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A Preliminary Report on Certain Physical Properties of Commercial Woven Wool and Wool-Blend Worsted Fabrics

by

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A PRELIMINARY REPORT ON CERTAIN PHYSICAL PROPERTIES OF COMMERCIAL WOVEN WOOL AND WOOL-BLEND WORSTED FABRICS

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ABSTRACT

Certain physical properties, such as air permeability, pilling, abrasion resistance, bursting strength, tear strength, breaking strength, extension at break, drape coefficient, cantilever bending length, AKU wrinkling and Monsanto crease recovery angle of commercial woven fabrics produced from all-wool and wool blends, were measured. The results were plotted against fabric mass per unit area, and the graphs so obtained can be used in practice as a basis of reference for the physical properties of commercial woven suiting type fabrics made from all-wool and wool blends.

INTRODUCTION

In practice, many tests are carried out on fabrics in an attempt to predict their durability and wear performance. Except where the tests are purely of a comparative nature or where internal "standards" exist, it is very difficult to interpret or assess the results, i.e. to draw valid conclusions as to the "quality" or performance of the fabric. Where minimum levels are specified, for instance by the SABS, or when testing against specification, there is no problem. But, it sometimes happens that a garment fails during wear and becomes the subject of a claim. In many such cases the garment is submitted to independent laboratories (e.g. SAWTRI or the SABS) for determination of the validity of the claim. Here, however, it is difficult to draw definite conclusions unless some reference level or basis of reference (e.g. minimum levels, average values, agreed specifications) is available. It is for these reasons that SAWTRI has been engaged in various projects aimed at establishing average or reference values for the physical properties of fabrics. A number of publications[1,2] have already appeared in this field.

The present report deals with a survey conducted on the physical properties of a wide range of commercial woven worsted (suiting type) fabrics in all-wool and wool blends, the aim being to establish average or reference values for those fabric properties normally tested in quality control laboratories.

To be entirely valid, however, such average or reference levels have to allow for fibre, yarn and fabric parameters which affect them and which in practice are open to choice. This aspect will be covered in a later report.

EXPERIMENTAL

Standard testing procedures as specified in an earlier report[3] were used. Except for the AKU wrinkling and the Monsanto crease recovery tests (in which case the fabrics were de-aged and then first conditioned and then creased at 75% RH/27°C and allowed to recover at 65% RH/20°C) all tests were carried out under standard atmospheric conditions (65 ± 2% RH and 20 ± 2°C) with the fabrics being allowed sufficient time to attain equilibrium. Commercial woven fabrics (mainly worsted) from different sources were used. These fabrics were classified according to structure and composition as shown in Table I.

RESULTS AND DISCUSSION

As in other reports[1, 2] it was considered best to plot the various properties against the fabric mass per unit area both for ease of use and because in practice fabrics are compared on the basis of equal mass per unit area. Distinction was made between composition (i.e. wool content) only, and not between different weaves and other structural variables such as sett, yarn linear density, weave crimp, cover factor and fabric thickness. The effect of weave and the other structural variables was ignored for several reasons. Firstly, there were generally insufficient samples of each weave to establish real differences between the different weaves within the three main groups of fabrics tested (see Table I). Secondly, the range of fabrics in terms of mass per unit area (and of other structural variables) within a weave was rather small. Thirdly, the fact that very little information was available concerning the finishing procedures applied to the fabrics, made comparison between different weave structures difficult for the limited number of fabrics covered here. The finishing procedure can cause large enough variations in some of the mechanical properties of the fabrics to mask the effect of weave and other structural variables.

The various graphs plotted can be used in practice for assessing or rating any fabric physical property relative to other commercial fabrics being produced. As a further aid, the average values of the various properties for each of the three groups of fabrics are given in Table II. Where relevant, regression lines have been superimposed on the points, and these represent the average values in each case.

Fibre and structural variables

Despite the variety and different origins of the fabrics it appeared that fibres of approximately the same mean diameter and coefficient of variation were used in their manufacture. For the all-wool fabrics the average fibre diameter was 21,2 μm and for the wool blend fabrics the wool fibre diameter was 20,6 μm while the average non-wool (mainly polyester) fibre linear density was about 4 dtex (see Table II).

Each weave appeared to be manufactured to approximately standard specifications since, within a particular weave within one of the main groups of fabrics, the sett, yarn linear density and weave crimp were (within limits) about the same. These factors determine the fabric mass per unit area.

TABLE I

DISTRIBUTION OF FABRICS ACCORDING TO STRUCTURE AND COMPOSITION

WEAVE	NUMBER OF FABRICS		
	All-wool	Wool blends	Non-wool
Plain weave	7	31	7
2/2 Twill	20	26	2
2/2 Twill (milled flannel)	6	–	–
Gaberdine	9	6	–
2/1 Twill (serge)	9	–	–
Whipcord	7	–	–
Barathea ($\frac{3\quad 1}{2\quad 2}$ step 3 twill)	4	–	–
Venetian (3/2 step 2)	8	–	–
Miscellaneous	–	16	16*
TOTAL	70	79	25

*From staple and filament yarns

Air permeability

For the fabrics under examination the fabric mass per unit area varied to a limited extent for each weave. It was therefore difficult to assess the effect of fabric mass per unit area on the air permeability for any particular weave (Fig. 1). Although the scatter is very large (due to the many variables such as finishing procedure, fabric thickness, etc. not allowed for) there appeared to be a tendency for the air permeability to *decrease* with an *increase* in fabric mass per unit area, which is to be expected. The air permeability tended to decrease more rapidly with an increase in fabric mass per unit area at the "lighter" mass per unit area values than for the "heavier" fabrics. At a fabric mass of 200 g/m^2 the average estimated air permeability was about 16 mℓ/s/cm^2 and at a mass per unit area of 350 g/m^2 it was approximately 6 mℓ/s/cm^2.

