9	14.0	50	154
8	70/30 56's wool/3-d viscose	Preprod	10.1	7.5	25.4	11.7	75	196
		Prod	7.9	8.1	21.4	11.6	66	172
9	70/30 56's wool/5.5-d viscose	Preprod	9.6	8.8	23.1	13.0	57	168
		Prod	6.6	10.2	17.8	16.1	53	151
10	85/15 wool/viscose	Preprod	7.9	6.2	19.8	8.3	64	169
		Prod	10.3	6.2	23.9	9.4	62	171
11	85/15 wool/nylon	Preprod	10.5	17.0	26.0	19.3	70	198
		Prod	7.9	11.2	27.8	23.0	64	216
12	70/30 wool/nylon	Preprod	12.8	18.9	30.4	22.7	90	278
		Prod	12.8	28.3	29.6	21.3	93	221
13	85/15 wool/Dacron	Preprod	7.5	8.6	22.1	16.1	64	190
		Prod	8.1	7.9	20.6	17.2	63	192
14	70/30 wool/Dacron	Preprod	7.9	9.9	30.3	24.5	62	236
		Prod	12.3	22.9	30.8	29.1	87	258
15	85/15 wool/dynel	Preprod	12.0	21.6	25.7	12.3	83	184
		Prod	9.0	16.7	23.0	23.9	70	179
16	70/30 wool/dynel	Preprod	7.9	13.4	20.3	14.5	68	198
		Prod	10.6	20.3	25.9	25.8	82	202
17	85/15 wool/Orlon	Preprod	8.2	8.0	23.2	13.3	62	176
		Prod	8.0	11.6	19.4	16.5	60	162
18	70/30 wool/Orlon	Preprod	11.4	11.6	17.6	26.3	96	203
		Prod	10.4	13.7	24.6	18.4	81	196
19	70/20/10 wool/viscose/nylon	Preprod	8.5	9.0	24.0	9.0	73	191
		Prod	9.6	13.0	23.4	17.0	78	197
20	85/15 wool/Acrilan		No preproduction fabric					
		Prod	6.8	11.7	22.2	17.6	68	172
21	70/30 wool/Acrilan	Preprod	No test made - yarn used for "Gam" for color approval*					
		Prod	9.6	14.3	25.2	23.2	86	199

*"Gam" - A small 5- to 8-yard experimental piece.

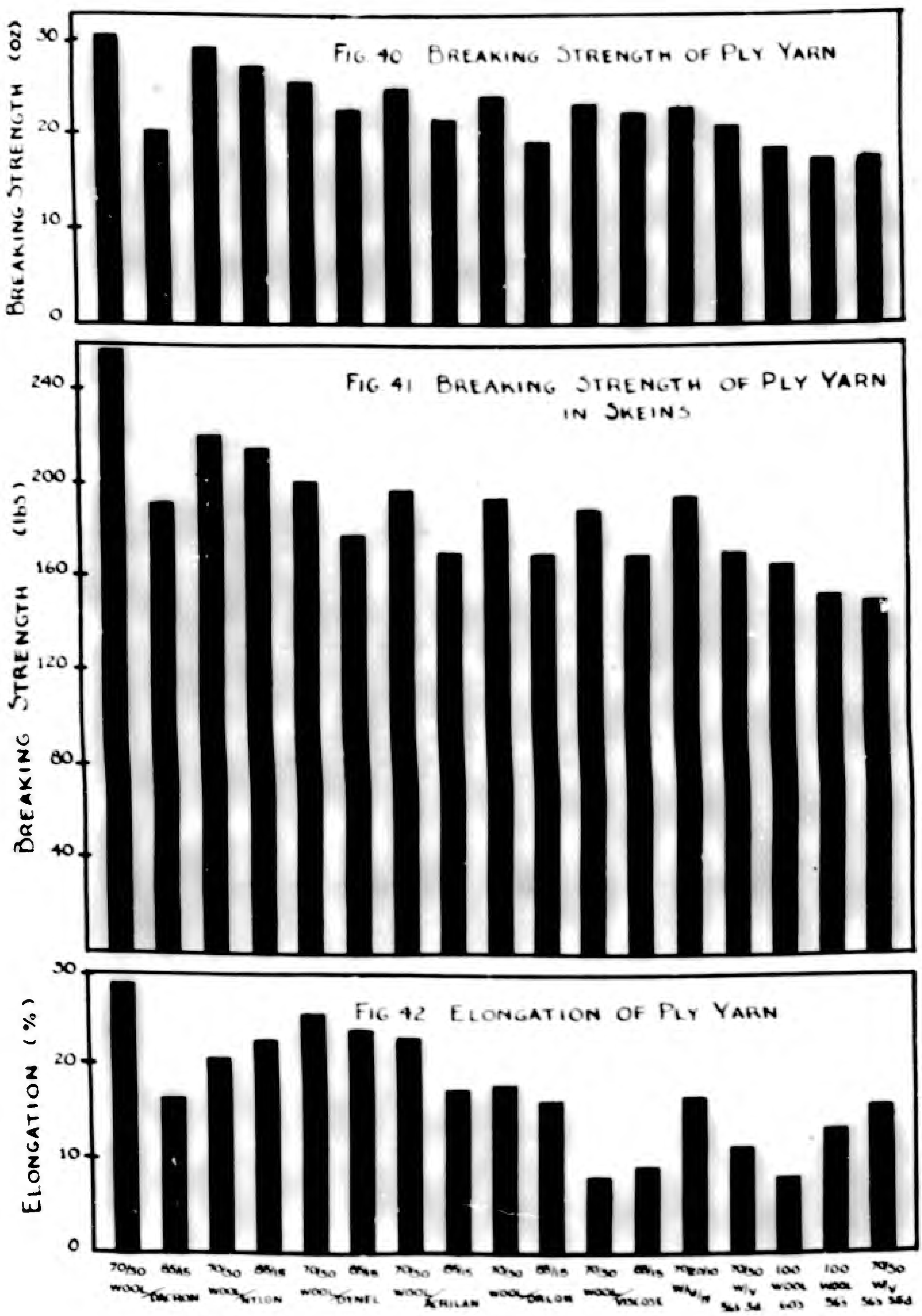


Fig 40 Breaking Strength of Ply Yarn
Breaking Strength (oz)
0
10
20
30
Fig 41 Breaking Strength of Ply Yarn in Skeins
Breaking Strength (lbs)
40
80
120
160
200
240
Fig 42 Elongation of Ply Yarn
Elongation (%)
0
10
20
30
70/30 wool/Dacron
70/30 wool/Nylon
70/30 wool/Dynel
70/30 wool/Acrilan
70/30 wool/Orlon
70/30 wool/Viscose
100 wool
100 wool

2. Fabrics: Preproduction series

The preproduction loom layout, and the off-loom and fulling mill data are shown in Table VII. The loom layout for items 1 through 7 were based on experience gained from the NRC and JI series of blended serges.* Both the NRC and JI series of serges were set at 56 ends per inch and a 70-inch reed width and adjusted to give 53 off-loom picks per inch. Fabrics so constructed met specification requirements for the 100% wool.

