Trials Evaluating Additional Measurements

Combined Reports for TEAM-1, TEAM-2 and TEAM-3
1981 – 2004

TRIALS EVALUATING ADDITIONAL MEASUREMENTS

TEAM–1, TEAM-2 & TEAM-3 Combined Reports

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TEAM-1

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TEAM 1

TRIALS EVALUATING ADDITIONAL MEASUREMENTS

REPORT ON TRIALS EVALUATING ADDITIONAL MEASUREMENTS

FINAL REPORT 1985

Report to the Raw Wool Measurement
Research Advisory Committee
of the Australian Wool Corporation.

January 1985

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This is the fifth report on progress of the TEAM Project given to the Wool Committee of IWTO.

The Project is now complete and this Report summarises the major findings as they relate to industry.

It has been submitted as a Final Report to the Wool Measurement Research Advisory Committee of the Australian Wool Corporation. This latter Committee supervised the financing of the Project by the Australian Wool Research Trust Fund.

PREFACE

The last decade has seen rapid change in the way wool is marketed in an industry previously steeped heavily in tradition. Much of this change has been made possible by the introduction of innovative procedures, and this continues. Research into additional measurements of staple length, staple strength, etc., and their relevance to industry follows the success of coretesting for specification of value-determining characteristics of wool and the establishment of sale by sample as the preferred marketing method.

By 1980, research instruments for measuring staple length and staple strength separately had been adapted by CSIRO Division of Textile Physics for use by AWTA. Recently, prototypes of automated instrumentation for measuring these characteristics were developed; commercial production of the CSIRO instrument is now underway. Meanwhile, a mechanical-tuft-sampling machine to draw tufts of staples automatically from grab samples was developed by AWTA Ltd. Australian standards for all these instruments and procedures are nearly complete.

For three years the TEAM Project has provided industry with an opportunity for participation and debate, while developing an understanding of the potential application of additional measurements of greasy wool to wool processing and wool trading. Both conceptually and in practice, the TEAM Project has been an industry project. Many organisations and industry sectors have cooperated to permit the research to be planned, procedures to be designed and implemented, and data to be collected and analysed.

The involvement of the industry throughout this period reflects the awareness of the industry for the need to experiment, to refine strategies in trading and processing of wool, and to examine new technology and concepts which have the potential to improve efficiency in the industry.

In particular, the Australian Wool Corporation became committed to study the feasibility of Sale by Description, leading to its involvement in detailed planning and promotion for the introduction of Sale with Additional Measurement and, ultimately, Sale by Description into the industry.

The aim of the TEAM Project was to enable processors of Australian combing wools to evaluate the new measurements of staple length, staple strength, position of weakness and clean colour. In so doing, considerations included:

– the confirmation of the importance of raw wool characteristics on processing performance and fibre length characteristics of top;

– the development of formulae to predict processing performance and fibre length characteristics of top;

– the establishment of a database of greasy wool and processed wool characteristics which can expand the technical knowledge concerning factors influencing processing;

– the comparison of processing performance both within mills and between mills;

– an economic evaluation of benefits from raw wool specification; and

– the communication of TEAM research findings as they developed, which has given industry experience in the use of the new measurements.

The TEAM Project has been planned and executed jointly by Australian Wool Testing Authority Ltd and CSIRO Division of Textile Physics, maintaining close association with the Raw Wool Services Department of the Australian Wool Corporation. Officers from each of these groups formed a Management Committee.

Communication with the industry has been a feature of the work. Throughout the Project, frank and detailed discussions were held with the major participants, the combing mills. In January, 1984, an Interim report was released which summarised preliminary findings and trends. Over the three-year period of the Project, four progress reports were presented to the Wool and Technical Committees of the International Wool Textile Organisation, and several reports have appeared in industry journals. Committee members have presented papers to trade seminars in Australia and at international forums.

The operations of the TEAM Project are now complete. After 36 months, we have data on 232 consignments for analysis. This report is a summary of the principal findings relevant to industry; a more detailed technical report is in preparation. It will be a compilation of scientific papers dealing in detail with all aspects of the Project.

The Management Committee takes this opportunity to thank all participants and industry groups for their cooperation.

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S. A. S. Douglas

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TEAM–1 CONTENTS

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1. SUMMARY OF THE REPORT - CONCLUSIONS & RECOMMENDATIONS

As a result of the Project a considerable improvement has been made in the understanding of the interaction between measurements of raw wool and subsequent processing behaviour. Prediction formulae for the fibre-length characteristics of the top and for noil were derived for a wide range of combing plants. Sufficient information is now available on comparative processing performance to enable the generalisation of these formulae. However, a considerable expansion of the total database will be required before the industry can be confident in the stability of the prediction process.

Conclusions

The principal conclusions of the TEAM Project are:

- In general, diameter, staple length, staple strength, and vegetable matter base are the most significant raw wool characteristics affecting fibre length in the top, and noil. The relative importance of each raw wool characteristic, or group of characteristics, is different for individual mills, and appears dependent upon the range and type of wools processed.

- It has been specifically demonstrated that the classification of wool soundness is significantly improved by using measured staple strength. Measurement overcomes the limitations associated with subjective assessment and enables wools of different processing potential to be detected.

- A general basis for the calculation of a theoretical Hauteur has been established. The formulae are based on the influence of important measured raw wool characteristics. *While the formulae developed in TEAM and presented in this report can be seen as establishing the principle of theoretical values they can by no means be regarded as representing the ultimate relationship. Results from more mills and consignments should be included before any status is granted to such formulae. Meanwhile, the ones published here serve for guidance.*

- In order to achieve a satisfactory general relationship across mills, it has been found preferable to group wools according to wool category (fleece or skirtings) and provide a separate formula for each category.

- The general formula to predict the Hauteur of consignments of fleece wool is:

$$H = 0.70D + 0.45L + 0.41S - 5.7$$

where H = Hauteur (mm)
D = Mean Fibre Diameter by Coretest (um)
L = Mean Staple Length (mm)
S = Mean Staple Strength (Newtons/kilotex)

- The general formula to predict the Hauteur of consignments of skirtings is:

$$H = 1.53D + 0.40L + 0.32S - 20.1$$

- Formulae can be established for individual mills, based on the measured raw wool characteristics of consignments combed at that mill. These formulae may generally provide a more accurate prediction for each mill than the general formula. They also provide the means for an overall comparison of a mill's performance with the general theoretical formula.

- The Hauteur predicted by the formula derived for a mill is generally more accurate and precise than the mill expectations. A parallel economic study has clearly identified substantial gains to processors, from using additional measurements, through increased predictability.

- Clean colour of Australian greasy wool has an indirect influence on the worsted processing performance through its association with wool type, but our work on its influence on top colour was inconclusive.

- Whilst topmakers may feel they are achieving optimum results with their present method of building processing batches, advances have been prevented by the lack of relevant specifications of the raw material. With the ability to use additional measurements, there is increased flexibility for the selection and manipulation of input material to provide best solutions for the end use.

- Understanding of the concepts and enthusiasm for their adoption have increased substantially as a result of the Project.

Recommendations

1. Using the formulae provided in the Report as a guide, industry should work towards the establishment of an internationally recognised general formula or set of general formulae to predict theoretical values for Hauteur from objectively measured raw wool characteristics. It is suggested that the International Wool Textile Organisation (IWTO) should accredit such formula or formulae and review regularly, as appropriate.

2. The possibility of accrediting similar general formulae to estimate noil should be investigated.

3. It is necessary to establish a database mill by mill in order to relate individual mill performance to the general formulae. Also the general formulae need to be expanded and refined. Every assistance should be given to industry to enable databases to be established, and/or enlarged to achieve these aims.

4. Constant attention must be paid to existing measurement methods used for raw wool and top, particularly in regard to standardisation, calibration, operating procedures, and harmonisation between mills and laboratories.

5. The logical outcome of improved estimation of processing performance using general predictive formulae is more efficient blending. The potential for least-cost solutions to blending of wools for topmaking should be appreciated. The use of computers enables inventories to be effectively allocated for topmaking. Where necessary, assistance should be provided to mills, topmakers, and woolbuyers, to enable them to adapt such concepts to their wool trading and processing roles.

6. The availability of presale measurements enables wool buyers to prepare consignments progressively to meet their client's needs without having to wait for post-sale testing and the potential risk of adjustment to consignments when measurements do not confirm subjective appraisal. Presale measurement of staple length and staple strength should be introduced as quickly as possible.

7. It is recommended that the implementation of colour measurement of raw wool receive lower priority for the present than that of staple length and strength of raw wool. On the other hand, a high priority should be given to both the refinement of measurement techniques and research into the factors relating the colour characteristics of wool measured at each stage of the processing chain.

8. The momentum of research and development on raw wool measurement processing consequences should be maintained, giving consideration to characteristics that require specification to improve the robustness of the predictive formulae, for example, the method of reporting the position of staple weakness.

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2. THE TEAM PROJECT: SCOPE AND OPERATION

Background

The TEAM Project (Trials Evaluating Additional Measurements) provided raw wool measurements of staple length, staple strength, position of staple weakness and clean colour to supplement coretest information of yield, vegetable fault content and mean fibre diameter on nominated commercial consignments of Australian wool combed at 14 mills in 9 countries. In exchange, the mills and/or topmakers cooperating in the Project provided processing results and top measurements. The Project commenced sampling and testing in October, 1981.

The aim of the Project was to enable processors to evaluate the potential of these measurements for greasy wool. Once sufficient data had been accumulated, the relationships between processing performance and the raw wool characteristics were analysed. The information gained from the Project will assist industry to evaluate economic and commercial benefits of additional measurements.

The TEAM Project has been designed and controlled by the TEAM Project Management Committee comprising:

Dr. M. W. Andrews (Chairman)	Assistant Chief CSIRO Division of Textile Physics
Mr. S. A. S. Douglas	General Manager – Operations AWTA Ltd
Mr. A. H. M. Ireland	Research Officer AWTA Ltd
Mr. R. J. Quirk	Manager - Raw Wool Services Australian Wool Corporation
Mr. R. A. Rottenbury	Senior Research Scientist CSIRO Division of Textile Physics

The Project has been supported by a special grant from the Wool Research Trust Fund administered by the Australian Wool Corporation to the extent of approximately A$300,000, principally to cover sampling and testing costs.

Industry Participation

A significant feature of the Project has been the involvement of a wide range of commercial interests within the world wool industry - combing mills, topmakers, wool buying firms and wool broking/private treaty merchanting companies. The list of firms cooperating in the Project is:

(a) Combing Mills

14 combing mills in nine countries participated in the Project. These mills are estimated to comb at least 50% of all wool top produced in the countries involved:

Bremer Woll-Kammerei	Germany
Burlington Industries Wool Co	United States of America
Canobolas Wool Topmaking Pty Ltd	Australia
Cheil Wool Textile Co Ltd	Korea
F. W. Hughes Pty Ltd	Australia
Nippon Keori Kaisha Ltd	Japan
Peignage Amedee	France
Pettinatura Italiana	Italy
Port Phillip Mills Pty Ltd	Australia
Raymond Woollen Mills Ltd	India
Riverina Wool Combing Pty Ltd	Australia
Sir James Hill & Sons Topmakers Ltd	United Kingdom
Toa Boshoku Co Ltd	Japan
W. & J. Whitehead Ltd	United Kingdom

Unfortunately, for commercial reasons, two of the original 12 mills were unable to meet commitments to process 20 consignments in the Project, and a further two mills were invited to participate.

(b) Topmakers

10 topmakers commission combed at five of the mills in the Project:

Australian Wool Corporation	Australia
Bloch & Behrens Pty Ltd	Denmark
Cargill Pty Ltd	Australia
Antoine Segard & Co	France
W. A. Fritze & Co	Germany
C. Itoh & Co	Japan
Kulenkampff & Konitzky	Germany
Lohmann & Co	Germany
Prouvost Lefebvre & Co	France
Simptra Dewavrin Pty Ltd	France

(c) Suppliers

26 Australian wool buying firms purchased TEAM Project consignments on behalf of topmakers and combers:

Australian Wool Corporation	Kanematsu-Gosho (Aust) Pty Ltd
Booth Hill & New Pty Ltd	Lempriere (Aust) Pty Ltd
Black & Baer Pty Ltd	Lohmann & Co Pty Ltd
Bloch & Behrens Pty Ltd	Marubeni (Aust) Pty Ltd
Cargill Pty Ltd	A. McGregor & Co
K. V. Chapman & Co	Mitsui & Co (Aust) Ltd
Compagnie D'Importation De Laines	P. J. Morris Pty Ltd
Dalgety Australia Ltd	Nissho Iwai (Aust) Ltd
A. Dewavrin Segard Pty Ltd	Port Phillip Mills Pty Ltd
W. A. Fritze & Co. (Aust) Pty Ltd	Prouvost Lefebvre & Co
Hart (Aust) Pty Ltd	J. Sanderson & Co (Aust) Pty Ltd
F. W. Hughes Pty Ltd	Simptra Dewavrin (Aust) Pty Ltd
C. Itoh & Co. (Aust) Ltd	Wesfarmers Europe

(d) Broker and Private Treaty Merchants

55 Australian companies assisted by providing samples for the measurement of the additional characteristics:

Adelaide Wool Co
Albany Wool Stores Pty Ltd
Australian Estates Co Ltd
Australian Mercantile Land and Finance Co Ltd
Bennetts Farmers Ltd
Burns Wool Pty Ltd
Central Classing Pty Ltd
R. E. Chadwick Pty Ltd
Colyer Wilcox
Crompton & Son Pty Ltd
Dalgety-Winchcombe
Dennys Strachan Mercantile
A. C. & K. Dibb
Economic Wool Producers
Elders IXL Ltd
Farmers Grazcos Pty Ltd
Fermil Wool Facility Pty Ltd
Glenelg Warehousers
G. K. Heffernan
Henty Wool Services Pty Ltd
Hume Warehousers
Jemalong Wools
Lohmann & Co (Aust) Pty Ltd
G. H. Michell & Son Pty Ltd
Newcastle Warehousers
New Zealand Traders
Pitt Son & Badgery Ltd
I. L. Pinniger & Co Pty Ltd
Plimex Pty Ltd
Port Adelaide Wool Co Pty Ltd
Primac
Primaries of W.A. Pty Ltd
Queensland Wool Centre
Roberts, Stewart & Co Ltd
E.P. Robinson
Schute Bell Badgery Lumby Ltd
V. H. Smythe Pty Ltd
Starlotters & Wool Auctions of Australia
Sydney Wool Brokers Ltd
Tourwool Pty Ltd
Victorian Producers Co-Op Pty Ltd
Watswool Pty Ltd
WAVCOP
Western Wool Traders
Westralian Farmers Co-Op Pty Ltd
Websters Wool Growers Pty Ltd
Western Livestock Pty Ltd
Westwools
Wool Agency Co
Wool Lot Builders
Wool Marketing Service
Wool Handling Centre
Woolcombers W.A. Pty Ltd
Wool Warehousers Geelong
Yennora Warehouse

Procedures

All procedures in the Project were commissioned by the Management Committee. AWTA Ltd were delegated to conduct the operations related to the sampling and testing and supervision of quality control procedures devised by the Management Committee. CSIRO Division of Textile Physics was required to develop procedures for data management and to develop and apply appropriate analytical techniques.

Detailed procedures used in the conduct of the Project were:

– the mill or topmaker nominated a consignment for the Project to their Australian supplier and to AWTA Ltd acting for the Project;

– the supplier advised AWTA Ltd of sale lots purchased for that consignment;

– AWTA Ltd officers collected the display grab sample and forwarded it to one of five regional centres, Brisbane, Sydney, Melbourne, Adelaide or Fremantle, for staple subsampling. If the sample had been discarded or the lot had not been sold by sample, arrangements were made to grab sample the lot;

- the staples were forwarded to AWTA Ltd Sydney for staple length and strength testing on each lot. Broken staples for each lot in a consignment were blended, scoured, carded and measured for colour;

- after quality control checks on the sampling and testing procedures, display samples were returned to the broker or private treaty merchant. Regular round trials were conducted to monitor sampling performance;

- a Customer Report on the consignment was prepared for distribution to the mill, topmaker, and supplier after combing data had been received. The report summarised the coretest and additional measurement data for each sale lot in the consignment and the combined values for the consignment. Data analysis was conducted by CSIRO Division of Textile Physics;

- the mill combed the consignment in the normal way but wastes were collected and top samples taken at specified intervals. Quality control records for each stage of processing were maintained. A Processing Report forwarded to AWTA Ltd specified quantities of top, noil and wastes and relevant measured top characteristics. Samples of top were also forwarded;

- on receipt of the Processor Report, AWTA Ltd distributed the Customer Report to the mill, topmaker and supplier;

- the top samples received were measured for top-length characteristics and colour. Checks were made on any anomalous results. Provision has been made for further testing;

- from time to time, confidential progress reports were prepared for each mill; and

- at least every year, each participant was visited by members of the Management Committee. Initially, this was on an *ad hoc* basis but in the last two years special visits were organised.

Description of Wool in the Project

The selection of wool types for the Project was entirely dependent upon the comber or topmaker concerned. For reasons of economics and logistics, it was necessary to confine consignment sizes to approximately 300 bales or less, and to ensure consignments consisted entirely of Australian wool and were either sold by sample or were able to be sampled prior to shipment. Consequently, a comprehensive range of types was not always possible. As part of their normal practice, some mills specialise in particular types; others comb a wider range of wools. However, the TEAM Project Management Committee encouraged participants to select a wide range of types with a range of raw wool characteristics.

Based on the measurements of 232 consignments, a general description of the range of wool in the Project is as follows:

* **Wool Type**

Fleece types only:	70%
Skirtings types only:	20%
Fleece/Skirtings blends:	10%

* **Diameter**

Finer than 20.0 µm:	20%
Fineness between 20.0 - 23.0 µm:	58%
Fineness between 23.1 - 25.0 µm:	8%
Coarser than 25.0 µm:	14%

* **Vegetable Matter**

Less than 1.0% VM base:	38%
VM base between 1.1 - 3.0%:	36%
More than 3.0% VM base:	26%

* Average consignment size in the Project (bales):	155
* Average number of lots per consignment:	17
* Total bales included in the Project:	36,000

In almost all cases, deliveries were on the basis of coretest for yield, mean fibre diameter and vegetable matter base. Other characteristics considered important to achieve a specific top length were subjectively appraised by the commercial interests. Staple length, staple strength, position of staple weakness, coefficent of variation of staple length of each sale lot, and colour of each consignment were measured as part of the Project. These results were not made available to the commercial interests until after combing.

It can be seen that in terms of wool type, diameter and vegetable matter base, the wools used in the Project are fairly representative of the Australian clip.

In respect of those additional measurements which were not available at sale or at the time the consignment was assembled, Figure 1 shows the distribution of mean staple length and mean staple strength of all consignments in the TEAM Project.

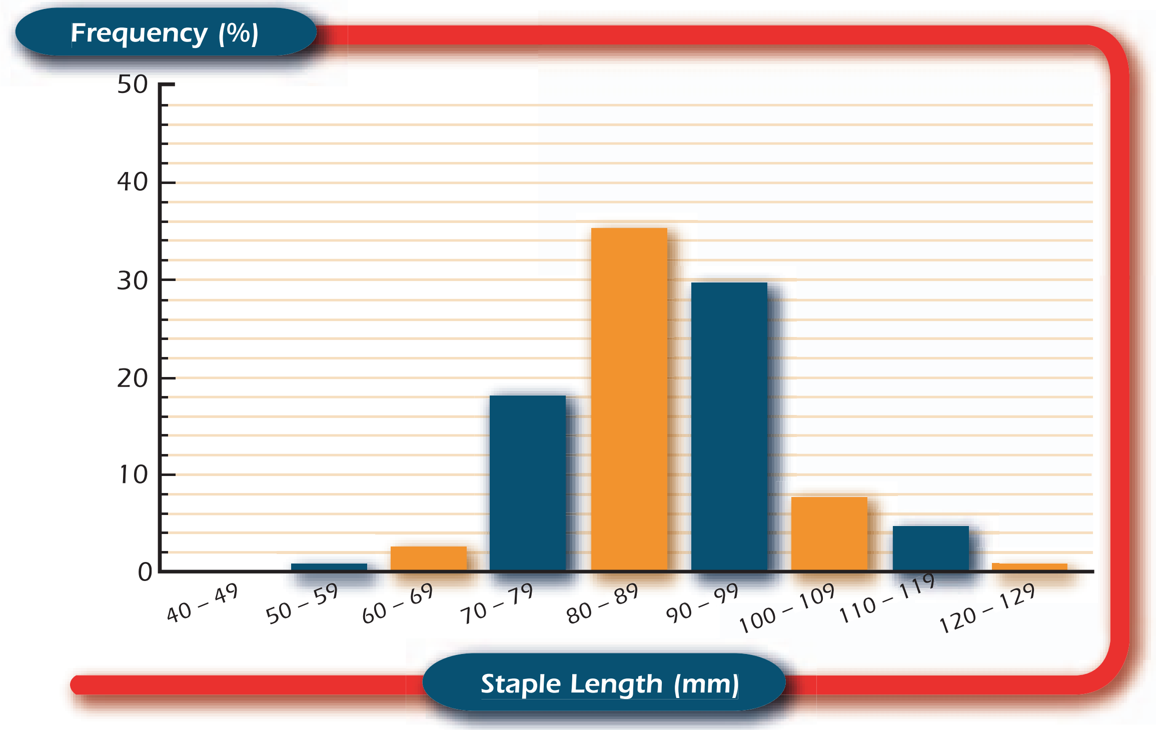
Between-Consignment Comparisons

Figure 2 compares the mean and range of the mean values for each raw wool characteristic of the consignments processed by each mill.

