

Wool Processing on the Cotton System: A Comparison Between Cut-Top Wool and Six-Month Shorn Wool in a Blend With Polyester¹

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ABSTRACT

Fiber blends composed of cut-top wool/polyester and short-shorn wool/polyester in the ratio of 60:40 were processed on the short-staple system of spinning into 49.2 mg/m (12/1 N_e) and 98.4 mg/m (6/1 N_e) yarns. Subsequently, apparel and home-furnishing fabrics were woven and their physical properties were measured. Generally, fabrics containing cut-top wool exhibited higher grab strengths than their short-shorn wool counterparts. Conversely, resistance to flex abrasion tended to be better in the case of the fabrics composed of short-shorn wool/polyester. Other fabric properties including tear strength, shrinkage due to home launderings, and appearance after home launderings were very similar.

Introduction

The consumption of wool in the United States has dropped from 317.5 million kg (700 million lb) in 1950 to a scant 49.9 million kg (110 million lb) in 1978 (Table I). In the last decade the wool consumption of U. S. mills has declined from 108.9 million kg (240 million lb) in 1970 to 49.0 million kg (108 million lb) in 1977 (Table II). Domestic production of wool has dropped from 73.3 million kg (161.6 million lb) in 1970 to 45.9 million kg (101.3 million lb) in 1978 (Table III). One consoling fact that emerges is that wool has managed to maintain a fairly constant share of the total fiber consumption in the U. S. since 1973, this being approximately 1%.

It is noteworthy that from 1974 to the present time the total of all fibers as well as the fiber ratios processed on U. S. woolen and worsted systems has also been fairly constant (Table IV). In order for the U. S.

TABLE I
U.S. FIBER CONSUMPTION, 1950-1978*
(Millions of Pounds)Δ

Fiber Type	1950	1960	1970	1978
Non-Cellulosics	135	650	3800	7750
Cellulosics (Man-Made)	1400	1100	1600	860
Cotton	4800	4200	3900	3045
Wool (Scoured)	700	490	280	110

¹ Presented at the Second Natural Fibers Textile Conference, Charlotte, North Carolina, September 18-20, 1979.

*Source: Modern Textiles, Vol. LX, No. 3, p. 40 (March, 1979)
ΔMultiply by 0.4536 to obtain millions of kilograms

TABLE II
FIBER CONSUMPTION BY U.S. TEXTILE MILLS*
(Millions of Pounds) Δ

Period	Total Mill Consumption	Cotton	Cotton % of Total	MMF	MMF % of Total	Scoured Wool	Wool % of Total
1970	9,595.0	3853.8	40.2	5500.9	57.3	240.3	2.5
1971	10,706.5	3985.8	37.2	6529.2	61.0	191.5	1.8
1972	11,648.3	3864.0	33.2	7565.7	64.9	218.6	1.9
1973	12,473.1	3657.6	29.3	8664.2	69.5	151.3	1.2
1974	11,100.5	3309.0	29.8	7698.0	69.4	93.5	0.8
1975	10,553.3	3026.7	28.7	7416.6	70.3	110.0	1.0
1976	11,588.6	3413.9	29.5	8053.0	69.5	121.7	1.0
1977	12,190.9	3182.6	26.1	8900.2	73.0	108.1	0.9
1978 (½ yr.)	6,319.1	1577.3	24.9	4680.5	74.1	61.3	1.0

*Compiled by the U.S. Department of Agriculture, Commodity Economics Division, Economic Research Service
 Δ Multiply by 0.4536 to obtain millions of kilograms

TABLE III
U.S. PRODUCTION OF SHORN WOOL*
(Millions of Pounds, Clean Basis) Δ

Year	Total Production
1970	161.6
1971	161.2
1972	158.9
1973	145.2
1974	133.0
1975	129.2
1976	110.8
1977	107.2
1978	101.3

*Source: Cotton and Wool Situation, CWS-14, February, 1979;
U.S. Department of Agriculture

Δ Multiply by 0.4536 to obtain millions of kilograms

textile industry to consume more wool in future years, it appears that one or more of the following conditions must prevail. First, wool must control a larger share of the existing capacities of woollen and worsted mills; secondly, the woollen and worsted industries must expand to accommodate more wool, the ratio of fibers used being assumed to stay constant; thirdly, non-traditional uses for wool must be found; finally, wool must gain a larger share of the total fiber consumption by being spun on nontraditional systems. It has been to this latter possibility that this and numerous other groups of researchers [1-19] have addressed their efforts.

A review of the literature reveals some of the problems that are encountered when wool is processed on the short staple system in 100% form. King *et al.* [8] concluded that it was impossible to make a suitable full lap using pure wool on the picker. Also, due to the inability of the sliver lapper to make a suitable

TABLE IV
U.S. MILL CONSUMPTION OF WOOL ON WOOLEN AND WORSTED SYSTEMS*
(Average Weekly in Thousands of Pounds-Scoured Basis for Greasy Wools) Δ

	1972	1973	1974	1975	1976	1977	1978 (½ yr.)
Apparel Wool							
Worsted System							
60's and Finer	945	695	407	297	396	428	519
Coarser than 60's	664	557	333	474	561	506	589
Total Worsted System	1,770	1,312	805	1,010	1,090	905	999
Woolen System							
60's and Finer	384	262	209	604	610	483	625
Total Woolen System	967	800	635	774	959	934	1,105
Total Apparel Wool	2,729	2,104	1,440	1,778	2,049	1,839	2,104
Carpet Wool	1,472	794	*358	302	290	241	255
Total Raw Wool ¹	4,201	2,898	1,798	2,079	2,339	2,079	2,359
Noils, etc. ²	1,356	1,227	1,019	916	906	942	984
Man-Made Fibers ³	6,900	8,006	7,153	6,487	6,630	6,612	7,414
All Other Fibers ⁴	101	96	71	53	50	47	82
Total All Fibers ⁵	12,456	12,139	9,970	9,470	9,875	9,649	10,758