The air permeability tended to increase as the wool content decreased. This relationship, however, depends upon the finishing procedure. At any specific fabric mass per unit area the non-wool (staple) fabrics invariably had higher air permeabilities than the all-wool and wool blend fabrics. The few fabrics con-

TABLE II

AVERAGE VALUES FOR SOME FABRIC PROPERTIES*

Physical Property	All-Wool Fabrics		Wool/Polyester Blend Fabrics		Wool/Acrylic Blend Fabrics		All-Polyester Fabrics		All-Acrylic Fabrics	
Number of Fabrics	70		55		24		16		9	
Wool Fibre Diameter (μm)	21,2	(3)	20,8	(3)	20,1	–	–	–	–	–
Synthetic Fibre Linear Density (dtex)	–	–	3,7	(9)	4,1	(20)	4,8	(10)	2,9	(46)
CV (%) of Fibre Diameter:										
Wool Component	23,2	(7)	23,5	(6)	24,1	–	–	–	–	–
Synthetic Component	–	–	10,6	(21)	–	–	10,6	(18)	13,3	(10)
Sett (threads per cm): Warp	32,5	(8)	28,4	(14)	23,4	(4)	31,3	(19)	24,9	(20)
: Weft	25,8	(9)	25,0	(14)	19,2	(3)	28,0	(18)	21,4	(5)
Resultant yarn tex : Warp	45,7	(13)	45,8	(15)	42,4	(2)	37,4	(14)	43,0	(4)
: Weft	46,2	(12)	44,8	(16)	42,2	(2)	37,4	(13)	42,9	(3)
Composition (% wool)	100,0	(0)	49,1	(42)	50,0	(40)	0,0	(0)	0,0	(0)
Weave Crimp (%) : Warp	13,0	(21)	9,8	(29)	–	–	16,4	(34)	7,6	–
: Weft	8,9	(17)	8,1	(66)	–	–	8,6	(59)	5,3	–
Cover Factor**	25,8	(4)	24,6	(4)	21,5	(2)	24,6	(7)	22,7	(6)
Mass per Unit Area (g/m^2)	283	(9)	252	(15)	189	(2)	235	(15)	206	(11)
Fabric thickness (mm)	0,72	(11)	0,59	(15)	0,48	(9)	0,67	(18)	0,53	(10)
Fabric Density (g/cm^3)	0,40	(9)	0,43	(11)	0,40	(9)	0,37	(11)	0,39	(10)
Air Permeability (mℓ/s/cm^2/98Pa)										
– measured at 98Pa	9,7	(50)	12,8	(56)	14,7	(36)	28,1	(36)	27,5	(56)
– measured at 490 Pa	8,7	(40)	9,9	(48)	11,6	(27)	19,4	(30)	18,8	(45)
Atlas Pilling										
IWS or ICI rating after 30 min.	5	(0)	4,5	(14)	5,0	(0)	4,8	(15)	4,7	(4)
IWS or ICI rating after 60 min.	5	(0)	4,7	(11)	5,0	(0)	4,8	(15)	4,8	(2)
Martindale Abrasion (% mass loss at 10 000 cycles using 794 g load)	5,2	(47)	2,9	(62)	5,2	(31)	0,30	(160)	4,2	(20)
Bursting Strength (kN/m^2)	1081	(7)	1958	(24)	1184	(16)	2755	(8)	1684	(10)
Elmendorf Tear Strength (N):										
Warp	34,3	(14)	48,0	(23)	29,4	(10)	57,5	(5)	43,7	(24)
Weft	24,4	(20)	44,3	(31)	26,7	(12)	57,9	(7)	42,3	(21)
Fabric Breaking Strength (N):										
Warp	517	(10)	1024	(28)	558	(17)	1757	(19)	880	(21)
Weft	385	(14)	917	(35)	461	(20)	1505	(16)	706	(16)
Fabric Breaking Extension (%):										
Warp	43,5	(16)	37,1	(17)	27,6	(9)	46,4	(13)	33,5	(9)
Weft	30,9	(16)	30,7	(14)	26,2	(7)	35,8	(13)	28,9	(22)
Fabric Breaking Tenacity (cN/tex)										
Warp	7,3	(7)	16,5	(26)	11,4	(19)	31,4	(5)	16,4	(6)
Weft	6,8	(9)	16,5	(29)	11,4	(19)	29,8	(10)	15,5	(12)
Drape Coefficient (%)	58,7	(11)	63,7	(9)	52,6	(14)	63,2	(10)	59,9	(15)
Cantilever Bending Length (cm)	1,81	(8)	1,98	(11)	1,80	(6)	2,09	(7)	1,99	(12)
Cantilever Flexural Rigidity (mN.mm)	17,3	(28)	21,7	(39)	11,0	(20)	22,7	(32)	16,8	(39)
AKU Wrinkling – Wrinkle Height in mm (de-aged)	0,26	(22)	0,17	(27)	0,23	(11)	0,15	(26)	0,23	(16)
AKU Wrinkling – W.R. Rating	2,7	(13)	2,9	(23)	2,0	(3)	3,0	(17)	2,1	(8)
Monsanto Crease Recovery Angle (in degrees – de-aged)	279	(3)	291	(3)	269	(5)	297	(2)	265	(9)

*Figures in parenthesis are the coefficients of variation.

**The cloth cover factor (Kc) was calculated from : $Kc = 0{,}1045 (n_1 \sqrt{Tex_1} + n_2 \sqrt{Tex_2} - 0{,}00373 x\, n_1\, n_2 \sqrt{Tex_1, Tex_2})$ where n_1 and n_2 are the number of warp and weft threads per centimetre and Tex_1 and Tex_2 are the warp and weft yarn linear densities.

structed from continuous filament yarns, and included for the sake of interest had, at the same fabric mass per unit area, air permeabilities significantly higher than fabrics made from all-wool and wool blends. This may be partly due to differences in fabric structure.

Pilling Propensity

The majority of fabrics had pill ratings of 5 (i.e. they did not pill). The worst all-wool fabrics had ratings of 4-5.

Martindale Abrasion

The percentage mass loss after 10 000 cycles of abrasion tended to decrease with an increase in fabric mass per unit area (Fig 2). However, for the all-wool fabrics some weaves (e.g. 2/2 twill milled flannel, gaberdines and plain weaves) had mass losses during abrasion which were above average while others (e.g. whipcords) displayed mass losses which were below average. The resistance to abrasion tended to increase as the wool content decreased.

Bursting strength

The fabric strength in the direction of minimum strength tends to control its bursting strength. This should correspond to that fabric direction in which the product of threads per unit length (i.e. sett) and yarn linear density (i.e. tex) is the lowest (assuming the same blend ratio in warp and weft directions). A plot of bursting strength against this lowest product of sett and tex (Fig 3) presented a clearer picture of the effect of blend level on the bursting strength than if bursting strength was plotted against fabric mass per unit area (Fig 4). Similar conclusions, however, could be drawn from both graphs. The bursting strength increased as the above defined product increased (or as fabric mass per unit area increased) and as the wool content decreased.

