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# A Comparison of Certain Physical Properties of Plain Weave Fabrics From Cotton Blended with Different Polyester Fibre Types

## Part 1: Untreated Fabrics

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# A COMPARISON OF CERTAIN PHYSICAL PROPERTIES OF PLAIN WEAVE FABRICS FROM COTTON BLENDED WITH DIFFERENT POLYESTER FIBRE TYPES

## PART I : UNTREATED FABRICS

*by I. W. KELLY*

### ABSTRACT

*The physical properties of a series of plain weave fabrics (approximately 140 g/m² ) from cotton blended with polyester were measured and compared. The cotton was blended with three types of staple polyester fibres: normal, low-pilling and high bulk, at five blend levels, 100, 80, 60, 40 and zero per cent cotton content.*

*The breaking strength, breaking extension and resistance to flex abrasion increased with increasing polyester content for all three polyester types. The resistance to flat abrasion of the blends with normal and high-bulk polyester increased with increasing polyester content whereas that of blends containing the low-pilling polyester decreased with increasing polyester content.*

*The wrinkle recovery, appearance after washing and dimensional stability improved as the polyester content of the fabrics increased. Of the three polyester types used in this investigation the blends with the low pilling polyester showed better recovery from creasing and appearance after washing than the other two.*

### KEY WORDS

Cotton/polyester blends – mechanical properties – abrasion resistance – pilling – wrinkling – plain weave – easy-care – high bulk polyester – low pilling polyester – normal polyester – crease recovery.

### INTRODUCTION

There is, at present, a considerable demand for easy-care cotton fabrics, that is, fabrics which do not require ironing after washing and which shed wrinkles formed during wear. Easy-care properties can be imparted to cotton fabrics either by the use of aminoplast resins or by blending cotton with a synthetic fibre, for example polyester, or a combination of both. Although resin-treated all-cotton fabrics may have acceptable easy-care properties, this improvement is usually accompanied by a severe and often unacceptable decrease in the abrasion resistance and tear and tensile strength of the fabrics[1]. Recently, however, a process involving mercerisation of the cotton fabric, to relieve strains in the cotton fibres, followed by a uniform application of the resin to the fabric, has been claimed by the International Institute for Cotton to produce a fabric having both acceptable easy-care and abrasion resistance properties. This process is, however, not yet fully commercial[2]. As an alternative to resin treatment, the recovery from wrinkling, and appearance after washing of cotton fabrics can be enhanced by blending polyester with cotton to increase cotton's inherent poor recovery from creasing[3, 4] which has been attributed to the poor elastic recovery of the cotton fibres[5, 6].

A recent techno-economic survey of the South African textile industry indicated that locally there was a lack of independent information on the optimum blend ratios of polyester blended with either cotton or wool[7], although some work had been carried out along these lines. For instance, incorporating 67% polyester in the blend has been shown to give a fabric having a Shirley crease recovery angle of about 270° compared with that of about 160° obtained on a pure cotton fabric[4]. A Monsanto crease recovery angle of approximately 243° has been quoted for cotton durable press fabrics having smooth drying properties[8] while Harper *et al*[9] report crease recovery angles of 280–300°, measured according to the Monsanto test for durable press cotton fabrics.

Blending polyester with a selection of cottons has recently been reported to markedly alter the tensile strength of the yarns[3]. The blended yarns were frequently found to be weaker than the pure cotton yarns. In the same publication it was noted that the breaking extension of the yarns slowly increased with polyester content, up to 50% polyester content but more rapidly thereafter.

Although blending polyester with cotton also increases the abrasion resistance of the fabric over that of an all-cotton fabric[3] the improvement in easy-care and abrasion resistance is often accompanied by a deterioration in the resistance to pilling, handle and moisture absorption of the fabrics. A comprehensive study of all the important fabric properties is therefore necessary when investigating the influence of blend level upon fabric easy-care properties.

The principal objective of this investigation was to identify blend ratios of untreated and resin treated fabrics having an acceptable standard of easy-care and abrasion resistance properties and to compare the properties of fabrics produced from blends of cotton and normal, low-pilling and high-bulk polyester types. This report compares the physical properties of a range of *untreated* lightweight, plain weave fabrics comprising various blends of cotton with either normal, low pilling or high bulk polyester. The physical properties of the same series of cotton/polyester fabrics but treated with various resins will be reported on later.

## MATERIALS AND EXPERIMENTAL METHODS

A range of yarns was produced by blending cotton in turn with three types of Trevira polyesters, namely type 120 (normal), type 340 (low-pilling), and type 140 (high bulk). Each yarn was produced in five blend levels namely 100, 80, 60, 40 and zero *per cent* cotton. Relevant details of the fibres are given in Table I.

All the yarns were spun to the same linear density (count) and twist to provide nominal R27 tex S 500/2 Z1 000 yarns. The physical properties of the various yarns are given in Table II. The yarns were then woven into plain weave (square) fabrics of nominally 22 picks and ends per centimetre and 140 grammes per square metre (see Table III). One series of thirteen fabrics so produced was finished under the same conditions, involving scouring, peroxide bleaching, drying, heat-setting and cropping. The fabrics were scoured for 30 minutes at 50°C in a solution of 2 g/*l* sodium carbonate and 2 g/*l* Kieralon OL (BASF) and then rinsed with warm and cold water successively.

The fabrics were bleached in a solution containing 7 g/*l* sodium silicate, 0,05 g/*l* sodium hydroxide, 0,18 g/*l* sodium carbonate and 1 ml/*l* 50% hydrogen peroxide at 100°C for 1 hour.