*Source: U.S. Department of Commerce, Bureau of Census

Δ Multiply by 0.4536 to obtain thousands of kilograms

¹Shorn and pulled wool of the sheep. ²Reprocessed and reused wool, and other animal fibers (mohair, alpaca, vicuna) and other specialty fibers as well as tops and noils consumed in woollen spinning, and mohair consumed in worsted combing. ³Excludes top converted from man-made fiber tow without combing. ⁴Includes cotton, jute, and other vegetable fiber, animal fibers other than raw wool mohair consumed in worsted combing are also included in this item. ⁵Does not include raw wool, and wool tops consumed in cotton system spinning. NOTE: Most recent data are preliminary.

product for presentation of fibers to the cotton comb, the same authors concluded that it was impossible to comb 100% wool using a cotton comb. Tokumari [18] reported results of an investigation of the short-staple spinning of pure wool that had been Heltra stretch-broken [4]. Using the Heltra breaker, picking and short-staple carding were eliminated, and good quality yarns were spun using ring spinning (33 mg/m; 18/1 N_c) and open-end spinning (50 mg/m; 12/1 N_c). The favorable spinning conditions were arrived at by the application of drawing oil (2.95%) to the slivers. Veldsman and Taylor [19] and Spencer and Taylor [14] also found that it was commercially impossible to produce an all-wool lap in the blowroom. With the increasing use of chute feeds, some of the objections to processing pure wool on the short-staple system have been overcome.

A recent technico-economic feasibility study [17] performed by the International Wool Secretariat concluded that there are five strong reasons why wool processing on the short-staple system may be desirable in the future: These are: textile production is gravitating towards low-labor-cost countries, whose machinery installations are predominately short staple; a possible downturn in the manufacture of conventional wool-processing equipment, due to the poor share of wool in the total fiber market; the availability of significant quantities of wool fiber of suitable length for processing on the short-staple system, whether this be shorn, cut, or stretch broken; it could help the demand for wool fiber from newly-emerging producer countries who might otherwise use man-made fibers; and finally, it could expand the product base for wool, particularly in lighter-weight fabrics using singles yarns. They also reported that there may be a slight cost advantage in favor of this system of processing.

We at the Textile Research Center of Texas Tech University are also convinced that a major opportunity for wool exists in its greater utilization on the short-staple system.

Many cotton manufacturers over the last thirty years have made serious efforts to process wool on short-staple machines, particularly with cotton and polyester in wool-poor blends. Wool has been blended on the cotton system with other fibers for several reasons. Primarily, the addition of small quantities of wool to either cotton or polyester provides improved aesthetics, drape, and hand, as well as other characteristics that cannot be obtained by using one fiber alone. Similarly, additions of relatively small quantities of cotton and synthetic fibers allows the production of stronger wool-rich yarns with increased utility using the short-staple system. The physical properties relating to durability and comfort are combined to obtain the best from both fiber types, while at the same time poorer properties of the individual fibers are suppressed. The most well known producer of wool/cotton blends in the United Kingdom is undoubtedly

Viyella, who use a modified short-staple system and produce 55/45 and 20/80 wool/cotton blends. Following the IWS study, a UK spinner and weaver is now commercially producing a light-weight wool/polyester fabric for use in women's dresses and blouses. Several firms in Germany are currently utilizing worsted top on the short-staple system in various products. Italian and Taiwanese firms are also offering wool/polyester fabrics produced on the short-staple system. Here in the U. S. the Directory of American Wool Spinners, compiled by the Wool Bureau Inc., currently lists eight companies as American Short Staple or Cotton System Spinners of Wool. Extensive development work involving the use of wool in blends with both cotton and polyester on the short-staple system is currently in progress in Germany, France, Australia, Italy, Spain, Japan, South Africa, and the USA.

The IWS estimates that approximately 3% (50 million kg per year (110 million lb per year)) of the world wool clip would be suitable for processing on the short-staple system without further fiber modification. Shortages of suitable wools could result if the development (*i.e.* wool on the cotton system) were extremely successful. Consequently, approaches utilizing cut and stretch-broken fibers are being investigated. More frequent shearing has been deemed economically inviable in countries without cheap labor, and there have been numerous biological as well as economic objections to this particular practice.

The following information is presented to partially overcome some of these objections. In some areas of Texas it is necessary for both the health of the sheep and the quality of the fleeces that the sheep be shorn twice a year. This is done on both 8-month/4-month and 6-month/6-month cycles. In May 1979 the auction price of this type of wool (64's, 30.5 mm (1.2 in.) mean fiber length) in the grease was \$2.56/kg (\$1.16/lb). At that same time a comparable cut-top wool was being sold for processing on short-staple systems for \$6.39/kg (\$2.90/lb).

The objectives of this particular study were twofold: first, to obtain further data concerning the processing of short wools on the cotton system; secondly, to ascertain if the more expensive raw material can be replaced with a six-month shorn wool to yield comparable products. More specifically, this project was designed to compare the performances of these two raw materials when utilized in a 60/40 wool/polyester blend in both apparel and home-furnishing types of product.

