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is dependent on having detailed measurements on individual lots prior to amalgamation. This technology cannot be fully exploited until all of the important wool characteristics are measured.

SUMMARY

The most fundamental purpose of objective measurement is to make wool more competitive with other fibres. A detailed specification is an essential

requirement for successfully marketing any product. This is increasingly the case with textile fibres, as competitive synthetic fibres are fully specified.

Total wool testing costs in New Zealand are estimated at \$7 million. This represents less than 0.05% of raw wool exports or about 2 cents/kg. However, more than half of this is spent on moisture testing scoured wool. Additional tests such as length/strength, bulk and medullation are likely to add considerably to testing costs but are essential for complete specification.

Interpretation of objective measurements of wool by the manufacturer

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ABSTRACT

The importance of the objective measurement of 6 wool properties, namely mean fibre diameter, medullation, fibre length after carding, colour, bulk and vegetable matter content is discussed. The necessity of accounting for all these properties when determining wool price differentials or the suitability of a wool lot or blend for a particular end-use is emphasised. An assessment is made of the manufacturing consequences of unit changes in each property along with end-use suitability, based on textile technology knowledge. This is supported by prices for New Zealand wool, analysed with account taken of availability, end-use and textile properties.

INTRODUCTION

The desire of manufacturers for objective measurement of wool properties arises from a need to optimise the selection and blending of different wool types in order to improve the properties of the end-product, to ease the processing of raw material with natural variation and to lower overall costs. Manufacturers will interpret the various objective measurements on a basis of their knowledge of the influence that each wool property has on these factors.

The demand for objective measurements has been heightened in recent years by modernisation of processing plants and the growth of processing in areas of the world where there is a lack of personnel with traditional wool skills. However, what may prove to be a technological development which most influences the total acceptance and use by manufacturers of objective measurements is a wish to make use of computer applications which rely on the input of these measurements of wool properties, such as, for example, methods of optimising blending, wool purchases, and stock-holding (Carnaby *et al.*, 1985), computer simulation models of the manufacturing of wool yarns (Elliot, 1985a), and the computerised-dye-recipe prediction of colour (Nash, 1983).

At the present stage of development of measurement technology, greasy or scoured wool characteristics

are best appraised by a combination of objective and subjective methods, as internationally accepted test methods are not available for measuring all the characteristics considered of real technical significance (Andrews, 1983; Carnaby, 1985). However, the technology needed for a first-generation complete specification of New Zealand scoured blends is imminent (Carnaby, 1985; Simpson, 1986). Properties to be measured will include:

- (i) mean fibre diameter;
- (ii) medullated fibre content;
- (iii) 'length after carding';
- (iv) loose wool bulk;
- (v) colour; and
- (vi) vegetable matter (VM) content.

The specification of these 6 properties is necessary to meet the requirements set by computer blending technology (Carnaby, 1983) and has been shown to be both necessary and sufficient for woollen processing (Carnaby *et al.*, 1983a and 1983b). Of these, tests for 'length after carding' and 'loose wool bulk' will be new to the industry. Time will be needed for a wide appreciation of their relevance. The significance of colour tests is currently undergoing its apprenticeship with respect to use and appreciation by manufacturers.

The significance of objective measurement and

the importance of individual test results can be expected to vary among manufacturers. Obviously the interpretation of objective measurements varies in accordance with a manufacturer's experience in their use. But more importantly the interpretation and the significance of individual test results will vary according to a manufacturer's processing system (i.e., whether it is worsted, semi-worsted, or woollen), the end-product and the extent to which different lots of wool are blended prior to manufacture. Among the most obvious of examples, apparel v carpets, pastel v dark-colour dyeing and fine soft-handling fabric v coarse-bulky fabric will place varying demands on certain wool properties either singly or in combination and in addition will place restrictions with respect to upper or lower limits on which wools will be acceptable or unacceptable.

These factors lead to 3 important points which I wish to clarify in this paper. The first is that differences between manufacturers in their interpretation of objective measurements of wool properties make a mockery of attempts to place relative economic values on individual wool traits without qualification. It is wrong to expect that price will change in a linear manner over the full range of values possible for a single wool trait. This can best be illustrated by a look at the graph depicting price v fibre diameter (Fig. 1, 2). Technical reasons can be given for the changes in slope that occur, as will be discussed.