The results obtained with these fabrics were used to determine the loom layout of the remaining twelve preproduction fabrics (items 8 through 19). Therefore they will be discussed fully before covering the remainder of the series. (Preproduction of the two wool/Acrilan blends (items 20 and 21) was omitted because their behavior was expected to be similar to that of wool/Orlon and wool/dynel.)

a. Loom layout No. 1: It should be noted in Table VII that although the first seven fabrics were set to the same reed width and ends in the loom, and although they showed the same number of off-loom picks per inch, the off-loom number of ends per inch and the width and weight varied. The variation in the number of off-loom ends per inch was caused by the variation in width, within the limits of experimental error. The variation in weight correlates fairly closely with off-loom widths (Fig. 43) indicating that weight differences result from differences in the length of the filling yarns.

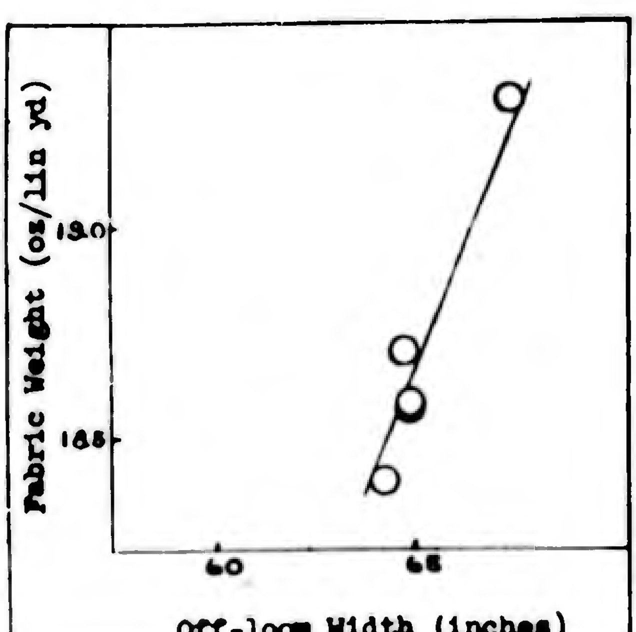


Figure 43. Correlation of Fabric Weight with Off-loom Width for Wool Viscose Blends (Effect of Weave Series)

* National Research Council (NRC) and Joint Industry (JI) series of fabrics are discussed in Hollies, N.R.S. et al, "Blends of Wool-Type Fabrics", QM R&E Textile Series Report No. 98, August 1958.

202 753

TABLE VII: PREPRODUCTION SERIES - FOR TWO LOOM LAYOUTS, OFF-LOOM AND FULLING MILL DATA

Item No.	Blend & Weave	Off-Loom Yarn (count)	Off-Loom Width (in)	Off-Loom Weight (oz/1in yd)	Fulling Mill Time (hr)	Fulling Mill Length Shrink. (in/yd)	Fulling Mill Width (in)	Fulling Mill Area Shrink. (%)	Fulling Mill Weight (oz/1in yd)
Loom Layout No. 1: Reed width 70"; 53 picks per inch off-loom; 56 ends per inch in loom									
1	100% 60's wool	2/23.5	65-1/4	18.5	2-1/2	2	58	18.6	19.8
2	70/30 wool/viscose, 2 x 2 twill	2/23.5	64-3/4	18.7	1	3	56-1/2	19.4	19.8
3	70/30 wool/viscose, gabardine	2/23.5	67-1/4	19.3	1	3-1/2	60	19.2	19.8
4	70/30 wool/viscose, crowfoot	2/23.5	65	18.6	1	3	56-1/4	19.6	18.7
5	70/30 wool/viscose, Mayo twill	2/23.5	64-1/4	18.4	1	4	54	32.0	19.0
6	70/30 wool/viscose, satin	2/23.5	65	18.6	1	3	57	19.1	18.5
7	100% 56's wool	2/23.5	63-3/4	18.2	2-1/2	2-1/4	58	16.9	17.8
Loom Layout No. 2: Reed width 67"; 52 picks off-loom; except item 14 - 53 picks off-loom; 58 ends per inch in loom									
8	70/30 56's wool/viscose	2/23.5	63-1/2	18.3	1	2	57-1/2		19.0
9	70/30 56's wool/5.5-d viscose	2/23.5	64	18.5	1	2	58		19.2
10	85/15 wool/viscose	2/23.5	64	18.0	1	2	57		18.9
11	85/15 wool/nylon	2/23.5	62	18.3	1	2	56-1/2		18.5
12	70/30 wool/nylon	2/23.5	62	18.5	1	2	56-1/2		19.5
13	85/15 wool/Dacron	2/25	62	17.5	1	2	56-1/4		18.0
14	70/30 wool/Dacron	2/25	62	17.7	1	2	56		18.4
15	85/15 wool/dynel	2/23.5	63	18.0	1	3	56-1/2		18.6
16	70/30 wool/dynel	2/23.5	63	18.5	1	2	57		19.2
17	85/15 wool/Orlon	2/25	62-1/2	17.2	1	2	56		17.9
18	70/30 wool/Orlon	2/25	63	17.6	1	2	56-1/2		18.1
19	70/20/10 wool/visc/nylon	2/23.5	62	18.1	1	3	56-1/2		19.8
20	85/15 wool/Acrilan	2/23.5			No preproduction sample				
21	70/30 wool/Acrilan	2/23.5			No preproduction sample				

Unless otherwise specified: 60's grade wool; 3-denier synthetic fiber; and 2 x 2 twill weave.
All weights based on full length and width of 15-to 20-yard pieces in a non-conditioned atmosphere.
Specification calls for weight after fulling of a minimum of 18 ounce for a minimum of 56 inches width.

The width of the cloth off-loom does not correlate with the float length (note Fig. 30 showing weave patterns) since the satin weave, with the longest float (4 yarns) has the same off-loom width as the crowfoot, with a float of only 3 yarns. The crowfoot, Mayo twill, and gabardine, all with maximum float lengths of 3 yarns, differ in off-loom widths. No explanation for the differences in the off-loom widths of fabrics of different construction is known at this time.

Scheduling difficulties did not permit all seven fabrics to be fulled in one mill. Five of the fabrics (items 2 through 6) were fulled in one machine for 1 hour; and the two all-wool fabrics (items 1 and 7) were fulled in another machine for 2½ hours. This time difference would make it appear that the all-wool fabrics gave greater difficulty in fulling than the blends of wool and viscose. Actually this was not the case. Fulling as such is still an art to the extent that fulling time for new fabric constructions depends on the experience and judgment of the fulling mill operator. Therefore no estimate can be obtained as to the relative fulling properties of the fabrics. Each lot must be considered separately.