Tear Strength

For the all-wool fabrics the tear strength (i.e. the mean of the warp and weft tear strength) increased as the fabric mass per unit area increased (Fig 5). The effect of weave on the tear strength should be kept in mind, however, since in a previous report[3] it was found that a 2/2 twill weave had a higher tear strength than a plain weave fabric of the same mass per unit area, all other variables being constant. In this report the plain weave fabrics also had the lowest tear strength, although on the whole they were also the lightest. Weaves such as 2/2 twills, 2/1 twills, 3/2 step 2 twills and whipcords of approximately the same mass per unit area had approximately the same tear strength.

Fabric breaking strength

It is mainly the type and the number of fibres present in a fabric cross-section which control the fabric breaking strength. The average of the warp and weft fabric breaking strength was found to increase as the fabric mass per unit area increased and the level of wool in the blend decreased (Fig 6). Possible effects due to weave and other structural variables were ignored until such time that sufficient data have been accumulated for a more thorough analysis.

To illustrate the effect of mass per unit area it can be seen that for the all-wool fabrics the breaking strength increased linearly from about 330N to about 570N for an increase in the fabric mass per unit area from 200 g/m^2 to 350 g/m^2.

Fabric breaking extension

The fabric mass per unit area only had a slight effect on the breaking extension (mean of the warp and weft – see Fig 7). The mean breaking extension of most of the fabrics lay between 25% *and* 45%. The reason for the large scatter of the results is unknown but could possibly be due to factors such as weave (weave crimp), yarn variables and even fibre and finishing variables.

Fabric stiffness properties

A linear relationship was found between the drape coefficient and the bending length (Fig 8). At the same bending length the wool blends and non-wool fabrics tended to have slightly lower drape coefficients than all-wool fabrics. This could be due to differences in shear as a result of factors such as more loose weave construction or lower fibre frictional properties, both of which reduces shear properties of the fabric and thus the drape coefficient. To facilitate the use of the results, both the drape coefficient and the bending length were plotted against fabric mass per unit area (Figs 9 and 10). The scatter of results was large and only in certain cases was the drape related to the fabric mass per unit area (Fig 9).

The bending length (Fig 10) results are even more scattered but similar conclusions could be drawn with respect to the blend level. In addition, the bending length tended to increase as the fabric mass per unit area increased. A plot of the flexural rigidity (Fig 11) against fabric mass per unit area gives a similar (and perhaps clearer) picture than a plot of bending length against fabric mass per unit area.

AKU wrinkling and Monsanto crease recovery angle

Again it is stressed that, because the finishing procedures are not known and because finishing affects the wrinkling and creasing properties of fabrics, no attempt was made to explain these results in detail. The values have been plotted graphically merely to present the data compiled here in such a way as to facilitate use in practice.

Both the AKU wrinkle height and the Monsanto crease recovery angle were plotted against the fabric mass per unit area (Figs 12 and 13). These graphs may be used to assess the wrinkle and crease recovery performance of a fabric (i.e. ignoring all variables which could effect the wrinkling and creasing properties) in practice.

SUMMARY AND CONCLUSIONS

A study was made of the physical properties of a range (174 in all) of commercial woven fabrics in wool and wool blends. The aim was to establish average values or reference levels for the various fabric properties, which can be used in practice to compare a particular fabric with other similar fabrics being produced commercially. An opinion can then be formed as to whether the fabric under question is "average", "below average" or "above average" in terms of its respective physical properties (i.e. compared with these fabrics). Such "reference" levels are particularly important when a fabric or garment becomes the subject of a claim.

Because of the rather limited number of fabrics available in each weave structure, blend level and mass per unit area class, no attempt was made to differentiate between different structures although a broad classification of the fabrics in terms of blend level was made. For the above reasons the effects of other fabric, fibre and yarn structural variables, open to choice in practice and often having a significant effect on fabric properties, have been ignored. This will form the subject of a later publication when additional data have been compiled.

To facilitate the practical use of the results compiled here, the various fabric properties were plotted against fabric mass per unit area. These graphs also illustrated the distribution of results.

A table of average values has also been given.

Briefly, the air permeability tended to decrease with an increase in fabric mass per unit area and to increase as the wool content decreased. The tensile properties improved as the mass per unit area increased. In most cases the fabric drape appeared to be independent of mass per unit area while the bending length tended to increase as fabric mass per unit area increased. The fabric flexural rigidity tended to decrease as the wool content decreased (i.e. the fabrics became softer).

ACKNOWLEDGEMENTS

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Permission by the Wool Board to publish these results is also greatly appreciated.

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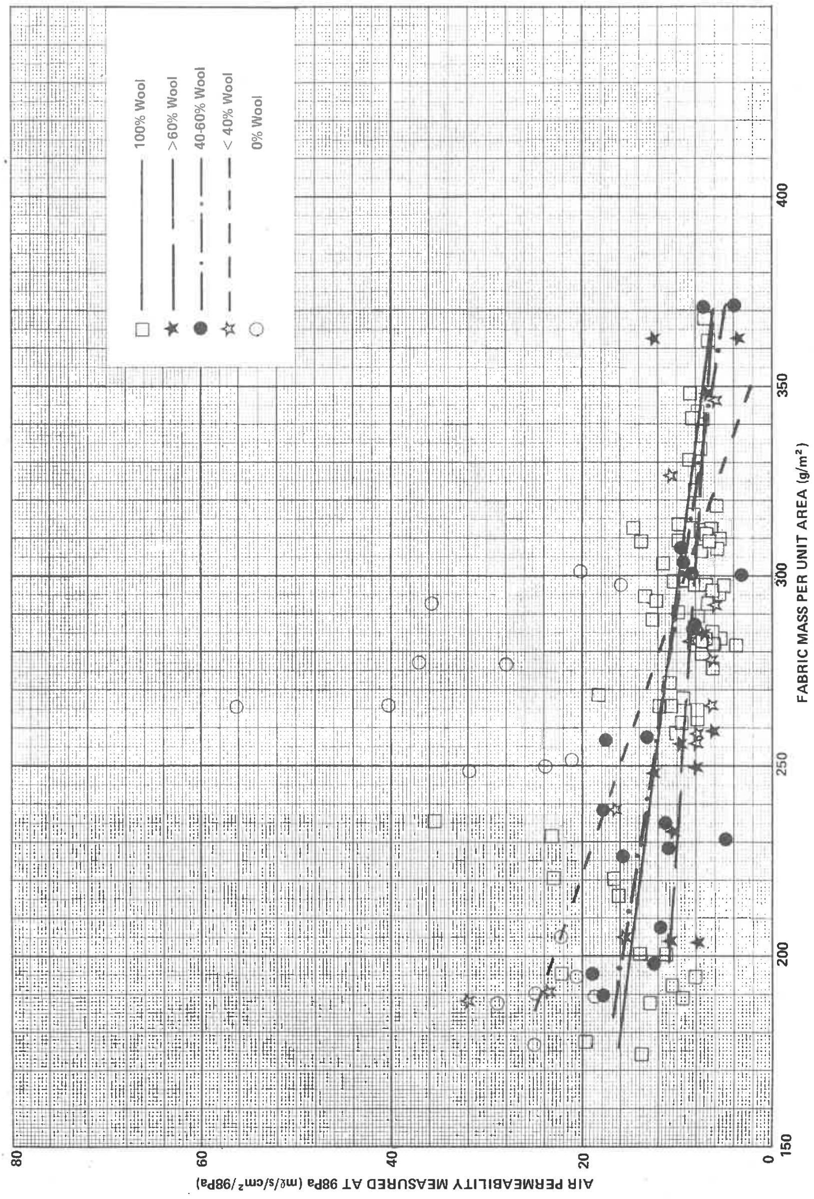