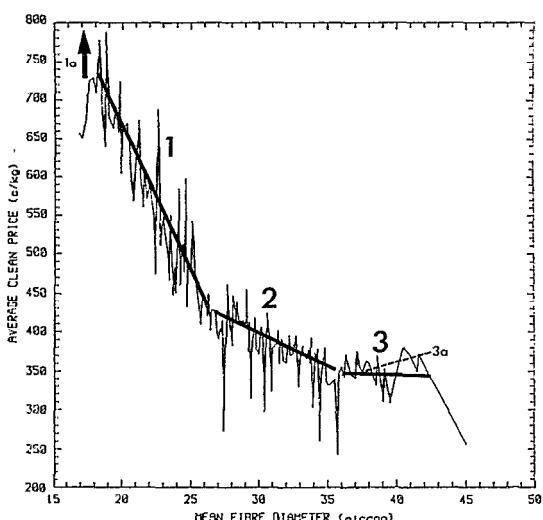


FIG. 2 Variation of price with fibre diameter. Source: based on Stanley-Boden (1985), p. 37.

A second point is that, when analysing a graph or table of wool trait v price, care must be taken in determining whether any premium or discount shown is solely due to that trait and is not being distorted by another trait. For example, across several breed-types

of wool, higher-bulk wools tend to be finer and hence an analysis of price premiums for bulk could be distorted by a premium for fineness.

Finally it must be remembered that a sale lot of wool has a collection of fibre properties all of which may be taken into account when a decision is made to purchase it. There is a possibility that though many of the property values are acceptable to a particular manufacturer, in some instances there need only be 1 which if unacceptable could exclude that wool from consideration and hence purchase. For example, take the requirements of a semi-worsted machine-knitwear yarn manufacturer. Specification for mean fibre diameter, length after carding, medullation, loose wool bulk, colour and VM content may be tight and if 1 property is not up to a certain standard (e.g. VM content is too high) then, although other properties are at a desirable level and a price premium could be expected (e.g. for high bulk), the wool would not be bought for that manufacturer and it might in fact be sold at a discounted price relative to a similar line not showing the VM fault. Similar situations could be found when analysing price premiums for colour and fluctuations along the price-diameter graph of Fig. 2 are in part due to this reason. Examples of this occurring would be more prevalent in worsted and the more sensitive semi-worsted yarn manufacturing where the blending of widely differing wools is practised less than in the woollen system.

On the other hand, where the blending of a large number of lots of differing wool types is practised, the property values of an individual wool lot—and in particular a fault—may be balanced (or compensated for) by the property values of other wool lots included in the blend being compiled. Price sensitivity analysis associated with linear programming of, for example, a 10% change in a property value above or below the blend specification for each trait then becomes an appropriate method of determining the market demand for each trait. The sensitivity of individual wool properties is likely to vary according to the various blend specifications set and according to the season and hence the pool or supply of wool (usually a particular auction sale) being analysed at any particular time.

In the remainder of this paper each of the above 6 wool properties will be examined with attention on the technical justification for price differences. This discussion will be supported by results from 2 recently published theses. The first is an analysis of the price and availability of New Zealand wools according to their technical properties (Stanley-Boden, 1985). This thesis is unique and quite superior to past attempts at analysing wool prices in that models were developed to analyse the variation in wool prices in terms of end-product and process suitability. Values for the 6 main wool properties were estimated by a WRONZ developed computer program, CONVERT (Carnaby *et al.*, 1983a).

This program is dependent on derived relationships between the New Zealand Wool Board's subjectively assessed Wool Type Code and objective measures of each property.

The second thesis releases data derived from a computer simulation model of the manufacture of semi-worsted yarns (Elliott, 1985a). The model can be used to determine the technical consequences of variation in the properties of a scoured wool blend and so gives a better appreciation of the degree of difference in a particular trait that is required to cause a practically significant difference in yarn properties or processing efficiency parameters.

FIBRE DIAMETER

While it is generally accepted that the mean fibre diameter is the most important wool characteristic from the point of view of quality and commercial value, this importance varies depending on the actual fibre diameter. Fig. 2 indicates 3 distinct regions:

1. less than 26 microns;
2. between 26 and 35 microns; and
3. greater than 35 microns.

Two departures (arrow 1a and the dotted line 3a) have been included to indicate prices for superfine wool and lustre wools respectively.

The importance of fibre diameter arises mainly from its effect on the spinning performance and the handle of fabrics, finer wools enabling a better spinning performance to be achieved and imparting a softness of handle.