If a financial advantage when using short-shorn wool instead of cut-top wool were to be demonstrated, then wool on the cotton system presumably could be an even more attractive proposition than it currently is. It should be added that a parallel study is presently being conducted at Texas A & M University on the biological effects (particularly on lambing traits) of shearing sheep twice a year.

Raw Materials and Methods

MECHANICAL PROCESSING. The sequence used for spinning these blends of wool with polyester is shown in Figure 1. All blending was performed at the first possible opportunity in an attempt to ensure an intimate blend. In opening, cleaning, picking, roving, and spinning the relative humidity and temperature were maintained at 55 to 58% and 299K (26°C). In order to operate at reasonable production speeds, it was found necessary to increase the humidity in carding and drawing to 70%. This particular sequence of machines was originally programmed for running 100% cotton. Every effort was made to produce optimal quality wool/polyester yarns on this system with minimal changes in machine settings.

BLENDING		James Hunter Blender, 4 Feeder, Model 240 BFC
CLEANING		James Hunter Superior Cleaner
PICKING	465 g/m lap (15 oz/yd lap)	Saco Lowell One Process Picker
CARDING	18.1 kg/hr, 3.54 g/m sliver (40 lbs/hr, 50 gr/yd sliver)	J.D. Hollingsworth High Production Card
BREAKER DRAWING	3.75 g/m sliver (53 gr/yd sliver)	Saco Lowell 2-Delivery Drawing Frame, Model DE7C
FINISHER DRAWING	3.90 g/m sliver (55 gr/yd sliver)	Saco Lowell 2-Delivery Drawing Frame, Model DE7C
ROVING	984 mg/m, 0.94 TM (0.60 hank, 0.94 TM)	Saco Lowell Rovematic Roving Frame, Model FC1B
SPINNING	49.2 mg/m, 4.00 TM (12/1 Ne, 4.00 TM) 98.4 mg/m, 3.50 TM (6/1 Ne, 3.50 TM)	Saco Lowell Spinning Frame, Model SF-3H
WINDING		Leesona Uniconer Automatic Winder, Model 644
WARPING		Barber Colman Warper and Creel, 500 ends, Model FW
SLASHING		West Point Slasher, 5 can Drying Section, Model L189
WEAVING		50" Crompton and Knowles, CB, 16 Harness Dobby 4x1 Box Loom
DESIZING		Henriksen VH Super 600 Jig, Type J10
SCOURING		Henriksen VH Super 600 Jig, Type J10
BLEACHING		Henriksen VH Super 600 Jig, Type J10
DRYING		Fleissner-Famatex-Gerber Maxi RT Range (Perforated Drum H.T. Unit)
SEMI-DECATING		Gessner Semi-Decater, Model ST 1183

FIG. 1. Mechanical and wet processing of wool/polyester blends.

BLENDING, OPENING, CLEANING, AND PICKING. The raw material characteristics are shown in Table V. What is not evident from this table are the physical states of the three starting materials prior to mechanical processing. The polyester was received in the

TABLE V
RAW MATERIAL CHARACTERISTICS

Wool:

Fiber Property	Test Method	Cut Top	6 Month Short Shorn
Mean Diameter (μm)	Maturimeter	22.07	22.15
Mean Diameter (μm)	Microprojection (ASTM D2130)	21.95	22.03
Coefficient of Variation of F.D. (%)		21.05	21.03
Mean Length (mm[in])	(ASTM D519)	25.9 [1.02]	30.2 [1.19]
Coefficient of Variation of Mean Length (%)		31.6	55.1
Solvent Extractables (%)	Benzene/Methanol Solvent (ASTM D1574)	1.79	1.54
Vegetable Matter (%)	(ASTM D584)	0.03	1.89

Polyester:

Fiber Property	
Fiber Mass per Unit Length (mg/m[den])	0.28 [2.5]
Mean Fiber Length (mm[in])	38.1 [1.5]
Type	Hoechst Type 350

normal high-density bale directly from the manufacturer. The cut-top wool and scoured short-shorn wool were received from the topmaker-cutter and scourer, respectively, in relatively low-density bales. After cutting the bale ties, no time was lost between weighing the fibers and hand-loading the hopper feeders. Despite the fact that the short-shorn wool would obviously require more opening and cleaning than the cut-top wool, all machine settings (Table VI) remained the same for the purpose of running these comparative trials. Further, the settings were those that are normally used for cotton, with one exception. Due mainly to the relatively high bulk and sponginess of these blends, as compared to cotton, it was necessary to produce only half laps at the picker (average weight 11.3 kg (25 lb)). It was found that by restricting lap weights to this quantity, lap splitting was completely eliminated.

TABLE VI
PICKER MACHINE SETTINGS AND SPECIFICATIONS

Type of Beater	2-Blade	Kirshner
Beater Speed (rad/s [rpm])	104.7 [1000]	104.7 [1000]
Feed Roll to Beater Setting (mm[in])	9.52 [3/8]	4.76 [3/16]

CARDING. The carding performance of the wool/polyester blends on the J. D. Hollingsworth High-Production Card was satisfactory using elevated humidity and the card settings normally employed for cotton (Table VII). A production rate of 18.1 kg/h (40 lb/h) was utilized to produce a 3.54-g/m (50 gr/yd) sliver.