As a general observation, the distribution of mean staple length between consignments within a mill probably reflects a decision to purchase types of specific length, or particular types which might achieve a specific Hauteur in the top. However, the distribution of staple strength between consignments within mills is wide in all mills and reflects the low reliability of the subjective appraisal of staple strength. It is clear that some mills in the Project (e.g., Mills E and G), specialise in particular types which, with the exception of staple strength, appear well controlled in deliveries of wools to the required specification.

Figure 3 compares the mean and range of the mean values for Hauteur and noil for the consignments processed by each mill. The ranges for Hauteur and noil vary considerably from mill to mill.

Figure 1
Distribution of Mean Staple Length
and Mean Staple Strength of
232 TEAM Consignments



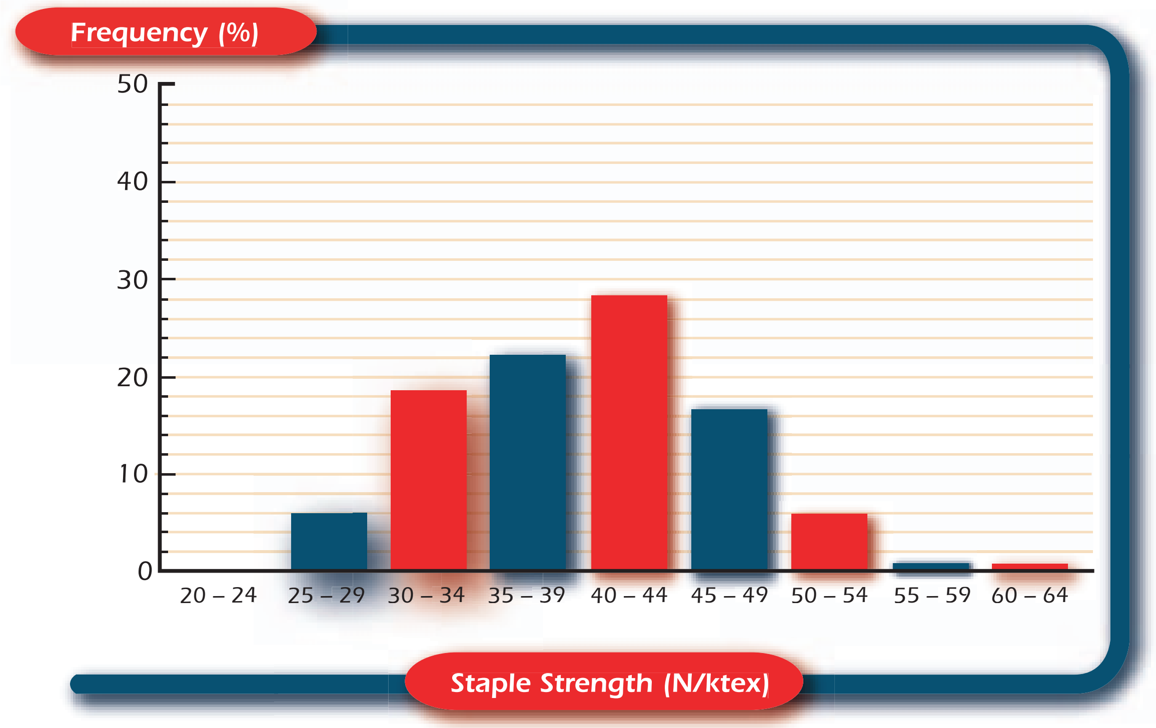


Figure 2

Range of the Mean Values of the Raw Wool Characteristics of Consignments

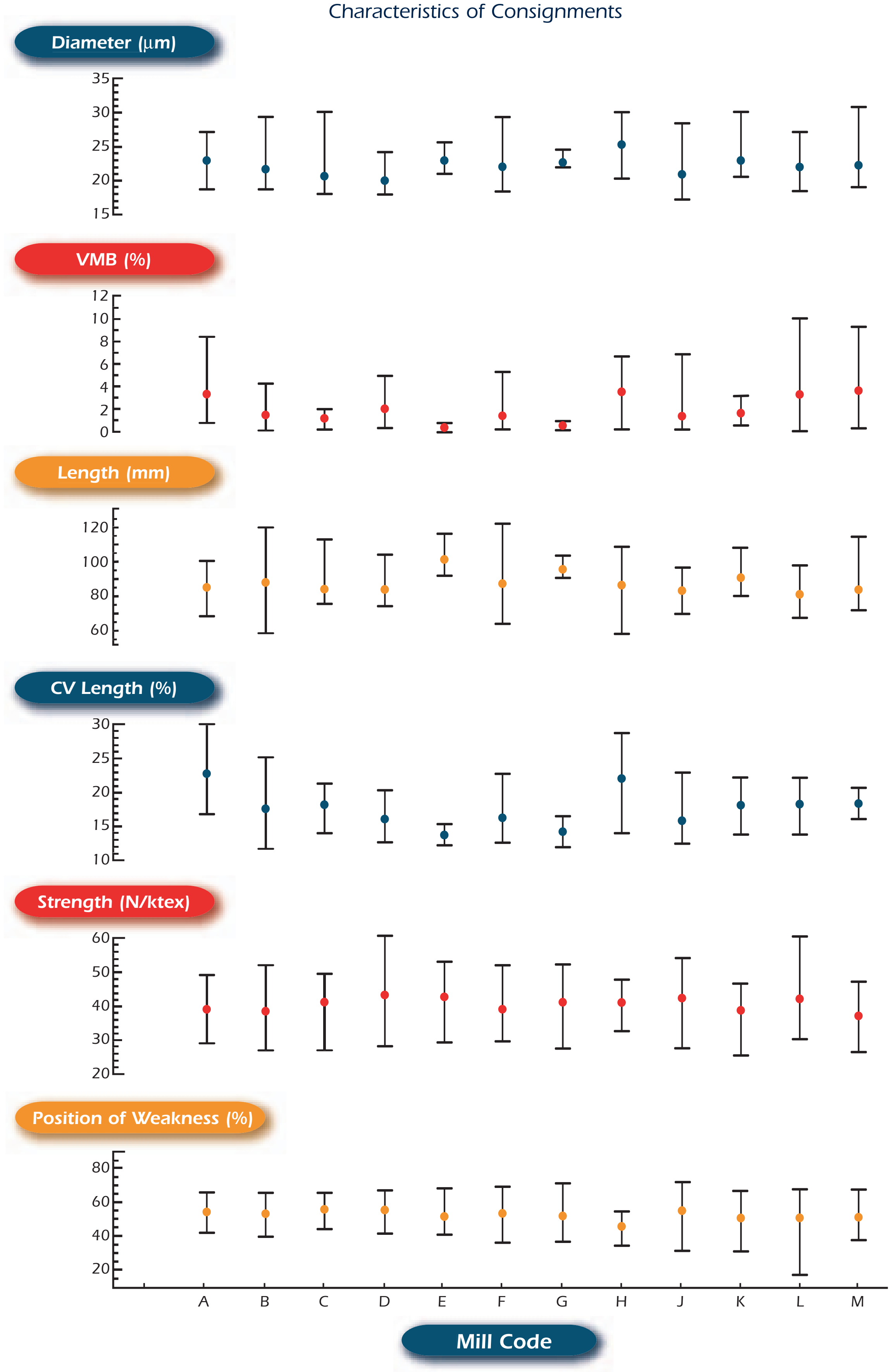
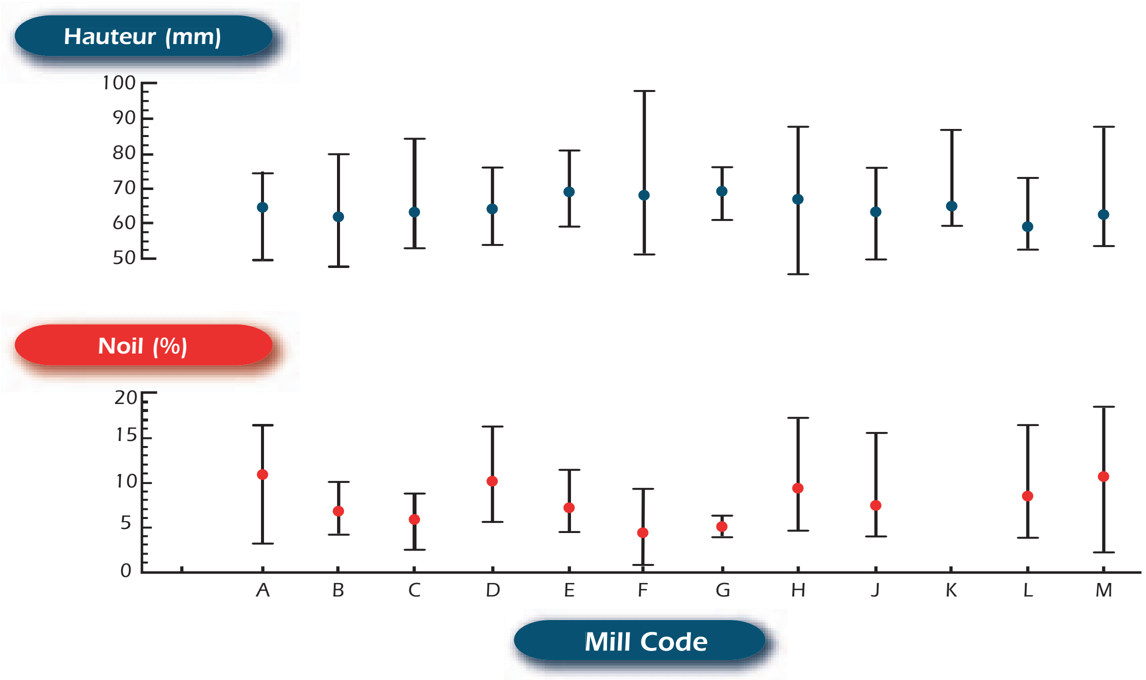


Figure 3
Range of the Mean Values of Hauteur and Noil*
of Consignments



* Noil data not available for Mill K

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Within-Consignment Variability

Each consignment comprised a number of sale lots which were purchased at auction or privately and then grouped for shipment to the combing mill. A few consignments consisted of pre-blended batches.

Examination of the test data for the component lots of individual consignments generally shows a wide spread of mean staple length and strength measurements from lot to lot. Table 1 summarises the mean, maximum and minimum ranges of the characteristics observed within consignments comprising auction sale lots.

The average range of staple length and staple strength between sale lots in a consignment is 27 mm and 30 Newtons/kilotex, respectively. These values of staple length and strength are the result of subjective matching of lots for each consignment. It is likely the range of values within consignments could be controlled if measurements for these characteristics were available at the time of assembling the consignment.

TABLE 1. WITHIN-CONSIGNMENT VARIABILITY

A. CORE TEST DATA

Range of Sale Lot Measurements Within Consignments	Mean Fibre Diameter (μm)	Vegetable Matter Base (%)	Schlumberger Dry Top and Noil Yield (%)
Average Range	1.5	2.6	12.3
Maximum Range	5.8	12.0	31.9
Minimum Range	0.3	0.3	1.4

B. ADDITIONAL MEASUREMENTS

Range of Sale Lot Measurements Within Consignments	Staple Length (mm)	Staple Strength (N/ktex)
Average Range	27	30
Maximum Range	76	55
Minimum Range	3	4

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3. PREDICTION OF PROCESSING PERFORMANCE

Introduction

Processing experiments ([1,2,3,4]) have confirmed the significance of certain greasy wool characteristics, such as staple length and staple strength, on top length and processing, and determined the level of their influence under controlled conditions. In some of these trials, held prior to 1980, wools were selected which had all the raw wool characteristics similar except one, which was varied among processing batches. As would be expected, if all other characteristics are similar, a longer staple length produces a longer fibre length in the top. Similarly, a higher staple strength will give a longer fibre length in the top.

Perhaps the most significant contribution ([5]) was the measurement and analysis of 39 consignments at one Australian mill during 1980, which established a high level of association between a processing factor and a selection of the characteristics of greasy wool. This work provided strong evidence that Hauteur could be predicted from a formula dependent upon only a few raw wool characteristics. More recently (6), statistical techniques for the development of predictive formulae have been examined.

It became evident that the potential to estimate Hauteur and other top characteristics from objective specification should be evaluated in other mills and on an international level. Further, as most of the greasy wool produced in Australia is exported, the involvement of a selection of Australia's wool customers seemed desirable to enable them to assess the usefulness of the new specifications. Consequently, the TEAM Project was initiated in 1981.

Previous progress reports on the TEAM Project have provided some insight into the following:

- the data being obtained;
- the methods of analysis;
- the variability within and between consignments;
- the suitability of using raw wool measurements to predict processing performance;
- the potential commercial implications; and
- the effect of staple strength.

The concept of a general formula to predict Hauteur of wool tops was introduced in earlier reports (7) but it was too early to comment with certainty on the suitability of this approach. With data now complete, and analyses updated, progress in this area has been substantial. In fact, the highlight of this report is the confirmation of the considerable generality that exists among mills with respect to the influence of raw wool characteristics on early-stage worsted processing.

The development of the analysis of results proceeded in three stages. In the first stage, with only limited numbers of consignments processed by each mill, preliminary analyses were conducted in order to gain some idea of the level of consistency of the relationships between the raw wool characteristics and the parameters of processing and the characteristics of the top.

The next stage was to develop formulae to enable the processor to predict the level of noil and the fibre-length characteristics of the top from the measurements available on the raw wool, a different formula for each processing factor for each processor, for ranges of wool types, and, in the case of commission combers, for each topmaker's wool. Such formulae were progressively updated, using results from further consignments, a process which should be continued to the point where the database is large enough for the formulae to be reliable and robust.

It is important to bear in mind the distinction between the objectives of the first two stages ([6]):

(i) Explanation: the screening of the raw wool measurements to determine those which have a significant effect on the processing factor, and

(ii) Prediction: arriving at the most effective formula for predicting future results.

There are, of course, factors limiting prediction. Other characteristics of wool that have a certain level of importance are not taken into account, for example, crimp and style; batch composition may influence processing; and machine settings and mill procedures need to be reproducible.

In the third and ultimate stage of the Project, with the total number of consignments exceeding 200, it became possible to commence the testing of hypotheses with respect to the generality of the relationships across mills between the raw wool and the processing. Once again there was a clear distinction between the explanation of the processing behaviour in terms of the characteristics of the raw wool, and the development of methods of prediction.

1-16 The work will be reported as follows:

– General formulae for Hauteur: general formulae are submitted as initial estimates which will be subject to refinement as the database is expanded; validation procedures are outlined.

– Analyses of the individual mills for all processing factors: emphasis is placed on the essential requirements for robust predictive formulae for individual mills. In these analyses we are better placed to deal with the effects of range and interrelationships of characteristics, local factors, wool types, etc.

– Applicability of formulae: this includes an assessment of the performance of mill formulae for Hauteur in comparison with the subjective estimates provided by topmakers/combers.

Development of a General Formula for Hauteur

Formulae were given in Chapter 1 to predict Hauteur of a consignment, for fleece types and for skirtings types. These were:

Fleece: $H = 0.70D + 0.45L + 0.41S - 5.7$

(based on results for 9 mills and 130 consignments)

Skirtings: $H = 1.53D + 0.40L + 0.32S - 20.1$

(based on results for 4 mills and 50 consignments)

where H = Predicted Hauteur (mm)

D = Mean Fibre Diameter (µm)

L = Mean Staple Length (mm)

S = Mean Staple Strength (N/ktex)

The methods that were used to obtain these formulae, the stability of the relationships found, their application to future consignments, and their usefulness to processors are discussed below.

Essentially, by analysing actual data for each consignment and each mill, a mathematical formula can be derived which expresses the relationship between the raw wool measurements and top characteristics, such as Hauteur. This formula then enables the substitution of actual raw wool measurements of subsequent consignments, so that the predicted Hauteur can be calculated. The usefulness of this formula to the mill, topmaker, or wool buyer, will depend on how close the values of predicted Hauteur are to the actual values of Hauteur.

A general formula can only be considered reliable if it reflects similar behaviour for all the mills used in the analysis. Analysis of 10 mills, involving 180 consignments has shown that in order to achieve a satisfactory general relationship across these mills, the database has had to be grouped according to wool category (fleece or skirtings). That is, a formula has been developed for each of these categories separately. When a consignment consisted of both fleece and skirtings types, it was included in the skirtings category.

The reduction in the numbers of mills and consignments used in the general analysis from 12 and 232, respectively, requires an explanation. The analytical method for the general analysis can only include data from mills, which have combed a sufficient number of consignments of fleece or skirtings. In addition, two mills were excluded from the general analysis because their data were inappropriate for pooling with the remaining data. In one case, consignments had been processed on different machinery lines within the mill. Significant differences between lines were apparent and insufficient consignments existed for each line. In the second case, some data were missing, and only subjective estimates for noil were provided.

The best formula to predict Hauteur was obtained using multiple linear regression procedures ([8]). Measurements made on the CSIRO Almeter were used. An exhaustive search ([9]) was made of combinations of raw wool characteristics to find the subset which produced the best relationship with Hauteur. The subset of raw wool characteristics so found for Hauteur was diameter, staple length, and staple strength.

After a relationship between raw wool measurements and Hauteur has been established, the usefulness of the formula in predicting processing performance of future consignments must then be confirmed. The process of making this confirmation is called cross validation ([6]). Two methods were used to validate the formulae for Hauteur. Firstly, one mill was excluded from the analysis, and a formula was produced using the data for the remaining mills. This formula was then applied to the data for the mill which had been excluded, and the Hauteur of each consignment was calculated individually. The procedure was repeated leaving out each of the mills in turn. Secondly, all mills were included in the analysis, but one consignment was excluded at random from each mill. As in the first method, a formula was found without these consignments and predicted values for Hauteur were calculated for them. The excluded consignments were then replaced and the procedure repeated 10 times.

For each validation for each method, the difference between the measured value for Hauteur and the value found using the formula was calculated. A formula that performs well in prediction should have a low residual error, and in validation should not produce differences that are consistently positive or negative; these differences should be scattered about zero and their average, or mean bias, should be near to zero. Both of the methods described showed no significant bias in prediction for the general formulae for fleece and skirtings given above.

Raw Wool Characteristics

From the general formulae, it will be evident that diameter, staple length, and staple strength, are the dominant raw wool characteristics influencing Hauteur. These have not been selected in any subjective way, but have been determined by complex statistical analyses, which have also evaluated the importance of other raw wool characteristics measured on the consignments. The other measurements considered in the analyses were:

WB	=	Wool Base by coretest (%)
VM	=	Vegetable Matter Base by coretest (%)
POB	=	Position of Staple Weakness (%)
CV(L)	=	Coefficient of Variation of Staple Length (%)
L*	=	Colour - lightness (CIE units)
b*	=	Colour - yellowness (CIE units)

Whilst these other measurements may be important in formulae developed for individual mills, they do not appear as significant in the analyses to determine general formulae for the prediction of Hauteur.

It is a source of satisfaction to note that the characteristics dominant in the general relationship are the factors which, together with vegetable matter content, would be expected, *a priori*, to have most influence. Viewed from the behaviour of fibres in a textile system the most important fibre characteristics for influencing fibre length after processing are fibre length and strength in the raw material. The factors directly related to these in raw wool are staple length, staple strength, and fibre diameter. Vegetable matter content will also have an influence, but it has most likely been accommodated in our analysis by the separation into two categories, fleece and skirtings.
With respect to the fact that two formulae are necessary to explain the relationships between raw wool and top length, it is possible that further stratification of the data will be necessary as the database is expanded, i.e., different types, origins, etc. On the other hand, it is possible that inclusion of other characteristics utilised as additional measurements may remove this requirement for stratification.