**TABLE I**

**FIBRE PROPERTIES**

| FIBRE | FINENESS | | BUNDLE BREAKING STRENGTH (gf/tex) |
|---|---|---|---|
| | decitex | Micronaire | |
| Cotton (Mature, fair ginned, few neps, short fibre content fair, staple length 33,3–34,9 mm) | – | 4,0 | 22,0 |
| Normal Polyester Trevira Type 120, 40 mm | 1,7 | – | 35,8 |
| Low Pilling Polyester Trevira Type 340, 40 mm | 1,9 | – | 27,8 |
| High Bulk Polyester Trevira Type 140, 40 mm | 1,7 | – | 34,4 |

## TABLE II

### TWO-PLY YARN PARAMETERS AND PROPERTIES

| FIBRE | Linear Density (tex) | Irregularity (CV in %) | Plying Twist (t.p.m.) | Breaking Strength (gf) | Extension at break (%) | YARN FAULTS PER 100 KM (CLASSIMAT) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total | $B_4 + C_3 + D_2$ |
| 100% Cotton | 29,9 | 12,5 | 512 | 697 | 7,6 | 465 | 8,3 |
| 80% Cotton/20% Trevira 120 | 27,4 | 12,9 | 504 | 645 | 8,4 | 771 | 4,8 |
| 60% Cotton/40% Trevira 120 | 27,8 | 12,1 | 504 | 713 | 9,8 | 764 | 8,8 |
| 40% Cotton/60% Trevira 120 | 28,2 | 12,1 | 500 | 841 | 11,5 | 594 | 1,2 |
| 100% Trevira 120 | 29,8 | 12,1 | 494 | 1 144 | 14,1 | 252 | 4,4 |
| 80% Cotton/20% Trevira 340 | 27,2 | 13,0 | 506 | 506 | 7,5 | 461 | 1,6 |
| 60% Cotton/40% Trevira 340 | 26,2 | 13,1 | 500 | 522 | 8,1 | 685 | 5,3 |
| 40% Cotton/60% Trevira 340 | 28,5 | 12,8 | 498 | 537 | 11,6 | – | – |
| 100% Trevira 340 | 28,0 | 13,8 | 490 | 740 | 15,0 | 1 438 | 21,9 |
| 80% Cotton/20% Trevira 140 | 26,8 | 12,6 | 500 | 546 | 7,6 | 463 | 1,7 |
| 60% Cotton/40% Trevira 140 | 28,0 | 13,3 | 502 | 546 | 9,2 | 615 | 6,6 |
| 40% Cotton/60% Trevira 140 | 28,7 | 12,5 | 500 | 716 | 14,7 | 499 | 3,0 |
| 100% Trevira 140 | 27,7 | 14,4 | 498 | 870 | 17,4 | 205 | 1,5 |

The fabrics were heat-set at 195°C for approximately 45 seconds. In addition, since 100% polyester fabrics would not normally be bleached, one of each of the pure polyester fabrics was finished as above but omitting the bleaching stage. Furthermore, an additional all-cotton fabric was finished as before but with the heat-setting operation omitted. There was little difference, however, between the results of tests on this additional series of fabrics and the tests on the all-polyester or all-cotton fabrics. The results of tests on the all-polyester fabrics which had not been bleached or of the all-cotton fabric which had not been heat-set have therefore not been presented.

## TEST METHODS

**Fibre Tests:**

A Stelometer bundle breaking strength tester was used to measure the breaking load of both the polyester and the cotton fibres at a gauge length of 3,2 mm ($\frac{1}{8}''$).

**TABLE III**

**FABRIC DETAILS**

| BLEND | SETT | | FABRIC MASS ($g/m^2$) | COVER FACTOR |
|---|---|---|---|---|
| | Ends/cm | picks/cm | | |
| 100% Cotton | 23,8 | 24,7 | 147,1 | 20,9 |
| 80% Cotton/20% Trevira 120 | 23,8 | 23,9 | 140,4 | 20,1 |
| 60% Cotton/40% Trevira 120 | 23,1 | 25,3 | 146,7 | 20,4 |
| 40% Cotton/60% Trevira 120 | 22,7 | 24,7 | 143,4 | 20,2 |
| 100% Trevira 120 | 22,7 | 25,8 | 149,8 | 20,9 |
| 80% Cotton/20% Trevira 340 | 22,8 | 24,4 | 134,3 | 19,9 |
| 60% Cotton/40% Trevira 340 | 22,8 | 23,8 | 137,0 | 19,4 |
| 40% Cotton/60% Trevira 340 | 23,1 | 24,8 | 137,1 | 20,4 |
| 100% Trevira 340 | 22,7 | 23,9 | 137,6 | 19,9 |
| 80% Cotton/20% Trevira 140 | 23,1 | 24,3 | 138,9 | 19,8 |
| 60% Cotton/40% Trevira 140 | 22,8 | 24,7 | 140,5 | 20,2 |
| 40% Cotton/60% Trevira 140 | 22,8 | 24,7 | 146,8 | 20,4 |
| 100% Trevira 140 | 23,1 | 25,1 | 155,8 | 20,3 |

**Yarn Tests:**

The breaking strength and breaking extension of both the single and two-ply yarns were measured on an Uster Automatic Breaking Strength Tester, 200 tests per yarn being carried out. Yarn twist was measured on a Zweigle Automatic Twist Tester while the yarn linear density (tex) was calculated from the mass of four 100 metre lengths of yarn. Yarn irregularity was measured on the Uster series of evenness testing equipment with 2 000 metres of yarn tested per sample. During the normal winding and clearing operation the Classimat results were also obtained (see Table II).

**Fabric Tests:**

The fabric breaking strength and extension at break were measured on an Instron Tensile Tester according to the ISO draft standard(10). Five strips of fabric, 5 centimetres in width, for both warp and weft directions were extended at a constant rate such that the time to break was 30 ± 5 seconds. The tests were carried out at a gauge length of 20 centimetres with a pretension equal to 1% of the breaking load.

The tear strength of the fabrics was measured on an Elmendorf Tear Strength Tester. Fabric bursting strength was determined on a Standard Mullen tester with ten tests carried out for each fabric. The mass per unit area and sett were determined according to standard procedures. The cloth cover factor Kc was calculated from(11).

$$K_c = 0{,}1045 \sqrt{tex}\,[W_p + W_f - 0{,}00373 \sqrt{tex}\,(W_p \times W_f)]$$

where $W_p$ and $W_f$ are the number of warp and weft threads per centimetre and the yarn tex is the same in the warp and weft directions. A WIRA Air Permeameter was used to measure the air permeability of the fabrics at a water pressure of 5 cm.