TABLE VII
CARD SETTINGS AND SPEEDS

Settings	mm	ins
Varga Doffing Roll to Doffer	0.127	0.005
Dof-Master to Doffer	1.219	0.048
Doffer to Cylinder	0.127	0.005
Lower Front Plate to Cylinder (ends)	0.305	0.012
Lower Front Plate to Cylinder (middle)	0.432	0.017
Upper Front Plate to Cylinder (Hard Point Flats)	1.041	0.041
Flats to Cylinder	0.254	0.010
Back Plate to Cylinder (Top)	0.559	0.022
Back Plate to Cylinder (Bottom)	0.559	0.022
Licker-in to Cylinder	0.178	0.007
Feed Plate to Licker-in	0.178	0.017
Licker-in Screen to Licker-in	0.559	0.022
Cylinder Screen to Cylinder (Back)	0.559	0.022
Cylinder Screen to Cylinder (Bottom)	0.864	0.034
Cylinder Screen to Cylinder (Front)	4.750	0.187
		(3/16)

Speeds		
Cylinder	31.41 rad/s	300 rpm
Licker-in	83.77 rad/s	800 rpm
Flats	139.7 mm/min	5½ in/min

Clothing		
Hollingsworth Metallic Clothing No. 35	0.8370 points/mm ²	540 points/in ² 10° point angle

DRAWING. Breaker and finisher drawing performance was satisfactory on the Saco Lowell, Model DE7C Drawing Frame at a machine speed of 159.1 m/min (522 ft/min). The 3-over-4 drafting arrangement was adjusted (Table VIII) to accommodate the slightly longer average fiber lengths. In the case of breaker drawing, the input weight was 8×3.54 g/m (50 gr/yd), while in finisher drawing it was 8×3.75 g/m (53 gr/yd). It was not found necessary to change the bore of the output trumpet of the coiler tube to accommodate the increased bulk of the sliver.

ROVING. Satisfactory roving was produced at a flyer speed of 149.2 rad/s (1425 rpm) without any modifications to the Saco Lowell Rovematic Roving Frame, Model FC1B other than those required to lower the twist and accommodate the slightly longer fibers (Table VIII). The lower twist level was necessitated by the higher cohesion of wool as compared to that of cotton.

TABLE VIII
DRAW FRAME, ROVING AND SPINNING FRAME SETTINGS

	mm	ins
Roll Settings on Draw Frame:		
First to Second (Mean Fiber Length +)	6.35	1/4
Second to Third (Fixed)	38.10	1 1/2
Third to Fourth (Mean Fiber Length +)	3.17	1/8
Roll Settings on Roving Frame:		
First to Second	42.86	1 11/16
Second to Third (through apron)	57.15	2 1/4
Roll Settings on Spinning Frame:		
First to Second	50.80	2
Second to Third (through apron)	44.45	1 3/4

SPINNING. The wool/polyester yarns were produced on a Saco Lowell Model SF-3H spinning frame utilizing 3-over-3 roller drafting with apron control in the front zone. A spindle speed of 607.4 rad/s (5800 rpm) in conjunction with a 50.8-mm (2-in.) ring diameter; a No. 12 traveler was used for both the 98.4-mg/m (6/1) and 49.2-mg/m (12/1) yarn. For commercial applications a larger ring size would be indicated, especially when producing the coarser of the two yarns. Generally, a compromise situation was reached between the optimum yarn strength and yarn liveliness with consideration to subsequent utility and processing.

SLASHING. After winding and warping, the warp yarns were sized using a mixture of 5.65% polyvinyl alcohol and 0.10% paraffin wax to yield a dry increase in weight of 4.68% and 4.71% for the cut-wool and short-shorn wool warp yarns, respectively. No difficulties were encountered at this stage of processing.

WEAVING. No difficulties were encountered when weaving these plain weaves on a 1.27-m (50-in.) Crompton and Knowles C8, 16 Harness, Dobby 4×1 Box Loom.

In line with the main objectives of this project, yarn sizes and fabric weights and constructions were chosen, following preliminary trials, to represent definite commercial possibilities. It was not our intention to establish impractical spinning and weaving limits for these two blends, but rather to manufacture fabrics from them with commercial potentials well within the capabilities of existing traditional cotton spinning and weaving systems.

WET PROCESSING. These fabrics were not singed, although in retrospect they could have benefitted by having been subjected to this process. Desizing, scouring, and bleaching were performed in a Henriksen VH Super 600 Jig, Type J10. Desizing and scouring consisted of treating the fabrics in open width with a solution containing 1.5% owg hydrogen peroxide (35% w/w), 0.5% owg nonionic detergent, and 0.5% owg acetic acid at 369K (96°C) for 1 h using a liquor-to-goods ratio (L:G) of 10:1. Rinsing completed the operation. Bleaching was achieved by treating the fabrics at 318K (45°C) for 3 h with a solution containing 1 g/l. nonionic detergent, 2 g/l. sodium pyrophosphate, and 20 g/l. hydrogen peroxide (35% w/w) at pH 9 to 9.2 (with ammonium hydroxide) and utilizing a L:G = 20:1.

After thorough rinsing, the fabrics were treated with a solution containing 3 g/l. sodium hydrosulfite at 318K (45°C) for 2 h. After rinsing, a final acidification with 0.5 g/l. acetic acid (glacial) at 298K (25°C) for $\frac{1}{2}$ h was followed by drying. After bleaching and dyeing, fabrics were semi-decated using the following sequence: 2 min steam, 4 min vacuum, 2 min steam, 4 min vacuum. The fabrics were not heat-set.

PHYSICAL TESTING. All physical testing was performed at 294K (21°C) and 65% RH. All the tests reported were conducted in compliance with the referenced test methods. It is noteworthy, however, that the Uster machine used was the Uster Model B Evenness Tester.