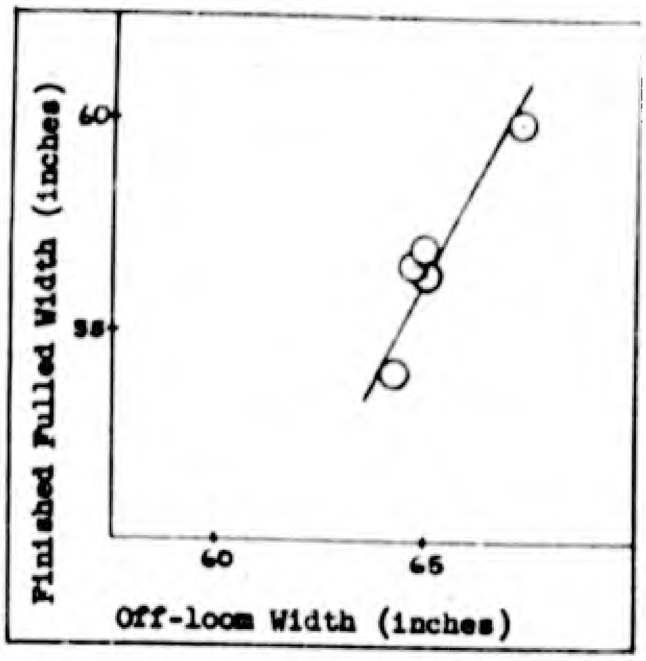


Figure 44. Correlation of Finished Fulled Width with Off-loom Width for Wool Viscose Blends (Effect of Weave Series)

Among the fabrics that were fulled for only 1 hour, it can be seen that the Mayo twill (item 5) differs significantly in area shrinkage from the others. The remaining four fabrics are approximately the same in area shrinkage and, with the exception of the gabardine, are approximately equal in width after fulling, within limits of experimental error. The finished fulled width of these fabrics follows closely the off-loom widths (Fig. 44). Therefore, given identical blends, yarn count, and loom layout, the off-loom width of a fabric appears to be a good indication of the relative ease of fulling in finishing. Shrinkage in length is found to correlate with the degree of yarn packing, or the tightness of the yarns in the fabric. The difference between the maximum weavable picks and the actual greige off-loom picks is shown below, together with warp head shrinkage. This difference represents a measure of yarn packing or tightness, and the greater the difference, the more easily the fabric will shrink in length (the greater the warp head shrinkage).

Effect of Yarn Packing on Warp Head Shrinkage

Weave	Off-Loom picks/in. (no.)	Max. Weavable picks/in. (no.)	Difference (no.)	Warp Head Shrinkage (in./yd.)
2x2 twill	53	69	16	3.0
Gabardine	53	74	21	3.5
Crowfoot	53	69	16	3.0
Mayo twill	53	83	30	4.0
Satin	53	74	21	3.0

Similarly, it can be shown that of the fabrics fulled for 2½ hours, the 56's wool (item 7) will not shrink as readily as the 60's wool (item 1). For the same initial loom layout, the off-loom width is narrower for the 56's wool than for the 60's, despite the fact that the 56's wool did not shrink as much in fulling as the 60's. For the same fulling time, the area shrinkage of the piece containing the coarser wool was less, although the finished width was the same after fulling.

The weights of each of the fabrics in this layout, except the fulled 56's wool, exceeded the specification minimum of 18 oz/56" width. It may be somewhat surprising that, with so much area shrinkage, the finished weights should differ so little from the off-loom weight. This is due to the scouring process in finishing, which may remove up to 20% of the greige goods' weight and more than offset any gain in weight caused by shrinkage in fulling.

b. Loom layout No. 2: The loom layouts for the remaining fabrics were adjusted to obtain uniformity in width and weight as well as in finishing time. These adjustments and the reason for each are described below.

It was desirable to reduce the weight slightly and, since the widths after fulling and the area shrinkages of these fabrics were so nearly alike, weight reduction could best be achieved by setting the cloth narrower in the loom (67 inches) and proportionately increasing the warp ends to 58 ends per inch. The narrower reed setting would save 3 inches of filling for each pick and obviously would result in some weight reduction. Because of the closer warp setting, one less filling pick per inch was used to facilitate weaving and to avoid yarn packing.

The gabardine weave did not shrink enough during fulling. However, its area shrinkage was nearly equal to that of the 2 x 2 twill under similar conditions of fulling. Since the fulling width shrinkage for the gabardine amounted to 7.25 inches, in order to arrive at a 56-inch finished width (instead of 60 inches), this fabric was eventually set to 63 inches reed width in the loom with 52 picks per inch off-loom.

The Mayo twill, with its propensity to shrink in fulling, had to be set wider in the loom. Its proper loom setting was a 72-inch reed width, again with a 52 pick-per-inch off-loom construction. To reduce the width of the 60's and 56's all-wool fabrics, they were set at 67 inches in the loom. Based on the above, the looms for the remaining preproduction fabrics were set at a reed width of 67 inches in the loom and 52 picks off-loom except for the 70/30 wool/Dacron which was inadvertently set at 53 picks per inch.

The revised layout (No. 2) for the preproduction samples proved a fortunate one since 1 hour of fulling time proved sufficient to produce the desired width of 56 inches minimum with an allowance of no more than an additional 1½ inches. The 70/30 wool/5.5-denier viscose blend (item 9), which finished at 58 inches, was slightly beyond the maximum tolerance for widths. Fabrics finishing with more than the desired weight of 18 ounces, with an allowance of an additional ounce, were the 70/30 wool/5.5-denier viscose (item 9), the 70/30 wool/nylon (item 12), the 70/30 wool/dynel (item 16), and the wool/viscose/nylon (item 19). Rather than change the loom layout to correct the differences in these blends, it was felt that compensations could be made during the finishing of the bulk yardage.

c. Physical properties: The physical properties of the preproduction samples are shown in Table VIII. Here the weights were reevaluated in the laboratory under standard textile atmospheric conditions. Four pieces did not meet the minimum specification requirement of 18 ounces for weight on a 56-inch width basis (items 1, 3, 14 and 17). Of these, the 100% 60's wool and the 70/30 wool/viscose gabardine were 59 and 61 inches wide respectively, which probably accounts for their greater weight. The thinner yarns of the wool/Dacron and wool/Orlon may account in part for their lower weights. Four of the fabrics showed weights of over 19 ounces for a 56-inch width (items 2, 5, 9 and 12). One of these, the 70/30 wool/viscose Mayo twill, shrank excessively. Adjustments were made in the new loom layout to take into account the weight of the remaining three weaves.

Eight fabrics fell below the specification minimum for ends per inch, and four exceeded the specification minimum. Five fabrics fell below the specification minimum for picks per inch. Most of these were in the synthetic fiber series. In view of the weights of these fabrics, and if their weight is to be kept within specifications, the number of picks per inch could be increased only by reducing yarn size. The only exception might be the 70/30 wool/Dacron (item 14) and the 85/15 wool/Orlon

TABLE VIII: PREPRODUCTION SERIES - PHYSICAL PROPERTIES

Item No.	Blend & Weave	Weight (oz/yd/56")	Width (in)	Finished Ends/in. (no.)	Finished Picks/in. (no.)	Breaking Strength Warp (lb)	Breaking Strength Filling (lb)	Shade
Specification MIL-C-823 (minimum):		18	56	68	54	110	100	USAF 84
1	100% 60's wool	17.4	59	66	56	133	110	too heavy
2	70/30 wool/viscose	19.8	58	67	56	134	106	OK
3	70/30 wool/viscose, gabardine	17.8	61	68	56	135	105	OK
4	70/30 wool/viscose, crowfoot	18.7	58	66	54	130	107	OK
5	70/30 wool/viscose, Mayo	19.4	54	70	56	130	110	OK
6	70/30 wool/viscose, satin	18.2	58	66	55	128	104	thin blue
7	100% 56's wool	18.2	59	66	56	137	113	OK
8	70/30 56's wool/viscose	18.5	56	66	52	142	106	OK
9	70/30 56's wool/5.5-d viscose	19.2	56	68	56	142	115	OK
10	85/15 wool/viscose	18.6	57	68	52	142	107	OK
11	85/15 wool/nylon	18.4	57	70	56	225	176	too blue
12	70/30 wool/nylon	19.6	56	68	55	261	225	bright blue
13	85/15 wool/Dacron	18.0	56	66	52	203	155	OK
14	70/30 wool/Dacron	17.3	56	68	52	233	187	too thin
15	85/15 wool/dynel	18.6	59	66	54	188	149	too thin
16	70/30 wool/dynel	18.2	56	70	52	201	163	too thin
17	85/15 wool/Orlon	17.2	57	68	54	142	107	too thin
18	70/30 wool/Orlon	18.1	57	70	56	147	122	too thin
19	70/20/10 wool/visc/nyl	18.4	57	68	55	178	143	OK
20	85/15 wool/Acrilan			No preproduction sample				
21	70/30 wool/Acrilan			No preproduction sample				

Unless otherwise specified, 60's grade wool; 3-denier synthetic fiber; and 2 x 2 twill weave.
Specification calls for weight after fulling of a minimum of 18 ounces for a minimum of 56 inches width.
Tests: Breaking Strength, Grab Method 5100; Weight, Method 5041 (Federal Specification CCC-T-191b).

