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# THE CARDING AND COMBING OF WOOLS OF DIFFERENT FIBRE LENGTHS

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# THE CARDING AND COMBING OF WOOLS OF DIFFERENT FIBRE LENGTHS

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## ABSTRACT

*The processing performance of six lots of 64's Merino wool of similar style and character, differing only in mean fibre length was investigated. Fibre breakage in carding increased approximately linearly with an increase in fibre length. More open carding settings resulted in more efficient processing. Amount of noil obtained and mean fibre lengths (m.f.l.'s) of the tops showed that considerable losses in fibre length are encountered during the processing of long fibres due to breakage in carding.*

## KEY WORDS

Carding – Combing – fibre lengths – neps – percentage noil – fibre breakage.

## INTRODUCTION

When processing wools with different characteristics it is always difficult to predict the processing performance. This is due to the many variable factors involved in the conversion of raw wool to tops and the considerable fibre breakage which takes place at the various stages of processing. The reduction in fibre length during carding and combing is considerable and the degree to which this occurs may well depend upon the characteristics of the wool itself. Ross *et al*[1] showed that a reduction in staple strength of coarse wools resulted in a lower tear during Noble combing due to more fibre breakage in carding and combing. The same authors subsequently reported similar observations for finer wools[2].

Fibre breakage during carding was studied by Townend and Spiegel[3], but they mainly considered factors of a mechanical nature and did not compare different wools. During a study on carding, Bownass[4] compared the processing of different wools, but the characteristics of the wools used were not the same and it was, therefore, not possible to compare fibre breakage and m.f.l. Indications are, however, that higher amounts of breakage were obtained for longer wools. He obtained very little breakage in Noble combing and no trend, as far as m.f.l. is concerned, was observed. Bacon-Hall *et al*[5] investigated the processing performance of wool from different breeds of sheep. They observed that despite large differences in the mean fibre length of the raw wool, carding tended to bring the m.f.l. of the top within a narrow range. Dyson and Happey[6] reported an increase in fibre breakage on the Noble comb for an increase in fibre length.

Anderson[7] showed that a hypothesis of length-biassed breakage lead to much better agreement with the measured fibre length distributions than a hypothesis of constant probability of breakage.

This paper describes the study of the processing performance of wools which differed in m.f.l., but which otherwise possess almost identical characteristics.

## EXPERIMENTAL

### Raw Materials

In these experiments six lots of 64's Merino wool from the same area in the Southern Free State of South Africa were used. The lots varied in length from 6/8 months to 12 months but otherwise were of similar style (good Topmaker's/Spin-

TABLE I

RAW WOOL CHARACTERISTICS

| LOT | FIBRE LENGTH | |
|---|---|---|
| | m.f.l. (cm) | C. of V. (%) |
| 6/8 | 4.89 | 30.0 |
| 7/9 | 5.73 | 31.7 |
| 8/10 | 6.47 | 35.4 |
| 9/11 | 7.01 | 31.2 |
| 10/12 | 8.24 | 32.4 |
| 12 | 10.83 | 24.7 |

TABLE II

SCOURED WOOL CHARACTERISTICS

| LOT | FIBRE DIAMETER | | YIELD AFTER SCOURING (%) | ETHER EXTRACTIBLE MATTER (%) |
|---|---|---|---|---|
| | m.f.d. ($\mu$) | C. of V. (%) | | |
| 6/8 | 20.2 | 24.1 | 62.1 | 0.65 |
| 7/9 | 22.6 | 20.9 | 58.4 | 0.51 |
| 8/10 | 21.8 | 22.2 | 62.2 | 0.56 |
| 9/11 | 22.7 | 20.5 | 62.0 | 0.54 |
| 10/12 | 21.5 | 21.3 | 61.5 | 0.57 |
| 12 | 22.7 | 22.6 | 53.3 | 0.58 |

## TABLE III

## SWIFT/WORKER SETTINGS USED IN CARDING (B.W.G.)

| SETTING | LOT AND SUBLOT | FIRST SWIFT WORKER 1 2 3 4 | SECOND SWIFT WORKER 1 2 3 4 |
|---|---|---|---|
| OPEN | 6/8 0 to 12 0 | 12 14 16 18 | 20 22 24 26 |
| MEDIUM | 6/8 M to 12 M | 14 16 18 20 | 22 24 26 28 |
| CLOSE | 6/8 C to 12 C | 16 18 20 22 | 24 26 28 30 |

ner's, nearly free of vegetable matter) except for the 6/8 months wool which was finer than the other lots. For reference purposes these lots are designated as 6/8, 7/9, 8/10, 9/11, 10/12 and 12.

The wools were specially selected by the authors with the cooperation of a local wool broker, and each lot was subsequently sorted and blended at SAWTRI to ensure uniformity in each group.

The m.f.l. and percentage coefficient of variation (C.V.) of fibre length of the raw wool are given in Table I.