FIGURE 1

Air permeability vs fabric mass per unit area

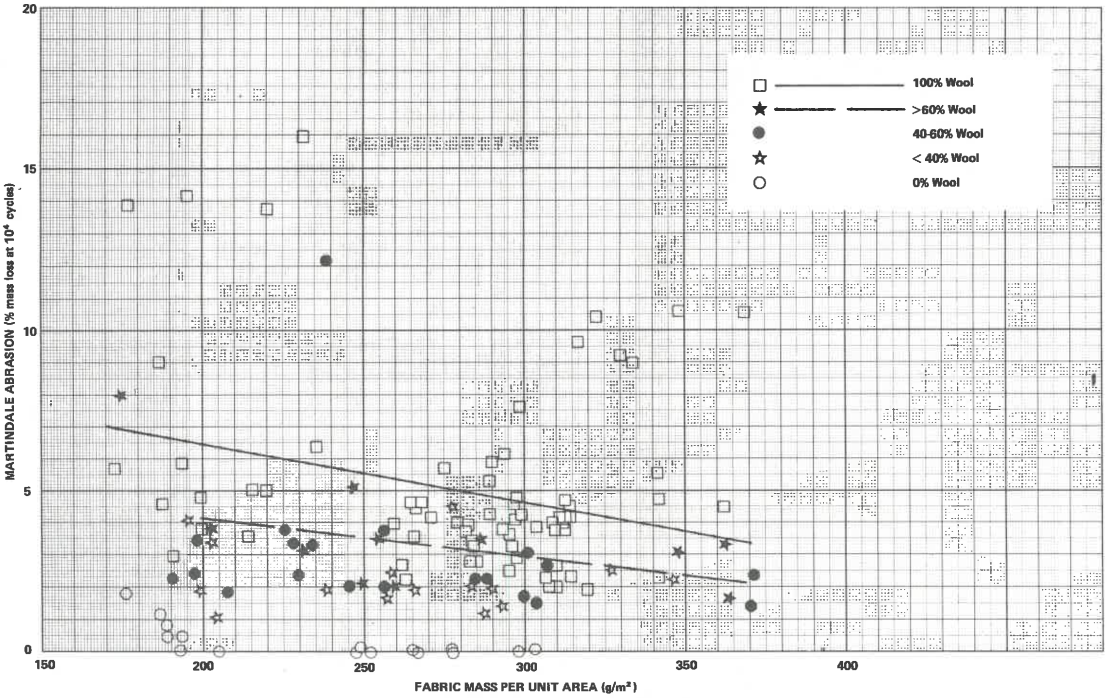

FIGURE 2

Mass loss after 10 000 cycles abrasion on Martindale tester vs fabric mass per unit area

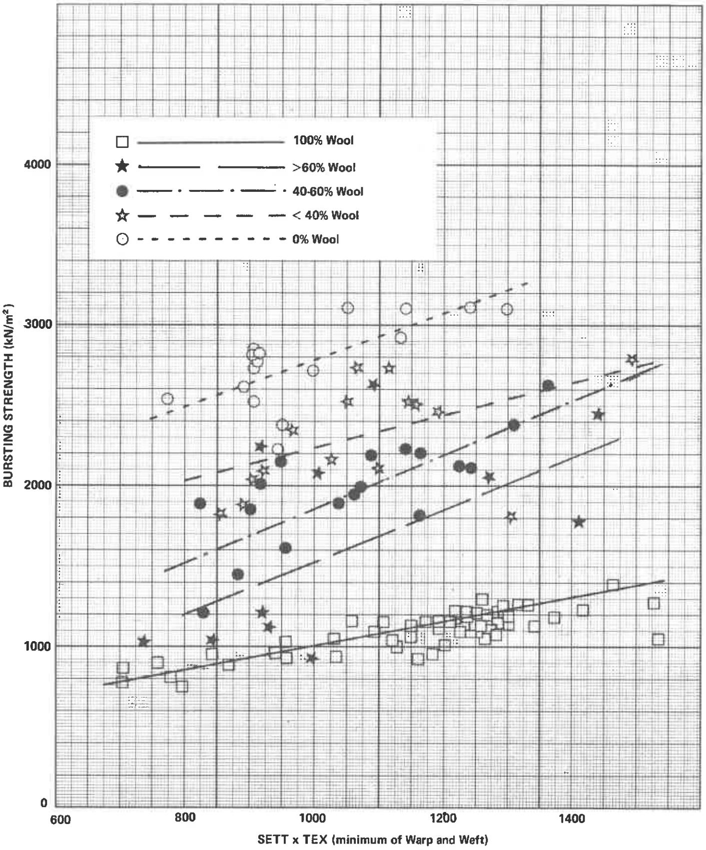

FIGURE 3

Bursting strength vs product of sett and tex (minimum warp and weft)