The crease recovery of the fabrics was measured under standard conditions (i.e. 65% R.H., 20°C) on a Monsanto Wrinkle Recovery Tester(12). The wrinkling performance of the fabrics was assessed in terms of the wrinkle severity index ($H \times T$ in mm $\times 10^2$)(13) following the method developed by Slinger(14). The fabrics were wrinkled under both standard conditions (20°C, 65% RH) and wet (20°C) for 20 minutes in an AKU tester and allowed to recover for 24 hours before being measured. Samples used in the wet wrinkling test were wet for 24 hours in tap water prior to wrinkling.

Appearance after home laundering was measured according to the AATCC method(15). The shrinkage of the fabrics after washing was also measured. The flexural rigidity of the fabrics was measured by the cantilever method and their drape on a Cusick Drapemeter.

**Deformability:**

Both the "immediate" and "delayed" deformabilities of the fabrics were measured according to the technique used by Shiloh except that a higher applied load, viz. 8 kg, was used since the breaking strength of the fabrics tested in the present report was higher than in the previous report[16].

**Abrasion Resistance:**

The abrasion resistance of the fabrics, in terms of percentage mass loss at ten thousand cycles, was measured on a Martindale Abrasion Tester with an 800 g head weight.

## RESULTS AND DISCUSSION

**Yarn Properties:**

The results of the fibre bundle tests are presented in Table I while the yarn properties are given in Table II and Figure 1. Increasing the polyester component in the low pilling and high bulk yarns produced an initial decrease in the breaking load followed by a progressive increase in the breaking load as the polyester content of the yarn increased. Similar results have previously been reported for blended yarns[3, 17, 18]. There is, however, no evidence of a minimum in the graph of breaking strength versus polyester content for the normal polyester blend yarns. Differences in the performance of the yarns from the blends of the three fibre types may well be due to differences in the load extension characteristics of the three fibre types since large differences between the initial moduli of the fibre components of the blend are believed to produce high localized stress concentrations thereby leading to premature rupture of the yarn[18].

For all three polyester types the yarn breaking extension increased as the polyester content increased (see Figure 2). The increase was approximately linear for the normal polyester blends, but for the high bulk yarns a large increase in the breaking extension was observed at about 50% polyester content, while at both low and high polyester contents the increase was small. This suggests that the breaking extension of the high bulk blend is determined mainly by the properties of the major component of the blend. A similar trend was noticed in the extension at break of the low pilling blends, though to a lesser degree.

No significant trends in the irregularity of the 13 yarns were observed.

**Fabric Tensile Properties:**

In Figure 3 the breaking strength of the fabrics is plotted against polyester content, the values given being the means of the warp and weft directions. Unlike the yarn breaking strength the breaking strength of the blended fabrics were all higher than that of the 100% cotton fabric.

The shape of the bursting strength curves, Figure 4, closely follows the shape of the yarn tensile strength curves of Figure 1. Once again minima occur for blends containing 20–40% polyester and the decrease is less marked for the normal polyester than for the other two polyester types. The same trend was observed for both loomstate and finished fabrics although small changes in the sett of the fabrics occurred during finishing.

As the polyester content of the blend increased so did the breaking extension. It is difficult, however, to make a meaningful comparison between the different polyester fibre types since the finished fabrics unavoidably had different amounts of yarn crimp.

**Crease and Wrinkle Recovery:**

The crease recovery angles of the blends are presented in Figure 5. It is apparent that the crease recovery angles increased consistently with an increase in the polyester content of the blend. In addition, the crease recovery angles of the low pilling polyester blends were significantly higher (at the 5% level) than those of the blends containing the other two types. In a previous publication it was also reported that low pilling polyester blends with wool recovered better from wrinkling than did normal and high bulk polyester/wool blends[19]. Whether the better recovery from creasing was due to the physical properties of the low-pilling polyester fibre, or to the fact that the low pilling fibres had a higher linear density than the other two, is not possible to say.

The improvement in the crease recovery angle (approximately 70°) by incorporating 60% polyester in the fabric, is similar to the improvement reported by other workers[3, 4]. There appear to be a linear relationship between the crease recovery angle and the amount of polyester in the fabric.

The recovery from wet wrinkling, measured on the AKU wrinkle tester is shown in Figure 6. Results of wrinkling at 20°C and 65% RH are lower but follow the same general trend. Once again there was a progressive increase in the recovery from wrinkling, exemplified by lower H x T values, as the polyester content of the fabrics increased. The low pilling cotton/polyester blend fabrics recovered better from wrinkling than did the normal polyester, in agreement with the results from the Monsanto crease recovery test. The recovery from dry wrinkling was considerably better than the recovery from wet wrinkling when the percentage of cotton in the fabric was high, but there was little difference between the wet and dry wrinkle recovery of the 100% polyester fabrics. This is to be expected since the physical properties of polyester, which is a hydrophobic fibre, are only slightly affected by the small changes in regain.

**Appearance after Home Laundering**

From Figure 7 it is clear that increasing the polyester content of the blend improved the durable press rating of the fabric in agreement with the results from a previous publication[20]. Once again the blends containing the normal polyester performed worse than those containing the other two types of polyester. Nevertheless, while increasing polyester content improved the durable press rating, the improvement was insufficient, except at high polyester content (above 80%), for the fabrics to exceed a durable press rating of four and therefore to be considered, "non-iron".

**Shrinkage During Home Laundering:**

Figure 8 shows the decrease in shrinkage during home laundering which occurred as the percentage polyester in the fabric increased. Although the improvement in the shrinkage occurred throughout the whole range of cotton/polyester blend ratios the improvement in shrinkage was most rapid between zero and 40% polyester content. For example, the shrinkage decreased from 3,3% for the pure cotton fabric to slightly more than 1% for the fabric containing 40% polyester. There appeared to be no significant difference in the performance of the fabrics from the three polyester types.

**Flexural Rigidity and Drape:**

A good correlation was found between drape and bending length (significant at the 1% level) and even better correlation between flexural rigidity and drape (significant at the 0,1% level).