### Scouring

All six lots were scoured under identical conditions on a rake type four bowl Petrie and McNaught pilot plant, using nonionic detergent in alkaline medium. A residual grease content varying from 0.5 to 0.65% for the different lots was obtained (see Table II).

The temperatures of the successive bowls were 55°, 55°, 50°and 40°C respectively. The temperature of the Fleissner drier was maintained at 70 – 75°C resulting in a regain of about 15% of the scoured wool. The scouring yields of the different lots are given in Table II.

### Carding

Each lot was carefully blended after scouring and sufficient wool carded at each setting so as to carry out the subsequent experiments on the rectilinear and Noble combs.

Prior to carding the regain of each lot was raised to 20% and 1% Eutectal (0.3% ether extractible matter) was added.

Carding was carried out on a 60" wide two-swift Italian F.O.R. Biella worsted card (4 workers on each swift) with flexible card clothing. The wool was delivered in ball form at a rate of 40 lbs/hr and at a swift speed of 82 r.p.m.

**Open, medium** and **close** worker settings were used on the first and second swifts for each length group (Table III). The settings on the forepart of the card remained constant throughout the investigation.

As the 6/8 months wool was significantly finer than any of the other lots and also contained a higher percentage ether extractible matter, it did not completely conform with the characteristics of the other lots. Therefore it was not included in the results on fibre breakage and nep formation in carding. It was nevertheless included for the experiments on the rectilinear comb.

## Gilling

All lots were gilled three times on a Schlumberger intersector gillbox having a pin density 16 p.p.i. Doublings and drafts at each gilling were identical for each lot and 0.2% Lissapol NX was added at the first gilling.

## Combing

The six lots, each carded at three different card settings, were combed on a St. Andrea Novara rectilinear comb. At least three different gauge settings were used together with an optimum gill feed for each lot. Fourteen slivers of 17.4 ktex (2.8 oz per 5 yds) each were fed into the comb, giving a total input of 243 ktex.

Noble combing, using a Mark VI comb, was performed on lots 9/11, 10/12 and 12 months. These lots, however, were only carded at **medium** card settings. The punch ball sliver weight was 46.5 ktex (7.5 oz per 5 yds) in each case, and the circle pin densities were 42 and 46 p.p.i. for the large and small circles respectively.

## Testing

Ether extractible matter was measured using the rapid Column- and-Tray method.

The microscope technique was used for all mean fibre diameter (m.f.d.) measurements.

All m.f.l. measurements on wool before carding and before combing were carried out on the W.I.R.A. Single Fibre Length machine, and m.f.l. measurements on tops were carried out on the new SAWTRI Fibre Length Tester[8] as well as on the abovementioned W.I.R.A. fibre length machine.

Fibre breakage during carding was calculated from the following formula:

$$\% \text{ Fibre breakage} = \frac{L_1 - L_2}{L_2} \times 100$$

where $L_1$ = m.f.l. of the scoured wool
$L_2$ = m.f.l. of the card sliver

Neps were counted visually by examining small tufts of fibres withdrawn until a total of 10 g of sliver had been examined. This was repeated three times for each sliver and the average of the three readings taken. All fibre clusters which could not disentangle during the withdrawal of the tuft were counted as neps. The neps were arbitrarily classified as "large" and "small" according to an internal standard.

**TABLE IV**

**CHARACTERISTICS OF CARD SLIVER USED IN EXPERIMENTS ON THE RECTILINEAR COMB**

**(Carded at open (o), medium (m) and close (c) settings)**

| LOT | | FIBRE LENGTH (cm) AFTER 3RD GILLING | | FIBRE DIAMETER | | Neps per Gram small/ large | Ether extractible matter (%) |
|---|---|---|---|---|---|---|---|
| | | m.f.l. (cm) | C. of V. (%) | m.f.d. ($\mu$) | C. of V. (%) | | |
| 6/8 | O | 4.05 | 36.5 | 20.2 | 24.0 | 75/9 | 1.42 |
| | M | 3.90 | 38.9 | 19.9 | 24.5 | 124/17 | 1.47 |
| | C | 3.72 | 41.5 | 19.9 | 24.0 | 87/17 | 1.59 |
| 7/9 | O | 4.87 | 42.3 | 22.6 | 22.1 | 36/5 | 0.57 |
| | M | 4.76 | 43.9 | 22.0 | 21.1 | 55/8 | 0.58 |
| | C | 4.56 | 43.5 | 22.1 | 22.3 | 54/8 | 0.59 |
| 8/10 | O | 5.46 | 37.5 | 21.9 | 21.5 | 87/14 | 0.76 |
| | M | 5.09 | 45.7 | 21.0 | 21.2 | 113/18 | 0.78 |
| | C | 4.97 | 43.7 | 21.5 | 22.3 | 60/7 | 0.78 |
| 9/11 | O | 5.71 | 40.4 | 22.5 | 20.8 | 68/8 | 0.67 |
| | M | 5.51 | 42.8 | 22.8 | 20.9 | 85/13 | 0.75 |
| | C | 5.65 | 41.3 | 22.2 | 21.4 | 50/3 | 0.78 |
| 10/12 | O | 6.45 | 41.9 | 22.1 | 21.5 | 85/16 | 0.73 |
| | M | 6.28 | 42.7 | 22.8 | 21.5 | 58/9 | 0.72 |
| | C | 5.85 | 48.2 | 22.0 | 21.1 | 89/13 | 0.80 |
| 12 | O | 7.53 | 50.3 | 22.7 | 19.3 | 96/17 | 1.05 |
| | M | 7.52 | 49.6 | 22.3 | 20.5 | 81/15 | 0.96 |
| | C | 7.45 | 47.6 | 22.4 | 20.6 | 65/13 | 1.28 |