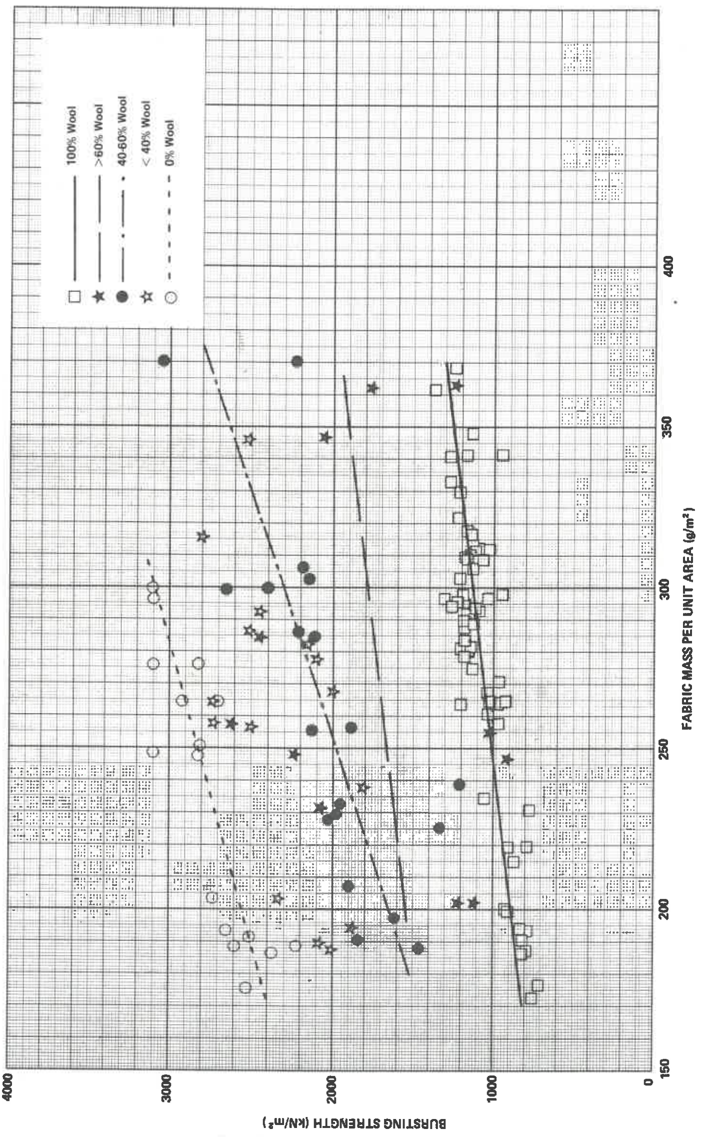

FIGURE 4

Bursting strength vs fabric mass per unit area

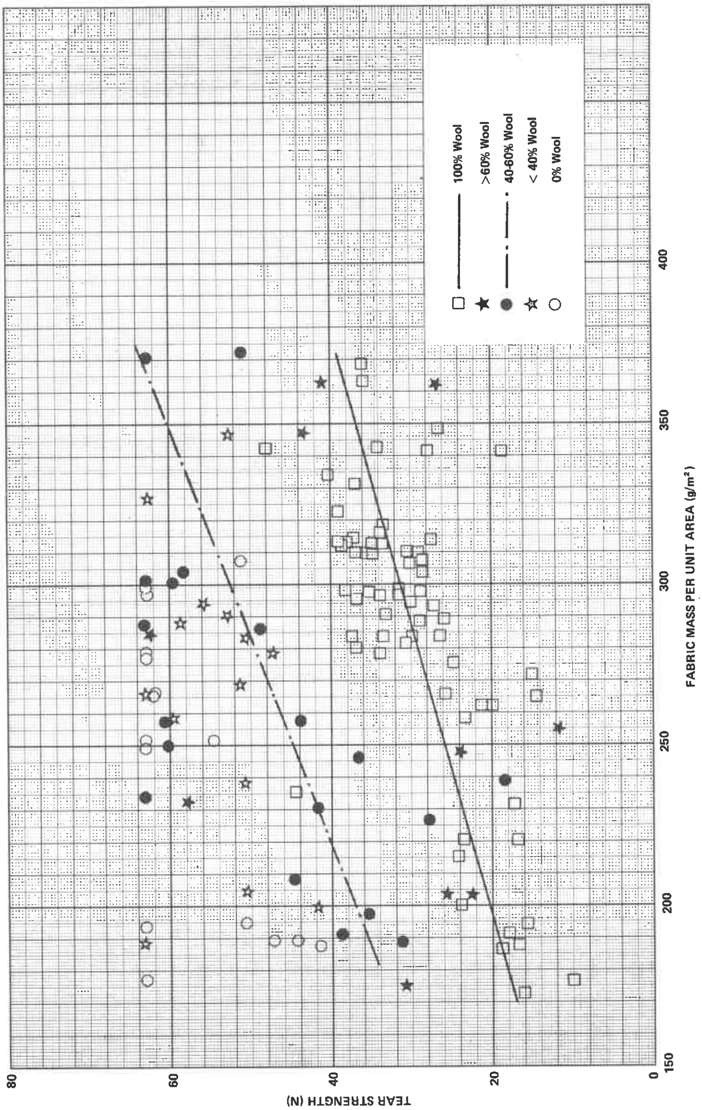

FIGURE 5

Tear strength vs fabric mass per unit area

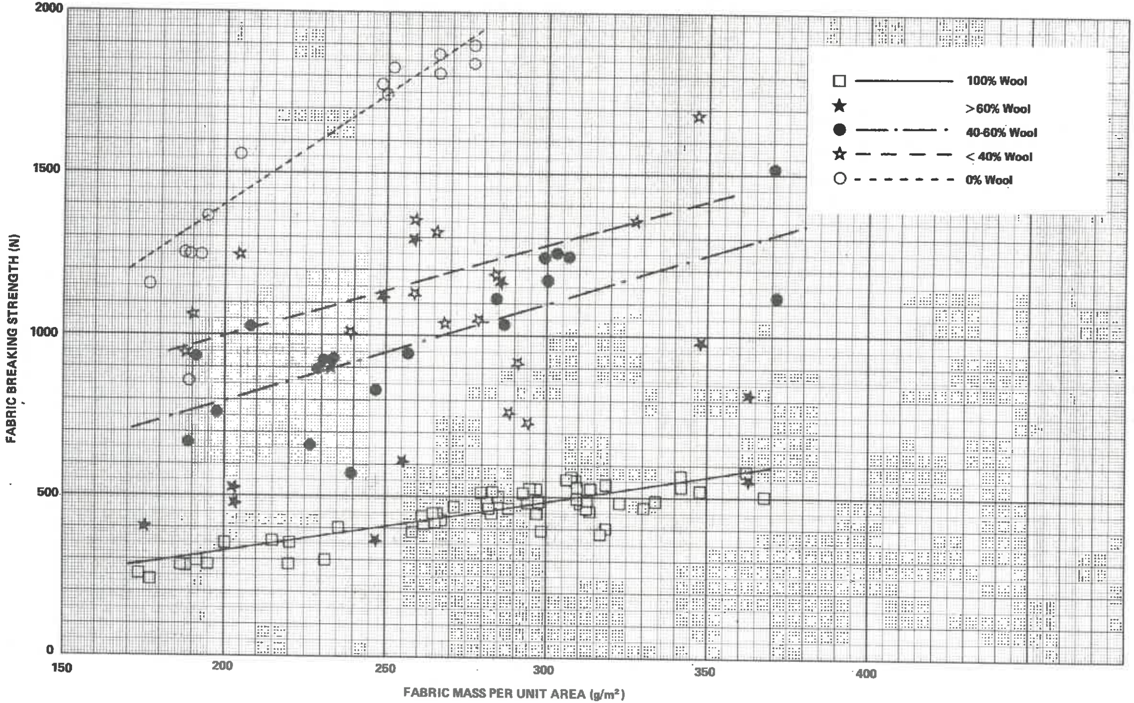

FIGURE 6