TABLE 1 Price premiums for increased length after carding.‡

Demand set*	Regression coefficient (/10mm barbe length)	Premium§ (c/kg clean/10mm barbe)
Woollen carpets	+ 0.0536	26.8
Woollen carpets worsteds handknitting and upholstery	+ 0.0730	36.5
Woollen carpets and woollen woven	+ 0.1050	52.5

* as defined by Stanley-Boden (1985)

§ premium price = regression coefficient x clean wool market indicator

‡ clean wool market indicator of 500 c used

A wool's spinning performance determines what is commonly recognised in the trade as the 'spinning limit'—the lowest linear density to which a yarn can be spun while maintaining an acceptable value for the

number of 'ends-down' or breakages during spinning. As ends-down increases, the yarn yield decreases owing to wastage of wool. But more importantly either labour units to 'piece-in' the broken ends must be increased or spindle speeds decreased, or both. A commercially acceptable optimum spinning speed is a high priority. The spinning limit is mainly, although not entirely, a function of the number of fibres in the yarn cross-section, with the number of end-breakages generally increasing approximately exponentially as the number of fibres decreases (Hunter, 1980). For economical spinning of fine worsted yarns the spinning limit is considered to lie at 40 to 55 fibres in the yarn cross-section, increasing to something like 120 fibres for woollen-spun yarns. Obviously the fewer fibres in the yarn cross-section the finer will be the yarn given constant fibre properties and a similar yarn twist value. But more importantly, when spinning near the limit the finer the wool the finer will be the yarn that can be spun.

In addition, the spinning performance will determine the 'yarn irregularity' which is a measure of the variation of thickness from place to place along the length of the yarn, and with this an associated variation in strength or incidence of weak places along the length of the yarn. Irregularity in thickness is of concern because of the possibility of causing unwanted blemishes and stripes in woven cloth and knitted fabrics, whereas irregularity in strength is of concern because of its influence on the yarn's breaking load and extensibility and hence its ability to withstand the tensions imposed during weaving, knitting, or the tufting of carpets. Again these are commercially very important properties.

A more regular yarn can be spun if the number of fibres in its cross-section is increased but obviously a thicker yarn will result. Increasing the twist will improve the spinning performance and slightly decrease the yarn thickness but a harder-handling yarn will result. Trade-offs are inevitable.

Price is most sensitive to changes in fibre diameter for wools of less than 26 microns (i.e. within region 1 of Fig. 2). Each unit micron decrease is of substantial value. This region relates to the use of Merino, New Zealand halfbred, and fine Corriedale wools and some Romcross lambswool. Such wools are used for making fine knitwear and woven cloth from finely spun worsted and woollen yarns. The highest quality fine soft-handling apparel fabrics require fine yarns which are free from blemishes and which process with a low incidence of breakages during weaving or knitting. The general rule to follow is that the finer the fibre diameter the greater the flexibility to produce a higher quality of fabric, provided (and this is important) length requirements are met and other quality parameters such as colour and vegetable matter content do not have a deleterious effect. Prices will be sensitive to faults in the wool. Wools will be priced accordingly within region 1, with superfine wool accentuating the softness-of-handle property of the end-product.

For wools in the 26 to 35 micron range (region 2 of Fig. 2) the importance of fineness and hence the price sensitivity is greatly reduced. These wools are used for making medium to heavy worsted fabrics, machine- and hand-knitting yarns, upholstery fabrics and blankets. A considerable quantity of wools greater than 30 micron, especially those having faults such as discolouration and unsoundness, may be used as 'fillers' in carpet blends. Wools in this region will be processed via the worsted, woollen and semi-worsted systems. Fibre diameter is of less importance to the manufacturer for 3 main reasons:

- while a softer handle is sought, it is generally accepted that these end products will not require the softness of handle associated with products made from wools of less than 26 microns;
- in the main, spinners will be spinning these wools at well above the spinning limit and fineness of yarn will not usually be a high priority; some attempts will obviously be made to manufacture finer yarns and spinning-limit considerations will then apply; and
- the carpet industry sets a lower limit on prices as poorer wools can be used to good effect in blends.

The manufacturer still needs to consider the effect of increasing ends-down and yarn irregularity and decreasing breaking load. These effects are illustrated in Fig. 3 for a 160 tex, medium-twist (158 tpm) semi-worsted yarn.