## TABLE V

## CHARACTERISTICS OF CARD SLIVER USED IN EXPERIMENTS ON THE NOBLE COMB

(Carded at medium card settings)

| LOT | FIBRE LENGTH AFTER 3RD GILLING | | FIBRE DIAMETER | | Neps per Gram small/ large | Ether extractible matter (%) |
|---|---|---|---|---|---|---|
| | m.f.l. (cm) | C. of V. (%) | m.f.d. (μ) | C. of V. (%) | | |
| 9/11 | 5.69 | 39.8 | 23.2 | 20.5 | 66/8 | 0.74 |
| 10/12 | 6.39 | 45.4 | 22.3 | 20.2 | 86/14 | 0.70 |
| 12 | 7.19 | 50.4 | 22.4 | 20.7 | 108/23 | 1.27 |

## TABLE VI

## COMBING PERFORMANCE (Rectilinear Comb)

| LOT | | FEED SETTING | GAUGE | TEAR | %NOIL | m.f.l. TOP (cm) | PRODUC-TION kg/hr |
|---|---|---|---|---|---|---|---|
| 6/8 | O | 5.5 | 24 | 12.15 | 7.60 | 4.22 | 6.24 |
| | M | | | 11.84 | 7.79 | 4.23 | 6.42 |
| | C | | | 11.84 | 7.79 | 4.20 | 6.57 |
| 7/9 | O | 5.5 | 24 | 15.99 | 5.89 | 5.08 | 6.75 |
| | M | | | 14.96 | 6.26 | 5.06 | 6.82 |
| | C | | | 15.06 | 6.23 | 5.00 | 6.69 |
| 8/10 | O | 6.5 | 26 | 17.22 | 5.49 | 5.50 | 7.94 |
| | M | | | 14.25 | 6.56 | 5.30 | 8.38 |
| | C | | | 15.17 | 6.18 | 5.38 | 8.16 |
| 9/11 | O | 6.5 | 26 | 21.81 | 4.38 | 5.75 | 8.15 |
| | M | | | 19.92 | 4.78 | 5.78 | 8.27 |
| | C | | | 21.60 | 4.41 | 5.68 | 8.14 |
| 10/12 | O | 7.0 | 28 | 22.42 | 4.27 | 6.46 | 8.87 |
| | M | | | 21.82 | 4.38 | 6.42 | 9.01 |
| | C | | | 21.15 | 4.51 | 6.44 | 8.48 |
| 12 | O | 7.0 | 28 | 22.33 | 4.29 | 7.39 | 9.19 |
| | M | | | 24.06 | 3.99 | 7.38 | 8.87 |
| | C | | | 21.43 | 4.46 | 7.32 | 9.27 |

## RESULTS AND DISCUSSION

### Carding:

The card settings used are given in Table III while the characteristics of the card slivers produced at these settings are summarised in Table IV. Each length group was carded first with open settings, then with medium settings and finally with close settings. From Table IV it is clear that for every length group the m.f.l. increased with more open settings. As far as neps are concerned there was little difference between the close and open settings, whereas the medium settings usually produced more neps.

These results show that the open settings resulted in the lowest amount of fibre breakage without any adverse effect on the formation of neps. Surprisingly this applied to all lots, which meant that both short and long wools favoured the open settings. When these settings were changed from medium to open the formation of neps dropped significantly, except for the two longest wools (10/12 and 12 in Table IV). The results on the combing of these lots (given later on) substantiate the findings above.