After an initial decrease, an increase in the polyester content was accompanied by a steady increase in the Cusick Drape Coefficient and the flexural rigidity, Figure 9, in the series of cotton fabrics blended with normal polyester. However, in the series of cotton/low pilling blends the opposite occurred and for the high bulk blends there was no pattern between polyester content and either the Drape Coefficient or the flexural rigidity.

**Flat Abrasion:**

There was a marked difference in the performance of the low pilling polyester blended fabrics and that of the other two polyester types, the mass loss at 10 000 cycles increased as the polyester content of the low pilling blends increased while the reverse occurred with the normal and high bulk polyester blend fabrics (see Figure 10). The reduction in the resistance to abrasion of the low pilling blends is probably due to the lower tenacity of the low pilling fibres, Table I.

**Flex Abrasion:**

The resistance to flex abrasion of all three polyester blend fabrics was greater than that of the all-cotton fabric.

The abrasion resistance of the normal and high bulk polyester blend fabrics containing more than 40% polyester exceeded 3 000 cycles, at which point the test was terminated and they may therefore be considered to be very resistant to flex abrasion.

On the other hand the flex abrasion results of the low pilling polyester followed a different pattern. Better values of abrasion resistance were obtained for blends containing 40% and 60% polyester than for those of both higher and lower polyester contents.

**Deformability:**

The "delayed" deformability was generally greater than the "immediate" while the deformability both "immediate" and "delayed" decreased as the polyester content increased. There was no noticeable difference in the performance of the three polyester types.

**Pilling Propensity:**

An assessment of the pilling propensity of the fabrics was carried out on the Martindale Abrasion Tester concurrent with the abrasion test. The pilling assessment was carried out at regular intervals when both the size and the number of pills were noted. None of the fabrics showed a marked tendency towards pilling although a few very small pills were observed for some of the blends, in particular those containing 60% polyester. There was no noticeable difference between the pilling propensity of the three polyester fibre types, for the fabric construction used in this report, in agreement with the findings of an earlier report[19].

**Air Permeability:**

Figure 11 shows the influence of polyester content on the air permeability of the blended fabrics. The air permeability increased as the polyester content of the fabrics increased and the effect was most pronounced at polyester levels in excess of 40%.

An analysis of variance showed that the type and amount of polyester and the type – amount interaction had a significant affect on air permeability (significant at the 1% level). No significant correlation was found between air permeability and cover factor which is not surprising, since the fabrics were designed to have the same construction and hence the same cover factor.

**Tear Strength:**

The results in Figure 12 indicate that the percentage polyester in the fabric has no significant affect on the tear strength of the fabric. Taylor[21], however, has shown tear strength to depend mainly on the spacing and strength of the threads being torn and in addition the force required to make them slip over the crossing threads. Since no relation was found between yarn thread strength and tear strength it would appear that, although the fabrics were designed to have the same geometrical construction, differences in yarn interfrictional forces and possibly also sett and crimp have obscured any trend which might exist between tear strength and blend composition.

## SUMMARY AND CONCLUSIONS

The tensile properties of cotton/polyester fabrics and yarns were found to depend upon the type and amount of polyester in the blend. In general, the breaking strength of the yarns and the bursting strength of the fabrics showed a minimum value at a polyester content of about 40% while the breaking strength of the finished fabrics consistently increased with increasing polyester content. Increasing the polyester content increased the breaking extension of both the yarns and the fabrics.

The wrinkle recovery and appearance after washing improved approximately linearly with increasing polyester content, with the blends containing the low pilling polyester performing better than the others.

Flex and flat abrasion resistance of the blend fabrics depended upon the type and amount of polyester in the blend. The flat abrasion resistance decreased with increasing polyester content for blends containing the low-pilling polyester type while the abrasion resistance of both the normal and high bulk polyesters increased as the polyester content increased.

The dimensional stability of the fabrics improved as the polyester content increased, with most of the improvement effected by incorporating 40% polyester in the blend.

Both the type and quantity of polyester affected the flexural rigidity of the blended fabrics; the flexural rigidity of the low pilling blends decreased with increasing polyester content while the flexural rigidity of the normal blends increased. The flexural rigidity of the high bulk polyester blends showed little change with an increase in polyester content.

There was no noticeable difference in the pilling propensity between blends of the three polyester types.

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## THE USE OF PROPRIETARY NAMES

The fact that products with proprietary names have been used in this investigation in no way implies that there are not others as good or even better.

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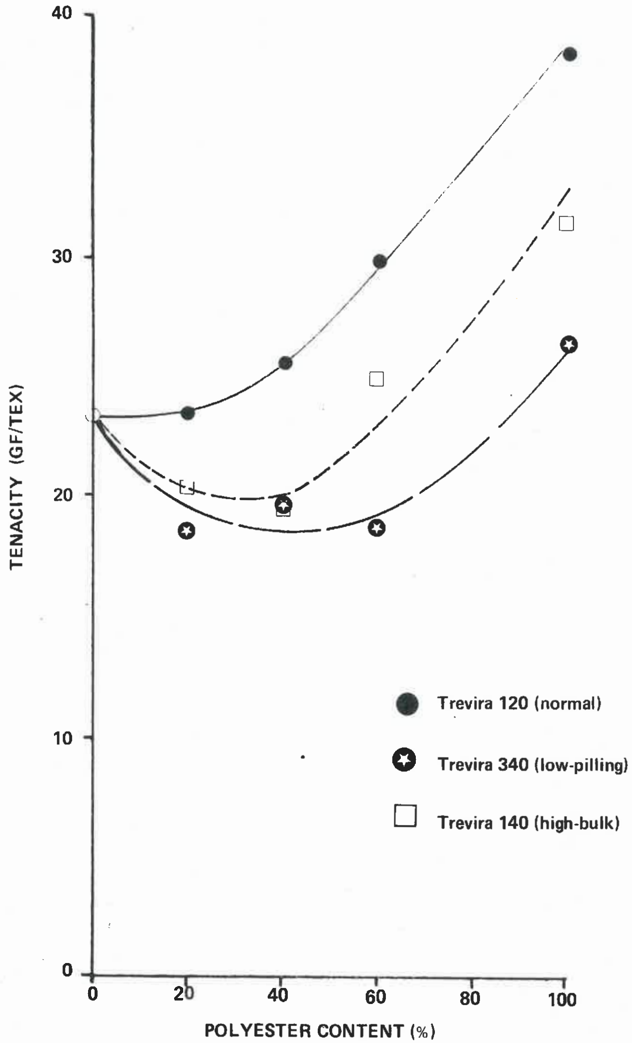