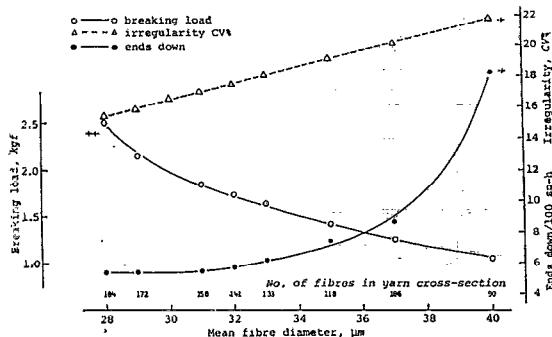


FIG. 3 The consequences of variation in mean fibre diameter on ends down, yarn irregularity, and yarn breaking load. Source: Based on Elliott (1985a), p. 248.

Finally, in region 3 for wools of greater than 35 microns, considerations of fibre fineness with respect to spinning limits and softness of handle no longer apply. Essentially these wools are being used by the carpet industry and in upholstery fabrics after having been spun to coarse yarns well above spinning-limit considerations. Extensive processing trials with Romcross wools and blends designed to determine the effect of fibre diameter on the production and properties of tufted carpets and woven upholstery fabrics have shown little or no difference between processing lines

ranging from 30 to 40 microns in mean fibre diameter (Ross *et al.*, 1980). In this region the mean fibre diameter will be of little concern to the manufacturer, apart from perhaps indicating that a greater fibre diameter may be associated with the harsher handle desired in some carpets, and with stronger wools giving a greater length after carding.

MEDULLATION

Depending on their content in a blend, medullated fibres affect the dyed appearance of wool as well as causing yarns and ultimately the end-products to have a crisp (as opposed to soft) handle and a distinctly hairy or rough appearance. Because they take dyes poorly, kemp fibres, which are grossly medullated and usually associated with highly medullated wools, accentuate the above medullation effects. The presence and effect of medullation may be viewed as either desirable or undesirable, depending on the end-product.

While a standard test method using a projection microscope does exist for measuring the extent to which a wool lot may be medullated, it is seldom used in practice. Manufacturers currently rely on the subjective assessment and goodwill of their supplier and of those making up a blend to keep it either essentially free of medullated fibres (e.g. for apparel manufacturers) or to keep the extend of medullated fibres within fairly broad tolerances (e.g. for carpet manufacturers).

In carpet blends, where medullation is often desirable to impart an acceptable crisp handle and improve carpet appearance properties, the heavily medullated traditional carpet wool types such as Drysdale or Scottish Blackface wool will be specified by grade and breed-type name as a percentage component in the blend. The less obviously medullated cross-bred crutchings can be similarly specified.

In an early experiment with apparel end-products Townend and McMahon (1944) reported an inability to determine a processing difference of any significance between Romney fleece wools with clearly visible hairiness and those free from hairiness. However, where hairiness is visibly present the dyed appearance and handle of woven or knitted fabrics will be noticeably affected and inferior to those of medullation-free garments. Manufacturers processing Romcross wools accept that a proportion of medullated fibres will be present and rely on keeping these in check by specifying the mean fibre diameter and by instructions to woolbuyers.

It would be fair to say that most manufacturers, if presented with objective measures of medullation content, would be unfamiliar with the processing consequences of such test results apart from recognising the effects of obvious differences. Differences between medullation contents of $< 1\%$, 5% and $> 10\%$ by area of medullated fibre should be appreciated, particularly if accompanied by a fibre diameter distribution test

result indicating the percentage of kemp or heavily medullated fibres present. Subtle differences between these values would probably be difficult to detect and hence their consequences would be difficult to forecast. However, experience with computer-blending technology is now indicating that as familiarity is being obtained some carpet manufacturers are refining their original medullation specifications and it seems certain that the existing projection microscope test will form 1 of the 6 key tests in the first-generation system for scoured wool specification. However, in the longer term a better test will be needed.

LENGTH AFTER CARDING

The mean fibre length after carding is important to the yarn manufacturer because it has a determining influence on the ends-down during spinning and as a consequence influences yarn yields and the optimum spinning speed. In addition it has an important influence on yarn irregularity, strength and extensibility and as a consequence on subsequent processing efficiency parameters such as rates of yarn breakages during tufting and weaving.