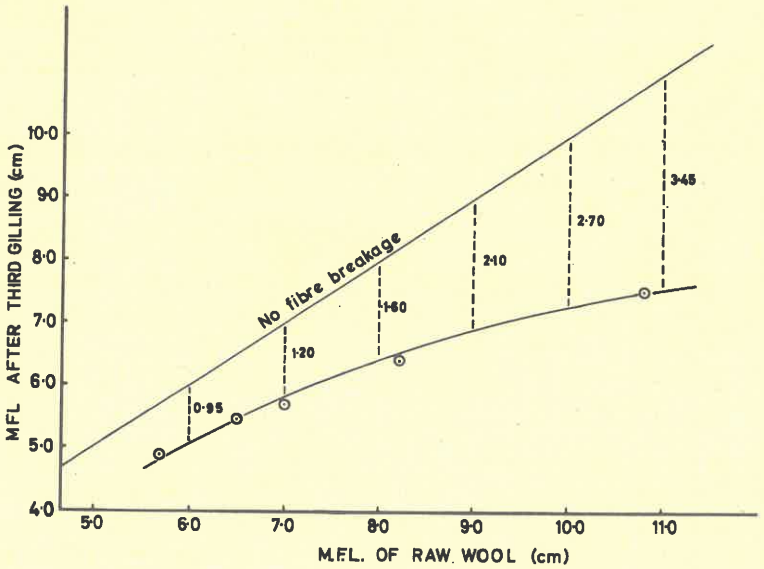



FIGURE 1

**Mean fibre length after third gilling versus m.f.l. of raw wool**
**(Open card setting)**

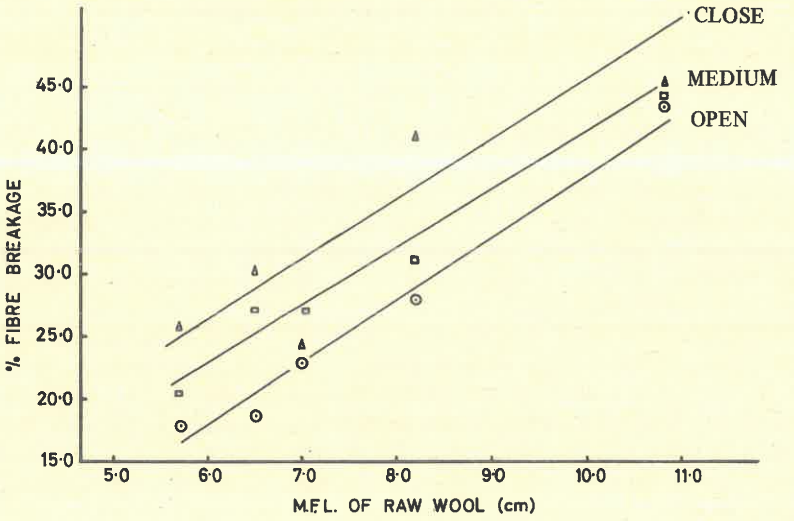



FIGURE 2

**Percentage fibre breakage versus m.f.l. of raw wool**

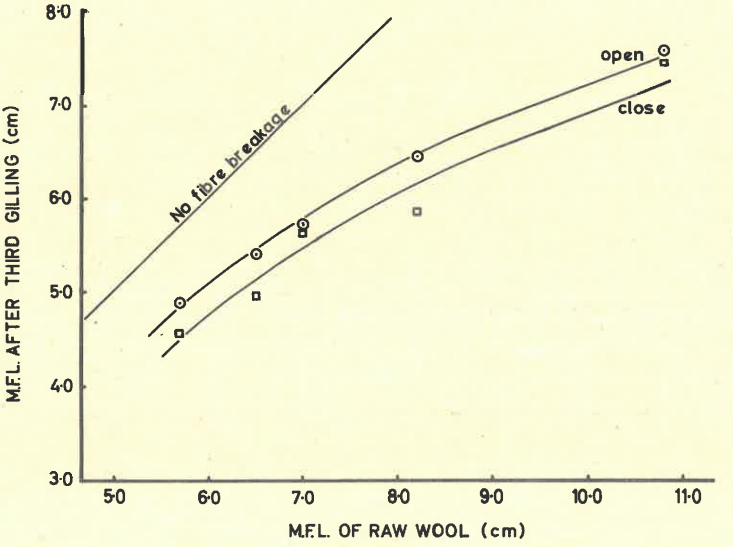



FIGURE 3

**Mean fibre length after third gilling versus m.f.l. of raw wool**

Three of the above lots (9/11, 10/12 and 12) were also carded separately at medium card settings followed by Noble combing. The choice of medium, instead of open card settings was rather unfortunate in view of the fact that open settings were shown above to give optimum results. However, this choice was made before the results on the card slivers were available. Characteristics of the card slivers for these three wools are given in Table V. There is a tendency for the number of neps to increase towards longer wools, although this tendency was not noticable in the previous experiments.

**Fibre Breakage in Carding**

In Fig. 1 the m.f.l. of the raw wool was plotted against the m.f.l. of the card sliver. Had no fibre breakage taken place during carding, the mean fibre lengths of the card slivers would have been as is shown by the straight line in Fig. 1. The decrease in m.f.l. due to breakage at different lengths of the raw wools is indicated by the vertical dotted lines with the actual reductions (in cm) written in. It is clear that this reduction in m.f.l. increases slowly from short to medium wools, and then much more rapidly from medium to long wools.