Predictive Capability

The strength of a regression relationship may be measured by two statistics. The coefficient of multiple determination (R^2) indicates the fraction of the variation in Hauteur between the consignments which is explained by the raw wool data used in the formula; it reflects the level of association between the raw wool variables and Hauteur and is often called the degree of association and expressed as a percentage ($100R^2$). The mean square error (MSE) is a measure of the reliability of the raw wool data as a predictor of Hauteur; a large MSE indicates a formula is less reliable.

The values of these statistics found in analyses for the general formulae for Hauteur were:

Fleece:	$100R^2 = 81\%$	MSE = 9.76 mm^2
Skirtings:	$100R^2 = 94\%$	MSE = 3.66 mm^2

Although it would seem that the formula for skirtings is more reliable than that for fleece wools, it should be noted that only four mills and 50 consignments were available for the analysis of skirtings types and in this sense it is less representative. The results for fleece types are more typical of the level of reliability that we expect to occur in a general formula for Hauteur. Expansion of the database for skirtings with inclusions of a greater range of wool types and more mills will result in changes, certainly in the magnitude of the coefficients in the formula and its mean square error, and perhaps in a different subset of raw wool characteristics.

Another important aspect to be emphasised in using the formula is the simplicity of the adjustment to the predicted value of Hauteur to allow for mill differences. Individual mills can comb consistently longer or shorter tops than the values for Hauteur predicted by the general formula. In the case of the general formula for predicting Hauteur for fleece wools, a range of 6 mm would be found across the nine mills if each was given identical fleece wool to process. Accordingly, a mill that has accumulated its own database would be in a position to estimate the adjustment appropriate to its own situation. The adjustment is in effect an additional constant factor to be added to the general formula.

An individual mill adjustment is determined in the following way. Raw wool measurements for a number of consignments which represent adequately the range of these characteristics for that mill are accumulated and the average values for diameter, staple length and staple strength and Hauteur are found. For fleece consignments the mill adjustment is calculated as follows:

$$A = \overline{H} - 0.70\overline{D} + 0.45\overline{L} + 0.41\overline{S} - 5.7 + A$$

and therefore,

$$A = \overline{H} - 0.70\overline{D} - 0.45\overline{L} - 0.41\overline{S} + 5.7$$

Where

$\overline{H}$	=	average value for Hauteur for the mill's fleece consignments
$\overline{D}$	=	average value for diameter for the mill's fleece consignments
$\overline{L}$	=	average value for staple length for the mill's fleece consignments
$\overline{S}$	=	average value for staple strength for the mill's fleece consignments
A	=	mill adjustment (mm)

The predicted value for a new consignment H′ will then be given by:

$$H' = H + A$$

where H = Hauteur predicted by the general formula.

There are advantages for a mill in developing a formula based on its own data. The general formulae provide predictions that are based on data for a number of mills and are therefore not necessarily the best for a particular mill. Results for analysis of individual mills are discussed in the next section.

It is appropriate to re-emphasise that the formulae developed in the TEAM Project and presented in the report can be seen as establishing the principle of general formulae for Hauteur, but they can by no means be regarded as representing the ultimate relationships. Results from more mills and consignments should be included before any status is granted to such formulae. Preliminary analyses have also investigated the development of general formulae for other processing characteristics, particularly noil, but as will be seen later in this chapter the reliability of formulae to predict noil for individual mills is not as promising as for Hauteur. This is due to the stronger influence of other factors on this characteristic, particularly mill practice.

Analyses for Individual Mills

Results from preliminary analyses of the data obtained for 11 mill participants were summarised in the Interim Report ([7]). The evidence presented confirmed earlier research ([5]), which demonstrated that within a particular commercial environment there can be a high level of association of raw wool characteristics with processing factors, particularly with the fibre length properties of the top. However, it was clear that the degree of association and the relative importance of particular raw wool characteristics depended on the population of wools and the range of each characteristic. This work has now been extended to include further consignments and analyses.

Here we are faced with the same problems that arise in the development of the general formulae in respect to the choice of variables, their method of selection and estimation of coefficients of a prediction formula. The process is not simply a question of feeding all measurable characteristics into an equation and estimating the coefficients from a limited set of data ([6]).

Top characteristics and processing variables, which have been examined in the analyses are:

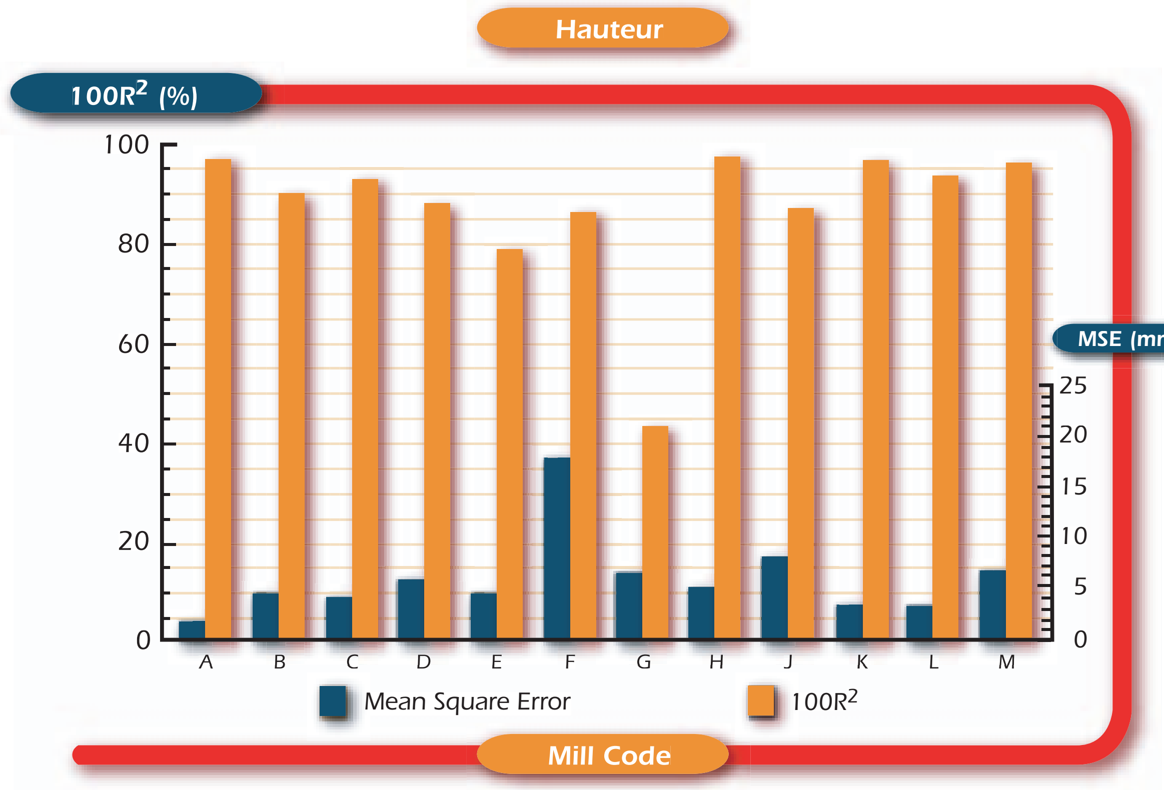
- Noil (%) (Romaine)
- Hauteur (mm)
- Coefficient of Variation of Hauteur (%)
- Barbe (mm)
- Short Fibre Content (%)
- Long Fibre Length (mm)

The raw wool data, which have been examined to establish the best relationship are:

	Symbol
Fibre Diameter (µm)	D
Staple Length (mm)	L
Staple Strength (N/ktex)	S
Vegetable Matter Base (%)	VM
Position of Staple Weakness (%)	POB
Coefficient of Variation of Staple Length (%)	CV(L)
Wool Base (%)	WB
Colour - Lightness (CIE Units)	L*
Colour - Yellowness (CIE Units)	b*
Category Factors	
- for mills with fleece and skirtings consignments only, one factor is sufficient	F
- for mills with fleece, skirtings, and fleece/skirtings blends, two factors are required	F1 & F2

The methods used for the subset selection have been outlined (5). The degree to which the best subset of raw wool variables is able to account for the consignment differences for Hauteur and other processing factors was measured by the mean square error (MSE) and the values for the degree of association ($100R^2$). The values for MSE and $100R^2$ for each mill are plotted in Figure 4 for Hauteur and noil to illustrate the trends observed across mills.

The best relationships are summarised in Table 2 and 3 for Hauteur and noil respectively and in Tables 4, 5, 6 and 7 for the other fibre-length factors. In each table the best subsets of raw wool variables are listed together with the corresponding values for MSE and $100R^2$. For Hauteur and noil the subset (D, L, S, VM) is included for each mill for comparison. Although the analyses sometimes involved significant higher-order terms (5), this aspect of the work is not presented here. For some mills with sufficient consignments of fleece, skirtings, or fleece/skirtings blends, a category factor F or as necessary F1 and F2 was included in the analyses to divide the population of consignments into two or three categories, respectively.



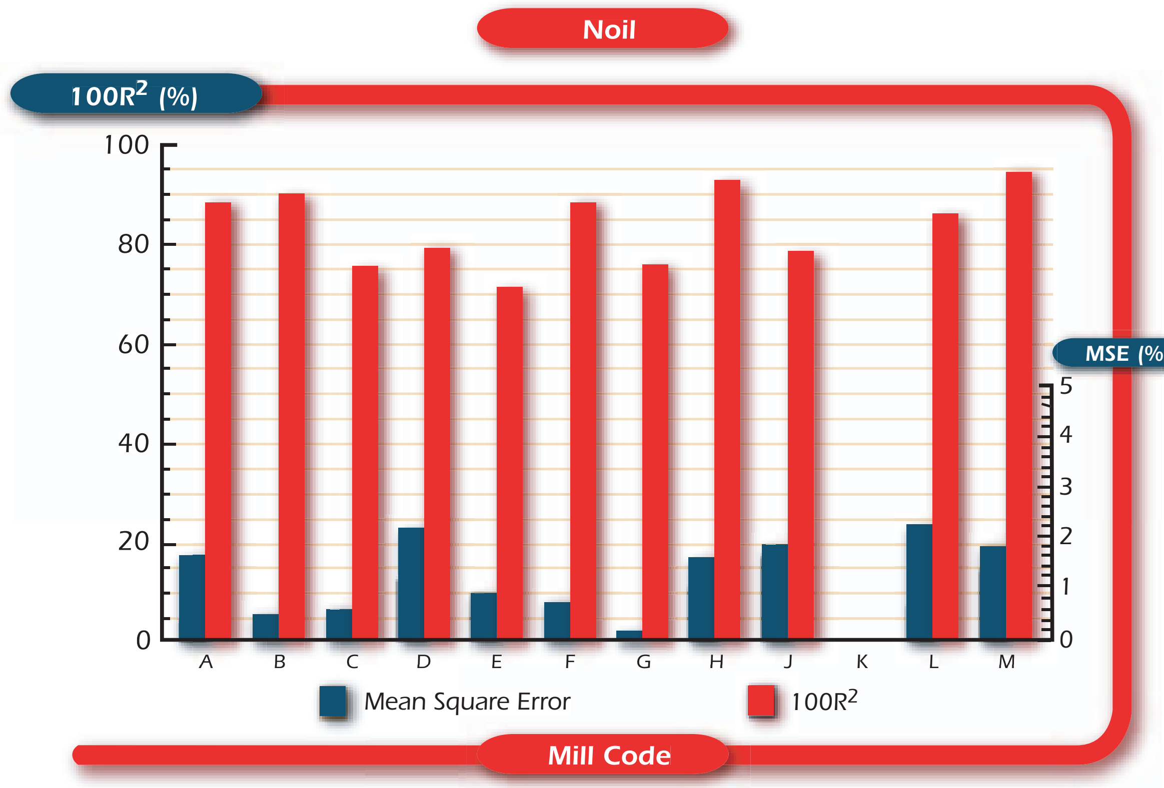


Figure 4
Plot Values for Mean Square Error and
$100R^2$ for Individual Mills

Figure 4 shows that for individual mills the subsets of raw wool characteristics are highly associated with Hauteur as adjudged by the low values for MSE and high values of $100R^2$. These MSE and $100R^2$ values are relatively constant from mill to mill with one exception in each case, Mill F has a markedly higher MSE than the other mills and Mill G has a low value for $100R^2$. The low value for $100R^2$ for Mill G arises because of the limited range of Hauteur found in the consignments; its MSE value, however, is comparable to other mills. For Mill F more scouring and processing lines were employed than in other mills and therefore the mill may have lacked some control in comparison.

Mill A achieved the best result for Hauteur; the MSE is only 2.4 mm^2 (which corresponds to a standard error* of just 1.5 mm) compared to the value of 18.5 mm^2 for Mill F. For Mill A, $100R^2$ is 97, i.e., 97% of the variation in Hauteur was explained by the raw wool measurements. The size of the standard error is approximately 2% of the mean Hauteur, which shows that predictive potential for Mill A is high.

Compared with Hauteur, the values for MSE and $100R^2$ for noil are not as good. There remains considerable error not accounted for and further work is required to determine the residual factors and how much the present limitations are due to inherent mill practice, sampling variability, and the effect of other characteristics not measured in the Project ([5]).

Table 2 gives the important raw wool characteristics influencing Hauteur for each mill. With regard to the best subset of raw wool characteristics it should be noted:

– the subset selected as the best subset is different from mill to mill;

– our selection criteria allowed the number of variables to vary from one to the maximum of five, the most common being four;

– with one exception there are always at least two of the characteristics, diameter, staple length, and staple strength, in the best subset for each mill;

– the subset (D, L, S, VM) was similar in performance, only slightly inferior in most cases, to the best subset;

– in some instances, a variable identifying the wool as fleece or skirtings types is included in the subset; and

– quite often there are other subsets which give similar values of MSE and $100R^2$ to those reported as the best subset. For example, for Mill C other equivalent subsets were (D, L, S, CVL, b*), (D, VM, WB, L*, b*), and (D, S, VM, WB, L*).

* *Standard error is the square root of the MSE and hence is an expression of the error in the units of the characteristic.*

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS##
FOR HAUTEUR

TABLE 2

MILL CODE	RAW WOOL VARIABLES	MSE (mm^2)	($100R^2$) (%)
A	D, S, VM, WB, F (D ,L, S, VM)	2.4 5.4	97 92
B	D, L, L* (D, L, S, VM)	5.1 7.8	90 86
C	D, L, S, L*, b* (D, L, S, VM)	4.6 7.9	93 87
D	L, S, POB, CV(L) (D, L, S, VM)	6.3 9.6	88 82
E	L, S (D, L, S, VM)	5.0 5.6	79 79
F	D, L, WB (D, L, S, VM)	18.4 18.2	86 87
G	S (D, L, S, VM)	6.8 6.5	43 56
H	D, L, S, F1, F2 (D, L, S, VM)	5.4 8.4	97 95
J	L, S, POB, WB (D, L, S, VM)	8.4 11.9	87 82
K++	D, L, WB (D, L, S, VM)	3.4 3.2	96 97
L	D, L, S, F (D, L, S, VM)	3.4 4.9	93 90
M	D, S, VM, b* (D, L, S, VM)	6.9 8.6	95 93

The subset (D, L, S, VM) is also reported for each mill.

++ *Based on a low number of observations; reported only for Hauteur.*

The selection of particular subsets by the analyses can be explained by a number of factors, particularly the type of wool being combed at the mill and therefore the range of the raw wool characteristics. For example, a mill, which consistently purchases wools within the 21 to 23 micron range, might not expect to find diameter as one of the important characteristics in a formula for the prediction of fibre length, since in this case the contribution of diameter to fibre length is fairly constant.

Conversely, a mill which regularly processes both free wools and wools with considerable vegetable fault is likely to find that vegetable matter base is an important characteristic in the subset used to predict fibre length.

The interrelationships or correlations between the raw wool characteristics of the consignments, which are combed at each mill, are also important. Examples of such correlations are vegetable matter base with wool base, and yellowness with diameter (particularly where both merino and crossbred wools are involved). Sometimes in these cases, only one of the correlated characteristics will appear as significant in the relationships with a processing factor. As an extension of this principle, the influence of yield and colour on processing probably arises indirectly through their connections with wool type and style ([5]).

A similar situation occurs for noil (Table 3). The subset selected as the best subset is different from mill to mill, with diameter the most predominant raw wool characteristic. The subset (D, L, S, VM) performs well for most mills.

The important raw wool characteristics appearing in the best subsets for other fibre length properties of the top are as follows:

- Coefficient of Variation of Hauteur (%) (Table 4)

  The best subset is different from mill to mill. However, staple strength, staple length, and vegetable matter base, appear most frequently.

- Barbe (mm) (Table 5)

  Staple length appears in all subsets predicting Barbe. Less important characteristics are staple strength and diameter.

- Short Fibre Content (% less than 25 mm) (Table 6)

  There is no dominant characteristic influencing short fibre content. Diameter, staple strength, yellowness, staple length and position of weakness each appear in several subsets.

- Long Fibre Length (Length at 1%) (Table 7)

  As might be expected, staple length is dominant, appearing in all subsets related to this top characteristic. Secondary characteristics include position of weakness and coefficient of variation of staple length.

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS##
FOR NOIL

TABLE 3

MILL CODE	RAW WOOL VARIABLES	MSE ($\%^2$)	$100R^2$ (%)
A	D, WB, F (D ,L, S, VM)	1.8 3.3	88 79
B	L, WB, L* (D, L, S, VM)	0.6 1.0	81 67
C	D, VM, L*, b* (D, L, S, VM)	0.7 1.2	75 57
D	D, WB (D, L, S, VM)	2.3 3.7	79 70
E	D, S (D, L, S, VM)	1.1 1.1	71 74
F	L, VM, POB (D, L, S, VM)	0.8 1.1	88 84
G	D, L, VM, L* (D, L, S, VM)	0.1 0.1	75 67
H	L, F2 (D, L, S, VM)	1.7 3.0	92 87
J	D, VM, POB, b* (D, L, S, VM)	1.9 2.4	78 73
L	D, L*, F (D, L, S, VM)	2.4 3.5	84 77
M	D, VM (D, L, S, VM)	1.9 2.1	93 93

The subset (D, L, S, VM) is also reported for each mill.

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS
FOR CV OF HAUTEUR

TABLE 4

MILL CODE	RAW WOOL VARIABLES	MSE ($\%^2$)	$100R^2$ (%)
A	D, L, S, CV(L), F	0.7	93
B	L, WB	17.3	55
C	VM, L*, b*	5.8	72
D	L, S, VM, POB, WB	2.0	89
E	S, VM	5.8	48
F	D, L, S, VM	7.6	74
G	VM, POB	4.9	81
H	D, L, S, VM, POB	3.2	85
J	S, POB, WB	8.0	74
L	D, L, S, L*, F	6.4	82
M	S, CV(L), WB	3.9	64

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS
FOR BARBE

TABLE 5

MILL CODE	RAW WOOL VARIABLES	MSE (mm^2)	$100R^2$ (%)
A	D, L, S, WB, L*	2.7	98
B	D, L, L*	8.6	94
C	D, L, S, CV(L), b*	7.3	94
D	L, S, CV(L)	7.3	87
E	L, S, b*	3.8	89
F	D, L, b*	10.2	95
G	L	9.2	14
H	L, VM, WB	10.8	96
J	L, S, POB, WB	5.9	90
L	L, S, F	4.0	93
M	L	11.0	94

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS
FOR SHORT FIBRE CONTENT (% less than 25mm)

TABLE 6

MILL CODE	RAW WOOL VARIABLES	MSE ($\%^2$)	$100R^2$ (%)
A	D, L, S, F	0.8	92
B	D, CV(L), b*	2.1	65
C	D, VM, L*, b*	3.5	70
D	S, POB, WB	3.1	78
E	S, b*	1.6	61
F	D, POB, WB	8.2	66
G	L, VM, POB	3.7	82
H	D, L, L*, b*, F2	0.7	94
J	L, S, POB, WB	5.9	77
L	S, CV(L), b*, F	4.2	73
M	VM, CV(L), WB	2.6	76

SUMMARY OF THE BEST MULTIPLE REGRESSION SUBSETS
FOR LONG FIBRE LENGTH (L @ 1%)

TABLE 7

MILL CODE	RAW WOOL VARIABLES	MSE (mm^2)	$100R^2$ (%)
A	D, L, POB, CV(L), F	6.0	98
B	D, L, S, VM, WB	20.6	96
C	D, L, CV(L), b*	7.1	98
D	L, CV(L), WB	13.5	84
E	L, CV(L), b*	7.8	93
F	L, CV(L)	16.8	96
G	L, POB	17.3	54
H	L, VM, L*	17.2	97
J	L, VM, POB, L*	8.3	91
L	L, POB, CV(L), WB	12.1	91
M	D, L, POB, L*	6.7	99

In terms of the relative errors involved, the reliability of the relationships for Hauteur, Barbe and long fibre length were superior to the reliability of the relationships for coefficient of variation of Hauteur, short fibre content, and noil.