**FIGURE 1**

**Breaking Strength vs Polyester Content for Two-ply Cotton/Polyester Blend Yarns**

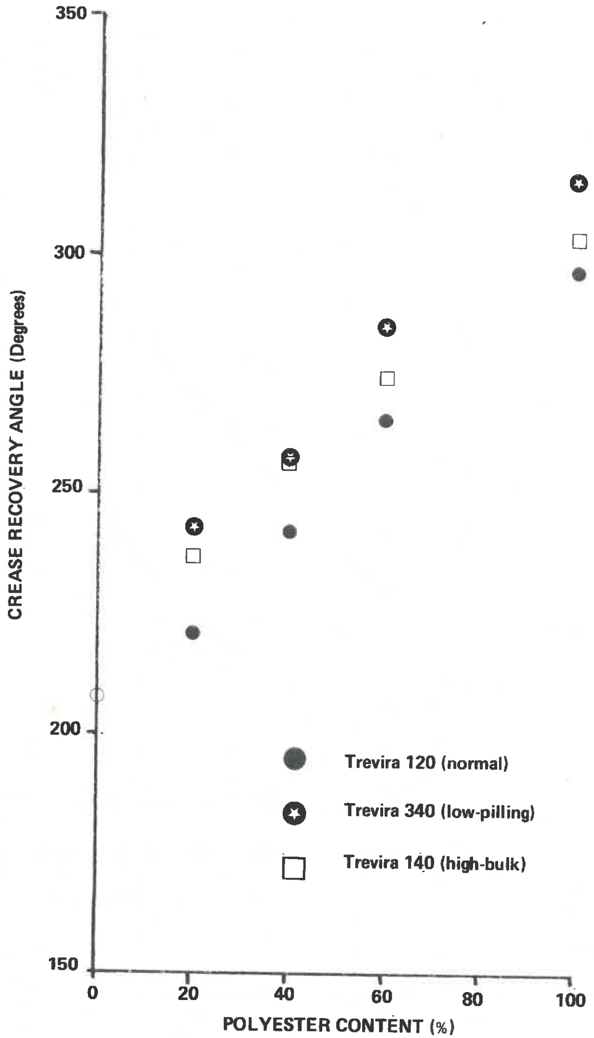


**FIGURE 5**
**Monsanto Crease Recovery Angle versus Polyester Content**

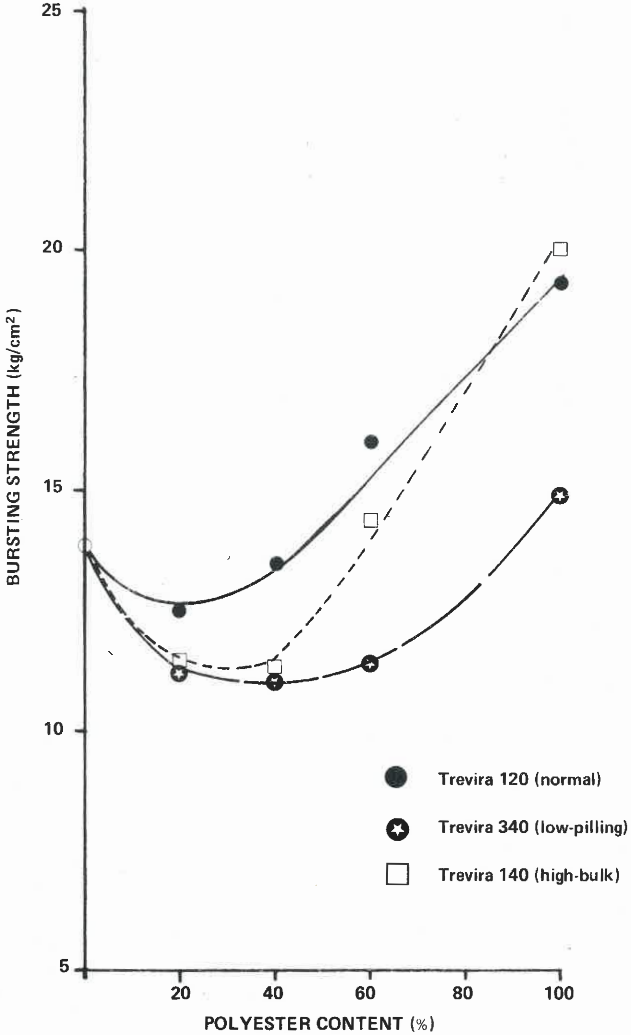


**FIGURE 4**

**The Relationship between Fabric Bursting Strength and Polyester Content**

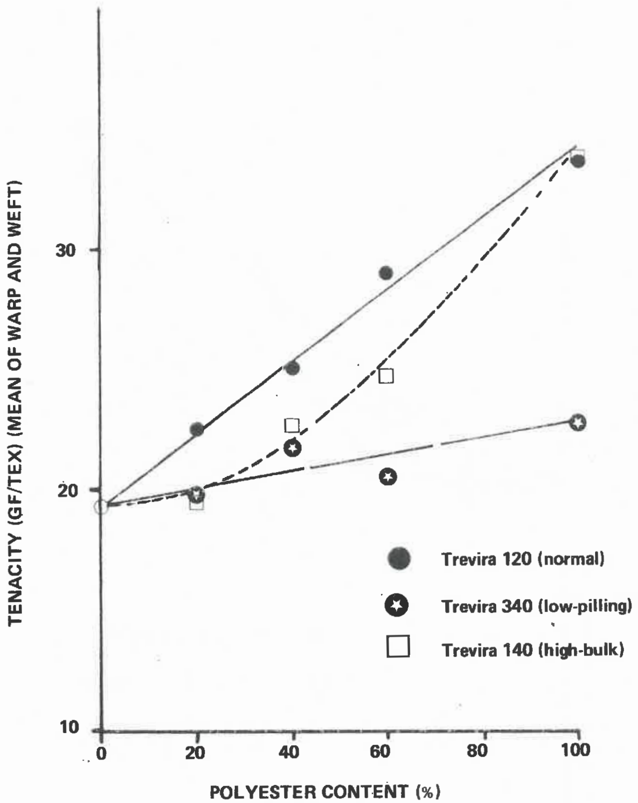