In Fig. 2 the actual percentage fibre breakage is plotted against the m.f.l. of the raw wool. Again the longer wools showed more fibre breakage than the shorter wools. It is obvious that close settings resulted in appreciably more fibre breakage than open settings. In order to demonstrate the effect of card settings on fibre length, the fibre length after the third gilling was plotted in Fig. 3 against the m.f.l. of the raw wool for both open and close settings on the card.

Typical fibre length frequency distributions of the wools used are shown in Fig. 4. The frequency distribution did not change in shape from raw wool to gilled sliver but only showed a general increase in the proportion of shorter lengths due to breakage in carding. The frequency distribution of the gilled sliver of 9/11 months wool is also shown by way of comparison with that of 7/9 months wool which was taken as a typical distribution. In Fig. 5 similar frequency distribution curves are given for the 12 months wool which was the only wool which did not conform in this respect. The distribution for the raw wool is similar to that of the others, but fibre breakage in carding resulted in an entirely different fibre length distribution in the card sliver. Comparing the short fibre portion of the gilled sliver of the 9/11 months wool (also included in Fig. 5) with that of the 12 months wool, it is clear that the 9/11 months wool contained fewer fibres in the length range 1.5 cm to 3.0 cm. This obviously affected the combing performance as will be shown later.

The fibre breakage in carding caused an increase in the C.V. of the fibre length from the raw wool to the card sliver. In the case of the 12 months wool the C.V. changed from 25% to 49% (Tables 1 and IV), and for all the other wools from about 32% to 42%.

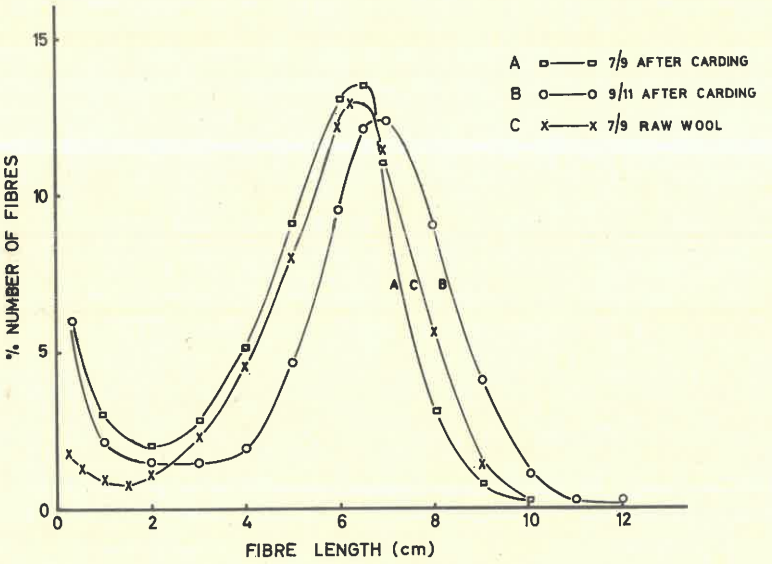



**FIGURE 4**

**Fibre length frequency distributions**

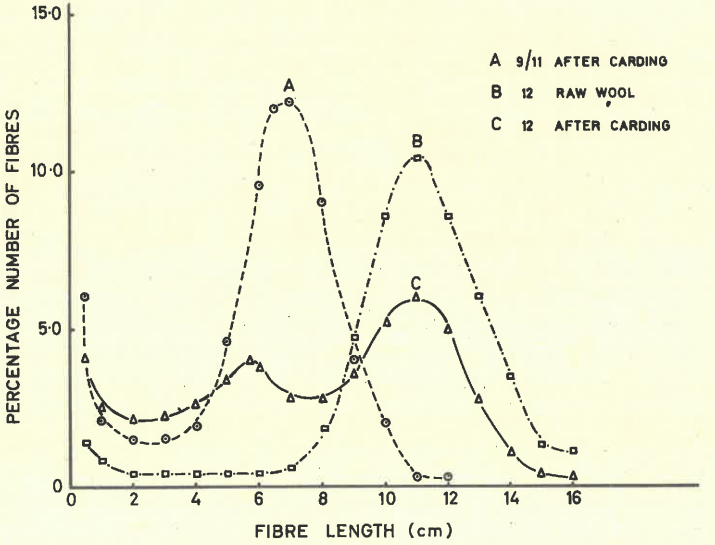



**FIGURE 5**

**Fibre length frequency distributions**

## Rectilinear Combing

### *Gauge Setting*

The comb settings, amount of noil, m.f.l. of the top and comb production for the various length groups carded at open, medium and close card settings are given in Table VI.