There still remains the question of verification of the predictive models obtained (6), since cross validation or verification of the relationships developed for individual mills have not yet been conducted. Further work by each mill is needed to establish the robustness of the relationships developed.

Factors Affecting Mill Performance

The effectiveness of a relationship between raw wool characteristics and top characteristics is mill dependent. In particular, whilst the worsted combing process is basically similar for all mills, various makes and models of machinery are used, and factory layout and production parameters differ. Furthermore, aspects of quality control and mill management can affect performance.

In comparing mills in terms of the measured characteristics of tops produced by each mill, it is not sufficient to say that one mill consistently produces shorter or longer tops than another. These differences may be qualified by considerations of the management of card waste i.e., whether they are re-incorporated or not, and the degree of cleanliness in the top. Thus, the interrelationship between Hauteur, noil, and top and noil yield, needs to be considered both in technical specification of the top and the economic consequences.

Several examples of mill influence on processing performance have been observed in the Project.

(i) Scouring and Processing Lines.

Most mills have more than one scour train, often of different makes and ages. Similarly, different sets of cards or combs may be used. In one mill, the allocation of TEAM Project consignments to different lines introduced too much variation into the analysis and the influence of raw wool variables on processing performance was masked. Within the Project, it was not possible to prevent the confounding of the influence of comb settings with that of other processing effects. It would seem possible at least to develop a database specifically for each processing line.

(ii) The Influence of Time.

Data were collected for the Project over a three year period. In some cases, processing of most consignments was completed in a much shorter period; in other cases it extended over the full time span. Thus, mill variation due to peaks and troughs of workload, delays in maintenance, changes in equipment or settings, must be considered. We believe the progressive feedback from the Project assisted some mill management in processing subsequent consignments. One mill adjusted its machinery during the Project after reviewing the progress data.

(iii) Measurement of Fibre Length of Top.

The results presented here for individual mills refer to those obtained using the Almeter method. As discussed in detail in chapter 6, some mills participating in the TEAM Project used methods other than the Almeter to determine mean fibre length in the top. In these cases, measurements used in this report were made at CSIRO with an Almeter AL-100 and Fibroliner. Often there were significant changes in the analyses of a mill's performance when its own results were substituted, particularly where the Almeter method was not employed. Predictions for Hauteur or Barbe can be made to within a few millimetres but good control over length measurements is required to achieve such results.

Application of the Formulae

The predicted values for new consignments should be compared with actual processing results. This is the ultimate test of the reliability of prediction from the regression equation. Such an equation can on average be expected to be reliable in use if wool types being assessed are within the range of types which were used to establish it. In any mill the database would be updated continually as each consignment is completed. The mill could then refine the subsets and the formula progressively to check the predictive power. In addition, as the database expands, the value of introducing other raw wool characteristics to improve predictability can be tested.

At this stage the best subsets of the raw wool characteristics which could be used to predict top characteristics are different for each mill, and for each top characteristic within a mill. Whether these subsets continue as the most relevant remains to be seen as more results are accumulated, but it would seem realistic to expect the most influential characteristics in predicting processing performance to fluctuate until a large database is established for each mill.

Preliminary data indicate a topmaker can obtain a more reliable relationship from his own consignments than is obtained from the complete database of the combing mill. The question also arises as to whether the topmaker can simply predict processing performance at a number of mills or whether separate formulae are necessary.

Mills and some topmakers who build up a database and establish their own formulae, will probably use their own formulae to assist in the prediction of processing performance. Consequently, the actual raw wool measurements are more useful to them than a theoretical Hauteur calculated from a general industry formula.

On the other hand, Australian suppliers and other topmakers who comb at a number of mills, could find it difficult to use individual mill formulae as they value or purchase each sale lot. In these cases, initial use of a general formula could enable a comparative set of data to be established by suppliers/topmakers. By comparing actual values obtained, with those predicted by the general formula, it should be possible to develop consistent relationships for each mill. This is similar to the use of IWTO test results for top and noil combing yields and mean fibre diameter by coretest.

In the same way that IWTO recognises the formulae and average processing allowances for the calculation of Estimated Commercial Top and Noil Yields by coretest, it is recommended that IWTO consider encouragement of the development of theoretical Hauteur formulae. As well as the additional measurements appearing on Test Certificates and in sale catalogues, a theoretical Hauteur calculated from recognised formulae could appear on these documents.

Comparison of Mills' Expectations with Predictions

It has never been claimed that the Project would provide a simple solution to the commercial application of additional measurements, but rather that it would provide the basis for processors and topmakers to interpret and analyse the new measurements, and furnish guidelines on how the resultant data may be used to improve efficiency in wool processing and commerce ([7]). Hopefully, in this way commercial implications associated with the introduction of additional measurements will become well understood by the topmaker and comber.

Neither the formulae for the individual mills nor the general formulae for fleece and skirtings types can be expected to predict the processed result exactly. The formulae are useful if they can be applied to estimate the processing result within acceptable tolerances, and in particular, if they can detect abnormal situations in advance. What is acceptable as a tolerance can differ from mill to mill, but to be useful, a prediction formula must be more reliable than the subjective expectations of the mill or topmaker.

Where it was possible, the values for the mill expectations were obtained. Table 8 compares predicted Hauteur and expected Hauteur with the actual Hauteur. The figures shown are the percentage of consignments which actually combed within 1, 2 or 3 mm etc., of the predicted and expected Hauteur. Revised codes were allocated to prevent identification of this information with the processing information.

The values of the mills' expectations were provided to us after the additional measurements were made available to the mill and after processing occurred.

The expectations of the mills/topmakers deviated by a greater margin from the actual Hauteur than results predicted by the mills' formulae. In terms of the mean deviation from the actual Hauteur, the mill/topmaker expectation tends to be an underestimate.

The data reported in Table 8 allow for both positive and negative deviations i.e., no particular distinction has been made between tops, which combed shorter than expected or predicted and those that have combed longer. We appreciate that the cost penalties of the two situations may be different but we are not in a position to adjust for them. While greater concern is expressed when tops comb shorter than expected, nevertheless improved predictions can reduce the conservatism often evident in estimating the expected length and thus will also have economic ramifications. This is discussed in the next chapter.

THE RELATIONSHIP OF EXPECTED HAUTEUR (MILL) AND PREDICTED HAUTEUR (FORMULA) TO ACTUAL HAUTEUR

Percentage of each mill's consignments which actually combed within 1,2, …, 9 mm of predicted and expected Hauteur.

TABLE 8

Deviation from Actual Hauteur	MILL 1		MILL 2		MILL 3		MILL 4		MILL 5		MILL 6		MILL 7		MILL 8		MILL 9	
	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)	Exp (%)	Pred (%)
0 - 1 mm	-	53	19	42	-	37	35	35	22	55	55	70	29	62	29	41	38	54
1 - 2 mm	6	23	19	23	16	42	10	20	28	17	10	25	38	24	12	24	30	38
2 - 3 mm	6	6	4	19	16	21	-	10	11	17	25	-	-	9	23	23	-	-
3 - 4 mm	12	18	15	8	5	-	10	15	11	11	10	5	5	5	6	-	8	-
4 - 5 mm	6	-	12	-	-	-	5	5	-	-	-	-	9	-	12	12	8	-
5 - 6 mm	17	-	8	4	21	-	10	10	16	-	-	-	14	-	6	-	8	8
6 - 7 mm	6	-	8	4	11	-	10	-	6	-	-	-	-	-	6	-	8	-
7 - 8 mm	6	-	-	-	10	-	-	-	6	-	-	-	-	-	6	-	-	-
8 - 9 mm	12	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
> 9 mm	29	-	15	-	21	-	20	5	-	-	-	-	-	-	-	-	-	-

Exp = Expected Hauteur advised by mill/topmaker
Pred = Predicted Hauteur from formula based on the best subset of raw wool variables for that mill
NOTE: Mill identities have been re-coded for this table

References

1. Andrews, M.W., Proc. Seminar - Staple Length and Staple Strength of Greasy Wool, CSIRO Div. Text. Physics, Ryde, Paper 5, (1979).

2. Turpie, D.W.F., and Gee, E., Proc, 6th Int. Wool Research Conf., Pretoria, 3, 293, (1980).

3. Hunter, L., and Gee, E., Proc. 6th Int. Wool Research Conf., Pretoria, 3, 327, (1980).

4. Andrews, M.W., and Rottenbury, R.A., J. Text. Inst., 66, 200, (1975).

5. Rottenbury, R.A., Andrews, M.A., and Brown, G.H., Text. Res. J., 53, 29, (1983).

6. Brown, G.H., Rottenbury, R.A., and Kavanagh, W.J., Text. Res. J., in press.

7. TEAM Project Interim Report, Australian Wool Corporation, Melbourne (1984).

8. Draper, N.R., and Smith, H., "Applied Regression Analysis", John Wiley & Sons, New York, (1968).

9. Miller, A.J., "Selecting Subsets of Regression Variables", Proc. Symp - Regression Analyses, Statistical Soc. of Australia, (1979) .

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4. ECONOMIC IMPLICATIONS

The adoption of additional measurement will have both technical and economic consequences for wool processors. Economic considerations arise in three main areas:

- improved accuracy and reliability of the prediction of top characteristics, processing performance and in the estimation, prior to combing, of the likely cost of a top;

- the potential for improvements in processing productivity; and

- improved control procedures for batching and blending wools to meet a given top specification at least cost.

Within the early-stage processing sector the potential benefits of additional measurement to individual firms will vary depending on their type of operation. Some companies produce tops against specific orders and attempt to minimise cost in purchasing greasy wool to meet the spinner's technical specification. Similarly, other mills produce standard tops but their commercial decisions relate more to selection of blends either at the time of purchase, or at the mill, to ensure costs are minimised. For the commission comber, improved processing efficiency and control are probably the main sources of benefit. For integrated mills, predictability, blending, and productivity, will play an interrelated role in profitability.

Economic Analysis of Prediction*

To be complete an economic analysis would consider overall benefits in terms of all the above factors. The TEAM Project data comparing the reliability of the prediction of Hauteur with a mill's subjective expectations provide information on one aspect of the economic benefits to be derived from additional measurement. Table 8 in Chapter 3 of this report shows the relationship of actual, predicted, and expected values of Hauteur for nine mills; the predicted values were based on the best formula derived for each mill at the completion of the Project.

Prior to the completion of this work, an economic analysis was conducted on data for five of the mills. Mills' Hauteur estimations, made without additional measurement, were compared with a Hauteur predicted, in each case, from a formula derived for each mill and comprising four raw wool variables - diameter, staple length, staple strength and vegetable matter base.

Using price relationships developed to represent average premiums/discounts applying to Hauteur ranges ([1]), the benefits, if any, of prediction over subjective expectation can be estimated. The serious consequences of outright rejection of a top failing to meet specification was not considered in this approach. This analysis detected favourable revenue effects using prediction from the raw wool measurements for four of the mills; however, one mill estimated Hauteur more accurately than the predicted results.

* *The analyses summarised in this section were provided by M.L. Spinks and C. Monty, Economics Department, Australian Wool Corporation.*

The economic analysis for Hauteur concluded that:

- on average, additional measurement would have increased gross revenue per consignment by about $760. However, this varied between an average cost of $24 for one mill to an average benefit of $1,256 for another;

- the results for individual mills and all mills are highly variable. In other words, the benefits (costs) of additional measurement ranged from a cost of $2,911 to a benefit of $4,432 on individual consignments; and

- after adjusting the results for the quantity in each consignment, the benefit to the mills from using a formula to predict Hauteur is about 6 cents/kg clean or 4 cents/kg greasy.

The analysis showed that processors have a better chance of producing top to specifications and consequent financial benefit if they use additional measurement.

In all the wider aspects of topmaking and combing, benefits exist and these will be quantified in future economic evaluations.

Potential for Productivity Improvements

With increasing acceptance of additional measurement, and establishment of databases by topmakers and combers, many innovative concepts can be expected to emerge. Provision of detailed raw material specifications to the combing mill, will enhance its ability to adapt processing procedures to optimise processing results. For example, the effects of changes of procedures designed to reduce fibre breakage will be better identified. A comber on long runs of a standard top type may be able to increase carding speeds and other machine settings for higher staple strength wools, whilst compensatory action could be taken for weaker or more variable length wools.

Flexibility in Blending

It can be expected that additional measurement will assist description of wool for computerised optimisation techniques, which will enable a variety of blends to be proposed to meet a desired top specification. This benefit will flow from the increased ability to predict processing performance of components of a blend.

Perhaps the greatest commercial potential for additional measurement exists in the application of techniques to enable topmakers to prepare blends of wool from a greater range of types and at least cost ([2, 3]). It can be expected that major topmakers in the worsted industry will follow examples already evident, e.g., in blend preparation for carpet yarns in New Zealand ([4]).

References

1. Bell, P.J.M., Proc. Seminar on Additional Measurement for Wool, Ichinomiya, Japan, (1984).

2. Dent, W.T., J. Text. Inst., 67 286-291, (1976).

3. Bell, P.J.M., Wool Technol. Sheep Breeding, 26, Nov. 4, 29-37, (1978).

4. Carnaby, G.A., Computer Blends - I. Principles, WRONZ Communication No. C81, (1983).

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5. THE SIGNIFICANCE OF STAPLE STRENGTH

The influence of staple strength on top length and other processing characteristics has already become evident from earlier sections of the report. Staple strength appears in the general formulae derived for the prediction of Hauteur and in almost all of the individual mill formulae relating raw wool measurements to Hauteur.

This is of particular significance because it has been shown that subjective appraisal of staple strength is unreliable in "sound" wools. Whilst most appraisers can make a clear distinction between "tender" and "sound" wools, they will have difficulty in ranking "sound" wools or in estimating the Newtons/kilotex value of particular lots. In addition, the superiority of the test across the whole range of strength is due in large part to the level of sampling (approx. 60 staples) and the fact that it is random.

The vast majority of consignments in the TEAM Project comprised wools subjectively appraised as sound. As Table 1 and Figure 2 showed, the range of measured staple strength within and between consignments was large. Further evidence of the impact of staple strength measurement is detailed below.

The Effect of Staple Strength on Processing

At the request of one mill, before processing, four consignments were split in two parts by the TEAM Management Committee by re-allocating component lots according to raw wool measurements. Three consignments were split solely on the basis of staple strength of the component lots and one consignment was split on the basis of the values of staple strength and staple length. The raw wool measurements and the Hauteur and noil produced after combing are summarised in Table 9.

Whilst all consignments were ordered and delivered as sound wool, simple grouping of component lots on the basis of objective measurement clearly illustrated the influence of staple strength on processing. In general, an increase of 10-15 N/ktex between consignments produced tops 5-6 mm longer. These results are comparable in magnitude to those found in pilot-scale processing studies ([1]).

There were associated changes in the noil produced for each consignment comparison. Lower values for noil were found with higher staple strength.

It should be made clear that the purpose of this exercise was to establish the value of knowing the average staple strength and length of a consignment before processing in order to predict Hauteur more accurately. It offers little information on the value or otherwise of separating sale lots for the purpose of controlling variability.

SUMMARY OF SPLIT-CONSIGNMENT PROCESSING TRIALS

TABLE 9

	PART A	PART B
CONSIGNMENT 1		
Diameter (µm)	23.6	23.4
VM Base (%)	0.5	0.5
Staple Length (mm)	112	112
Staple Strength (N/ktex)	38	50 (+12 N/ktex)
Position of Weakness (%)	62	69
Hauteur (mm)	76	82 (+6 mm)
Noil (%)	5.9	5.0 (-0.9%)
CONSIGNMENT 2		
Diameter (µm)	25.1	25.1
VM Base (%)	0.5	0.4
Staple Length (mm)	111	110
Staple Strength (N/ktex)	37	47 (+10 N/ktex)
Position of Weakness (%)	60	56
Hauteur (mm)	67	74 (+7 mm)
Noil (%)	5.4	4.5 (-0.9%)
CONSIGNMENT 3		
Diameter (µm)	21.9	21.9
VM Base (%)	0.8	0.7
Staple Length (mm)	95	95
Staple Strength (N/ktex)	32	47 (+15 N/ktex)
Position of Weakness (%)	44	45
Hauteur (mm)	63	69 (+6 mm)
Noil (%)	8.6	7.2 (-1.4%)
CONSIGNMENT 4		
Diameter (µm)	21.2	21.3
VM Base (%)	0.7	0.7
Staple Length (mm)	93	100 (+7 mm)
Staple Strength (N/ktex)	29	40 (+11 N/ktex)
Position of Weakness (%)	42	55
Hauteur (mm)	61	66 (+5 mm)
Noil (%)	11.3	9.0 (-2.3%)

Seasonal Variation in Staple Strength

Data for staple strength measurements can be analysed for seasonal trends and regional differences (2). Sufficient data from sale lots of TEAM consignments were available to enable comparison of fleece wools of 20-23 micrometres sold in Sydney, Melbourne, Newcastle and Goulburn throughout each quarter of each season from 1981/82 up to the end of March 1984. The trend over the three seasons is shown in Figure 5. The staple strength of the fleece lots selected in TEAM Project consignments from these eastern Australian centres averaged approximately 45 N/ktex during the 1981/82 and 1982/83 seasons. The drought during 1982/83 was reflected in the strength measurement of wool sold in the first half of the 1983/84 selling season. Fleece lots in the TEAM Project from these same centres averaged less than 30 N/ktex during this period.

This marked decrease in strength within the 1983/84 season should be viewed in the context of reports from commercial delegates at the IWTO Conference in Paris, January 1984, that Australian wools purchased during September-November, 1983 were processing much shorter than expected yet, subjectively, appeared to be sound.

Suppliers and processors are already aware of many of the effects of staple strength due to seasons, regions and countries of origin. The example presented here illustrates how these effects can be quantified in objective terms.

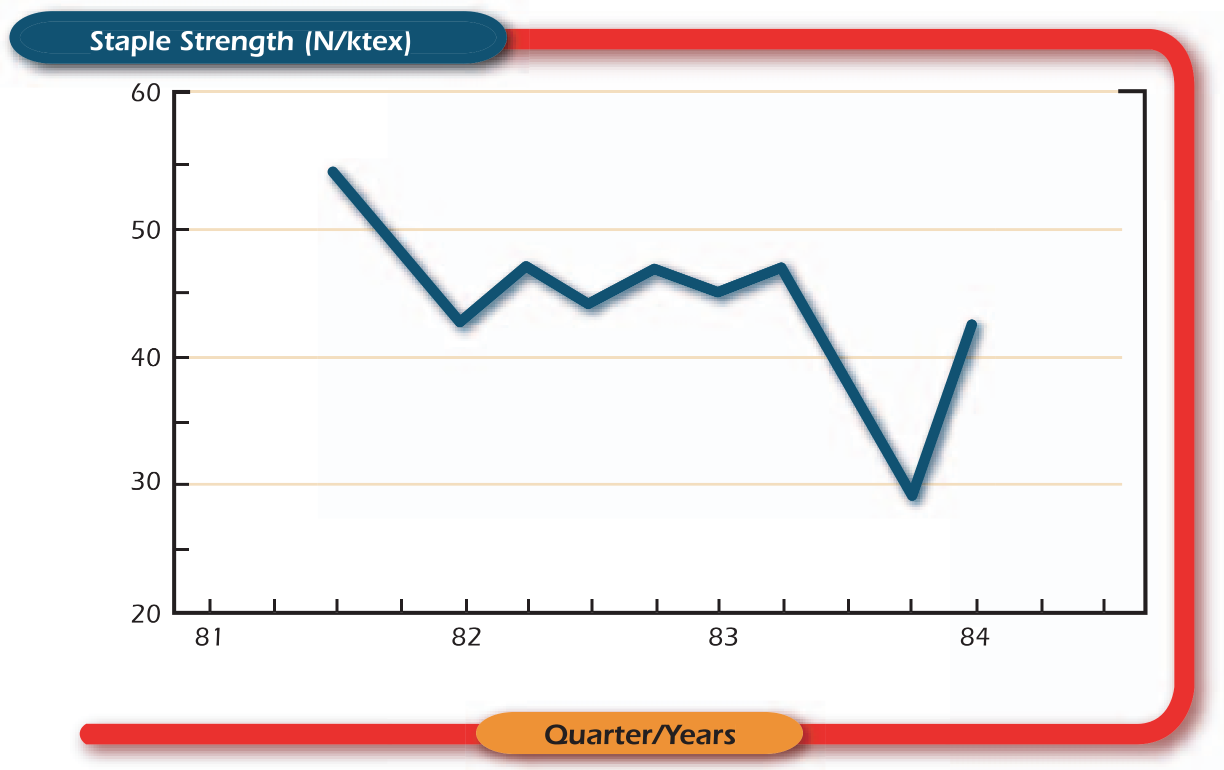

Figure 5

Seasonal Variation of Staple Strength
Combined Data for Sydney, Melbourne,
Newcastle and Goulburn.