Results and Discussion

Table IX summarizes the results of physical measurements that were made on the laps, card slivers, drawframe slivers, and rovings. The uniformity of the cut-wool/polyester slivers was slightly better than that

of the short-shorn wool/polyester. However, the situation was reversed at the roving stage. Certainly, up to this stage, the differences in mechanical performance and product quality between the two types of blends had been negligible. Differences were readily apparent, however, in both the quantities and types of waste that were lost in these mechanical processes. Table X shows that in the case of the cut-wool/polyester blend most of the 8.40% waste was made in carding, as compared with only 0.5% in opening, cleaning, and picking. Considerably more short-shorn wool/polyester was lost in opening and picking. A similar situation held for carding, where again the short-shorn wool/polyester blend lost 9.43% of its weight as compared to 8.40% for the cut-wool/polyester.

TABLE X
FIBER WASTAGE UP TO CARDING

Type of Waste	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Opening and Picking (% of stock fed):		
Opener Motes	0.2	2.0
Blending Reserve	0.1	0.2
Beater No. 1	0.1	0.2
Beater No. 2	0.1	0.2
Total O&P Waste	0.5	2.6
Carding (% of picker lap fed):		
Flat Strips	4.51	5.45
Pneumafil	3.48	3.56
Motes and Fly	0.41	0.42
Total Card Waste	8.40	9.43
Overall Waste	8.86	11.78
Composition of Waste (calculated on bone dry basis)	88.0% Wool 12.0% Polyester	100% Wool (+ Vegetable)

TABLE IX

PHYSICAL PROPERTIES OF THE WOOL/POLYESTER LAPS, SLIVERS AND ROVINGS

Property	Cut Wool/Polyester	Short Shorn Wool/Polyester
Lap Weight (kg/m [oz/yd])	0.4650 [15.0]	0.4650 [15.0]
Nep Count in Card Web (neps/100m ²)	0	0
Card Sliver Weight (g/m [gr/yd])	3.54 [50.0]	3.54 [50.0]
CV of Card Sliver (%)	4.00	5.40
Breaker Drawing Sliver Weight (g/m [gr/yd])	3.82 [53.9]	3.79 [53.0]
CV of B.D. Sliver (%)	4.75	5.00
Finisher Drawing Sliver Weight (g/m [gr/yd])	3.90 [55.0]	3.90 [55.0]
CV of F.D. Sliver (%)	4.30	4.60
Roving Size (mg/m [Nc])	984.2 [0.60]	984.2 [0.60]
CV of Roving (%)	7.75	7.50

A comparison between these two sets of waste figures can be meaningful and useful. However, much importance is not attached to the absolute values of the individual waste figures because they are abnormally high. These high waste figures are attributed to the relatively small quantities of raw materials processed in these particular trials. True production waste can only be assessed after full-production runs involving larger quantities of fiber. The relative proportions of the waste, as well as their composition, can be easily rationalized by recalling the physical properties and states of the raw materials. On the one hand, a predominantly combed material, free from vegetable contamination and entanglements, was being mechanically processed, while on the other hand, the natural component of the blend was composed of a relatively entangled fiber mass containing nearly 2% vegetable material.

Table XI shows the changes in count strength products (CSP) resulting from changing the twist multiplier (TM) in the 49.2 mg/m (12/1 N_c) yarns. In the case of the cut-wool/polyester yarn, a maximum CSP (1369) was obtained at a TM of 4.50. In the case of the yarn containing short-shorn wool, a TM of 4.50 was also required to obtain a maximum CSP of 1237. For the subsequent production of fabrics, TM's of 4.00 were used in both cases (Fig. 2).

The characteristics of the 49.2 mg/m yarns are given in Table XII. The cut-wool/polyester yarn has more elongation-at-break, is more uniform, stronger, and has a slightly better grade than the short-shorn wool/polyester yarn. In the case of the 98.4 mg/m (6/1 N_c) yarns (Table XIII) the cut-wool/polyester yarn is again more uniform than its counterpart made with shorn wool. However, the latter has slightly better elongation-at-break and single-yarn strength.

TABLE XI
CHANGES IN COUNT STRENGTH PRODUCTS RESULTING FROM CHANGING
THE TWIST MULTIPLIERS IN 49.2 MG/M (12/1 N_c) YARNS

60/40 Cut Wool/Polyester						
Twist Multiplier	Yarn Size (mg/m)	Skein Strength (kg)	Count Strength Product (kg,mg/m)	Yarn Size (N _c)	Skein Strength (lbs)	Count Strength Product (N _c ,lb)
3.00	46.2	30.75	1421	12.77	67.8	866
3.25	46.7	42.14	1968	12.63	92.9	1173
3.50	46.6	45.31	2111	12.66	99.9	1265
3.75	47.2	48.22	2276	12.52	106.3	1331
4.00	47.2	49.40	2332	12.50	108.9	1361
4.25	47.7	49.62	2367	12.37	109.4	1353
4.50	47.7	50.17	2393	12.38	110.6	1369
60/40 Short Shorn Wool/Polyester						
3.25	48.3	31.39	1516	12.23	69.2	846
3.50	47.5	39.74	1888	12.42	87.6	1088
3.75	47.5	41.14	1954	12.43	90.7	1127
4.00	47.8	44.45	2125	12.36	98.0	1211
4.25	48.0	45.59	2188	12.30	100.5	1236
4.50	48.1	45.72	2199	12.27	100.8	1237
4.75	48.8	43.00	2098	12.11	94.8	1148



FIG. 2. Yarn photographs (49.2 and 98.4 mg/m (12/1 and 6/1 N_c)).