The amounts of noil at different gauge settings on the rectilinear comb were plotted in Fig. 6 for the various length groups. The expected increase in amount of noil with an increase in gauge was obtained. It is also clear that the shorter the wool, the more noil was obtained, and the greater the change in the amount of noil with a change in gauge setting. The amount of noil obtained at 26 gauge was plotted against m.f.l. of the raw wool in Fig. 7, from which it can be seen that more than double the amount of noil was produced for the short wools than for the long wools at 26 gauge. It is, however, impractical to comb the short wools at this gauge, and gauge values were, therefore, selected at which these wools would normally have been combed, i.e. 23 gauge for 6/8, 24 gauge for 7/9, etc., and 27 gauge for both 10/12 and 12 months wool. The amounts of noil obtained at these more practical gauge values were plotted in Fig. 8 against m.f.l. of the raw wool. From this graph one can deduce what amount of noil is to be expected from a raw wool of a certain m.f.l. There are, however, two factors which could affect the relationship. The first factor is the number of short fibres present in the card sliver. If more short fibres are present (possibly due to more breakage on the card caused by bad scouring or adverse weathering) then more noil will be obtained, and vice versa. In Fig. 8 the point for the 9/11 months wool (7.01 cm m.f.l.) is below the fitted curve. This was due to the relatively few short fibres as was shown in the discussion of Figs. 4 and 5. Consequently the 9/11 months wool gave a lower amount of noil than was expected for this order of m.f.l. The second factor is the amount of vegetable matter present. The wools tested were all free wools, but with more vegetable matter present in the raw wools larger amounts of noil would have been produced.

### *Card Settings*

Fig. 9 shows a typical variation of percentage noil obtained at open, medium and close card settings for three different gauge settings on the comb, the specific example being the 7/9 months wool. The medium card settings were the worst while the open settings were the best as regards noil production. These results agree with the results obtained on the nep production. Due to the greater number of neps present when medium card settings were used, more noil was produced than when close settings were used although the latter produced more fibre breakage during carding.

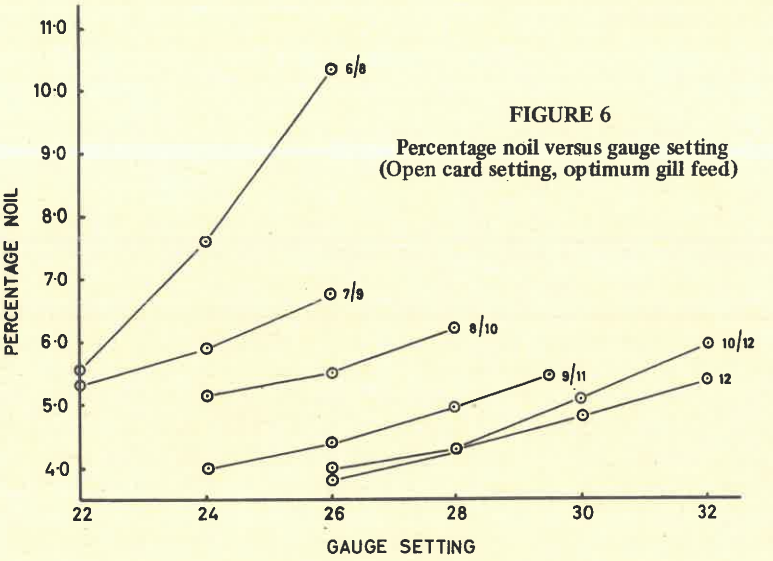



**FIGURE 6**

**Percentage noil versus gauge setting (Open card setting, optimum gill feed)**

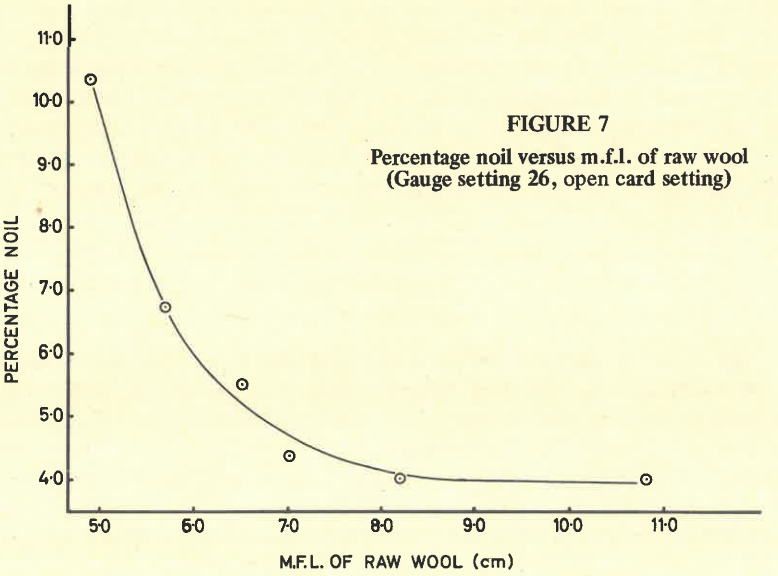



**FIGURE 7**

**Percentage noil versus m.f.l. of raw wool (Gauge setting 26, open card setting)**

**Mean fibre length of tops**

In Fig. 10 the m.f.l. of the top is plotted against the m.f.l. of the raw wool. It is clear that, although longer fibre lengths in the top are obtained for longer raw wools, the relationship is not linear. This deviation from linearity is due to the difference in fibre breakage on the card for the different fibre lengths. A future publication will deal with breakage obtained during combing.