(item 17), the weights of both of which were low enough to permit additional picks to be added without an excessive increase in weight.

The breaking strength of all the fabrics exceeded the minimum specification requirements. Weave and wool grade had little or no influence on the breaking strength of the fabrics. The addition of synthetic fibers, such as nylon and Dacron, markedly improved the breaking strength and this increase was proportional to their ratio in the blend. Dynel also increased the breaking strength but not to the extent of nylon and Dacron. The remaining synthetic fibers did not have any marked influence on breaking strength.

Although every care was exercised in the control of color in order to match AF Blue 84, nine preproduction fabrics were beyond the tolerance limits for shade. Four of these were fabrics containing the acrylic fibers Orlon or dynel. The acrylic blends did not conform to the conventional shade and the color match obtained in the pad could not be reproduced in the yarn. Apparently acrylics spin to the center and force the pearl color to the surface, yielding a thin shade. Since the acrylics replaced the red-blue component of the all-wool blend, adjustments in blending were necessary in order to allow for preferential migration of fibers.

Two of the off-shade pieces were nylon blends. If nylon is to be used, the color will have to be modified or a special blue primary developed, otherwise the red-blue primary appears too bright. The off-shade of the satin weave is probably due to the difference in the light reflection of that weave, since other weaves using the same yarns were rated as satisfactory. The too-heavy color of the 100% 60's wool indicated that adjustment in blending would be required for the production lots.

3. Fabrics: Full production series

a. Loom layout: Based on the performance of the majority of fabrics, loom layout No. 2 was used for the production series without change. Table II shows the production layout plus off-loom widths and picks and fulling data.

The full yardage was woven and finished in the four fabric groups as listed in Table II: (A) initial alternates, (B) viscose blends varying in weave, (C) fabrics varying in fiber grade or denier, and (D) blends varying in types and levels of synthetic fiber content.

In the main, the off-loom widths were found to reflect the changes made in the loom settings. Again fabrics set at one reed width varied in width off the loom. Fulling time could not be held to the desired 1

TABLE IX: PRODUCTION SERIES - LOOM LAYOUT* AND OFF-LOOM AND FULLING MILL DATA

Fabric Group**	Item No.	Blend & Weave***	Off-Loom Data Greige Width (in)	Fulling Mill Data Time (hr)	Length Shrinkage (in/yd)	Width (in)	Weight (oz/lin yd)
A,B,C,D	1	100% 60's wool (control)	63	1	3	56	--
A,B,C,D	2	70/30 wool/viscose	63	1	2-1/2	56	--
B	3	70/30 wool/viscose, gabardine	61	1	3-1/8	56	--
B	4	70/30 wool/viscose, crowfoot	63	1	2-1/2	56	--
B	5	70/30 wool/viscose, Mayo twill	66-7/8	1	3-1/2	56	--
B	6	70/30 wool/viscose, satin	62-5/8	1	3-1/8	56	--
C	7	100% 56's wool	63-7/8	2	2	56	18.1
C	8	70/30 56's wool/viscose	64	2	2	57	19.4
C	9	70/30 56's wool/5.5 denier viscose	63-3/4	2	2	57	19.4
D	10	85/15 wool/viscose	63-3/4	1	2	56	18.9
A	11	85/15 wool/nylon	63-1/4	2	2	56	18.6
D	12	70/30 wool/nylon	61-7/8	2	2	56	19.6
D	13	85/15 wool/Dacron	62-1/2	1-5/12	3-1/4	57	18.6
D	14	70/30 wool/Dacron	62-7/8	1	2	56	18.4
D	15	85/15 wool/dynel	62-1/2	2	2	56-1/2	19.4
D	16	70/30 wool/dynel	62-7/8	2	2	55-1/2	19.2
D	17	85/15 wool/Orlon	63-1/4	2	2	56	17.9
D	18	70/30 wool/Orlon	63-1/2	2	2	56-1/4	18.5
A	19	70/20/10 wool/viscose/nylon	63-1/4	1	2	56	19.2
D	20	85/15 wool/Acrilan	--	2	2	57	19.7
D	21	70/30 wool/Acrilan	63-1/2	2	2	56-1/2	19.5

*Loom Layout: Reed width 67"; picks off-loom 52; ends per inch in loom 58; except for the gabardine, which was set 63" reed width in loom, and the Mayo twill, which was set 72" in loom.

**Following division of Table II: A = initial alternates; B = varying weaves; C = varying fiber grade or denier; D = varying types and levels of synthetics.

***Unless otherwise specified, 60's grade wool; 3-denier synthetic fiber; and 2 x 2 twill weave.

hour for all of the fabrics. The best that could be done was to maintain a constant fulling time within each group, but even this was not possible for the 85/15 wool/nylon and the 70/30 and 85/15 wool/Dacrons. For some fabrics, extra fulling time was required for adequate shrinkage. However, where additional fulling time was required, the rate of fulling was less for the larger full production pieces than for the smaller preproduction lots, as shown by comparing the times required to obtain essentially the same length shrinkage.

Data on weight after fulling is incomplete, but reference may be made to the weights as determined in the laboratory.

b. Physical properties: Table I shows only the 85/15 wool/Orlon of the production fabrics to be below the specification minimum weight of 18 ounces for 56-inch width. Eleven fabrics varied between 18 and 19 ounces and the remaining nine were over 19 ounces. The weight spread amounted to 2.0 ounces, which was greater than desired for this program but was still not unreasonable considering that we are dealing with an 18-ounce fabric.

Finished widths taken under controlled atmospheric conditions show that the majority of the full-production fabrics met the specification requirements for width. Only four fabrics fell below 56 inches and these by only 1/8 to 1/4 inch, which is not considered significant.

All the fabrics except the 100% 56's wool, the 70/30 wool/viscose crowfoot weave and the 70/30 wool/nylon met the minimum specification requirements for number of ends per inch. However, twelve fabrics, including the 100% wool control, had fewer than 54 picks per inch. The remaining nine fabrics met the specification requirements for picks per inch. In fact, one of the blended fabrics (the 70/30 wool/Acrilan) appeared to stretch, having fewer picks per inch after fulling than in the off-loom state. This demonstrates a difference between the fabrics in shrinkage and fulling, and suggests the inherent danger of having one set of specification requirements for all possible blends. It indicates the need for and direction of further study on specification requirements for specific fiber blends and fabric constructions.