In the processing of wool, by far the major proportion of fibre breakage occurs during carding and the extent of it is quite considerable. Resulting decreases in mean fibre length in the region of 20 to 50% are common. The extent of breakage will depend on the original fibre length; longer fibres generally suffer more breakage and are thus affected more than shorter fibres. In addition, the strength of individual fibres and the degree of fibre entanglement of scoured wool will affect the extent of breakage. The degree of entanglement of scoured wool will be influenced by the cottedness of greasy wool and its propensity to felt during scouring, properties for which New Zealand wools show considerable variation (Elliott and Lohrey, 1983). Considerable quantities of New Zealand wools show a seasonal fleece tenderness (Bigham *et al.*, 1983b) and the varying position of a 'break' along the staples will also influence the extent of fibre breakage and the fibre length after carding.

Those known interacting factors were in part behind the decision of WRONZ to develop a test for the length after carding of scoured wool, based on a card, gill, Almeter test. The Almeter is an internationally accepted standard test instrument for measuring the mean fibre length of combed wool tops. In addition to a mean length, valuable information may be obtained from an Almeter test on the distribution of fibre lengths, in particular, the proportions of short and long fibres.

In the analysis of variation in price with an estimated fibre length after carding Stanley-Boden's (1985) graph (Fig. 4) shows that at any fibre length after carding there are high and low valued uses depending on associated fibre characteristics such as,

for example (and in particular), fibre fineness, colour and VM content. This graph emphasises the need to consider price in terms of processing system and end-use product. When Stanley-Boden did this, price premiums for increased length after carding were always evident although, as the multiple regression coefficients in Table 1 indicate, these varied according

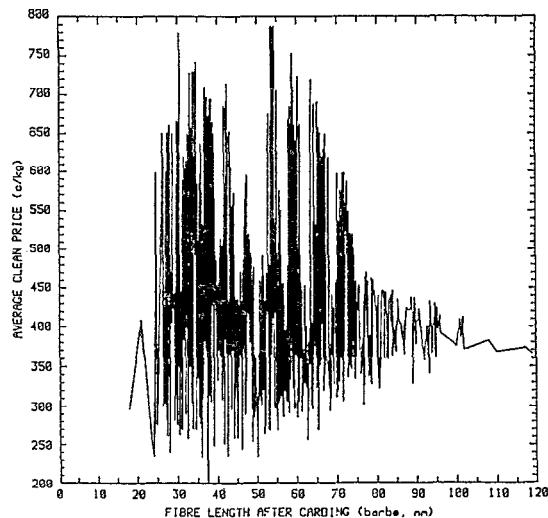


FIG. 4 Variation of price with fibre length after carding.
Source: Stanley-Boden (1985), p. 39.

to the particular wool demand set analysed. Three have been shown for a Christchurch wool sale. Their values, ranging from 26.8 c/kg to 52.5 c/kg / 10mm increase in length after carding, reflect the increasing importance of length as a move is made from less to more length-sensitive end-products.

In his review, Hunter (1980) points out the particular importance that length has in relation to price when it implies a change in the processing system. Semi-worsted processing is particularly sensitive to length. The reasons for the tight greasy wool specifications of sound, freely opening wools of 100 to 120 mm with a minimum length of at least 70 mm can be deduced from Fig. 5. It can be seen that there is a critical length after carding below which spinning performance greatly deteriorates. Manufacturers are aware of this.

Because of the importance to the spinner of length after carding, the use of an Almeter test or similar post-carding fibre length distribution measurements has been essential for quality control for many years within industry and research alike. Manufacturers know how to interpret the results for their particular products. As a consequence, there should be few difficulties with interpretation by manufacturers of the results from the WRONZ length after carding test for scoured wool when this becomes a standard test.

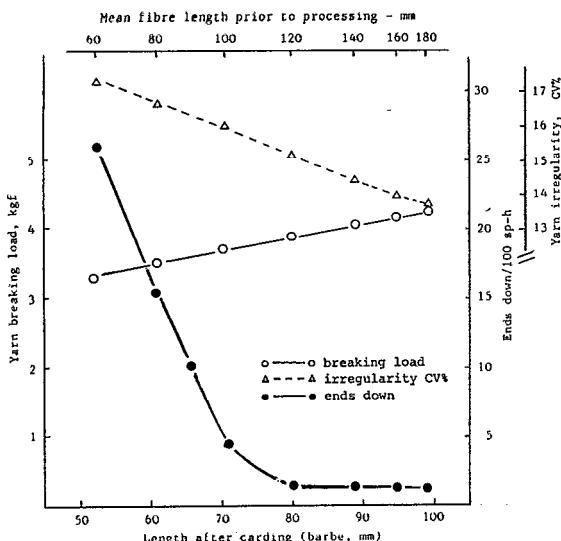


FIG. 5 The consequences of length after carding on ends down, yarn irregularity, and yarn breaking load. Source: Simulated results using the model of Elliott (1985a).