**Noble Combing**

The amounts of noil obtained and the m.f.l.'s on the top for Noble combing are given in Table VII. A comparison of results obtained on the Noble and rectilinear combs are given in Table VIII. The m.f.l. of the top from the Noble comb is much longer for the 9/11 months wool but the difference decreases for the long wools, whereas the amounts of noil produced in Noble combing are much higher than those in rectilinear combing. Similar percentages noil were obtained from the Noble and rectilinear comb for the 10/12 and 12 months wool at gauge settings between 30 and 32. At these similar noil levels the m.f.l. of the Noble combed top was the same as that of the rectilinear combed top in the case of the 12 months wool and

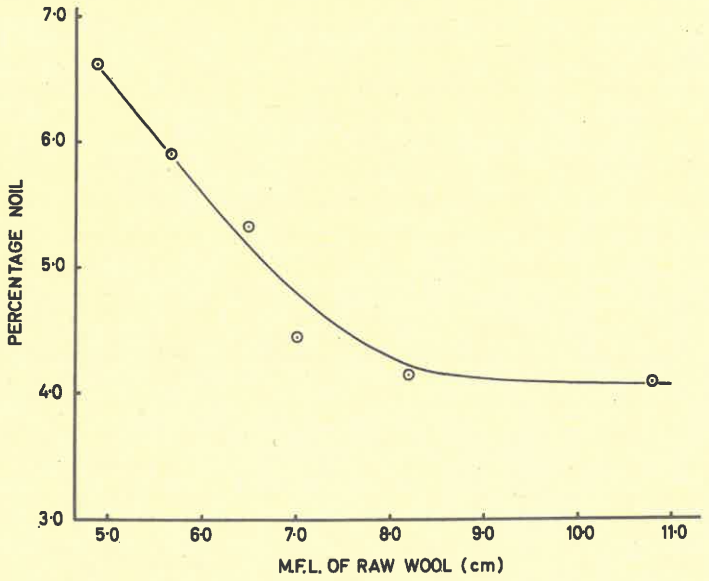



**FIGURE 8**

**Percentage noil versus m.f.l. of raw wool**

## TABLE VII

### COMBING PERFORMANCE
### (Noble Comb)

| LOT | PRODUCTION kg/hr. | % NOIL | m.f.l. TOP (cm) |
|---|---|---|---|
| 9/11 | 27.4 | 6.10 | |
| | 29.8 | 6.27 | 6.53 |
| | 32.7 | 6.69 | |
| 10/12 | 20.6 | 4.90 | |
| | 22.3 | 5.50 | 6.85 |
| | 24.8 | 5.74 | |
| 12 | 19.1 | 5.14 | |
| | 20.2 | 5.24 | 7.37 |
| | 22.0 | 5.57 | |

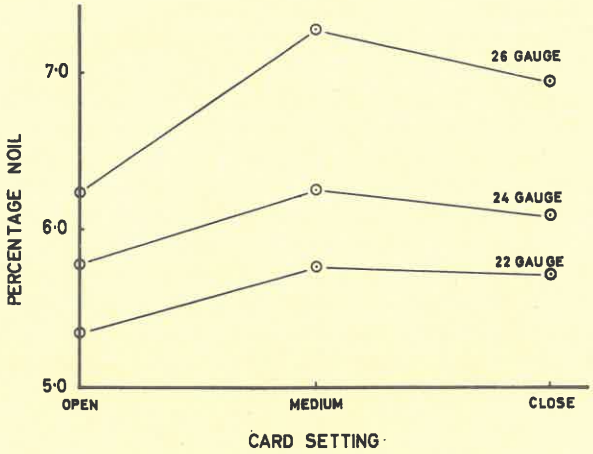
## TABLE VIII

### COMPARISON OF TOP IN m.f.l's FOR RECTILINEAR AND NOBLE COMB
### (Carded at medium settings)

| LOT | RECTILINEAR | | | NOBLE | |
|---|---|---|---|---|---|
| | Gauge | %Noil | m.f.l. TOP (cm) | %Noil | m.f.l. TOP (cm) |
| 9/11 M | 26 | 4.78 | 5.75 | 6.35 | 6.35 |
| | 28 | 5.36 | 5.93 | | |
| | 30 | 5.88 | 5.90 | | |
| 10/12 M | 28 | 4.38 | 6.42 | 5.41 | 6.85 |
| | 30 | 5.27 | 6.53 | | |
| | 32 | 6.00 | 6.62 | | |
| 12 M | 28 | 3.99 | 7.38 | 5.32 | 7.37 |
| | 30 | 4.70 | 7.27 | | |
| | 32 | 5.46 | 7.43 | | |

FIGURE 9

Percentage noil versus card settings for different gauge settings. (7/9 months wool)