The breaking strength of the fabrics, with a few exceptions, showed an increase in strength over that of the preproduction samples. All values far exceeded the specification minimum and confirmed the data obtained from the preproduction samples.

Before concluding this study, it would be desirable to compare the relationships between the 120-yard yarn breaks and the fabric breaking strength. Figure 45 shows the data plotted around a 53° line drawn so that an equal number of points fall on each side. In a perfect corre-

TABLE X: PRODUCTION SERIES - PHYSICAL PROPERTIES

Item No.	Blend & Weave	Finished Width (in)	Weight (oz/yd/56")	Ends/in. (no.)	Picks/in. (no.)	Break. Str. (lb) Warp	Break. Str. (lb) Filling	Shade
Specification MIL-C-823 (minimum)		56	18.0	68	54	110	100	USAF 84
1	100% 60's wool	57-1/8	18.8	68	52	176	136	OK
2	70/30 wool/viscose	57-1/8	19.6	68	54	157	121	thin blue
3	70/30 wool/viscose, gabardine	55-7/8	19.6	68	52	170	121	OK
4	70/30 wool/viscose, crowfoot	56-5/8	19.2	69	54	156	121	thin red green
5	70/30 wool/viscose, Mayo twill	56-1/4	19.7	68	52	144	116	OK
6	70/30 wool/viscose, satin	56-1/8	19.3	70	53	155	117	thin red
7	100% 56's wool	57-1/4	17.9	67	53	147	122	OK
8	70/30 56's wool/viscose	57-1/8	18.6	68	56	145	111	OK
9	70/30 56's wool/5.5 denier viscose	57	18.5	69	54	142	111	OK
10	85/15 wool/viscose	56-3/8	18.6	70	52	140	106	OK
11	85/15 wool/nylon	56-3/4	18.9	70	55	221	173	OK
12	70/30 wool/nylon	55-3/4	19.2	66	55	304	251	within tolerance
13	85/15 wool/Dacron	56-1/2	18.9	69	55	204	157	thin green flat
14	70/30 wool/Dacron	55-3/4	19.2	70	52	236	188	thin red frosty
15	85/15 wool/dynel	55-3/4	18.8	70	55	186	151	thin red
16	70/30 wool/dynel	56-7/8	19.6	69	55	215	169	thin red
17	85/15 wool/Orlon	56	17.6	69	54	161	124	red violet
18	70/30 wool/Orlon	56-1/8	18.0	70	52	180	138	thin red
19	70/20/10 wool/viscose/nylon	56-1/2	18.2	70	55	175	139	OK
20	85/15 wool/Acrilan	56-1/4	19.2	70	55	177	131	thin red
21	70/30 wool/Acrilan	56-1/8	18.9	70	50	190	145	thin red

Unless otherwise specified, 60's grade wool; 3 denier synthetic fiber; and 2 x 2 twill weave.
Tests: Breaking Strength - Grab Method 5100, Federal Specification CCC-T-191b.

lation, all points should fall along a straight line. Since this chart shows wide scattering, only a rough correlation exists between yarn and fabric breaking strength and therefore only gross comparisons are possible.

The 60's all-wool control fabric and the 85/15 wool/nylon, both of which were unsatisfactory for color in the preproduction run, were brought within tolerance for color in the production run. The 70/30 wool/nylon was brought to a barely acceptable shade in production, i.e., "inside tolerance". The gabardine, Mayo twill, all three fabrics using 56's wool, the 85/15 wool/viscose, and the 3-fiber blend were acceptable for color during both runs. The 2 x 2 twill, the crowfoot weave, and the 85/15 wool/Dacron were satisfactory in preproduction but were outside tolerance in production. The satin and the rest of the synthetic fiber blends gave difficulty in shade matching in both runs. It is therefore indicated that more experience is needed in the techniques of blending, taking into account the effect of such processing variables as spinning and possibly finishing or dyeing.

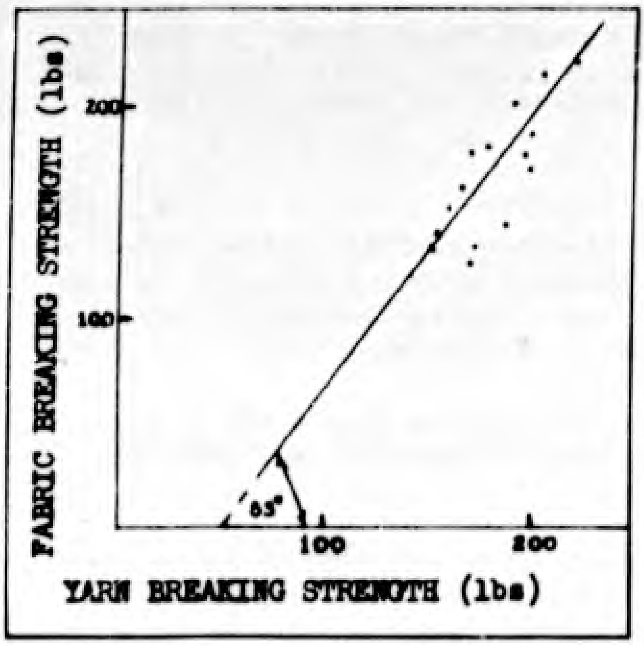


Figure 45. Relationship of Fabric and Yarn Breaking Strength

All of the experimental fabrics were compared with the specification requirements for the standard 100% wool. Further evaluation of the fabrics will be discussed in terms of appearance, comfort, and wear according to their experimental groupings (effect of construction, wool grade and/or fiber denier, and blending with synthetic fibers) in Parts II and III of this report.

D. Conclusions

1. Sufficient yardages for testing 20 experimental serge alternates, plus an all-wool control, were produced on the conventional Bradford worsted system. No greater production difficulty was encountered than is normally met in processing the all-wool standard fabric.

a. Four hundred yards of each of the initial alternate fabrics (85/15 wool/nylon, 70/30 wool/viscose) and a ternary blend (70/20/10 wool/viscose/nylon) were produced in AF Blue 84 and shipped to the Air Force for acceptability trials.

b. Two hundred yards each of a wool/viscose blend, in four different weaves, and three fabrics using coarser grades of wool or denier of viscose were developed and produced for durability determinations. Fifty yards of each of these fabrics were shipped to the Air Force.

c. One hundred yards each of blends containing either 15% or 30% of most of the readily available synthetics were developed and produced using the denier, staple length, and crimp recommended by the fiber producer. Ten yards of each of these were shipped to the Air Force.

2. The efficiency in spinning and weaving the blends was comparable to that for all wool even for the limited yardages required for this program. Yarn yields were high.

3. The synthetic fibers were dyed to shade and blended in an attempt to match AF Blue 84. However, greater experience must be gained by the mills for satisfactory shade production under the terms of a government contract for military fabrics.

4. The constructional data contained in this report indicate that new specification requirements must be developed for each blend.

5. All of the experimental materials can readily be finished on conventional machinery now in use by industry.

6. The Quartermaster and Air Force Laboratories are in the process of evaluating the fabrics for ease of tailoring, durability, comfort, appearance, and protective properties. The Air Force is primarily concerned with field acceptability trials while the Quartermaster Corps is primarily concerned with durability as determined by laboratory and field tests. The results of these evaluations will be summarized in later sections of this report.