LOOSE WOOL BULK

During the last 10 years WRONZ has conducted research on the wool property, bulk, which is traditionally associated with wool's springiness, 'loftiness' and 'filling power'. This property is of primary interest to the carpet industry where wools with higher loose wool bulk result in bulkier yarns and carpets with increased cover and knitwear where bulky yarns are essential for obtaining lightweight garments offering maximum insulation and better wear performance.

The early work at WRONZ was based on a laboratory bulk test using full length samples (as opposed to cores) of wool which were carefully prepared by washing and hand-carding before being measured in a hand-operated bulkometer. Extensive trial work with this test method established the variability in bulk between and within recognised breed wool types (Elliott, 1981) and the processing effects which this variability had on the properties of carpets and knitwear (Elliott and Carnaby, 1980; Elliott, 1982a; Carnaby *et al.*, 1984). Subsequent work has illustrated an association between loose wool bulk and the felting propensity of wools (Elliott and Lohrey, 1983), and an ability of loose-wool-bulk measurements to rank wools for lustre (Elliott, 1986a). The measurement of loose wool bulk has become an integral part of quality control testing for WRONZ and mill processing studies (e.g. Wood and Carnaby, 1982; Wood, 1983) as well as a blend specification property associated with mill usage of computer blend technology (Carnaby *et al.*, 1983b).

Typical loose-wool-bulk values for New Zealand fleece wools are shown in Table 2. Some exceptions are likely to be found, a notable one being that crossbred crutchings may have loose-wool-bulk values in the vicinity of 27 cm³/g.

TABLE 2 Bulk values for New Zealand wools.

Wool type	Breed	Bulk (cm ³ /g)
Lustre	Leicester/Lincoln	16-19
Strong-medium		
Crossbred	Romney/Coopworth	19-24
Medullated	Drysdale	21-25
Medium-fine crossbred	Perendale	22-32
Medium wool	Corriedale/Halfbred	22-33
Fine wool	Merino	23-33
Crimpy	Down/Cheviot	30-36

Stanley-Boden's (1985) graph of variation of price with estimated bulk value (Fig. 6) illustrates a number of features concerning the probable interpretation by manufacturers of the consequences of bulk. For this paper they have been labelled as Regions 1 to 6. Probable interpretations are as follows:

- (i) in region 1 (~20 cm³/g) the average prices indicate a small premium for lower bulk, reflecting the higher prices are obtained for lustrous wools;
- (ii) Region 2 (~20 to 25 cm³/g) shows a constant average price for low-bulk wools indicating that within this region the differences in bulk values are probably only a secondary consideration for the majority of manufacturers;
- (iii) Region 3 (25 to 28 cm³/g) indicates where a price premium for increased bulk may occur as a consequence of moving into a bulk value sought by the semi-worsted knitwear trade or as a higher-bulk blend component for carpets; it can be expected that the steepness of this apparent price-premium graph is being overly exaggerated by an associated premium for finer Corriedale and halfbred wools;
- (iv) Region 4 probably reflects low prices paid for bulky crossbred crutchings used as filler wools in carpet blends;
- (v) Region 5 appears to be due to higher-priced Merino wools having these high bulk values, and as a consequence it is not likely to be a reflection of a demand for bulk per se, but rather one for fineness; and
- (vi) Region 6 shows a premium for the very high-bulk Down-type/Cheviot wools used in wool-filled quilted products; high-bulk and, as a

consequence, a high fibre crimp frequency is an essential property for these products where maintenance of an initial loftiness is sought together with a resistance to felting and fibre migration which lead to matting-down and lumpiness of the fill material; these wools are also used in specialist knitwear and tweeds where bulkiness is sought.