TABLE XII

YARN CHARACTERISTICS - 49.2 MG/M (12/1 N_c) YARN

Nominal Yarn Composition	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Nominal Yarn Number (mg/m [N _c])	49.2 [12/1]	49.2 [12/1]
Twist Multiplier	4.00	4.00
Uster:		
Yarn Non-Uniformity (CV%)	19.82	22.22
IPI Count, Thin	165	297
IPI Count, Thick	186	613
IPI Count, Neps	22	604
Elongation Rupture (%)	17.8	15.9
Single Yarn Strength (g)	501.0	411.0
Yarn Strength Variation (CV%)	12.0	15.3
Yarn Tensile Strength (Rkm)	9.65	9.05
ASTM Yarn Grade	A	B+
Skein:		
Actual Yarn Number (g/m [N _c])	53.6 [11.02/1]	48.5 [12.18/1]
Yarn Number Variation (CV%)	1.39	1.45
Strength (kg [lbs])	57.1 [126.0]	44.5 [98.2]
Strength Variation (CV%)	3.28	11.19
Count Strength Product (mg/m x kg [N _c x lbs])	3060.6 [1371.6]	2158.2 [1199.3]
CSP Variation (CV%)	2.64	11.63

TABLE XIII

YARN CHARACTERISTICS - 98.4 MG/M (6/1 N_c) YARN

Nominal Yarn Composition	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Nominal Yarn Number (mg/m [N _c])	98.4 [6/1]	98.4 [6/1]
Twist Multiplier	3.50	3.50
Uster:		
Yarn Non-Uniformity (CV%)	18.14	19.59
IPI Count, Thin	79	108
IPI Count, Thick	42	227
IPI Count, Neps	2	38
Elongation Rupture (%)	19.1	21.0
Single Yarn Strength (g)	915.0	916.5
Yarn Strength Variation (CV%)	9.2	12.8
Yarn Tensile Strength (Rkm)	9.09	9.04
ASTM Yarn Grade	B+	B
Skein:		
Actual Yarn Number (g/m [N _c])	99.8 [5.92/1]	101.5 [5.82/1]
Yarn Number Variation (CV%)	0.60	3.12
Strength (kg [lbs])	118.7 [261.6]	105.6 [232.7]
Strength Variation (CV%)	3.08	5.52
Count Strength Product (mg/m x kg [N _c x lbs])	11,846 [1548.6]	10,718 [1351.1]
CSP Variation (CV%)	2.67	6.24

The remaining skein properties follow the same pattern as that for the 49.2-mg/m yarns.

Table XIV expands the yarn information and shows that some fiber breakage has occurred, except possibly in the production of the 49.2 mg/m cut-wool/polyester yarn. It is interesting to note, however, that this fiber breakage does not appear to be excessive, and that it is accompanied by an overall reduction in short (less than 12.7 mm ($\frac{1}{2}$ in.)) fiber content. As expected, the ratio of wool/polyester fibers in the yarn cross sections is a reasonable constant at 0.67 (average).

Tables XV and XVI contain the greige fabric characteristics for both constructions of fabric that

were woven from both types of fiber blend. The grab strengths and resistance-to-pilling of the greige fabrics containing cut wool were measurably superior to those of the fabrics composed of short-shorn wool and polyester. Tear strengths, shrinkage after home launderings, and appearance after home launderings were almost identical. In the case of the lighter-weight fabrics, the flex-abrasion resistance of the fabric composed of cut wool and polyester was much better than its shorn-wool counterpart. For some unexplained reasons the situation was completely reversed in the case of the fabrics containing 98.4 mg/m (6/1 N_c) filling. The fabric containing shorn wool exhibited far superior resistance to flex-abrasion wear.

TABLE XIV

PROPERTIES OF FIBERS IN THE YARNS

Fiber Property	Test Method	98.4 mg/m [6/1] Yarn		49.2 mg/m [12/1] Yarn	
		Cut Wool/Polyester	Short Shorn Wool/Polyester	Cut Wool/Polyester	Short Shorn Wool/Polyester
Calculated Mean Fiber Length (weight biased; mm [ins])		30.7 [1.21]	33.3 [1.31]	30.7 [1.21]	33.3 [1.31]
Actual Mean Fiber Length (Barbe; mm [ins])	ASTM D1440	29.0 [1.14]	32.5 [1.28]	32.8 [1.29]	29.7 [1.17]
Short Fibers (< 12.7 mm) Originally (%)	ASTM D519	6.1	12.8	6.1	12.8
Short Fibers (< 12.7 mm) in Yarn (%)	ASTM D1440	5.7	6.6	3.8	8.0
Number of Fibers in Cross Section		86W/127P	86W/117P	37W/72P	43W/57P

TABLE XV
GREIGE FABRIC CHARACTERISTICS
(49.2 MG/M WARP X 49.2 MG/M FILLING [12/1 N_c x 12/1 N_c])

Fabric Property	Test Method	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Grab Strength (Kg [lbs])			
Warp Direction	ASTM D1682	46.36 [102.2]	40.10 [88.4]
Filling Direction		34.38 [75.8]	31.39 [69.2]
Weight per Unit Area (g/m ² [oz/yd ²])	ASTM D2646	193.3 [5.70]	179.7 [5.30]
Width (m [ins])	ASTM D1910	1.105 [43.5]	1.079 [42.5]
Elmendorf Tear Strength (Kg [lbs])			
Warp Direction	ASTM D1424	4.00 [8.81]	3.87 [8.54]
Filling Direction		3.06 [6.75]	3.17 [6.99]
Flex Abrasion (cycles)			
Warp Direction	ASTM D1175	2421	1717
Filling Direction		2058	1248
Pick Count (picks/cm [picks/in])	ASTM D1910	15.0 [38.2]	15.7 [39.8]
End Count (ends/cm [ends/in])	ASTM D1910	19.0 [48.4]	19.4 [49.4]
Shrinkage after 3 Wash-Tumble-Dry (AATCC 143 Condition II) Cycles (%)			
Warp Direction		2.3	7.1
Filling Direction		5.4	4.3
Durable Press Rating	AATCC 124	3.00	3.00
Pilling Resistance (Random Tumble)	ASTM D3512	4.0	3.0