APPENDIX I

U. S. Wool Production and Mill Consumption

Wool has been considered as the most suitable fiber for the 18-ounce serge component of Air Force service and Army cold weather combat uniforms. Specifications for this fabric have required a 60's grade wool to meet processing, construction, and finishing requirements. Between 1940 and 1944, the Quartermaster Corps procured over 141 million yards of serge which, with normal allowance for manufacturing losses, is equivalent to 190 million pounds of scoured 60's wool, or an average yearly requirement of 38 million pounds. The estimated current annual production of this grade is 30.1 million pounds (Table XI). Assuming that future wartime requirements for 18-ounce serge would parallel those of World War II (38 million pounds annually), and relying only on anticipated domestic production, it is clearly seen that the supply of 60's wool falls at least 21% short of the annual needs of the military alone. Hence wool is listed by the Department of Defense as a material in critical supply (AR 754-10, Conservation of Materials).

TABLE XI

U. S. WOOL SUPPLY, SCOURED BASIS

Blood	Grade	Percent shorn and pulled, 1946, by grade*		Estimated amount available by grade in millions of pounds, 1954		
		Shorn	Pulled	Shorn	Pulled	Total
Fine	80's 70's 64's	46.7	9.1	47.5	3.0	50.5
1/2 Blood	60's 58's	16.3	41.0	16.6	13.5	30.1
3/8 Blood	56's	17.9	43.9	18.3	14.5	32.8
1/4 Blood	50's 48's	12.5	4.9	12.8	1.6	14.4
Low 1/4 Blood	46's	1.1	.2	1.2	.1	1.3
Common & Braid	44's 40's 36's	.3	.9	.3	.3	.6
Off Wools		5.2	-	5.3	-	5.3
		100.0	100.0	102.0	33.0	135.0

* Calculated from average shrinkage figures of total clip
Source: Bulletin, National Assn. Wool Manufacturers, 84, 2-29 and 2-30.

In 1942, the total U. S. wool production (scoured basis) was 202 million pounds. In 1950, production dropped to 119 million pounds. In 1954 it rose to 135 million pounds, as seen in Table XII.

TABLE XII

ANNUAL U. S. PRODUCTION AND MILL CONSUMPTION OF WOOL, SCOURED BASIS*

	Consumption (millions of pounds)	Production (millions of pounds)	Percentage by which production meets consumption requirements
1940	408	188	46
1942	604	202	33
1944	623	188	30
1946	748	170	23
1948	693	137	20
1950	635	119	19
1952	466	127	27
1954	383	135	35

* Estimated, using proportions reported in 1946.
Source: Bulletin, NAWM, 84, 2-10 and 2-28.

While domestic wool production has fluctuated, the production and use of synthetic fibers has steadily risen from 487 million pounds in 1940 to 1,499 million pounds in 1954.

TABLE XIII

ANNUAL U. S. MILL FIBER CONSUMPTION

	Cotton		Scoured Wool		Synthetic Fibers		Silk	
	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)
1940	3,953	81	408	8	487	10	36	1
1942	5,637	82	604	9	645	9	5	nominal
1944	4,792	78	623	10	753	12	1	nominal
1946	4,803	74	748	12	980	14	7	nominal
1948	4,461	70	693	11	1,224	19	7	nominal
1950	4,680	69	635	9	1,497	22	8	nominal
1952	4,437	70	466	7	1,471	23	7	nominal
1954	4,138	69	383	6	1,499	25	6	nominal

Weights in millions of pounds.
% = percent of total mill fiber consumption for the year.
Source: Bulletin, NAWM, 84, 2-10.

APPENDIX I

U. S. Wool Production and Mill Consumption

Wool has been considered as the most suitable fiber for the 18-ounce serge component of Air Force service and Army cold weather combat uniforms. Specifications for this fabric have required a 60's grade wool to meet processing, construction, and finishing requirements. Between 1940 and 1944, the Quartermaster Corps procured over 141 million yards of serge which, with normal allowance for manufacturing losses, is equivalent to 190 million pounds of scoured 60's wool, or an average yearly requirement of 38 million pounds. The estimated current annual production of this grade is 30.1 million pounds (Table XI). Assuming that future wartime requirements for 18-ounce serge would parallel those of World War II (38 million pounds annually), and relying only on anticipated domestic production, it is clearly seen that the supply of 60's wool falls at least 21% short of the annual needs of the military alone. Hence wool is listed by the Department of Defense as a material in critical supply (AR 754-10, Conservation of Materials).

TABLE XI

U. S. WOOL SUPPLY, SCOURED BASIS

Blood	Grade	Percent shorn and pulled, 1946, by grade*		Estimated amount available by grade in millions of pounds, 1954		
		Shorn	Pulled	Shorn	Pulled	Total
Fine	80's 70's 64's	46.7	9.1	47.5	3.0	50.5
1/2 Blood	60's 58's	16.3	41.0	16.6	13.5	30.1
3/8 Blood	56's	17.9	43.9	18.3	14.5	32.8
1/4 Blood	50's 48's	12.5	4.9	12.8	1.6	14.4
Low 1/4 Blood	46's	1.1	.2	1.2	.1	1.3
Common & Braid	44's 40's 36's	.3	.9	.3	.3	.6
Off Wools		5.2	-	5.3	-	5.3
		100.0	100.0	102.0	33.0	135.0

* Calculated from average shrinkage figures of total clip
Source: Bulletin, National Assn. Wool Manufacturers, 84, 2-29 and 2-30.

In 1942, the total U. S. wool production (scoured basis) was 202 million pounds. In 1950, production dropped to 119 million pounds. In 1954 it rose to 135 million pounds, as seen in Table XII.

TABLE XII

ANNUAL U. S. PRODUCTION AND MILL CONSUMPTION OF WOOL, SCOURED BASIS*

	Consumption (millions of pounds)	Production (millions of pounds)	Percentage by which production meets consumption requirements
1940	408	188	46
1942	604	202	33
1944	623	188	30
1946	748	170	23
1948	693	137	20
1950	635	119	19
1952	466	127	27
1954	383	135	35

* Estimated, using proportions reported in 1946.
Source: Bulletin, NAWM, 84, 2-10 and 2-28.

While domestic wool production has fluctuated, the production and use of synthetic fibers has steadily risen from 487 million pounds in 1940 to 1,499 million pounds in 1954.

TABLE XIII

ANNUAL U. S. MILL FIBER CONSUMPTION

	Cotton		Scoured Wool		Synthetic Fibers		Silk	
	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)
1940	3,953	81	408	8	487	10	36	1
1942	5,637	82	604	9	645	9	5	nominal
1944	4,792	78	623	10	753	12	1	nominal
1946	4,803	74	748	12	980	14	7	nominal
1948	4,461	70	693	11	1,224	19	7	nominal
1950	4,680	69	635	9	1,497	22	8	nominal
1952	4,437	70	466	7	1,471	23	7	nominal
1954	4,138	69	383	6	1,499	25	6	nominal

Weights in millions of pounds.
% = percent of total mill fiber consumption for the year.
Source: Bulletin, NAWM, 84, 2-10.