**FIGURE 3**

**The Relationship between Fabric Breaking Strength and Polyester Content**

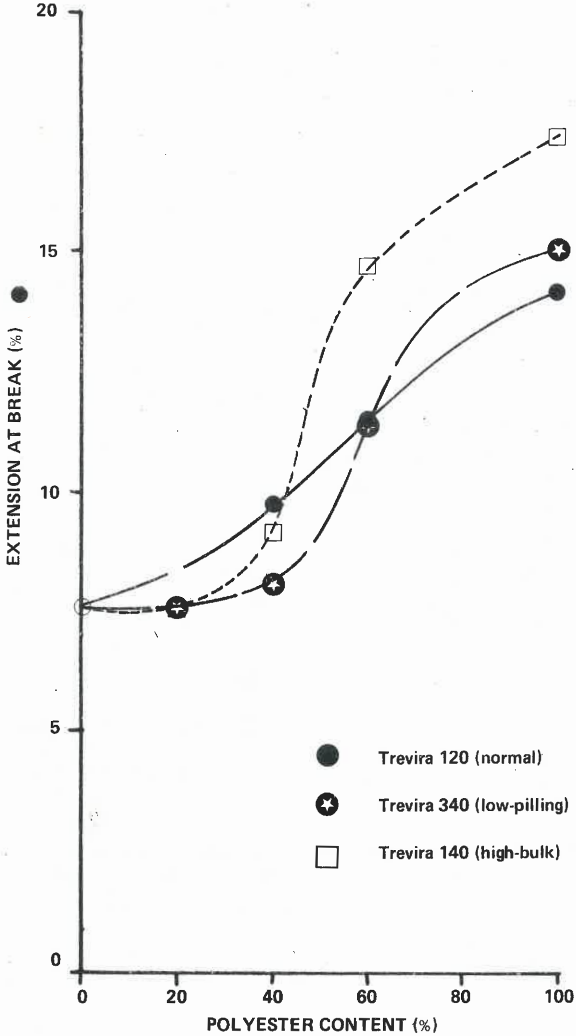


**FIGURE 2**
**Extension at Break of Two-ply Cotton/Polyester Blend Yarns versus Polyester Content**

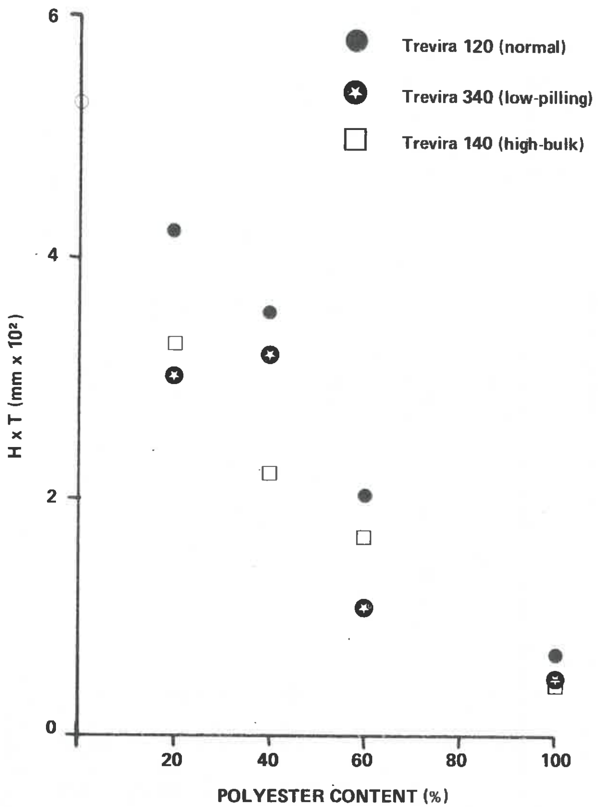


**FIGURE 6**

**Wrinkle Severity Index (H x T) versus Polyester Content (AKU Test-Wet)**

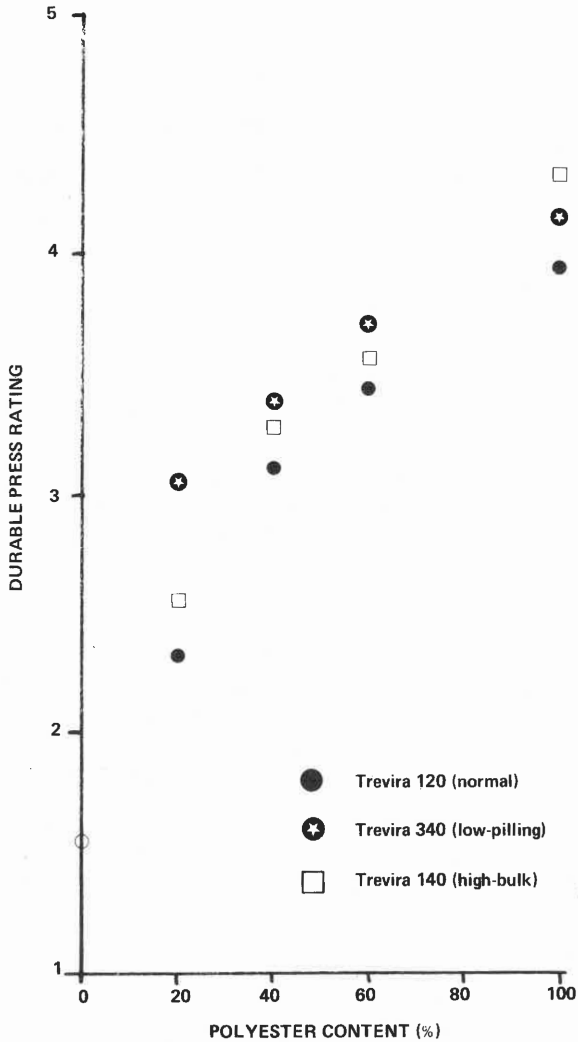