TABLE XVI
GREIGE FABRIC CHARACTERISTICS
(49.2 MG/M WARP X 98.4 MG/M FILLING [12/1 N_c x 6/1 N_c])

Fabric Property	Test Method	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Grab Strength (Kg [lbs])			
Warp Direction	ASTM D1682	45.90 [101.2]	41.96 [92.5]
Filling Direction		36.02 [79.4]	35.11 [77.4]
Weight per Unit Area (g/m ² [oz/yd ²])	ASTM D2646	217.0 [6.40]	210.6 [6.21]
Width (m [ins])	ASTM D1910	1.137 [44.75]	1.105 [43.5]
Elmendorf Tear Strength (Kg [lbs])			
Warp Direction	ASTM D1424	5.96 [13.15]	5.67 [12.50]
Filling Direction		5.63 [12.41]	6.04 [13.32]
Flex Abrasion (cycles)			
Warp Direction	ASTM D1175	1659	2508
Filling Direction		933	1309
Pick Count (picks/cm [picks/in])	ASTM D1910	10.3 [26.2]	10.5 [26.8]
End Count (ends/cm [ends/in])	ASTM D1910	18.7 [47.4]	19.1 [48.6]
Shrinkage after 3 Wash-Tumble-Dry (AATCC 143 Condition II) Cycles (%)			
Warp Direction		4.8	7.7
Filling Direction		5.5	2.8
Durable Press Rating	AATCC 124	3.25	3.50
Pilling Resistance (Random Tumble)	ASTM D3512	3.0	2.0

Tables XVII and XVIII show the results of physical testing for the desized and scoured fabrics. Again, the grab strengths of the fabrics containing cut wool were marginally superior to their shorn-wool counterparts. Tear strengths and appearances after home launderings were very similar. The scoured fabrics containing short-shorn wool now showed superior resistances to

flex abrasion in both constructions and also exhibited less tendency to shrink than the fabrics composed of cut wool and polyester. Both of the heavier constructions exhibited poor resistance to pilling. However, the lighter-weight fabric containing cut wool and polyester had even better pilling resistance than the original greige fabric.

TABLE XVII
SCOURED FABRIC CHARACTERISTICS
(49.2 MG/M WARP X 49.2 MG/M FILLING [12/1 N_c x 12/1 N_c])

Fabric Property	Test Method	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Grab Strength (Kg [lbs])			
Warp Direction	ASTM D1682	44.5 [98.2]	41.7 [92.0]
Filling Direction		32.1 [70.8]	27.8 [61.2]
Weight per Unit Area (g/m ² [oz/yd ²])	ASTM D2646	206.8 [6.10]	209.9 [6.19]
Width (m [ins])	ASTM D1910	1.060 [41.75]	0.971 [38.25]
Elmendorf Tear Strength (Kg [lbs])			
Warp Direction	ASTM D1424	4.27 [9.41]	4.34 [9.57]
Filling Direction		3.56 [7.85]	3.36 [7.41]
Flex Abrasion (cycles)			
Warp Direction	ASTM D1175	1843	2735
Filling Direction		1951	1444
Pick Count (picks/cm [picks/in])	ASTM D1910	15.7 [39.8]	16.5 [42.0]
End Count (ends/cm [ends/in])	ASTM D1910	19.7 [50.0]	22.1 [56.2]
Shrinkage after 3 Wash-Tumble-Dry (AATCC 143 Condition II) Cycles (%)			
Warp Direction		1.9	1.0
Filling Direction		0.9	0.5
Durable Press Rating	AATCC 124	3.00	3.50
Pilling Resistance (Random Tumble)	ASTM D3512	4.5	2
Fabric Composition (%)	AATCC 20A	55.6W/44.4P	52.2W/47.8P

TABLE XVIII
SCOURED FABRIC CHARACTERISTICS
(49.2 MG/M WARP X 98.4 MG/M FILLING [12/1 N_c x 6/1 N_c])

Fabric Property	Test Method	60/40 Cut Wool/Polyester	60/40 Short Shorn Wool/Polyester
Grab Strength (Kg [lbs])			
Warp Direction	ASTM D1682	44.63 [98.4]	41.73 [92.0]
Filling Direction		33.93 [74.8]	33.93 [74.8]
Weight per Unit Area (g/m ² [oz/yd ²])	ASTM D2646	243.8 [7.19]	250.2 [7.38]
Width (m [ins])	ASTM D1910	1.105 [43.5]	1.003 [39.5]
Elmendorf Tear Strength (Kg [lbs])			
Warp Direction	ASTM D1424	5.67 [12.50]	5.48 [12.08]
Filling Direction		6.02 [13.27]	6.16 [13.58]
Flex Abrasion (cycles)			
Warp Direction	ASTM D1175	1832	2318
Filling Direction		1266	1364
Pick Count (picks/cm [picks/in])	ASTM D1910	11.0 [28.0]	11.4 [29.0]
End Count (ends/cm [ends/in])	ASTM D1910	19.2 [48.8]	20.6 [52.4]
Shrinkage after 3 Wash-Tumble-Dry (AATCC 143 Condition II) Cycles (%)			
Warp Direction		3.5	2.5
Filling Direction		1.5	+0.7
Durable Press Rating	AATCC 124	3.50	3.25
Pilling Resistance (Random Tumble)	ASTM D3512	2	2
Fabric Composition (%)	AATCC 20A	55.6W/44.4P	52.2W/47.8P

Specific values for general appearance, drape, and hand are three fabric properties that are not apparent from the tables. General appearance and drape were very similar for both types of fabrics. The hand of the fabrics containing cut-top wool was noticeably softer and smoother than the fabric composed of short-shorn wool and polyester. Either type of hand would be acceptable for the intended end-use.