Position of Staple Weakness

Although pilot-trial research (3) has shown that position of staple weakness can influence Hauteur when other raw wool characteristics are controlled, in practice its influence is overshadowed by the influence of the level of staple strength. While position of weakness has appeared in the best subset of variables for Hauteur for some mills in the TEAM Project, the effect of commercial blending of wools of different staple lengths with a range of positions of weakness masks the direct influence position of weakness might have on the top characteristics.

On the other hand, position of weakness can influence the fibre length distribution of the top, even at high levels of staple strength (3). Accordingly, position of weakness appears in the best subsets for the characteristics of fibre length distribution and noil in the TEAM Project (see Tables 2-7).

References

1. Rottenbury, R.A., Andrews, M.W., Bell, P.J.M., and Bownass, R., Proc. IWTO Tech. Cttee, Paris, (1985).

2. Rottenbury, R.A., Proc. Seminar-Staple Length and Staple Strength of Greasy Wool, CSIRO, Div. Text. Physics, Ryde, Paper 2 (1979).

3. Rottenbury, R.A., Kavanagh, W.J., Eley, J.R., and Andrews, M.W., Proc. IWTO Tech. Cttee, Paris, (1985).

6. RAW WOOL AND TOP MEASUREMENTS

Colour Measurement in Raw Wool and Top

Colour measurement of raw wool is normally conducted on core samples. Because of logistical problems, this was not possible for TEAM Project wools. However, a colour measurement was determined for each consignment by conducting a colour test on the accumulated broken staples remaining after the strength tests. Preliminary comparison tests showed a satisfactory correlation between this technique and colour measured from core samples in terms of the lightness (L*) and yellowness (b*) parameters.

As will have been noted in Chapter 3, either L*, b*, or both have appeared in some of the groups of raw wool characteristics influencing Hauteur or noil. In one instance (Mill M), we note b* is correlated with staple length, which does not appear in the best group of characteristics to predict Hauteur. In other instances, the presence of the colour component probably provides an indication of wool style.

Analyses of the data for TEAM consignments ([1]) indicate that the spread of values for colour is quite narrow; 79% of the consignments having L* values which lie within the range of two units (from 88 to 90), and 68% of the consignments having b* values within the range of two units (from 12 to 14). Consignments of skirtings types had colour values inferior to those obtained on the fleece types.

Of interest are the equivalent measurements for wool top produced from these consignments. The range for top values reflected this low variation for greasy wool. L* and b* results for 3 mills, re-coded 1, 2 and 3 are plotted in Figure 6. Simple regression analyses were conducted for each mill to examine the relationship between the raw wool and top measurements. The regression of the L* values of tops against raw wool indicated that the degree of association between the two measurements was not high. For Mill 1, only 30% of the variation in the L* values for top was accounted for by changes in the L* values of the greasy wool. It was slightly improved for Mill 2 but worse for Mill 3. In the case of b* values, the degree of association between the measurements was improved, the highest degree of association being that found for Mill 2 where 62% of the variation in the b* values of the tops was accounted for by the greasy wool differences.

The poor relationship between the top measurements and those on greasy wool is not unexpected. It arises principally because of:

– the narrowness of the range for clean colour observed between mill batches;

– the limitations of the precision of the test methods employed, particularly for those on the greasy wool; and

– the variation arising from processing conditions.

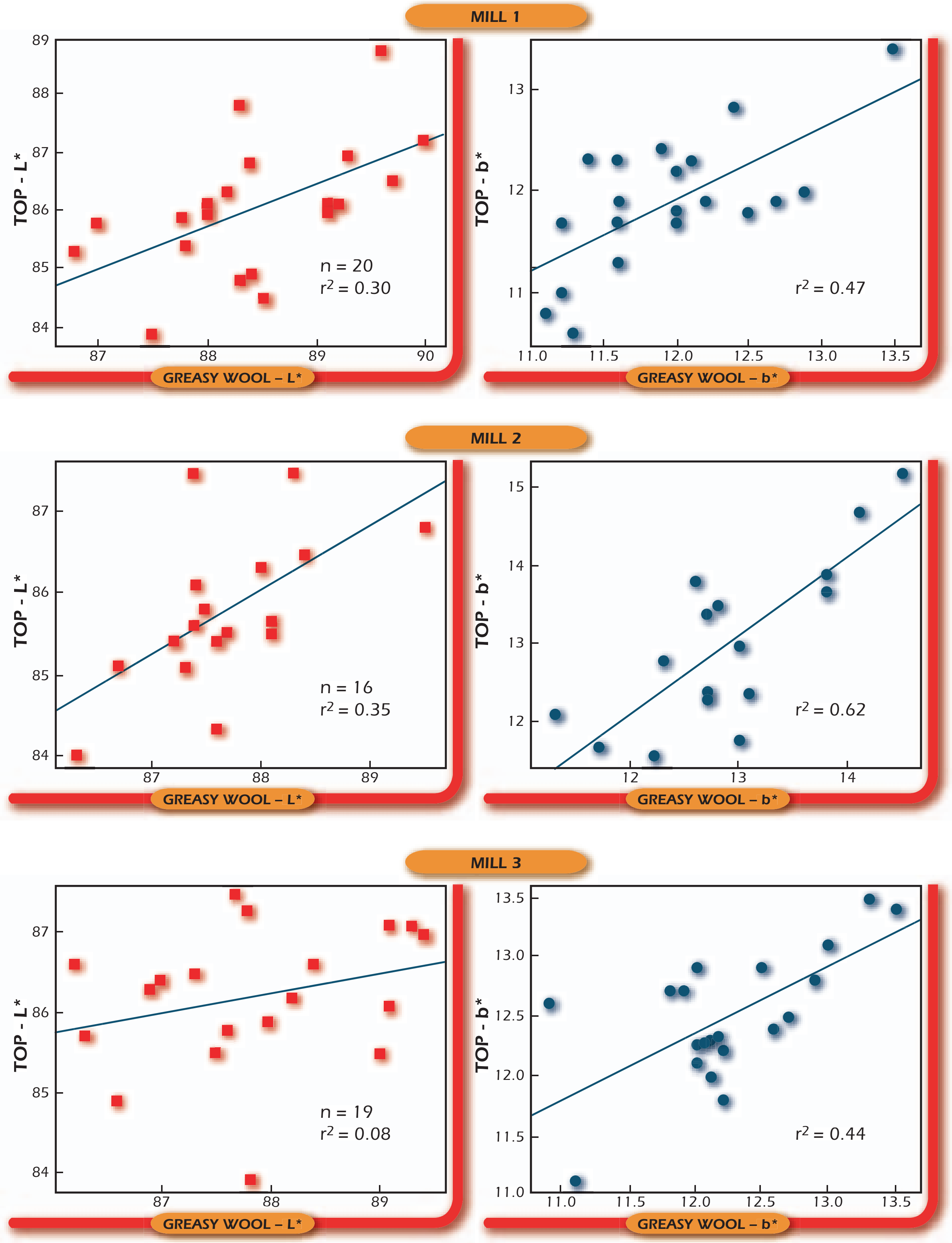

Figure 6
(extract from ref. 1)
L* and b* relationships between measurements
on top and greasy wool for three mills

1-44

The results tend to cast some doubts on the usefulness of the raw wool measurements for the processors if they are to be used for predicting closely the resultant colour of the wool after processing. However, they do not preclude their use for other purposes, such as their more general use for batching of wools to meet the colour requirements demanded for special end uses.

Relationship Between Airflow Measurements of Diameter in Top and Raw Wool

The TEAM Project has provided a database for study of the relationship between mean fibre diameter of greasy wool determined by coretest and the resultant top measured by the individual mill. In the Interim Report ([2]), data based on 11 mills and 149 consignments showed, overall, there was no significant difference between core and top (+0.01 µm).

The final data are based on 12 mills and 211 consignments, and are shown in Table 10. There is little change to the data presented in the Interim Report. Whilst the differences between top and core for individual mills range from +0.25 um to -0.44 µm, the combined difference is -0.03 µm, i.e., on average the top is 0.03 um finer than the core.

When core testing for fineness was introduced in the mid 1960's, a 0.5 um difference between top and core tests was generally expected. It was suggested that the noils removed in combing were finer than the resultant top, which was in turn coarser than the raw wool measurement. Data published in 1976 ([3]) comparing core/comb results on 122 consignments of Australian wool collected from 45 combing mills over the period 1964 - 1973 showed the difference between top and core was then 0.3 µm (the top being coarser). Now the latest TEAM data on 211 consignments show the difference to be non-significant statistically.

The reasons for differences between mills, different diameter groups and changes in the relationship over time are not clear, but it is our opinion that several factors which may have varied simultaneously are involved. These include:

- changes in processing machinery and speed of operation which can affect the amount and fineness of combing noil; and
- standardisation and calibration in airflow measurement of diameter of tops and greasy wool.

Relationship Between Dry Combed Top and Noil Yield and Estimated Yield by Coretest

The estimation of top and noil yield by coretest was the first application of coretesting to greasy wool trading. Although the IWTO method of test is confined to the determination of wool base and vegetable matter base, the information is only useful in trading when it is converted, using IWTO recognised formulae, to an estimated commercial yield.

COMPARISON OF MEAN FIBRE DIAMETER IN TOP AND RAW WOOL
FOR 12 MILLS, 211 CONSIGNMENTS*

TABLE 10

MILL CODE	MEAN FIBRE DIAMETER (AIRFLOW) CORE (µm)	TOP (µm)	DIFFERENCE (µm) (Top-Core)
1	22.41	22.38	-0.03
2	22.88	23.00	+0.12
3	21.64	21.58	-0.06
4	20.33	20.30	-0.03
5	20.06	20.01	-0.05
6	22.19	22.36	+0.17
7	22.14	22.02	-0.12
8	22.69	22.25	-0.44
9	25.43	25.68	+0.25
10	21.12	21.04	-0.08
11	23.10	22.89	-0.21
12	22.17	22.32	+0.15
Mean Results	**22.18**	**22.15**	**-0.03**

** Mill identities have been re-coded.*

COMPARISON OF DRY COMBED TOP AND NOIL YIELD WITH THE
ESTIMATED YIELD BY CORETEST FOR 12 MILLS, 227 CONSIGNMENTS**

TABLE 11

MILL CODE	TOP AND NOIL YIELD CORE (µm)	COMB (µm)	DIFFERENCE (%) (Comb-Core)
1	60.51	59.55	-0.96
2	57.18	59.00	+1.82
3	58.97	58.64	-0.33
4	62.66	62.34	-0.32
5	64.92	65.47	+0.55
6	63.84	63.97	+0.13
7	72.83	72.04	-0.79
8	64.40	63.58	-0.82
9	68.28	68.97	+0.69
10	63.32	63.72	+0.40
11	62.73	62.22	-0.51
12	62.20	62.65	+0.45
Mean Results	**64.44**	**64.42**	**-0.02**

*** Mill identities have been re-coded.*

The estimated commercial top and noil yield calculations include standard allowances for regain, residual fatty matter and ash, and tear (romaine). In addition, processing allowances based on vegetable matter base and its composition, are deducted during the calculation. The processing allowances are based on an original survey of 289 combing yields prior to 1964. Their relevance was confirmed in 1976 by a further survey of 397 consignments on Australian wools, which found that, on average, the estimated commercial top and noil yield, calculated in accordance with the IWTO formulae, accurately predicts the actual combing yield. That survey (3) also showed large differences in the relationship of core/comb yields between mills and variation in the relationship within mills.

The findings of that early survey are confirmed by the TEAM Project data summarised in Table 11. On average, the dry combing yield is 0.02% lower than the coretest yield. The mean difference between the core/comb yields for individual mills varies from +1.82 (combing yield greater than core) to -0.96% (combing yield less than core).

More detailed analysis of core/comb results from the Project will appear in the subsequent Technical Report.

Measurement of Fibre Length of Tops

Mills participating in the TEAM Project measured length routinely by either the Almeter, Almeter AL-100, WIRA Fibre Diagram Machine, and Suter Comb Sorter. Whilst raw wool characteristics for individual mills can be related to the top measurements obtained from each mill's instrument, values shown in the report have all been based on Almeter or Almeter AL-100 measurements. Where the mill did not have its own Almeter, top samples were measured in Australia at CSIRO using an Almeter AL-100.

In addition, top samples from mills who provided Almeter top length results for the Project were re-measured at CSIRO. This enabled a comparison of the CSIRO instrument and eight industry Almeters. Whilst differences between length measurement methods are well known, Table 12 shows the degree to which differences occur with the Almeter method. To maintain confidentiality, the mills have been re-coded. The difference between five of the mills and the CSIRO instrument is small but biases of -1.3 mm, -3.1 mm and -4.5 mm occur for three of the mills. The differences are reported in terms of the CSIRO instrument because it is the instrument common to all the comparisons.

COMPARISON OF MILL AND CSIRO ALMETER MEASUREMENTS
FOR 8 MILLS, 159 CONSIGNMENTS

TABLE 12

		AVERAGE DIFFERENCE (CSIRO-Mill)				
MILL CODE	HAUTEUR (mm)	CV HAUTEUR (%)	BARBE (mm)	% <25mm (%)	L @ 1% (mm)
1	-0.6	+0.8	-0.3	+0.5	+0.6
2	-0.5	-2.3	-2.0	-0.2	+2.7
3	-1.3	0.0	-1.6	n.a.	n.a.
4	+0.2	0.0	+0.2	n.a.	n.a.
5	-0.2	-1.3	-1.3	n.a.	n.a.
6	-3.1	+2.0	-2.6	+1.8	-3.0
7	-4.5	+6.3	-1.8	n.a.	n.a.
8	-0.9	-3.3	-3.5	+0.3	-0.3
Mean Result	**-1.4**	**+0.3**	**-1.4**	**+0.6**	**0.0**

Standardisation and Harmonisation

The variation in the relationships between raw wool and top measurements, or measurements of the same characteristic by different mills or laboratories, highlights the importance of standardisation of instrumentation and procedures, and the harmonisation of testing organisations and mill laboratories.

In the comparison of raw wool and top measurements for similar characteristics, it is quite clear that processing procedures used to convert raw wool to top will influence any comparison. Nevertheless, even with recognised testing procedures, constant vigilance is required to ensure that Standards are well defined, unambiguous, and repeatable. In this regard the responsibility given to Interwoollabs and other organisations conducting round trials of test methods cannot be underestimated.

References

1. Rottenbury, R.A., Wool Tech. and Sheep Breeding, in press.

2. TEAM Project Interim Report, Australian Wool Corporation, Melbourne, (1984).

3. Ward, D.J., and Douglas, S.A.S., Proc. IWTO Tech. Cttee., Paris (1976).

7. ACKNOWLEDGEMENTS

This is not the end of TEAM. To the Management Committee and their colleagues this report is the beginning of the task they face in properly documenting all of the results and analyses and the detail and conclusion leading from them.

It will take a year or more to draw together a technical compilation embodying a proper account of the Project and its immediate consequences. Valuable data have been put aside in order to follow the main thread of the Project. Important questions, secondary to the direct determination of the influence of raw wool characteristics on Hauteur and noil, remain to be answered.

Nevertheless, this is the appropriate time to mention the individual contributions of those who have guided and assisted the Management Committee to this point. We have already noted the wave of industry interest in the Project; the participants are listed and thanked elsewhere in the Report. As for our colleagues, it is an invidious task to mention some to the exclusion of others, because the technical environment prospers with the comments and criticisms of all colleagues. We shall do our best to be fair.

Mr. Peter Bell, Director-Europe, Australian Wool Corporation, has been a consultant to the Project from its inception and has been kept informed of all the deliberations of the Management Committee to enable him to operate efficiently in that role. Needless to say his advice was of great value and his direct assistance in maintaining contact with participants must also be mentioned.

The Committee was advised on all statistical matters by Dr. George Brown, CSIRO Division of Mathematics and Statistics, and by Mrs. Wilma Kavanagh of the CSIRO Division of Textile Physics. Under their guidance, systems of analysis were explored and the appropriate methods for our particular needs were worked out within the Project. In the later stages of the Project this task magnified in intensity and depth and they were supported by Mrs. Teresa Murphy, CSIRO Division of Textile Physics.

Right from its origin the Project was seen to have impact directly upon the questions that always affect change in industry - what will be the cost of introducing new methods, and particularly, what will be the economic benefits flowing to the whole industry as a result?

Because of the role of the Australian Wool Corporation in the industry and its particular concern to assess the economic balance of new procedures, the machinery was set in place for using the data and technical conclusions of the Project for examination of the costs and benefits of procedures arising from the Project. Mr. Murray Spinks and Ms. Corola Monty worked alongside the Project and some of their conclusions are summarised in Chapter 4. As with the technical material, much remains to be done, and we thank them for joining in this report with an indication of their progress.

Within the organisations that have fostered this Project there are many others who have gone much further than mere duty to assist the logistics and reporting of the Project. Without naming individuals, we thank you all for your help.

To the Chairman and members of the Australian Wool Corporation's Wool Measurement Research Advisory Committee, our report to you comes with our thanks for your confidence in us and in the concepts of the Project.

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TEAM2

TRIALS EVALUATING ADDITIONAL MEASUREMENTS

REPORT ON TRIALS EVALUATING ADDITIONAL MEASUREMENTS

1981 - 1988

Report to the Raw Wool Measurement
Research Advisory Committee
of the Australian Wool Corporation.

December 1988

First Printed by
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Melbourne, December, 1988

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PREFACE

The original TEAM Project (TEAM-1) was conducted between July, 1981 and July, 1984. The aim of this project was to enable processors of Australian combing wool to evaluate the new measurements of staple length and staple strength. Since the publication of the results of TEAM-1 in January, 1985, these measurements have become commercially available in Australia.

A new trial (TEAM-2) was commenced in July, 1986 to expand the database, investigate the current applicability of prediction formulae previously developed and, if relevant, extend and improve these formulae with information from further commercial consignments. In addition, more data was sought for economic analysis of the possible benefits of objective measurements. As for TEAM-1, this project was funded by wool growers through the Australian Wool Research and Development Council.

At the same time, a considerable number of results was being collected by AWTA Ltd through another scheme. This scheme, sponsored by AWTA Ltd and the AWC, was primarily designed to allow mills and topmakers who did not participate in either of the TEAM trials, to gain some experience in the application of staple length and staple strength measurements to their greasy wool purchases.

The data from these three sources have been included in this Report. In total, results were collected for over 600 combing consignments, combed in 28 different mills located in 12 countries. Of these, 545 results from 20 mills have been used in the final analysis, as not all the mills provided sufficient data for each consignment.

The TEAM Management Committee would like to express its thanks to all participants and industry groups for their cooperation in this Project. The primary aim of industry is to be profitable, which is not always compatible with the demands of a research project. The reason for participation in TEAM was mostly based on an appreciation of the medium to long-term benefits expected to be available to the processor, topmaker and industry with the wider introduction of additional measurements in Australia.

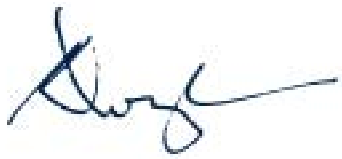
An important aspect of these trials is that they represent actual industrial practice. This means it is possible for immediate industrial application of the findings, as well as demonstrating to individual processors and topmakers the use of prediction techniques for their own applications.

TEAM-1 was successful in creating an awareness of the potential to use staple measurements for the prediction of Hauteur. In particular, it highlighted the influence of staple length and strength on Hauteur. The results of the TEAM-2 Project reflect expanded interest in these staple measurements. New mills have participated and more data is available. Interestingly, the environment has changed since TEAM-1. Seasonal conditions have generally been good, additional measurements are commercially available and sampling and testing techniques are now standardised. We are fortunate that a number of TEAM-1 participants were able to continue to participate in TEAM-2, enabling comparisons of the two project periods to be made.

As with TEAM-1, contact and communication with the industry has been a feature of the current trial, with regular visits to participants, and regular updates of progress being presented at IWTO meetings. The TEAM Management Committee acknowledges the interest of the IWTO in this international industry project. It has consistently provided a forum to present progress results and concepts to both technical and commercial interests, and we have again chosen an IWTO Meeting (December, 1988) to formally present the Final Report of the TEAM-2 Project to industry.

The results, conclusions and recommendations of this Report are such that they should encourage combers and topmakers to develop their own database. The Report is specific in defining ways to use the measurements and will encourage mills and topmakers to commence specifying staple length and strength measurements, and stimulate mills to be self sufficient and skilled in their own applications of the measurements.

The industry generally recognises that increased specification is one essential requirement to enable wool to compete effectively with manmade fibres and to maintain the long term viability of the industry. I hope that the concepts researched, and outlined in this Report, assist processors to make productive use of these specifications.