**FIGURE 7**

**AATCC Durable Press Rating of Cotton/Polyester Blend Fabrics after Home Laundering**

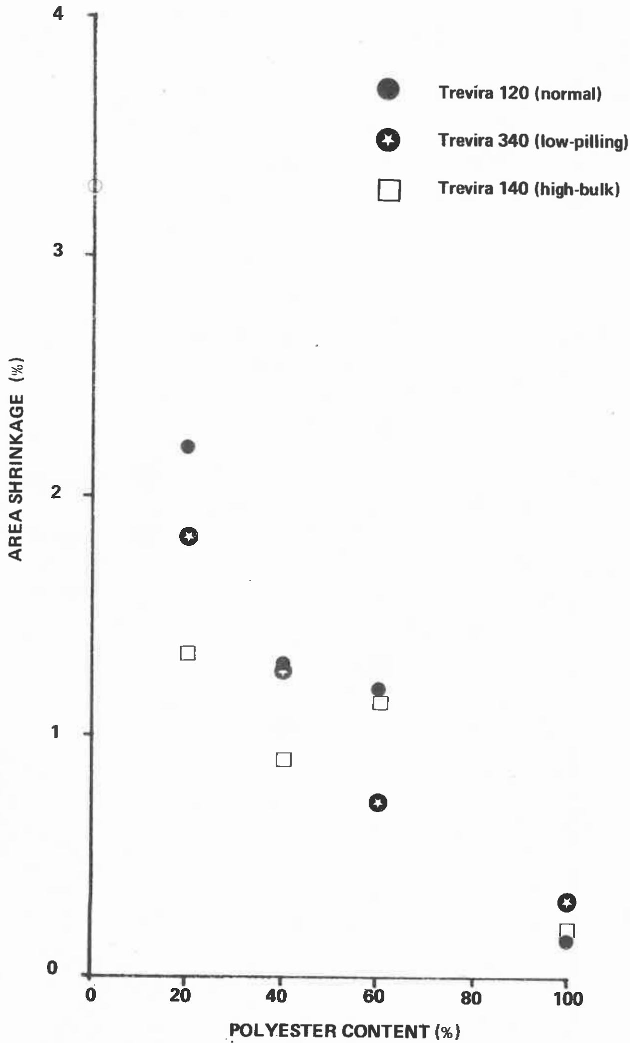


**FIGURE 8**

**Area Shrinkage During Home Laundering versus Polyester Content**

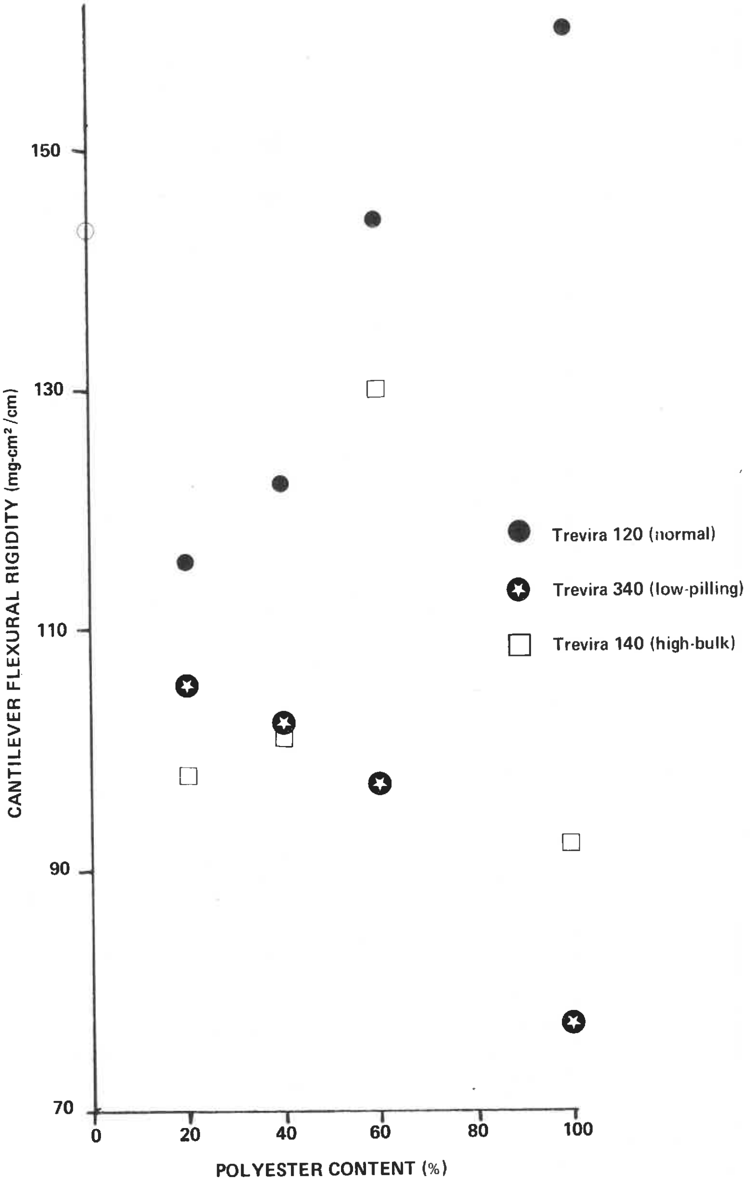


**FIGURE 9**

**Flexural Rigidity of Cotton/Polyester Blend Fabrics versus Polyester Content**

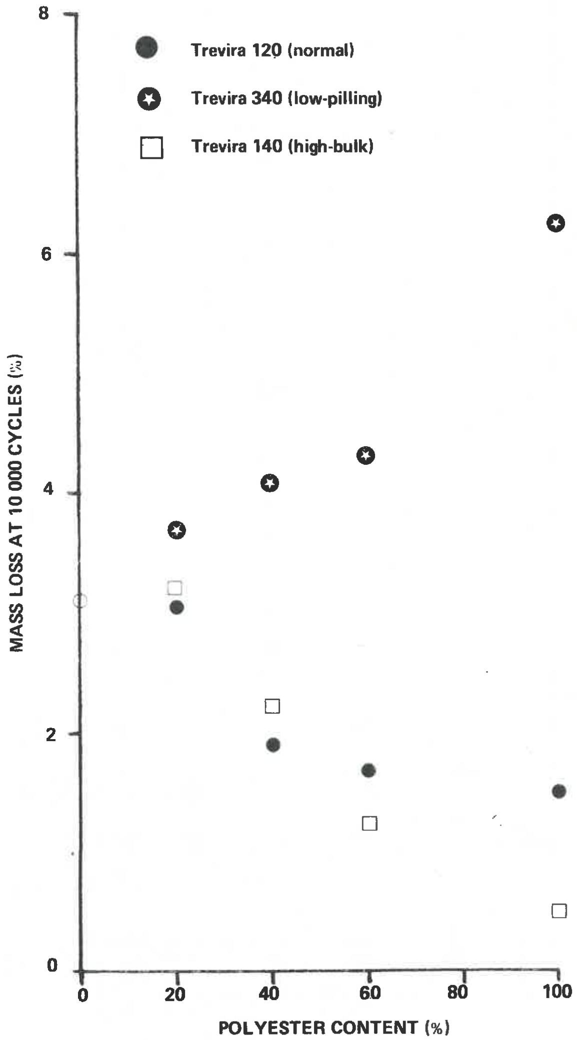