Fabric breaking strength vs fabric mass per unit area

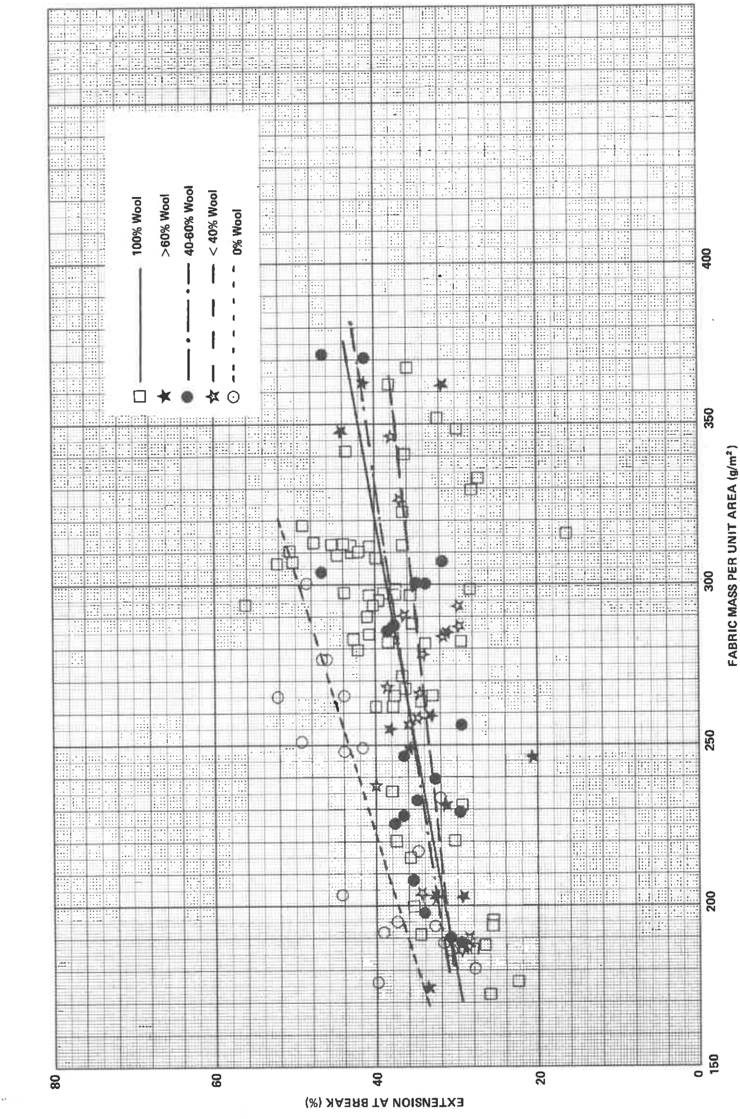

FIGURE 7

Extension at break vs fabric mass per unit area

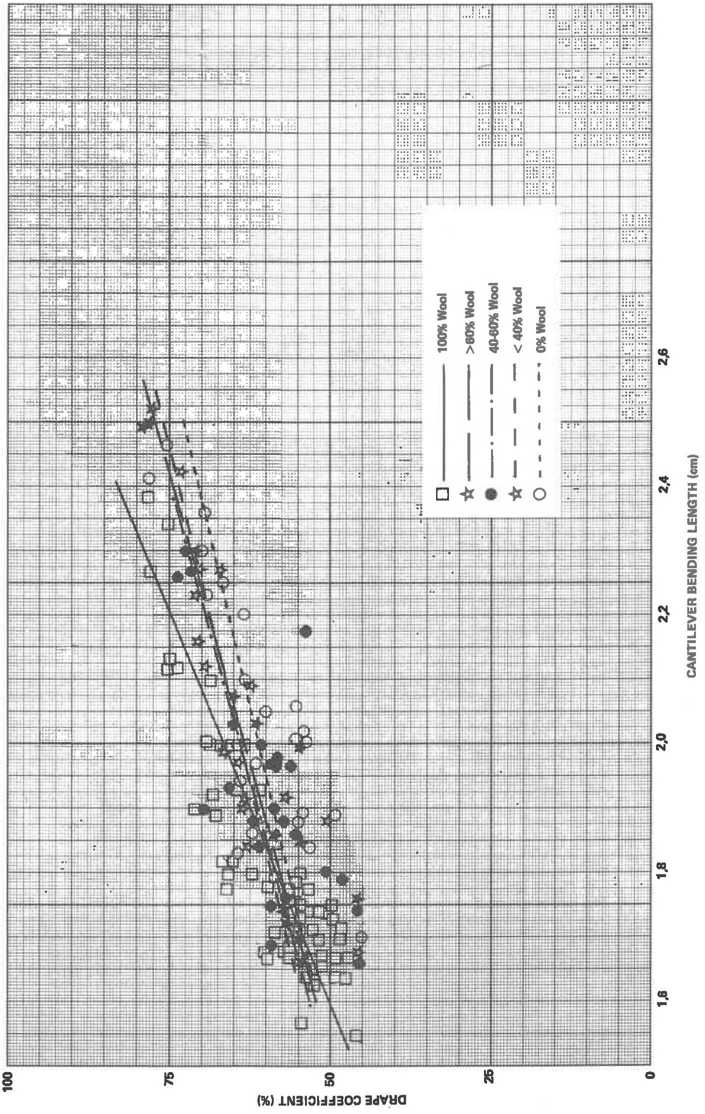

FIGURE 8
Drape coefficient vs cantilever bending length