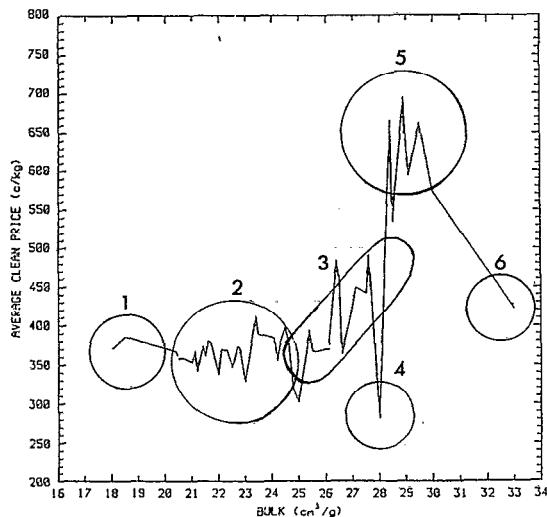


FIG. 6 Variation of price with loose wool bulk. Source: Based on Stanley-Boden (1985), p. 44.

Breaking the bulk \times price graph into regions demonstrates the care that is required to have price data on wools analysed with attention focused on technical considerations. By limiting an analysis to within the 25 to 30 cm³/g region and to wools which would not be discounted because of poor colour, VM content and tenderness, Elliott (1984) was able to demonstrate a premium for Perendale wools with increased fineness, staple length and bulk. It was concluded that the premium probably reflected their suitability for manufacture into knitwear.

The technical desirability of using higher-bulk wools to increase yarn bulk has been demonstrated by the work of Elliott and Carnaby (1980) and Elliott (1982a). Their results are combined in one graph and presented here as Fig. 7 which illustrates 2 important points:

1. The loose wool bulk-yarn relationship is dependent on the processing system, yarn twist and linear density. Improvement in the loose wool bulk is more conducive to increasing yarn bulk within semi-worsted-spun compared with woollen-spun yarns and in yarns with low twist, particularly when combined with a low linear density and hence a low twist factor, compared with high-twist yarns. It can be shown (Elliott, 1986a) that a large change

in twist level can have an effect which completely overrides the effect of the variability in loose wool bulk. The attention given to the loose wool bulk value of a blend will depend very much on the manufacturer's end-product.

2. For the yarn types illustrated here, typical of those for carpet or bulky knitwear, it can be expected that a difference of at least 1.0 cm³/g in yarn bulk is required for it to be of processing significance. In these yarns, which have been spun at favourable twist-factors to be responsive to improvements in loose wool bulk, an improvement of at least 2 to 3 cm³/g in loose wool bulk is actually required. By calculation it can be shown that quite dramatic changes in one or more blend components are required before a change of any consequence occurs.

Manufacturers will also be aware that changing the loose wool bulk value of a blend has other effects on yarn and end-product appearance properties as well as on processing efficiency (Elliott *et al.*, 1986). These are a direct influence of fibre crimp effects, e.g. on yarn tensile properties and pilling propensity. However, quite considerable changes in bulk values would need to occur for either of these departures in yarn properties to be of practical importance. The manufacturer will be aware of these effects and will be refining his yarn twist and linear density values in accordance with the blend chosen and his particular end-product.

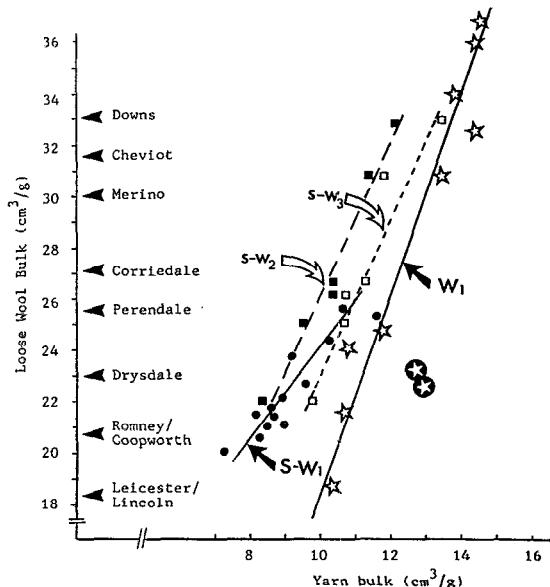


FIG. 7 Typical breed-type loose wool bulk values and their effect on yarn bulk. Source: W1 woollen yarn, S-W1 semi-worsted yarn (Elliott and Carnaby, 1980); S-W2 semi-worsted carpet yarn; S-W3 semi-worsted knitting yarn (Elliott, 1982a).