**FIGURE 10**

**Martindale Abrasion Resistance versus Polyester Content**

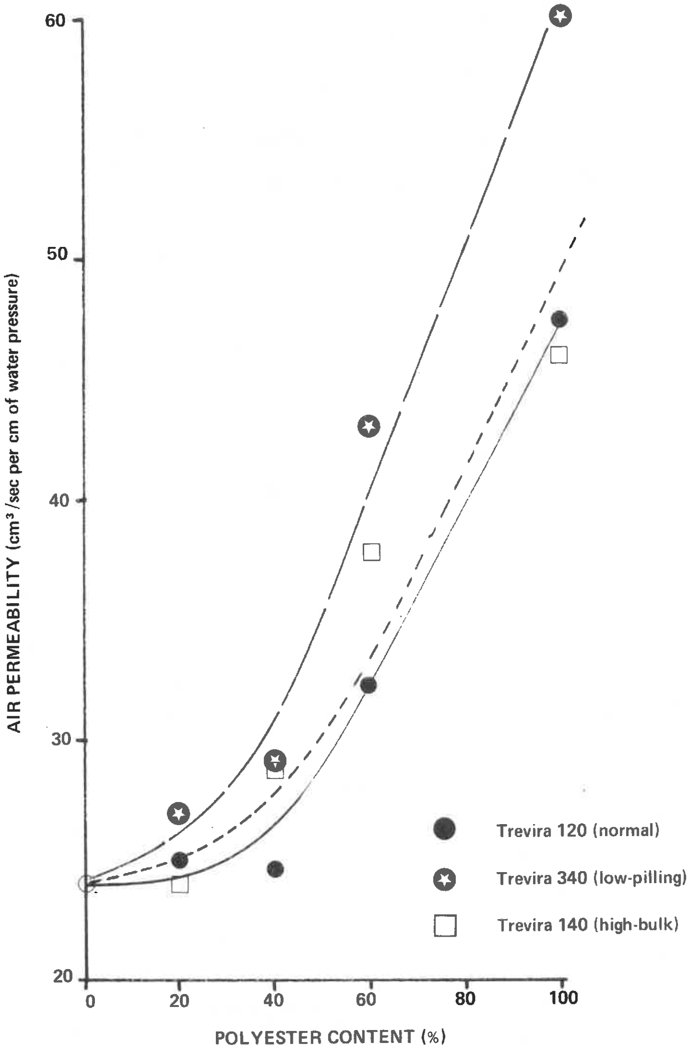


**FIGURE 11**
**Air Permeability of Cotton/Polyester Blend Fabrics**

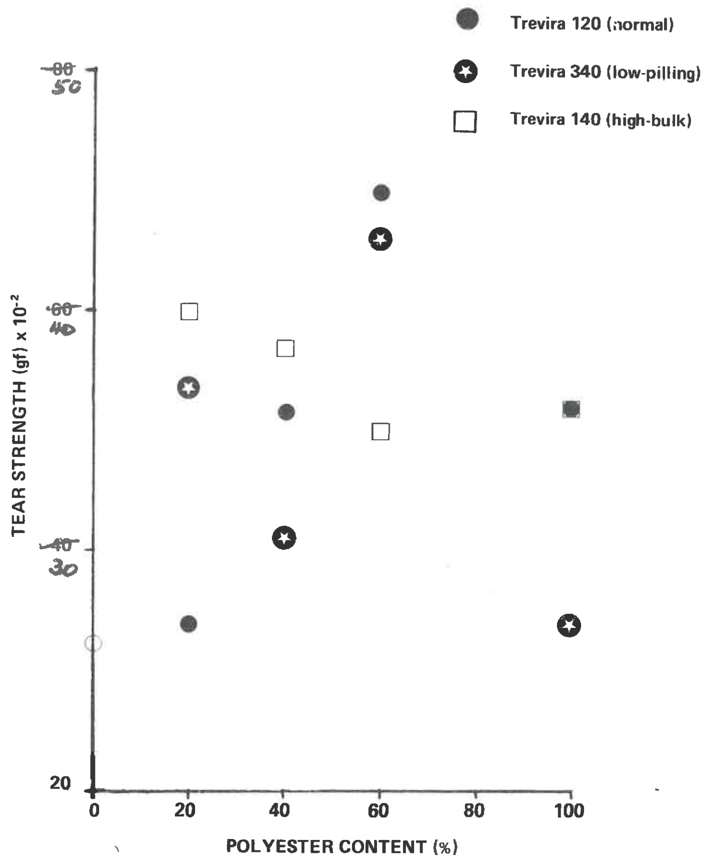


**FIGURE 12**

**Tearing Strength of Cotton/Polyester Blend Fabrics versus Polyester Content**

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