Summary and Conclusions

The two primary objectives of this study have been fulfilled. Further data concerning the processing of short wools in blends with polyester on the short-staple system of spinning have been generated. Fabrics containing short wool have been constructed, scoured, and tested and show obvious utility. The performances of

fabrics composed of cut-wool/polyester and short-shorn wool/polyester have been compared. Generally, fabrics containing cut-top wool exhibited higher grab strengths than their short-shorn wool counterparts. Conversely, resistance to flex abrasion tended to be better in the case of the fabrics composed of short-shorn wool/polyester. Other fabric properties, including tear strength, shrinkage due to home launderings, and appearance after home launderings were very similar.

It is still not possible to state categorically that short-shorn wool can be economically substituted for cut-top wool to yield comparable products. Production of fabrics of similar quality has been demonstrated, but there still remains the question of economics. The major unknowns at this time are the relative quantities of waste that would be obtained in full-scale production. The initial prices of the two materials, even after correction for scouring losses and cost of scouring, were \$1.47/kg (\$0.67/lb) in favor of the short-shorn wool. It remains to be seen, however, if the greater waste loss in the case of the short-shorn wool will completely nullify this initial financial advantage.

ACKNOWLEDGMENTS. This research was sponsored by the Natural Fibers and Food Protein Commission of Texas. The author gratefully acknowledges the complete cooperation and unified assistance of the whole research team of the Textile Research Center, so essentially necessary for the satisfactory completion of this project.

Literature Cited

1. Aldrich, D. V., "The Processing of Blends of Cotton and Wool on the Cotton System; Part 1: An Introductory Investigation," SAWTRI Tech. Rep. No. 248, 1975.
2. Aldrich, D. V., "The Processing of Blends of Cotton and Wool on the Cotton System; Part II: Yarn and Fabric Properties of a 67/33 Cotton/Wool Blend," SAWTRI Tech. Rep. No. 298, 1976.
3. Anon., Spinning Wool on Cotton Machinery, *WIRA News*, No. 28, 6 (1974).
4. Anon., Converter for Stretch Breaking Natural Fibers for Cotton System, *Canadian Textile J.* **90**, 71 (1973).
5. Ellis, B. C. and Robinson, G. A., "Processing Medium-Length Wools on the Short-Staple System," CSIRO Rep. No. G38, 1979.
6. Harry, A. A. and Robinson, G. A., "Processing of Wool and Wool-Rich Blends on the Short Staple System. I. A Modified System for Wools of Average 40 mm Length but with a Non-square Fiber Length Distribution," CSIRO Rep. No. G31, 1977.
7. Harry, A. A. and Robinson, G. A., "The Processing of Wool and Wool-Rich Blends on the Short Staple System. II-Noils and Carbonized Lambs Wool," CSIRO Rep. No. G32, 1977.
8. King, J. A., Arthur, H. E., and Kieke, H. E., "Determination of the Optimum Conditions for Using the Cotton Processing System to Produce Yarns Which are Blends of Wool and Cotton," Textile Research Center, Lubbock, Texas, USDA Contract No. 12/14/100/9511, 1974.
9. Leigh, R. A., "Bleaching of 55/45 Wool/Cotton Blend Fabrics, Part 1: Using Hydrogen Peroxide," SAWTRI Tech. Rep. No. 282, 1976.
10. Louis, G. L. and Pardo, C. E., SRRC Natural Fiber Blend Research, *Textile Res. J.* **50**, 130-136 (1980).
11. Oseguera Morones, H., Nouvelle Possibilite de Filature de la Laine Sur Material Pour Fibres Courtes, *Ind. Text. Belge* **9**, 31 (1973).
12. Oseguera Morones, H., La filabilite de la laine sur material fibres courtes, *L'Industrie Textile*, No. 1024, 365 (1974).
13. Robinson, G. A. and Layton, L., "Sizing of Singles Wool—Worsted Yarns. Part II. Wool-Blends Processed on the Cotton System," SAWTRI Tech. Rep. No. 413, 1978.
14. Spencer, J. D. and Taylor, H., The Minimum Amount of Cotton to Produce Laps of Wool/Cotton Blends in the Blowroom, *SAWTRI Bull.* **12**, 14-18 (1978).
15. Spencer, J. D. and Taylor, H., "Removal of Vegetable Matter from Scoured Wool during the Processing of Wool/Cotton Blends on the Cotton System," SAWTRI Tech. Rep. No. 440, 1979.
16. Spinning Wools on the Cotton System, *Canadian Textile J.* **96**, 59 (1979).
17. "The Use of Wool on the Short Staple System of Processing," Technical Information Bulletin No. Fact 21, IWS Technical Center, Ilkley, 1978.
18. Tokumari, F., "Wool Spinning by the Cotton Spinning System," IWS Ichinomiya Technical Centre, 1975.
19. Veldsman, D. P. and Taylor, H., "A Study of Various Parameters Affecting the Rotor Spinning of Wool," SAWTRI Tech. Rep. No. 412, 1978.

Manuscript received October 3, 1979.