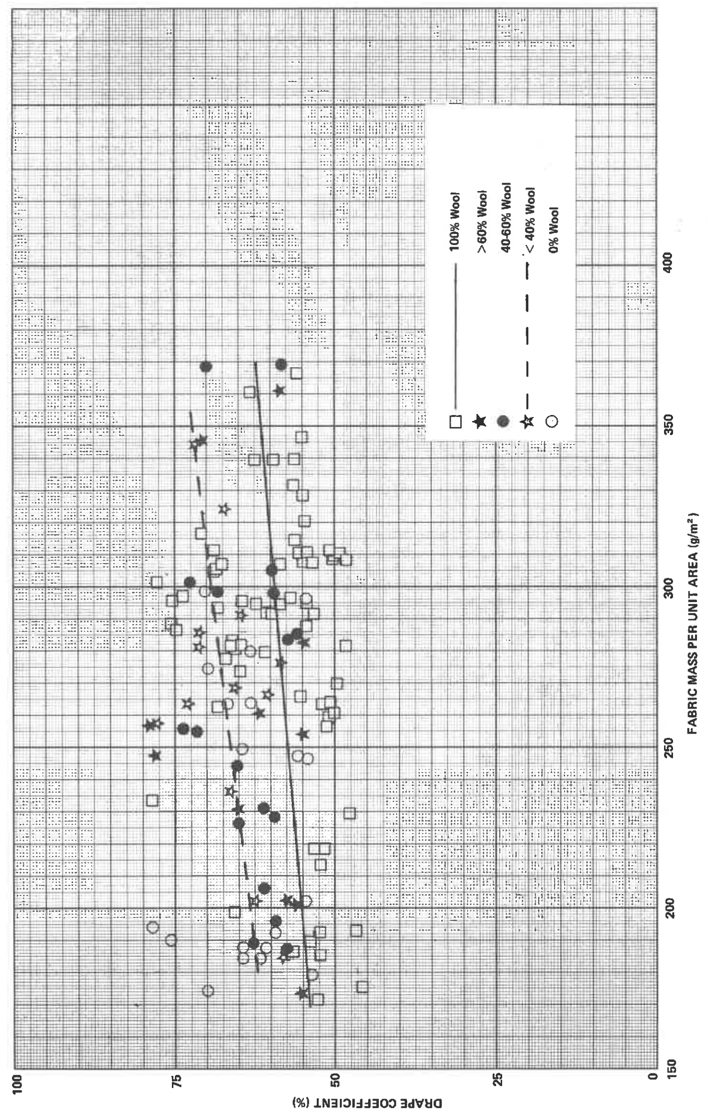

FIGURE 9

Drape coefficient vs fabric mass per unit area

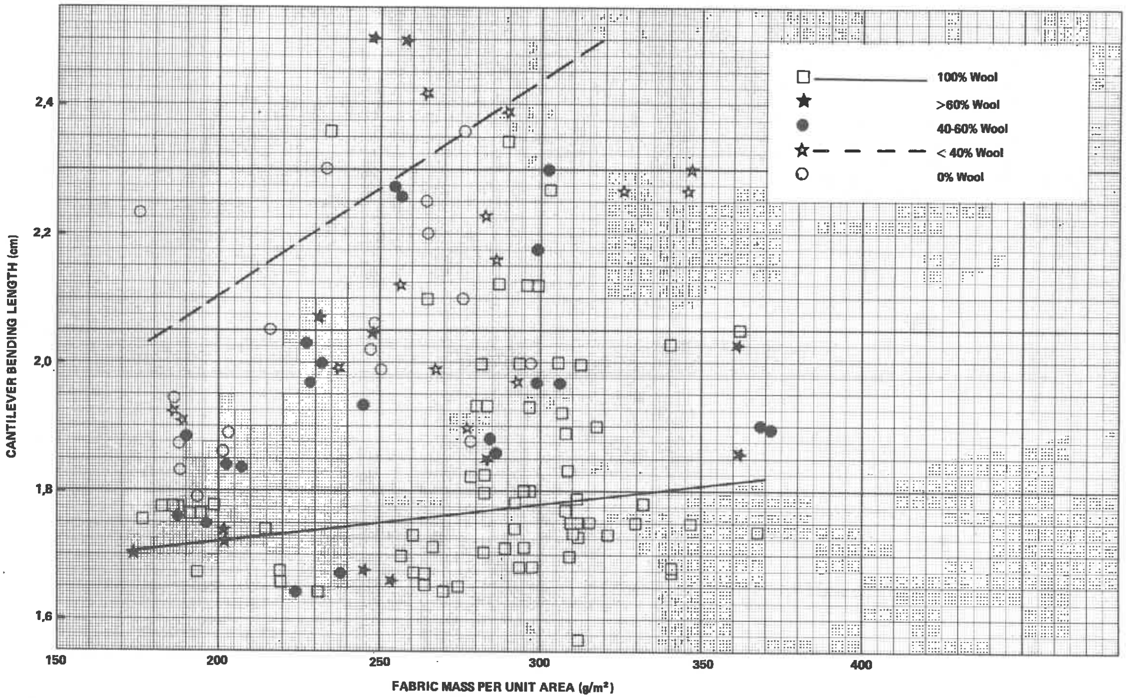

FIGURE 10
Cantilever bending length vs fabric mass per unit area

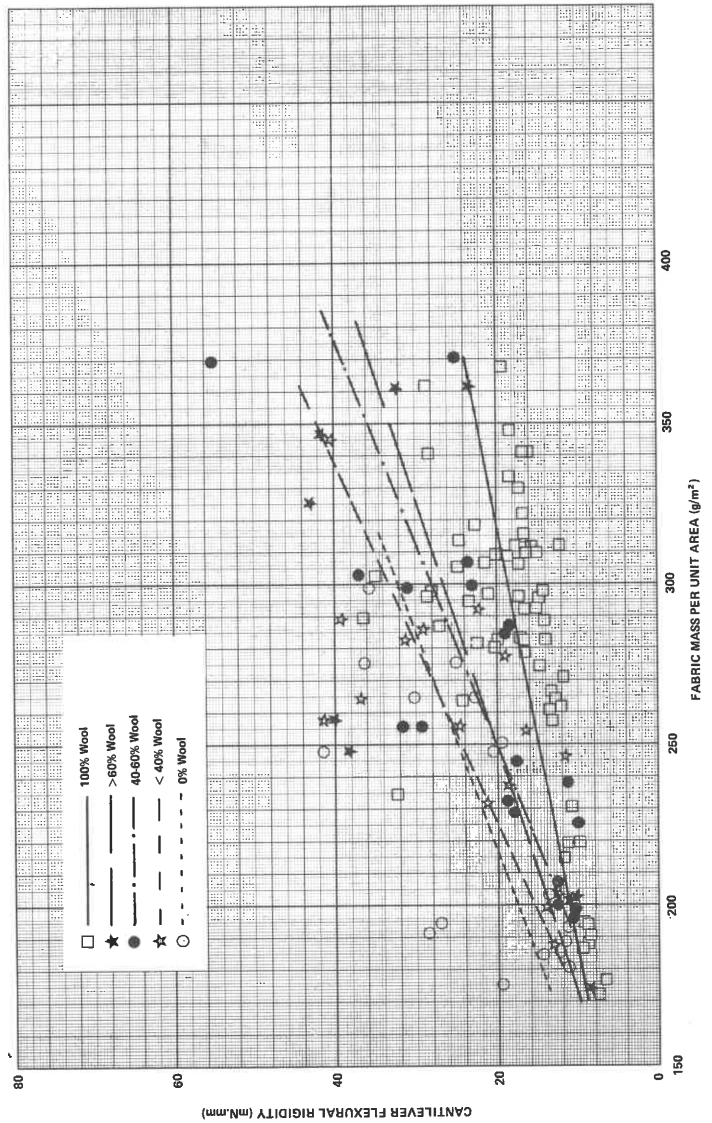

FIGURE 11