S.A.S. Douglas, Chairman
TEAM Management Committee

CONTENTS

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1. SUMMARY OF THE REPORT - CONCLUSIONS & RECOMMENDATIONS

During the period 1981-88, two research projects have evaluated the relationship of objective measurements on Australian raw wool consignments with the processing results and top specifications achieved after their combing in commercial mills. Known as TEAM-1 and TEAM-2, the projects obtained data from more than 600 consignments combed in 28 different mills located in 12 countries. This Report outlines the analyses and findings from the research.

Conclusions

The principal conclusions of the Project are:

- Staple length and staple strength are confirmed as the major raw wool characteristics influencing the resultant Hauteur of consignments. Fibre diameter and the position of break (measured as the percentage of staples exhibiting a middle break) are contributing characteristics, whilst vegetable matter base has a small, but significant, impact.

- In the time period between the two TEAM Projects, there has been a significant shift in the relationship between the prediction of Hauteur from the raw wool measurements and the actual Hauteur achieved. Mills are now combing longer tops than would have been expected from the formulae established in TEAM-1 and applied without adjustment. This effect is considered to reflect awareness of the use of a prediction formula to monitor comparative mill performance, the installation of more modern equipment, and the introduction of standardised sampling and testing procedures.

- There is now sufficient evidence to review previously published general formulae for the prediction of Hauteur and a new formula has been recommended. The new formula includes terms for percentage of middle breaks and vegetable matter base to acknowledge the effects extreme values of these characteristics can have on Hauteur of tops.

- There are appreciable differences between performances of mills. Unless individual mills have their own extensive database, this general formula appears to be the best formula to be used for prediction of Hauteur provided the constant term in the formula is suitably adjusted to compensate for the individual mill's performance.

- There are indications that improved prediction may be possible for individual mills as they collect and analyse their own database. Limited evidence exists of potential benefits to individual mills from grouping data (e.g., by length, type or processing line).

- As awareness of additional measurements improves and their application to wool marketing and processing becomes more familiar, greater use will be made of other prediction methods using computers. Increased availability of additional measurements on consignments will facilitate this process.

- Predictions based on the general formula published here performed better than expectations for three out of four topmakers who provided data. Topmakers' expectations of Hauteur have improved in the period between the two Projects, possibly because of more familiarity with the effects of staple characteristics on Hauteur. Economic implications must be viewed with caution as price premiums or discounts associated with changes in Hauteur can be masked by changes in other price determining characteristics, in particular, mean fibre diameter.

- Sufficient data is now available to publish initial general formulae as a guide for the prediction of Noil and Coefficient of Variation of Hauteur. However, their prediction is not as good as that for Hauteur.

- Core/Comb comparisons for fineness and yield show negligible change over the time period between the two TEAM Projects. Over all mills, the mean fibre diameter of the top is 0.05 mm coarser than the greasy wool, whilst the mill yield is 0.1% lower than the coretest yield.

Recommendations

1. Based on the total database, the TEAM Management Committee recommends the following general formula be used for prediction of Hauteur.

   $$H = 0.52L + 0.47S + 0.95D - 0.19M^* - 0.45V - 3.5$$

Where	H	=	Hauteur (mm)
	L	=	Staple Length (mm)
	S	=	Staple Strength (N/ktex)
	D	=	Fibre Diameter (µm)
	M*	=	Adjusted Percentage of Middle Breaks (%)
	V	=	Vegetable Matter Base (%)

   Whilst this formula may not necessarily be the best in all circumstances, it is considered more robust than earlier formulae. Other formulae derived for Noil and Coefficient of Variation of Hauteur should be used for guidance purposes only.

2. Mills need to establish their own database and develop their own formula(e), initially by using this general formula and determining and monitoring an appropriate constant adjustment. The opportunity for further development by independent regression analysis is recommended only after a substantial private database is accumulated. However, the opportunity for fine-tuning formulae for particular categories or types of wool is encouraged. Topmakers who comb at several mills should similarly establish databases for each mill and/or the broad categories of wool they use.

3. A facility should be maintained to assist combers and topmakers develop formulae and interpret raw wool/processing comparisons. Such a confidential advisory service could be provided by bodies, such as AWTA Ltd, who already have experience in this field.

4. To facilitate the implementation of the findings of the TEAM Project, it is important that the number of sale lots presale tested for staple length and strength increases substantially. Woolgrowers require continued encouragement to request these tests on their combing wool lines to ensure export consignments of fully measured lots can be assembled without the need for post sale testing. Topmakers should consider requesting staple measurements with their deliveries and exporters encouraged to provide them to their clients.

5. IWTO Combined Staple Test Certificates should report the percentage of middle breaks as a mandatory requirement to ensure the data is available, together with mean staple length and strength, for use in predictive formulae.

6. There may be other raw wool factors e.g., style, which may affect processing performance. Research programmes, which develop objective measurements for these other factors should continue, and their usefulness in improving prediction evaluated.

7. Processing control technology and computerised systems offer scope for alternative predictive techniques. Research in this area should continue.

8. Instrument calibration and quality control of fibre length and fibre diameter testing methods should be reviewed regularly to minimise between-mill and/or between-laboratory differences. Interwoollabs takes a major role in this area and it is recommended their importance in harmonisation be more widely promoted. Participation in harmonisation schemes by mills and laboratories must continue to be encouraged.

2. TEAM PROJECT: SCOPE AND OPERATION

2.1 Background

TEAM-1

The initial TEAM Project (TEAM-1) ran from July, 1981 to July, 1984.

This project was jointly managed by AWTA Ltd, the Australian Wool Corporation and CSIRO Division of Wool Technology (formerly known as the Division of Textile Physics). During that project, the results of 234 industrial combing consignments from 12 international combing mills were monitored.

The Final Report ([1]) to the Australian Wool Corporation summarised the principal findings of TEAM-1 in January, 1985. Apart from clearly identifying the major role of the influence of staple length and strength on the resultant mean fibre length of the top (Hauteur), separate general formulae for the prediction of Hauteur for fleece and skirtings types were published for guidance purposes only.

For consignments of fleece wools, the formula was:

$$\mathbf{H = 0.45L + 0.41S + 0.70D - 5.7} \quad \text{(1)}$$

For consignments of skirtings, the formula was:

$$\mathbf{H = 0.40L + 0.32S + 1.53D - 20.1} \quad \text{(2)}$$

where: H = Hauteur (mm)
L = Staple Length (mm)
S = Staple Strength (N/ktex).
D = Fibre Diameter (µm)

As there was uncertainty how these formulae were applied to consignments containing blends of skirtings and fleeces, and because it was felt by the trade that vegetable matter base was an important variable to be considered in processing, another general formula was published ([2]) which allowed for the prediction of Hauteur for either fleeces or skirtings. This formula, which performed nearly as well as the separate formulae, was:

$$\mathbf{H = 0.47L + 0.42S + 0.85D - 0.44V - 11.8} \quad \text{(3)}$$

where H, L, S and D are defined, as above, and V as vegetable matter base (%).

The TEAM-1 Project concluded that staple length, staple strength, fibre diameter, and vegetable matter base were the most significant raw wool characteristics affecting Hauteur and Noil. The relative importance of the raw wool characteristics could vary for each mill and appeared dependent upon the range and type of wools processed. While the formulae developed in TEAM-1 established the principle of calculated Hauteur values, they were not regarded as representing the ultimate relationship, but served for guidance.

It became clear that a much larger database would enable a more effective analysis of the relationship between raw wool characteristics and processing results. Consequently, this project (TEAM-2) was initiated.

TEAM-2

The TEAM-2 Project commenced in July, 1986. The basic objectives of this Project were:

- to expand the TEAM database on a formal basis;
- to review existing analyses and formulae for the prediction of Hauteur, Coefficient of Variation of Hauteur, and Noil;
- to extend the economic analysis of the use of objective measurements; and
- to investigate other techniques for prediction of processing results.

This project was set up along similar lines to the TEAM-1 Project, and coordinated by a TEAM Management Committee comprising:

The late M.W. Andrews *(Chairman, until his death in November, 1986)*	*CSIRO Division of Textile Physics* *Assistant Chief*
S.A.S. Douglas *(Chairman, since November, 1986)*	*Deputy Managing Director* *AWTA Ltd*
AWTA Ltd W.D. Ainsworth *(TEAM Project Manager)*	*Raw Wool Group,* *CSIRO Division of Wool Technology,* *(on secondment from IWS)*
R.A. Rottenbury	*Programme Leader – Raw Wool Group,* *CSIRO Division of Wool Technology*
J.W. Marler	*National Technical Manager,* *AWTA Ltd*
R.J. Quirk	*Group Manager-Industry Services,* *Australian Wool Corporation*
C. Vlastuin	*Senior Research Economist,* *Australian Wool Corporation*
P.J.M. Bell	*Director - Technical Services (Europe)* *Australian Wool Corporation*

Dr. G.H. Brown, from CSIRO Division of Mathematics and Statistics was engaged to assist in the analyses and their interpretation for this Final Report.

The target for the TEAM-2 Project was the collection of a further 200 combing consignment results over a two-year period from six selected processors operating in eight combing mills. For a number of reasons, only 117 consignments were fully completed in the period.

<u>AWTA Ltd and AWC Scheme, and Other Sources</u>

The expansion of the database was not confined specifically to the TEAM-2 Project. In 1985, an incentive scheme was initiated by AWTA Ltd to enable mills and topmakers, who did not participate in either of the TEAM trials, to gain some experience in the application of staple length and staple strength measurements. This scheme was co-sponsored by the AWC.

In addition, some data was provided voluntarily by several mills already evaluating additional measurements for their own interest.

A total of 17 combing mills, most of which had not participated in either TEAM Project, submitted results for 219 combing consignments.

Finally, data from trials carried out by CENTEXBEL-Verviers, Belgium, have also been made available to the TEAM-2 Project.

2.2 Industry Participation

A feature of the trial has been the large number of mills, topmakers, merchants, exporters and brokers who have been involved in the trials. In total, data from 603 consignments comprising 88,000 bales processed in 28 mills from 12 countries have been provided to the TEAM Committee for analysis. The lists of cooperating mills and topmakers is as follows:

Combing Mills	Country	Participation+
Canobolas Wool Topmaking Pty Ltd	Australia	T1
F W Hughes Pty Ltd*	Australia	T1
G H Michell & Sons (Aust) Pty Ltd	Australia	T2
Port Phillip Mills Pty Ltd*	Australia	T1
Riverina Wool Combing Pty Ltd	Australia	T1, T2
United Industries Uneklo SA	Belgium	S
Peignage Amedee SA	France	T1, T2
Peignage Dewavrin	France	S
Jaya Shree Textiles	India	S
Raymond Woollen Mills Ltd	India	T1
Shri Dinesh Mills Ltd	India	S
Lanerossi SpA	Italy	S
Manifattura Lane Gaetano Marzotto & Figli SpA	Italy	S
Pettinatura Italiana SpA	Italy	T1, T2
Kurabo Industries Ltd, Tsu Mill	Japan	S
Kurashiki Woollen Manufacturing Co	Japan	S
Nippon Keori Kaisha Ltd	Japan	T1, S
Toa Boshoku Co Ltd	Japan	T1, S
Toyobo Co Ltd	Japan	S
Tsuzuki Spinning Co Ltd, Sobue Mill	Japan	S
Unitika Wool Ltd, Miyagawa Mill	Japan	S
Malaysian Topmaking Mills SDN BHD	Malaysia	S
Cheil Wool Textile Co Ltd, Daegu Mill	South Korea	T2, S
Cheil Wool Textile Co Ltd, Gumei Mill	South Korea	T1, T2, S

Combing Mills (Continued)	Country	Participation+
Peinaje del Rio Llobregat SA	Spain	S
Chuwa Wool Industry Co Ltd	Taiwan	S
Burlington Industries Wool Co	USA	T1
Bremer Woll-Kammerie AG	West Germany	T1, T2

+ T1 = TEAM-1; T2 = TEAM-2; S = Other Schemes

** These mills are not operating currently as combing mills.*

Topmakers	Country
Australian Wool Corporation	Australia
Cargill Pty Ltd	Australia
Vandeputte SA	Belgium
Bloch & Behrens APS	Denmark
Antoine Segard & Co	France
Soc. Commerciale Prouvost & Lefebvre	France
Anselme Dewavrin Pere et Fils SA	France
C Itoh & Co	Japan
BWK Topmaking - Bremer Woll-Kammerie	West Germany
W A Fritze & Co	West Germany
Kulenkampff & Konitzky	West Germany
Lohmann & Co GmbH	West Germany

2.3 Description of the Database

Data Collection

Throughout this Report, reference is made to the **Total database**, the **TEAM-1 database,** and the **TEAM-2 database.** For simplicity, the TEAM-2 database includes all data accumulated in the TEAM-2 Project and other trials undertaken since the TEAM-1 Project. Data from these other trials, whilst not directly under the control of the TEAM Management Committee, were considered satisfactory for inclusion in analyses with TEAM-2 data.

The information obtained from the Projects can be divided into three groups, the Raw Wool Data, the Processing Data, and the Topmaker Expectations Data.

Raw Wool Data

For each consignment, TEAM required individual Test Certificates covering fineness, yield and staple characteristics for each of the constituent sale lots in the consignment. The number of lots per consignment ranged from 3 to 80, with an average of 17 lots. From these Certificates, the main raw wool variables, as listed in Table 1, were calculated for each consignment.

TABLE 1

MAIN RAW WOOL CHARACTERISTICS OF CONSIGNMENTS

PROPERTY	SYMBOL	UNIT
Wool Base	W	%
Vegetable Matter Base	V	%
Hard Heads Base	HHB	%
Mean Staple Length	L	mm
Coefficient of Variation of Staple Length	CVL	%
Mean Staple Strength	S	N/ktex
Percentage of Middle Breaks	M	%
Mean Fibre Diameter	D	µm

Difficulties arose with the complete collection of raw wool data for all consignments due to the following reasons:

– topmakers did not always retain complete sets of Test Certificates, and it was not always possible to recover file copies;

– at time of processing, decisions could be made to leave out some wool, i.e., outsorts, or some wool was misplaced during transport. In this situation recalculation of data was required, and could only be achieved when the bales and lots were clearly identified and individual Test Certificates supplied; and

– in some situations it was difficult for topmakers to ensure that the final consignment would consist entirely of tested sale lots. In this case, special arrangements were sometimes made for staple samples and core samples to be taken immediately prior to processing, and testing was carried out after combing.

Processing Results

For collection of processing results a proforma, listing all the data required, was provided to mills and topmakers (refer Appendix 1). Mills were also asked to provide any standard mill report or test sheets to support the results supplied.

As well as providing the principal results from the combing of the consignment, information requested was designed to provide enough detail to ensure that major modifications in processing conditions, such as scouring procedure, regain of products, use of different processing lines etc, could be identified.

In addition, representative samples of top were requested to enable Almeter measurements of the top by CSIRO Division of Wool Technology. This data provided a common measurement basis for the Total database.

The collection of processing results indicated a number of differences in mill procedures. Some examples were:

– the method of expressing regain values differed and some needed to be recalculated to a standard basis;

– methods of expressing combing yield results differed and again these were recalculated to a common basis;

– the basis for expressing top faults varied; and

– production pressures at a mill occasionally resulted in the collection of top and noil samples being overlooked.

Expectations Data

As with TEAM-1, the TEAM Management Committee asked topmakers and mills in the TEAM-2 Project to provide their processing expectations for Hauteur and Noil. In TEAM-2, expectations were sought both before and after access to the staple length and strength measurements on each consignment. This information was not always available, but data was provided by six mills.

Database for Analysis

Because of the difficulties in data collection referred to above, some of the consignments did not have all the required information. Further, some mills combed insufficient consignments for their data to be included in the Total database for analysis. Consequently, for prediction analysis purposes, a smaller data set was selected which included 20 mills and 545 consignment results, distributed as shown in Table 2. Furthermore, not all of these results were used for analysis of all the processing characteristics considered, as data for important measurements were missing in some cases. Conversely, some data insufficient for prediction analysis could be used for analysis of some specific processing characteristics (e.g., top and noil yield).

In all the Tables in this Report, the mills have been randomised and alphabetically coded to maintain confidentiality. Further, there is no relationship between the same codes in different Tables.

TABLE 2

NUMBER OF VALID CONSIGNMENTS IN THE TEAM TOTAL DATABASE

Mill Code	TEAM-1	TEAM-2	Total
A	20	29	49
B	21	27	48
C	21	27	48
D	30	17	47
E	0	46	46
F	19	24	43
G	18	22	40
H	20	8	28
I	0	21	21
J	0	20	20
K	0	20	20
L	19	0	19
M	18	0	18
N	18	0	18
0	17	0	17
P	0	17	17
Q	0	14	14
R	13	0	13
S	0	10	10
T	0	9	9
TOTAL	**234**	**311**	**545**

Distribution of Main Raw Wool Characteristics of Consignments

In all trials the selection of consignments was entirely at the discretion of participants, and although TEAM-2 topmakers were encouraged to process unusual consignments, the commercial realities and practicalities of processing such consignments meant that the distribution of the main raw wool characteristics for the Total database remained similar to that noted in TEAM-1. At this stage of adoption of additional measurements, consignments with average values outside the ranges given in Table. 3 are unlikely to be processed as regular commercial blends of Australian wool. However, increased availability of staple measurement data may in future give confidence to topmakers to process consignments more extreme in their raw wool characteristics.

In all cases, the mean and spread of the consignment characteristics were generally similar for each of the trials listed, although the standard deviations differed for some of the characteristics.

The broad type categories for the total database were 70% as fleece, 20% as skirtings and 10% as mixed consignments.

TABLE 3

RANGE, MEAN & STANDARD DEVIATION 0F THE RAW WOOL CHARACTERISTICS OF CONSIGNMENTS

	TEAM-1			TEAM-2			TOTAL DATABASE		
CHARACTERISTIC	MIN	MAX	MEAN SD	MIN	MAX	MEAN SD	MIN	MAX	MEAN SD
Diameter (µm)	17	31	22.2 2.7	18	28	21.8 1.8	17	31	22.0 2.3
Vegetable Matter Base (%)	0	10	2.2 2.0	0	8	2.0 1.4	0	10	2.1 1.7
Staple Length (mm)	59	123	88 10.9	65	108	85 9.1	59	123	86 10.0
CV Staple Length (%)	12	30	18 3.6	13	30	19 4.2	12	30	19 4.0
Staple Strength (N/ktex)	23	60	40 6.9	26	56	38 5.9	23	60	39 6.4

The distributions of the consignment mean fibre diameter, vegetable matter base, staple length, staple strength and coefficient of variation of staple length of the Total database are illustrated in Figure 1.

Distribution of the Main Processing Results of Consignments

Table 4 summarises the mean, range and standard deviation of the processing characteristics of consignments. This Report concentrates on the further development of prediction formulae for Hauteur, and presents preliminary formulae for Coefficient of Variation of Hauteur, and Noil.

TABLE 4

RANGE, MEAN & STANDARD DEVIATION OF THE PROCESSING CHARACTERISTICS OF CONSIGNMENTS

	TEAM-1			TEAM-2			TOTAL DATABASE		
CHARACTERISTIC	MIN	MAX	MEAN SD	MIN	MAX	MEAN SD	MIN	MAX	MEAN SD
Almeter Data* Hauteur (mm)	48	97	65 8.3	50	95	68 8.4	48	97	67 8.5
CV Hauteur (%)	37	61	50 4.2	31	61	48 5.0	31	61	49 4.9
Barbe (mm)	56	121	82 10.6	62	108	84 8.9	56	121	83 9.7
Short Fibre Content (% less than 25 mm)	2	20	10 3.3	0	18	8 3.6	0	20	9 3.6
Long Fibre Length (Length at 1%)	99	196	143 16.2	116	178	143 11.4	99	196	143 13.7
Noil (%)**	1	21	8 3.5	3	18	7 2.9	1	21	8 3.2
Top & Noil Yield (%)**	46	76	63 6.1	48	77	65 5.6	46	77	64 5.9
Mean Fibre Diameter (µm)**	17	31	22.2 2.7	18	28	22.0 1.8	17	31	22.1 2.3

*Based on CSIRO measurements ** Based on Mill calculations or measurements

The distribution of measurements of Hauteur, Coefficient of Variation of Hauteur, and Noil for consignments in the Total database are illustrated in Figure 2.