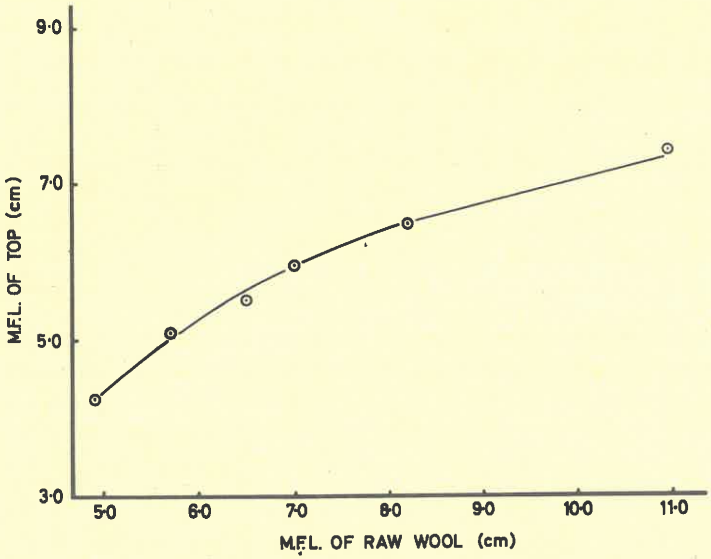




FIGURE 10

Mean fibre length of top versus m.f.l. of raw wool

slightly longer for the 10/12 months wool. In the case of the 9/11 months wool it was not possible to match the percentage noil. Therefore, while greater m.f.l.'s were obtained on the Noble with concommittant larger amounts of noil, the fibre breakage must have been slightly lower in the case of the Noble comb.

Belin *et al*[9] compared the Noble and rectilinear combs and concluded that the combs select fibres for top and noil in different ways. They observed that in the rectilinear combed top the short fibre content was higher and the nep content lower, compared with the Noble combed top. Comparing the two combs on the basis of similar percentage noil, they obtained a shorter m.f.l. for the rectilinear combed top.

In an investigation dealing with recombing Ogden[10] also compared the rectilinear and Noble combs. He came to the conclusion that the combing performance of the Noble comb was superior to that of the rectilinear comb as far as recombing was concerned due to advantages of production rate and better m.f.l. The rectilinear comb was better only as regards the cleanliness of the top. Ogden compared the combing performance of the two combs for one wool only.

The comparison of the rectilinear and Noble combs in this investigation agrees with the results obtained by Ogden and Belin *et al.*

## SUMMARY

Experiments were carried out in which the processing performance of six lots of 64's Merino wool of similar style (good Topmaker's/Spinner's, free/nearly free) differing only in m.f.l. was investigated.

Percentage fibre breakage in carding showed a linear increase with the m.f.l. of the raw wool. The reduction in m.f.l. due to carding was small (about 10%) for the shorter wools but increased rapidly to 30% for the longer wools. Fibre breakage also increased with a decrease in the swift-worker settings, whereas nep content of the card slivers showed a maximum at "medium" settings (28 gauge on last worker).

The expected increase in amount of noil with decrease in m.f.l. and increase in rectilinear comb gauge setting was obtained. Differences in the amount of noil obtained between lots were small for the longer wools (9/11, 10/12 and 12 months). The results on longer wools also showed much smaller changes in the amount of noil with changes in gauge setting. Although longer m.f.l.'s in the top were obtained for longer raw wools, the relationship was not linear. This can be ascribed to the increased fibre breakage on the card for longer wools.

For equal amounts of noil, the rectilinear comb produced the same m.f.l. in the top as the Noble comb for the 12 months wool and slightly shorter for the 10/12 months wool. In the case of the 9/11 months wool the rectilinear comb produced a shorter m.f.l. but also less noil, even for large gauge settings.

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## REFERENCES

1. D. A. Ross, R. L. Bratt and L. F. Storey, *J. Text. Inst.*, **51**, T907, (1960).
2. R. L. Bratt, D. A. Ross and L. F. Storey, *J. Text. Inst.*, **55**, T165 (1964).
3. P. P. Townend and E. Spiegel, *J. Text. Inst.*, **37**, T58 (1946).
4. R. Bownass, *J. Text. Inst.*, **51**, T1035 (1960).
5. R. E. Bacon-Hall, M. Lipson and G. W. Walls, *Third Int. Wool Text. Res. Conf.* (1965) Sect. IV, 319.
6. E. Dyson and F. Happey, *J. Text. Inst.*, **51**, T1016 (1960).
7. S. L. Anderson, *Ann. Sci Text. Belges*, (1), 30 (1963).
8. P. J. Kruger. To be published.
9. R. E. Belin, D. S. Taylor and G. W. Walls, *Third Int. Wool Text. Res. Conf.* (1965) Sect. IV, 71.
10. A. J. Ogden, *J. Text. Inst.*, **57**, T520 (1966).

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