Cantilever flexural rigidity vs fabric mass per unit area

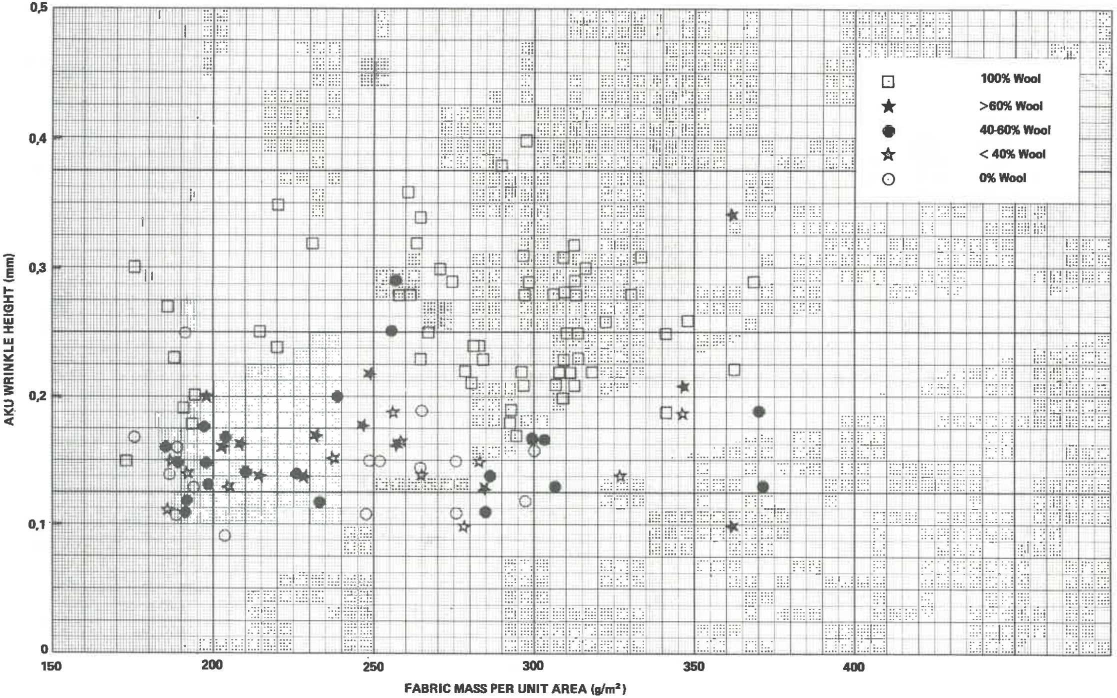

FIGURE 12

AKU wrinkle height vs fabric mass per unit area

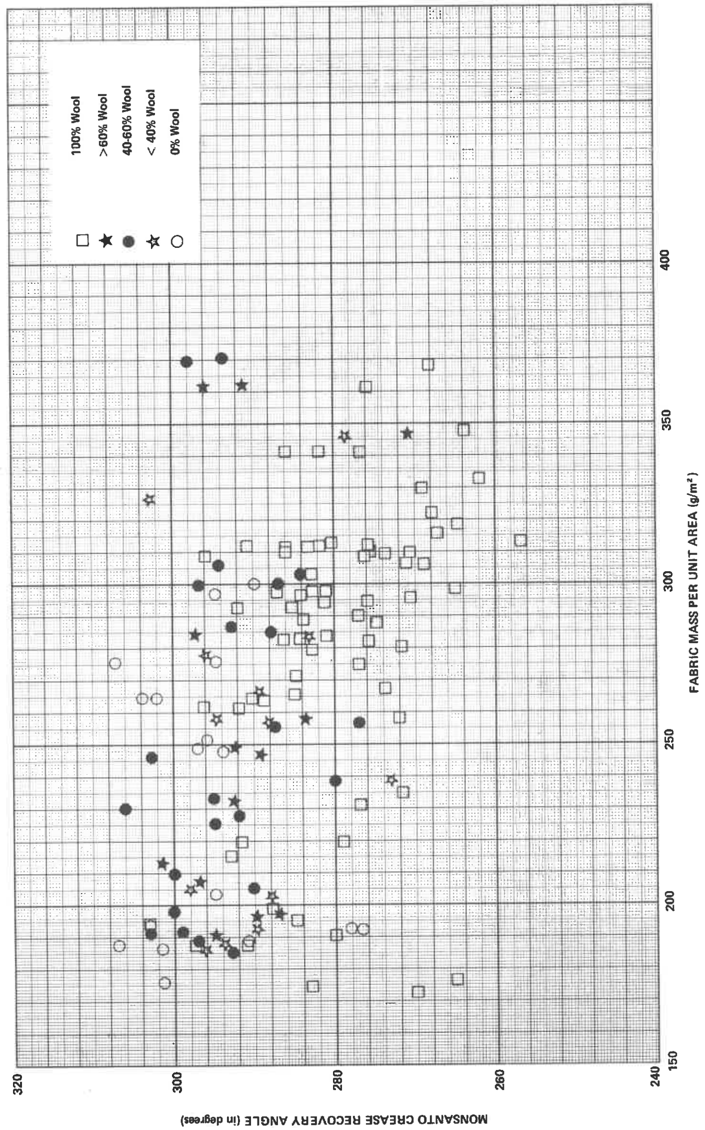

FIGURE 13

Monsanto crease recovery angle vs fabric mass per unit area