References

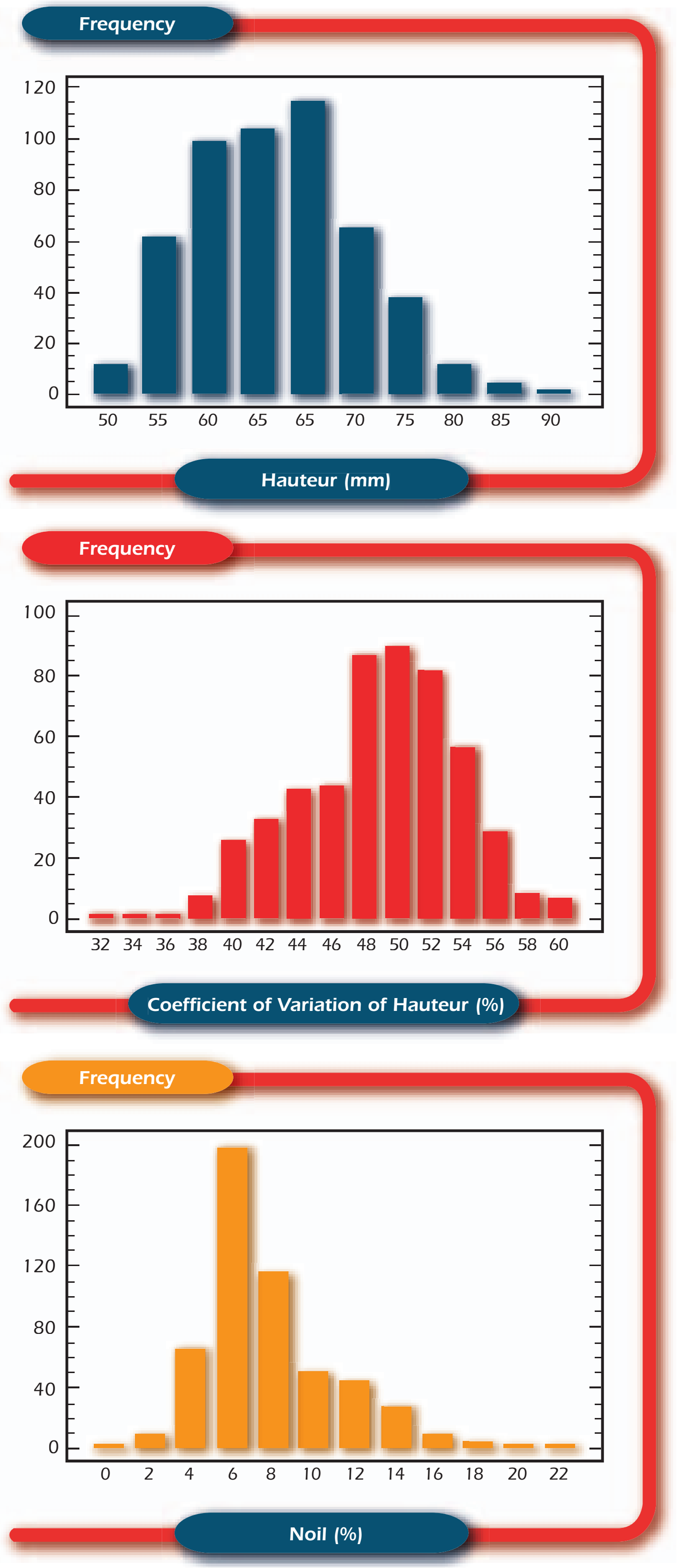
1. Final Report TEAM Project, January, 1985

2. Andrews, M.W., Douglas, S.A.S., Murphy, T.S. and Rottenbury, R.A., *Developments from the TEAM Project*; Proc GWF Metlan Wool Conference, Poland, June, 1986.

FIGURE 1

HISTOGRAMS OF CONSIGNMENT MEAN RAW WOOL CHARACTERISTICS IN THE TOTAL DATABASE.

FIGURE 2
HISTOGRAMS OF CONSIGNMENT PROCESSING RESULTS.



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3. PREDICTION of HAUTEUR

3.1 Introduction

There is considerable interest in the derivation of general formulae, which can be used by topmakers and combers to predict Hauteur. This concept has achieved industry acceptance since the initial TEAM project. However, sectors of the industry are looking forward to the time when sufficient data on raw wool characteristics and processing are available so that predictions based on it are completely robust. International recognition might then be warranted, perhaps by IWTO, along the lines of the standard formulae for calculation of combing and carbonising yields based on the coretest. An opportunity has been provided to progress this aim with the expanded TEAM database and increased research knowledge.

A feature of the general formulae published to date ([1,2]) has been their simplicity; a maximum of four raw wool factors, their purely additive effect, and their generality of use across various wool types and mills. The formulae used to predict Hauteur were developed using multiple regression procedures. There are, of course, other more sophisticated approaches, which can be used to predict processing, such as simulation modelling systems. These are discussed in section 5.

It is quite likely that, as the level of industry experience increases, new and individual mill prediction techniques may be developed. However, in the first instance, an important step in this process is to pursue the simplified general formula approach. Essentially, by analysing achieved data for each consignment and each mill, a mathematical formula can be derived which expresses the relationship between the raw wool measurements and top characteristics, such as Hauteur. This formula then enables the substitution of raw wool measurements of subsequent consignments, so that the predicted Hauteur can be calculated. The usefulness of this formula to the mill, topmaker or wool buyer, will depend on how close the values of calculated Hauteur are to the achieved Hauteur. A general formula can only be considered reliable if it reflects similar behaviour for all the mills used in the analysis.

3.2 Development of Prediction Formulae

Analysis Procedure

Analysis of the data was developed from the methods used and conclusions reached in the TEAM-1 Report. However, as has been noted in Progress Reports to the IWTO (3,4) there has been an upward shift of approximately 5 mm in the difference between the achieved Hauteur and the calculated Hauteur since TEAM-1. Causes of the shift are unclear, but several possible reasons have been suggested and include changes to processing machinery, changes in mill practices over-the time period of the two TEAM Projects, and the standardisation of sampling and testing methods.

The Total database provided the largest database to derive regression coefficients, but had the disadvantages of including the above time shift as well as a data inconsistency for the measurement of percentage of middle breaks (see Appendix 2). Alternatively, whilst analysis based on the more recent TEAM-2 data would overcome some of these deficiencies, less data were available. Hence, two approaches were used to derive general formulae for the prediction of Hauteur. The first was to perform an analysis on the Total database and the second was to restrict analysis to the TEAM-2 data only.

Analyses Based on Total Database

General prediction formulae were determined by multiple regression techniques from the Total database using the raw wool variables of staple length, staple strength, fibre diameter and vegetable matter base which were found to be important for predicting Hauteur in TEAM-1. Further analysis of the TEAM-1 database validated their selections and, thus, were an appropriate starting point for the Total database analysis.

The systematic difference between mills, highlighted in TEAM-1, and the time shift in Hauteur were taken into account by using "dummy" variables during the regression.

An updated general formula using L, S, D, and V fitted on the Total database gave:

$$\mathbf{H = 0.51L + 0.51S + 1.06D - 0.45V + C} \quad \text{.......}(4)$$

where H = Hauteur (mm)
L = Staple Length (mm)
S = Staple Strength (N/ktex)
D = Fibre Diameter (µm)
V = Vegetable Matter Base (%)
C = Constant to account for Time Shift and Mill Differences

TABLE 5

IMPORTANCE OF SELECTED RAW WOOL CHARACTERISTICS RELATIVE TO STAPLE LENGTH FOR THE PREDICTION OF HAUTEUR

CHARACTERISTIC	RELATIVE IMPORTANCE#
Staple Length (L)	100
Staple Strength (S)	97
Fibre Diameter (D)	53
Vegetable Matter Base (V)	20

As judged from the statistical significance of the regression terms

The relative importance of each variable in the regression formula is different, and Table 5 gives estimates for each variable used. The most significant factor, staple length, has been given a value of 100. For this relationship by far the most important variables are staple length and staple strength, with mean fibre diameter being about half as important and vegetable matter base of less importance.

The strength of a regression relationship may be measured by two statistics. The coefficient of multiple determination (R^2) indicates the fraction of the variation in Hauteur between the consignments, which is explained by the raw wool data used in the formula. It reflects the level of association between the raw wool variables and Hauteur and is often called the degree of association and expressed as a percentage ($100R^2$). The standard deviation of the differences between achieved and calculated Hauteur (SD) is a measure of the reliability of the raw wool data as a predictor of Hauteur - the larger the SD, the less reliable the formula.

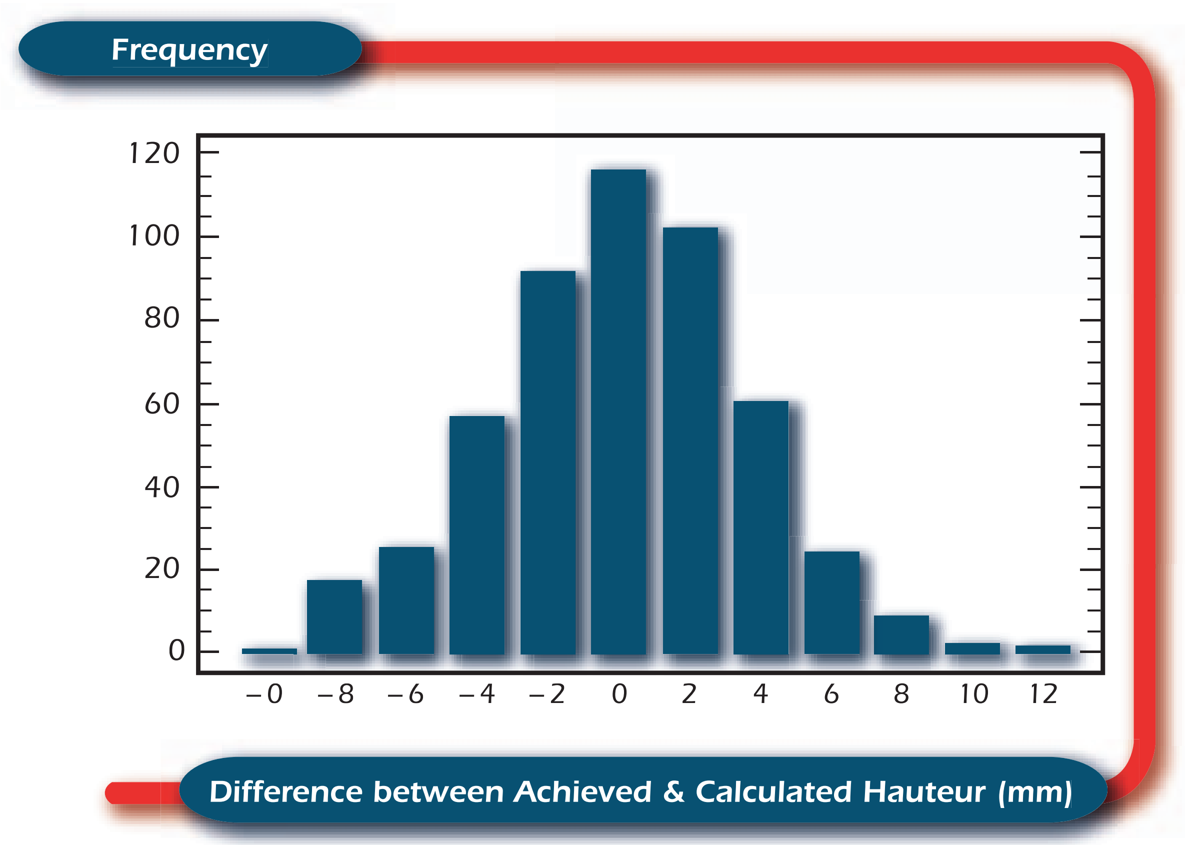
The values of these statistics found for the above general formula (4) are:

$100R^2 = 81\%$ SD = 3.7 mm

A histogram of the differences between the achieved and calculated Hauteur using formula (4) is given in Figure 3.

FIGURE 3

HISTOGRAM OF DIFFERENCES BETWEEN ACHIEVED AND CALCULATED HAUTEUR (FORMULA (4))



The differences range from -10 mm to +12 mm. Here, 75% of the calculated values fall within 4 mm of the achieved Hauteur values and 90% within 6 mm.

The corresponding general formula using L, S, D, V previously published (2) on TEAM-1 data was:

$$\mathbf{H = 0.47L + 0.42S + 0.85D - 0.44V - 11.8} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

with $100R^2 = 86\%$ SD = 3.0 mm

This formula (5) gave a slightly better result for TEAM-1 than formula (4) derived from the Total database. However, there has been little change in the coefficients associated with the four parameters. This is not surprising since the TEAM-1 database comprises 43 percent of the consignments used in the Total database.

Having determined a formula based on these variables, several diagnostic scatter plots of the "differences from the regression" (i.e., the difference between the achieved and calculated Hauteur) were graphed. Firstly, graphs were made of the differences against the raw wool variables used as predictors (L, S, D, or V). The purpose of this was to check for outliers and trends. There were no trends evident for these variables in these graphs.

In order to ascertain whether other raw wool characteristics (e.g., W, CVL, or M) should have been included in the formula, the differences were graphed against each in turn. These graphs indicated that the inclusion *of* the percentage of middle breaks (M) as a predictor variable for Hauteur was justified. However, based on TEAM-2 data only, the inclusion of M as a simple linear term in the analysis was considered in conjunction with more complex transforms as there was no obvious trend for M values to 45%, but from 46% to 100% a trend was evident ([6]).

A higher order M term (e.g., M^2) was examined and found to be not as good as a threshold approach (i.e., no effect up to 45%, but a linear effect from 46% to 100% for M). Thus, a transformed M has been selected, M*, which is called the adjusted percentage of middle breaks. All values of M up to 45% are replaced by a value of 45% as M*. For values of M greater than 45%, the measured value itself is used as M*.

The decision to use M* is based solely on the data collected during the TEAM trials. For most consignments the use of M instead of M* would have negligible effect on the calculated Hauteur. However, the relationship between percentage middle breaks and Hauteur needs to be further researched.

The formula resulting from the inclusion of M* as an additional predictive variable for the Total database is:

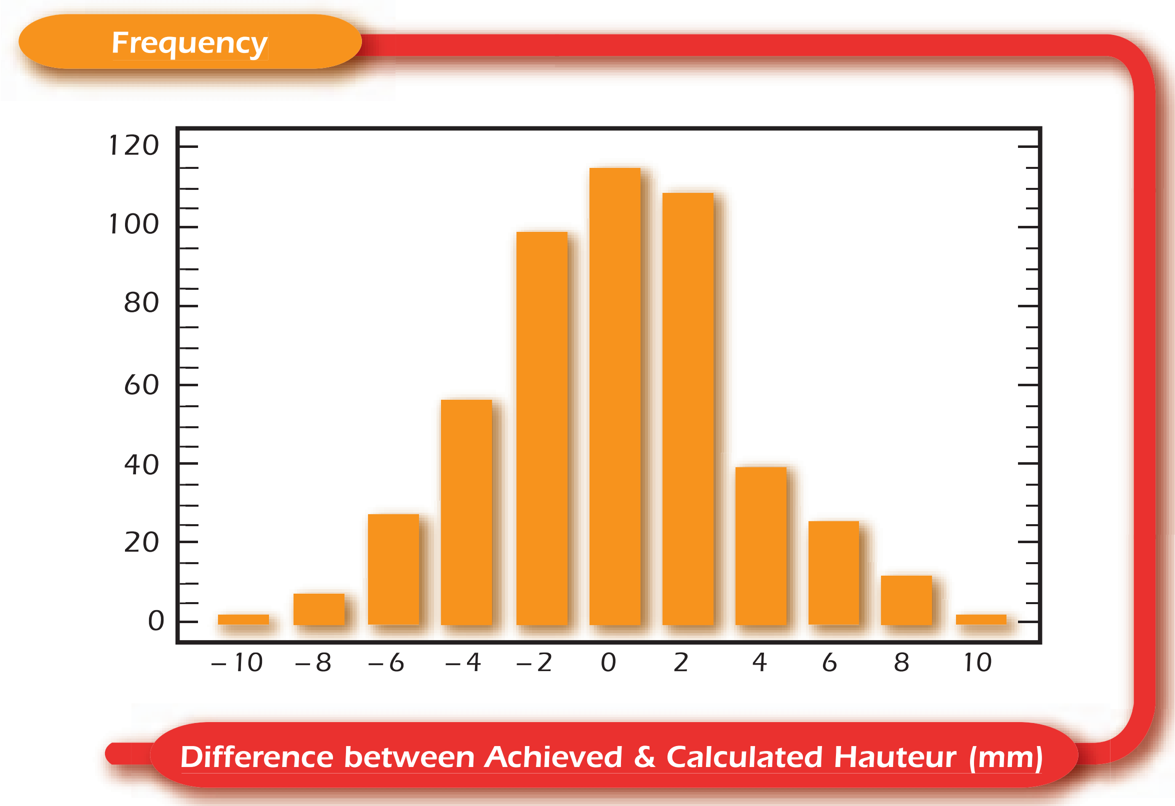
$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.45V - 0.19M^* + C} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

with $100R^2 = 84\%$ SD = 3.4 mm

The distribution of the differences between achieved Hauteur and Hauteur calculated using this formula (6) is given in Figure 4.

FIGURE 4

HISTOGRAM OF DIFFERENCES BETWEEN ACHIEVED AND CALCULATED HAUTEUR (FORMULA (6))



The differences range from -10 mm to +10 mm with 77% of the calculated values for Hauteur being within 4 mm of the achieved Hauteur and 92% within 6 mm.

An estimation of the importance of the terms in formula (6) is given in Table 6, where as before, the most significant variable (staple length) is given a value of 100. For this prediction of Hauteur, by far the most significant variables are staple length and staple strength, with the adjusted percentage of middle breaks and mean fibre diameter being about half as important, and vegetable matter base of less importance.

TABLE 6

IMPORTANCE OF SELECTED RAW WOOL CHARACTERISTICS RELATIVE TO STAPLE LENGTH FOR THE PREDICTION OF HAUTEUR

CHARACTERISTIC	RELATIVE IMPORTANCE#
Staple Length (L)	100
Staple Strength (S)	88
Fibre Diameter (D)	46
Adjusted Percentage of Middle Breaks (M*)	40
Vegetable Matter Base (V)	19

 # As judged from the statistical significance of the regression terms.

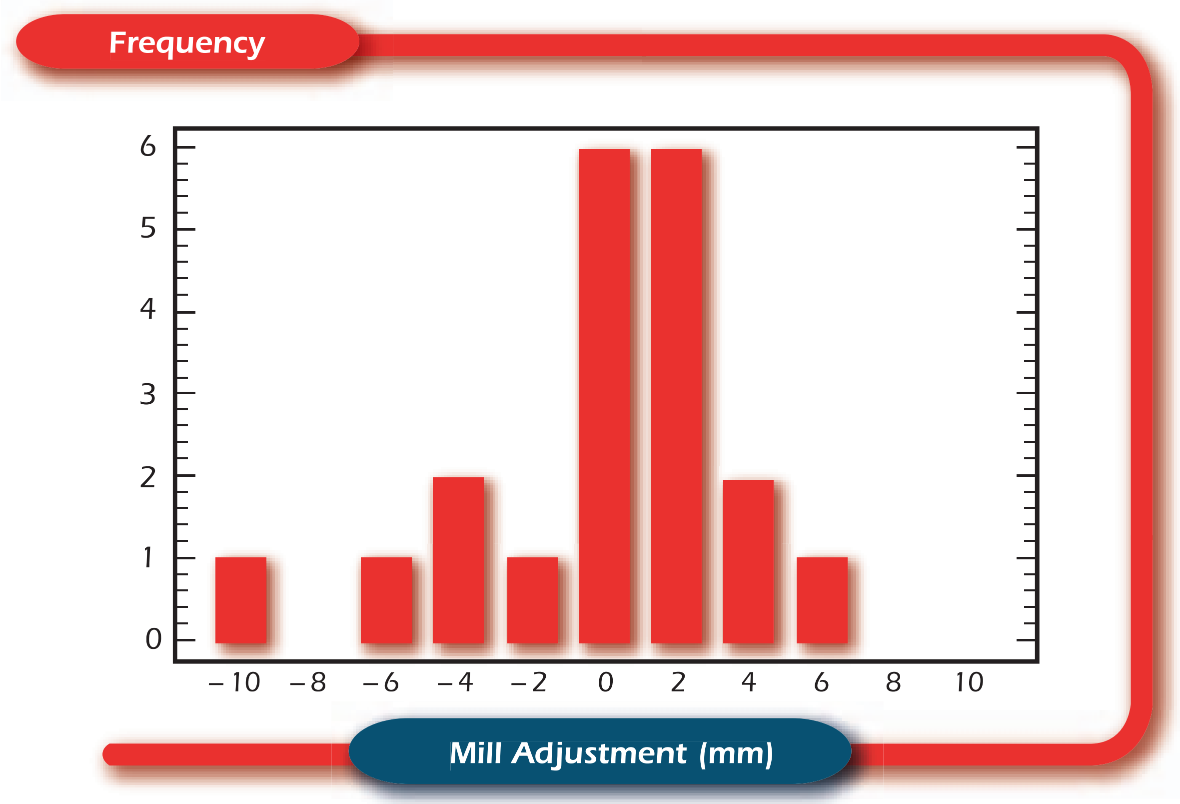
It should be noted that formula (6) contains a constant term, C, which includes an adjustment associated with individual mill differences, and an adjustment to allow for the shift from the calculated value since TEAM-1. For the Total database, the term C equals -3.5.