COLOUR

A knowledge of the 'base' colour of wool is of importance to the manufacturer as it affects the ultimate dyed colour. With a multitude of dyestuffs and thousands of dyeing recipes and colour shades available to the dyer, the manufacturer today is meticulous with respect to consistency and repetitiveness of batch-to-batch dyeings.

The standard test method for the objective measurement of wool colour uses a colorimeter to measure the amount of light reflected in 3 wavelength bands of a spectrophotometric curve (Hammersley and Elliott, 1983). The readings are known as 'tristimulus values' and are represented by X, Y and Z figures. Some typical values for scoured New Zealand fleece wools are shown in Table 3.

Technically all 3 values are required for a full appreciation of colour and it is not possible to combine them into a single index for colour. However, a sufficient description may be obtained by using Y as a measure of brightness and Y-Z as a measure of yellowness. Very good-coloured wools are generally both white and bright while inferior wools are yellow and dull.

It can be thought incorrectly that wools vary in yellowness alone, but considerable variations in brightness can occur for wools with the same X-Z yellowness reading. This can be seen in Fig. 8 which gives a plot of Y tristimulus values against the corresponding Y-Z tristimulus values obtained from more than 500 scoured New Zealand wool samples (Elliott, 1985a); it illustrates the typical range of values for New Zealand wools.

is desired to dye wool to a colour for which one or more of the tristimulus values would be higher than the present value, this will be impossible and hence the wool must be excluded from consideration. Pastel colours with their high post-dyeing tristimulus values are the most challenging in this respect.

The degrading effects of wet processes involving heat, such as steaming and overdrying, in terms of wool yellowing and dulling have long been appreciated by the trade. A question not yet answered by research is 'do wools vary in their susceptibility to further discolouration?' A preliminary investigation (Hammersley and Elliott, 1983) of the response to a blank-dyeing

TABLE 3 Typical tristimulus values for scoured wools.

Colour	Tristimulus value			
	X	Y†	Z	Y-Z*
Very good	64.5	65.0	64.0	1.0
Good	61.5	62.5	60.0	2.5
Average	58.5	60.0	56.0	4.0
Poor	56.0	57.5	51.5	6.0
Inferior	52.0	54.0	46.5	7.5

† an indication of brightness

* an indication of yellowness

treatment on New Zealand wools varying widely in colour has indicated that while the 'base' colour may become appreciably yellower and duller, in general the ranking of the wools is not likely to be changed significantly. The importance of this result, if it can be shown to be consistent on examination of a large number of wools, is that the processor may have confidence that differences in the colour of scoured wools will have a direct bearing on the shade of the dyed end-product.

Based on the repeatability results presented by Hammersley and Elliott (1983) and a study of the visual perception of the colour of scoured wool by Thompson and Whiteley (1981), it appears safe to assume that the differences in the tristimulus values shown above for each category of wool designated 'very good' to 'inferior' are sufficient to be of practical significance to a manufacturer sensitive to wool colour differences. Price differentials should therefore be apparent. The importance of the differences will depend on the manufacturer's end-product and its sensitivity to variations in the base colour of wool. Obviously the lighter pastel shades and those colours most sensitive to wool yellowness, such as blues and greys, will be most affected. Plain-shade carpets and fine apparel cloth which are sensitive to inconsistency in colour will cause a preference for higher tristimulus values in the hope of avoiding unsavourable yellow

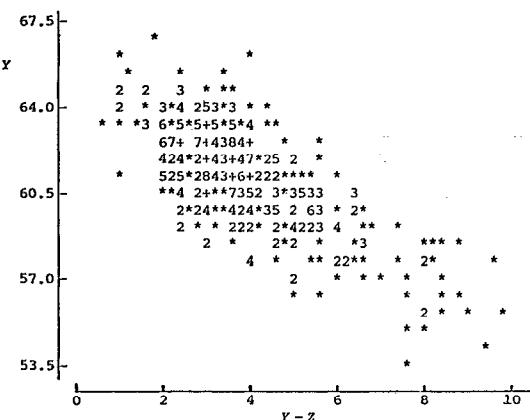


FIG. 8 Plot of Y tristimulus values against Y-Z tristimulus values obtained from scoured New Zealand wool samples. Source: Elliott (1985a), p. 70.

It is important to appreciate that tristimulus values for scoured wool represent the best colour of a given lot of wool and that any dyeing or other chemical treatment (with the exception of bleaching) will lead to lower tristimulus values. A corollary to this is that if it