APPENDIX I

U. S. Wool Production and Mill Consumption

Wool has been considered as the most suitable fiber for the 18-ounce serge component of Air Force service and Army cold weather combat uniforms. Specifications for this fabric have required a 60's grade wool to meet processing, construction, and finishing requirements. Between 1940 and 1944, the Quartermaster Corps procured over 141 million yards of serge which, with normal allowance for manufacturing losses, is equivalent to 190 million pounds of scoured 60's wool, or an average yearly requirement of 38 million pounds. The estimated current annual production of this grade is 30.1 million pounds (Table XI). Assuming that future wartime requirements for 18-ounce serge would parallel those of World War II (38 million pounds annually), and relying only on anticipated domestic production, it is clearly seen that the supply of 60's wool falls at least 21% short of the annual needs of the military alone. Hence wool is listed by the Department of Defense as a material in critical supply (AR 754-10, Conservation of Materials).

TABLE XI

U. S. WOOL SUPPLY, SCOURED BASIS

Blood	Grade	Percent shorn and pulled, 1946, by grade*		Estimated amount available by grade in millions of pounds, 1954		
		Shorn	Pulled	Shorn	Pulled	Total
Fine	80's 70's 64's	46.7	9.1	47.5	3.0	50.5
1/2 Blood	60's 58's	16.3	41.0	16.6	13.5	30.1
3/8 Blood	56's	17.9	43.9	18.3	14.5	32.8
1/4 Blood	50's 48's	12.5	4.9	12.8	1.6	14.4
Low 1/4 Blood	46's	1.1	.2	1.2	.1	1.3
Common & Braid	44's 40's 36's	.3	.9	.3	.3	.6
Off Wools		5.2	-	5.3	-	5.3
		100.0	100.0	102.0	33.0	135.0

* Calculated from average shrinkage figures of total clip

Source: Bulletin, National Assn. Wool Manufacturers, 84, 2-29 and 2-30.

In 1942, the total U. S. wool production (scoured basis) was 202 million pounds. In 1950, production dropped to 119 million pounds. In 1954 it rose to 135 million pounds, as seen in Table XII.

TABLE XII

ANNUAL U. S. PRODUCTION AND MILL CONSUMPTION OF WOOL, SCOURED BASIS*

	Consumption (millions of pounds)	Production (millions of pounds)	Percentage by which production meets consumption requirements
1940	408	188	46
1942	604	202	33
1944	623	188	30
1946	748	170	23
1948	693	137	20
1950	635	119	19
1952	466	127	27
1954	383	135	35

* Estimated, using proportions reported in 1946.
Source: Bulletin, NAWM, 84, 2-10 and 2-28.

While domestic wool production has fluctuated, the production and use of synthetic fibers has steadily risen from 487 million pounds in 1940 to 1,499 million pounds in 1954.

TABLE XIII

ANNUAL U. S. MILL FIBER CONSUMPTION

	Cotton		Scoured Wool		Synthetic Fibers		Silk	
	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)
1940	3,953	81	408	8	487	10	36	1
1942	5,637	82	604	9	645	9	5	nominal
1944	4,792	78	623	10	753	12	1	nominal
1946	4,803	74	748	12	980	14	7	nominal
1948	4,461	70	693	11	1,224	19	7	nominal
1950	4,680	69	635	9	1,497	22	8	nominal
1952	4,437	70	466	7	1,471	23	7	nominal
1954	4,138	69	383	6	1,499	25	6	nominal

Weights in millions of pounds.
% = percent of total mill fiber consumption for the year.
Source: Bulletin, NAWM, 84, 2-10.

On a per capita basis, the total demand for fibers, not only in the U. S. but throughout the world, increased from 27.5 pounds in 1953 to 44.4 pounds in 1950, with a drop in 1954 to 37.5 pounds. (See Table XIV.)

TABLE XIV

U. S. MILL CONSUMPTION OF FIBERS, PER CAPITA BASIS
(in pounds)

	Cotton	Wool	Man-Made Fibers	Silk	Total
1935	21.7	3.3	2.0	.5	27.5
1940	20.0	3.1	3.7	.3	37.1
1945	32.3	4.6	5.9	nominal	42.8
1950	31.0	4.2	9.2	nominal	44.4
1954	25.7	2.4	9.4	nominal	37.5

Source: Bulletin, NAWM, 84, 2-11.

Two possibilities for extending the present domestic supply of wool appear from the above figures: first, the use of 56's grade wool in addition to the 60's, which would double the amount of wool available; secondly, replacing the wool in part or entirely with the increasingly available synthetic fibers.

APPENDIX II

<u>Glossary of Standard Engineering Action Symbols</u>
<u>For Textile Processing and Operation Analysis</u>

To implement the study of fiber processing, Professor E. R. Schwarz, of the Massachusetts Institute of Technology, has proposed a set of action symbols. These symbols have been used in this report to describe the simple and fundamental actions which fibers undergo during the manufacturing of a fabric. A complete listing of symbols and terms is given on the following page.

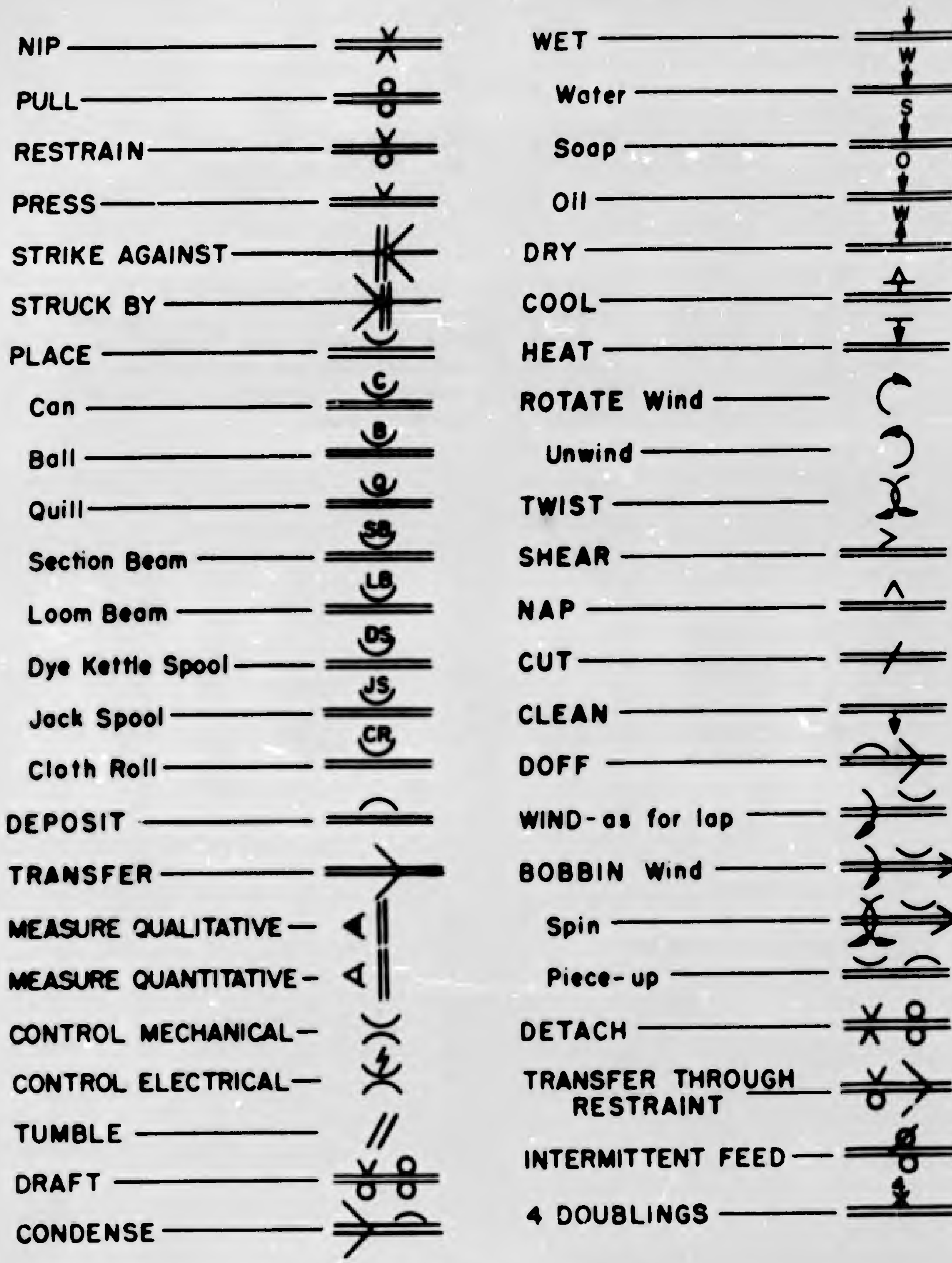


Figure 46. Glossary of Action Symbols

APPENDIX III

Laboratory Dyeing of Supplementary Colors
To Establish Dye Formulas

1. Wool

Dyestuff formulas have been determined by the Quartermaster Corps, conducted at the Textile Dyeing Laboratory Branch of the Textile, Clothing & Footwear Division, QM R&E Command. The basic studies were conducted by the laboratory under CSO&A (33-616) 53-221 (USAF). All the colors withstood 80 standard fading hours fastness "at the break".

The primary colors were matched and shade standards were prepared using the contractor's approved 60's and 56's grade top. Although at first there was a possibility that several dye formulas might be needed because of the difference in wool grades, it was found that with proper control one dye formula could be used to obtain a color match even when different grades of wool were used. The contractor was furnished with a copy of the suggested dye formula (Table XV) and also wool samples dyed for color matching.

2. Synthetic fibers

The introduction of synthetic fibers into military fabrics has presented many problems in dyeing techniques. As a result of their experiments and experience, the fiber producers, R&E Command representatives, dye manufacturers, and fabric contractors have agreed that, if the dyeing of all contemplated fibers could be dope- or spun-dyed (color pigments introduced into the mix used for spinning the fiber), the following advantages would be possible:

a. Large batches of material could be produced in a uniform shade and with maximum color fastness.

b. There would be fewer tangled fibers and hence better blending.

c. Subsequent troublesome top dyeing operations would be eliminated. However, in a survey of the trade, it was found that only viscose and dynel could be obtained commercially in a spun-dyed state; therefore, the remaining synthetic fibers would have to be procured in their natural color and dyed to shade in top form to match the viscose.

The viscose was spun-dyed to match a blend of the three supplementary blues (wool). However, upon delivery, the viscose did not match the blend as intended, although it did match the supplementary red-blue wool.

TABLE XV

DYE FORMULAS WOOL COMPONENT AIR FORCE BLUE 84
(in %)*

Dyestuffs & Chemicals	Pearl 60s	Pearl 56s	Slate 60s	Slate 56s	Blue 60s	Blue 56s	Red Blue 60s	Red Blue 56s
PR 206	0.33	0.33	0.35	0.35	- -	- -	- -	- -
CI 1080	0.12	0.12	- -	- -	- -	- -	- -	- -
PR 7	- -	- -	1.28	1.28	- -	- -	- -	- -
Chrome Cyanine BBL	- -	- -	- -	- -	2.20	2.20	3.00	3.00
Brilliant Alizarine Milling Blue BL	- -	- -	- -	- -	1.30	1.30	0.50	0.50
Alizarine Green CG Ex	- -	- -	- -	- -	0.20	0.20	0.10	0.10
Glauber Salt	5.00	5.00	5.00	5.00	- -	- -	- -	- -
Ammonium Acetate	10.00	10.00	- -	- -	- -	- -	- -	- -
Ammonium Sulfate	- -	- -	5.00	5.00	5.00	5.00	5.00	5.00
Acetic Acid (To exhaust)	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Nullapon	- -	- -	0.50	0.50	0.50	0.50	0.50	0.50
Sodium Dichromate	0.40	0.40	1.50	1.50	- -	- -	- -	- -
Chrome Mordant	- -	- -	- -	- -	2.50	2.50	2.50	2.50
(Method	Top Chrome		Top Chrome		Metachrome		Metachrome)	

* Percentage of dyestuffs by weight based on weight of the wool.

The dynel fiber was available in the spun-dyed state only as a blend, and not as a solid color; consequently a combination of 80% dark blue and 20% black fibers were blended to produce a dynel top that would match the dope-dyed viscose.

In accordance with modern trade practices and thinking, the following recommendations were made for the best possible dye formulation: for nylon staple, specially developed capracyl dyes; for Orlon staple, Sevron dyes; for Dacron and Acrilan staple, acetate dyes. These dyes were selected for fastness to light, and dry cleaning and laundering. Table XVI shows the dye formulas used with the respective synthetic fibers which gave a satisfactory color match to the viscose.

The proportion of base and supplemental colors to obtain a satisfactory color match for Air Force Blue 84 are shown in Table XVII.

The information contained in Tables XVI and XVII was given to the contractor for his guidance.

TABLE XVI

DYE FORMULAS SYNTHETIC FIBERS
(in %)

Dyestuffs	Nylon	Orlon	Dacron	Acrilan
Capracyl Blue G	5.00	- - -	- - -	- - - -
Capracyl Yellow 3RD	0.50	- - -	- - -	- - - -
Sevron Green B	- - -	3.0	- - -	- - - -
Sevron Red 4 G	- - -	1.5	- - -	- - - -
Celliton Violet 6 BA	- - -	- - -	2.75	3.00
Celliton Orange GRA	- - -	- - -	0.25	0.50
Celliton Navy Blue BRA	- - -	- - -	3.00	3.00
Ammonium Acetate	5.00	- - -	- - -	- - - -
Acetic Acid	- - -	.4 sol.	- - -	- - - -
Igepon Pgel	- - -	- - -	1.0	1.0
(Temperature	Boil	Boil	240°F	Boil)

TABLE XVII

BLEND COMPOSITION AIR FORCE BLUE 84
(in %)*

Fabric	Pearl	Slate	Blue	Red Blue
100% wool 60s	38	19	19	24
100% wool 56s	38	19	19	24
70/30				
wool/viscose	38	16	16	—
wool/viscose**	38	10	22	—
wool/nylon	38	10	22	—
wool/Orlon	38	16	16	—
wool/Dacron	38	16	16	—
wool/Acrilan	38	16	16	—
wool/dynel	38	16	16	
85/15				
wool/viscose	38	19	14	14
wool/nylon	38	19	14	14
wool/Orlon	38	19	14	14
wool/Dacron				
wool/Acrilan	38	19	14	14
wool/dynel	38	19	14	14

* Suggested percentages to be used as guide only in matching Air Force Shade.

** All blends were 60's wool except 70/30 wool/viscose which was 56's wool; all synthetics were 3d except 70/30 wool/viscose which was 5½ d.

UNCLASSIFIED

AD 217056

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR
MICRO-CARD
CONTROL ONLY

2 OF 2

UNCLASSIFIED