Thus, the complete formula for mill prediction of Hauteur now is:

$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.19M^* - 0.45V - 3.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

As in TEAM-1, differences between mills have again been identified and so another important aspect to be emphasised in using the formula is the adjustment of the calculated value of Hauteur to allow for mill differences. Individual mills can comb consistently longer or shorter tops than the values for Hauteur calculated from the general formula. These differences may be qualified by considerations of processing procedures e.g., whether card wastes are recycled, or the degree of cleanliness required in the top. The mill adjustments found for the 20 mills in the Total database are presented in histogram form in Figure 5. The adjustment is in effect an additional constant factor to be used to modify the general formula (^{7}) to make it mill specific.

FIGURE 5
HISTOGRAM OF INDIVIDUAL MILL ADJUSTMENTS TO HAUTEUR FORMULA (7)



For these 20 mills the mill adjustments ranged from -9 mm to +5 mm, a spread of 14 mm (although 11 out of the 20 mills were within a 3 mm range). This indicates there are appreciable differences between performances of mills and exceeds the spread of 6 mm found across nine mills only, which was quoted in the Final Report of the TEAM-1 Project. In addition, analysis suggests that for some mills these mill effects may drift over time. These considerations indicate the importance of monitoring and adjusting the prediction on a regular basis. As data accumulates, some method of continual mill adjustment may be implemented for prediction. The methods by which individual mills can calculate these adjustments and use them as a mill monitoring technique are discussed in Appendices 3 and 4, respectively.

Another important difference between mills is their consistency in predicting processing performance. The standard deviations of the differences for each mill represent a measure of this variation. Values for TEAM-2 ranged from 2.3 mm to 4.6 mm. This is comparable to the values of 1.8 mm to 4.3 mm reported in TEAM-1 for a prediction formula based on L, S, D and V only ([1]). This is an important factor that places a limit on the minimum standard deviations that can be achieved for a general formula. In such situations, deriving formulae that are mill specific, and simply improving the quality control during processing offer marked advantages for improving the prediction of Hauteur.

Analysis based on TEAM-2 data only

Data from TEAM-2 mills, which processed at least 15 consignments were selected for analysis. The available data were divided into two sets to allow validation.

In this case, analysis using stepwise regression was performed to select raw wool variable sets for further multiple linear regression. The cross-correlation between raw wool variables was carefully monitored to ensure the variables in the final formulae had minimal correlation with each other. The only variables selected in the formulae in this way were staple length, staple strength and percentage of middle breaks. Fibre diameter and vegetable matter base did not appear as significant variables in the TEAM-2 data analysis.

Once the formulae for each set had been determined, the alternate set was used for validation purposes. The results are summarised in Table 7:

TABLE 7

SUMMARY OF TEAM-2 DATA REGRESSION ANALYSES

	COEFFICIENTS			STANDARD DEVIATIONS	
	L	S	M	Fitted	Validation
SET 1	0.73	0.48	-0.14	2.8	2 .8
SET 2	0.76	0.53	-0.12	3.6	3.6

On this limited analysis, the terms which appear most important in calculating Hauteur from raw wool measurements are staple length, staple strength and the percentage of middle breaks. The formulae derived from combining the two sets together was:

$$\mathbf{H = 0.76L + 0.52S - 0.13M - 8.8} \quad \text{(8)}$$

with $100R^2 = 83\%$ SD = 3.4 mm

The relative importance of each variable in the regression formula is different and Table 8 gives estimates for each variable used. Staple length was the most important, staple strength being half as important and percentage of middle breaks of less importance.

TABLE 8

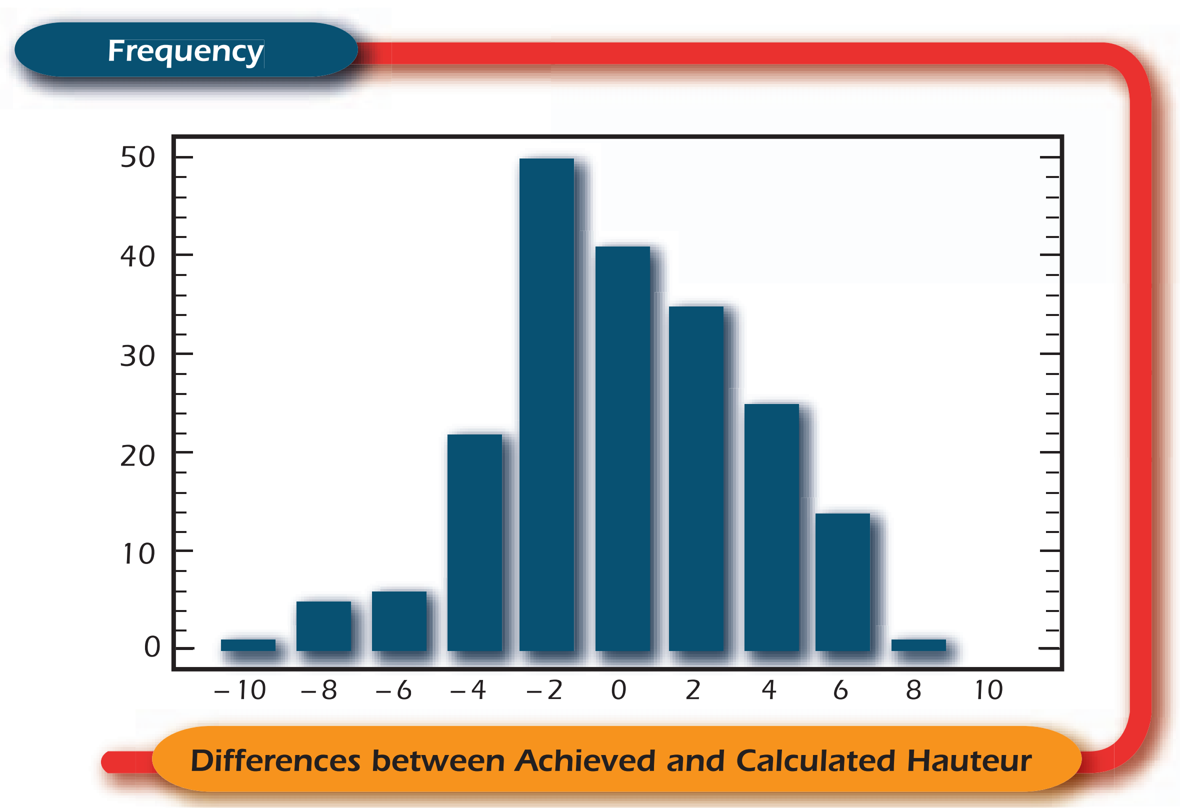
IMPORTANCE OF SELECTED RAW WOOL CHARACTERISTICS RELATIVE TO STAPLE LENGTH FOR THE PREDICTION OF HAUTEUR

CHARACTERISTIC	RELATIVE IMPORTANCE#
Staple Length (L)	100
Staple Strength (S)	48
Percentage of Middle Breaks (M)	27

 # As judged from the statistical significance of the regression terms.

The distribution of the differences between the achieved Hauteur and the Hauteur calculated using this formula (8) is given in Figure 6. The differences range from -l0mm to +8mm with 74% of the calculated values for Hauteur being within 4mm of the achieved Hauteur and 92% within 6mm.

FIGURE 6
HISTOGRAM OF DIFFERENCES BETWEEN ACHIEVED AND CALCULATED HAUTEUR (FORMULA (8))



The inclusion of the variables D and V, although not warranted from a statistical analysis of the TEAM-2 data, could be useful to mills that are interested in monitoring the effects of changes in these variables. The subsequent formula becomes:

$$\mathbf{H = 0.66L + 0.51S + 0.68D + 0.04V - 0.12m - 14.9} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

with $100R^2 = 84\%$ SD = 3.4 mm

Discussion

It is clear that from either analysis of the Total database, or the TEAM-2 data only, staple length and staple strength are the major raw wool variables required to predict Hauteur. Fibre diameter and percentage of middle breaks are contributing characteristics, whilst vegetable matter base has a smaller effect.

Whilst it is possible to use a number of alternative formulae to predict Hauteur, the TEAM Project Management Committee recommends the use of the following formula as a general starting point for mill prediction of Hauteur:

$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.19M^* - 0.45V - 3.5} \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where H = Hauteur (mm)

L = Staple Length (mm)

S = Staple Strength (N/ktex)

D = Fibre Diameter (µm)

M* = Adjusted Percentage of Middle Breaks (%)

(For M = 0-45%, use 45 for M*; for M = 46-100%, use the measured value)

V = Vegetable Matter Base (%)

Whilst this formula may not necessarily be the best in all circumstances, it is based on a larger number of mills and a larger database than all other formulae. It should be the starting point for any mill using objective measurement for the prediction of Hauteur.

3.3 Influence of Raw Wool Characteristics

From the point of view of textile processing, the most important fibre characteristics influencing Hauteur are the fibre length, fibre strength and fibre diameter of the input feed to the card. The raw wool characteristics related to these are staple length, staple strength and fibre diameter. Therefore, it is not unexpected that these take a dominant role in the derived general formula.

High values of position of break (as percentage middle breaks) could also be expected to affect Hauteur[8]. Hence, its appearance in the general formula. However, its relationship to Hauteur is less clear for lower values and this is demonstrated by the recommendation to use an adjusted percentage of middle breaks (M*) rather than the measured M for values 45% or less. In most consignments, where adequate blending occurs, the extreme effects are masked either because of the mixing of wools with ranges of positions of break and staple lengths, or the influence of secondary zones of weakness. However, when wools are used from a single source or from regions where similar growth conditions have applied and give an abnormally high value, there can be an effect on the Hauteur.

The relatively low importance of vegetable matter base in the general formula probably means its impact is taken into account by mill management decisions. Trade practice is to minimise the adjustment of processing machinery by treating high vegetable matter blends on specific machinery set to treat such blends at optimum conditions. The best way to account for the effects of vegetable matter may be to establish specific adjustments to predictive formulae for these specialised processing lines.

Early analysis of the developing TEAM-2 database [4] indicated that coefficient of variation of staple length had a small influence on Hauteur prediction. Analysis of the complete TEAM-2 and Total database did not confirm its significance in a general formula. It may still be significant for a mill specific formula (see Appendix 3).

The results presented have confirmed earlier research which demonstrated that within a particular commercial environment there can be a high level of association of raw wool characteristics with processing factors, particularly with the fibre length properties of the top ([9-11]). However, it was clear that the degree of association and the relative importance of particular raw wool characteristics depended on the population of wools and the range of each characteristic in the particular database. The Total database used in this Report, whilst considerably larger than the original TEAM-1 data, is still far from ideal. It covers the extended time span of seven years and involves the combination of what are essentially two separate databases. Whilst there were advantages in considering only the most recent data, the Committee made the decision to recommend analyses based on all the available data.

There are, of course, factors limiting prediction. Other characteristics of wool that have a certain level of importance are not taken into account, for example, crimp and style. Processing can also be influenced by the composition of a blend as well as the reproducibility of machine settings and mill procedures. These must, therefore, contribute to a loss in predictive capability. Comb setting was investigated as a possible predictor variable for a general formula over all mills, but was not found to be significant. However, in particular mills with their own large database, it could be expected to be important.

3.4 Application of Formulae to Sale Lots

The ultimate test of the reliability of prediction from regression formulae is the comparison between the calculated values for new consignments and their achieved processing results. A formula can, on average, be expected to be reliable if the various raw wool characteristics are within the range of those used to establish the formula.

The TEAM Management Committee has previously stressed that the published TEAM general formulae have been developed from the average raw wool characteristics of combing consignments. Application of these formulae to sale lots could lead to unusual results, due to the raw wool characteristics of the sale lot being outside those normally obtained for consignments. It has also been stressed that other variables, not taken into account in previous formulae, such as position of break, should be considered when valuing sale lots.

Nevertheless, the wool trade has expressed the view that it is important that TEAM-type formulae be available to assist in the valuation of sale lots. Using TEAM-1 data it has been shown ([12]) that no matter whether a formula is applied directly to the mean raw wool characteristics of a combing consignment, or whether it is applied to the individual sale lots and these in turn are then combined to form a consignment or combing blend prediction, the calculated values for Hauteur are virtually identical. This does not mean that the formula can predict the results of separately processed sale lots, but that the combined results from forming blends using the TEAM formula will give similar predictions of the consignment results.

Recent studies by CSIRO ([13]) on the processing of individual sale lots have shown that by refining the formulae and including additional information about the lot, better relationships can be obtained. This is because the extreme values of some raw wool characteristics found in some sale lots are taken into account in the relationship. In consignments, these effects tend to be averaged out because a normal consignment comprises a large number of sale lots.

References

1. Final Report TEAM Project, January, 1985.

2. Andrews, M.W., Douglas, S.A.S., Murphy, T.S. and Rottenbury, R.A. *Developments from the TEAM Project*, Proc GWF Metlan Wool Conference, Poland, June 1986.

3. Progress Report TEAM-2 Project, IWTO Palm Beach, January, 1988.

4. Progress Report TEAM-2 Project, IWTO Avignon, June, 1988.

5. Rottenbury, R.A., Murphy, T.S., Andrews, M.W. and Brown, G.H. *Further TEAM Analyses: Predictive Relationships for Hauteur for Individual Mills.* IWTO Tech. Committee, Report No 4, January, 1986.

6. Brown, G.H. *Report to TEAM Committee on the Prediction of Top Characteristics,* November, 1988.

7. Turpie, D.W.F. *Recent Work in South Africa on the Effect of Raw Wool Blending on Subsequent Processing Performance, Wool Technol.* Sheep Breed. **25**, 33, 1977.

8. Rottenbury, R.A., Kavanagh, W.J., Eley, J.R. and Andrews, M.W. *The effect of the Strength Properties of Wool Staples on Worsted Processing. Part II. The Location of Staple Weakness*, J. Text. Inst. **77**, 191, 1986.

9. Rottenbury, R.A., Andrews, M.W., and Brown, G.H. *The Association between Raw Wool Characteristics and Processing to Top.* Text. Res. J. **53**, 29, 1983.

10. Brown, G.H., Rottenbury, R.A., and Kavanagh, W.J. *Statistical Procedures for the Prediction of Length Characteristics of Top from Raw Wool Measurements*. Text. Res. J. **55**, 143, 1985.

11. Turpie, D.W.F. and Gee, E. *The Properties and Performance during Topmaking and` Spinning of a Wide Range of South African Wools.* Proc. 6th Int. Wool Text. Res. Conf. **3**, 293, 1980.

12. Ainsworth, W.D. *Comparison of Two Procedures for the Prediction of Top Mean Fibre Length (Hauteur) of Combing Consignments using the Team Prediction Formula.* IWTO Tech. Committee, Report No 9, December, 1988.

13. Mooy, L. *The Processing Prediction of Individual Sale Lots and Wool Types.* Proc. CSIRO Sale by Description Seminar, July, 1988.

4. PREDICTION OF COEFFICIENT OF VARIATION OF HAUTEUR AND NOIL

4.1 Introduction

In TEAM-1, the development of general formulae for processing factors in addition to Hauteur was also investigated. It was concluded ([1]) that the reliability of formulae to predict Noil for individual mills was not as promising as for Hauteur because of the stronger influence of other factors on this characteristic, particularly mill practices. No formulae were reported.

However, analyses were presented for eleven individual mills showing the degree of association of various subsets of raw wool characteristics and Noil and other Almeter parameters including Coefficient of Variation of Hauteur. Results were similar, in broad terms, to those found in other research studies conducted in Australia ([2]) and South Africa ([3]), although the effectiveness of the relationship between raw wool characteristics and processing factors was mill dependent.

There remains considerable trade interest in the potential for prediction of Coefficient of Variation of Hauteur and Noil and use of generalised formulae. The expanded TEAM database now available was examined with this in mind and the procedures employed were similar to those used for the prediction of Hauteur in Section 3.

4.2 Prediction of Coefficient of Variation of Hauteur (CVH)

Analysis showed that the adjusted percentage of middle breaks, M*, (as described in Section 3), had a pronounced effect and that vegetable matter base, V, did not have a significant influence. Therefore, the general formula, which is considered by the TEAM Management Committee, as being the best formula for the prediction of CVH that can be achieved from the data available is:

$$\mathbf{CVH = 0.12L - 0.41S - 0.35D + 0.20M^* + 49.3} \qquad \ldots\ldots\ldots\ldots(11)$$

with $100R^2 = 63\%$ SD = 2.8%

Figure 7 demonstrates how this formula fits the TEAM-2 data, with 83% of results falling within ±4%.

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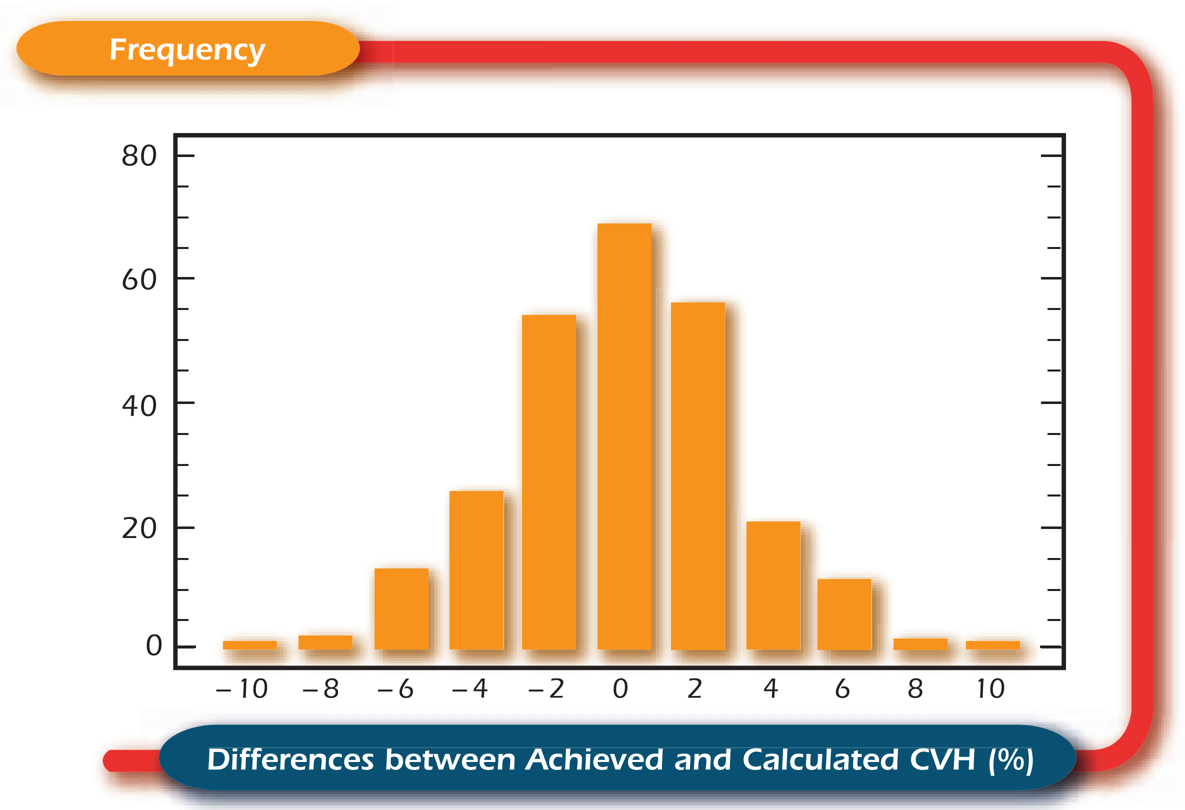
The term **noil** is used to describe the quantity of short fibres combed from the carded sliver in the topmaking process. The quantity of **noil** is used to calculate either **noil % or romaine**. In this report when **noil %** is calculated, it refers to the value of $\frac{\text{noil}}{\text{top \& noil}}$ expressed as a percent.

In some sections of the industry this is referred to as **romaine**, so care needs be taken when using the results discussed.

FIGURE 7
HISTOGRAM OF DIFFERENCES BETWEEN ACHIEVED AND CALCULATED CVD



Relative Importance of Characteristics

It is important to note that the relative importance of each variable in prediction of CVH is quite different. An estimation of the relative importance is given in Table 9, where the most important variable is given a value of 100. For the prediction of CVH, the most important variables are staple strength and adjusted percentage of middle breaks, with staple length and fibre diameter being less important.

TABLE 9

RELATIVE IMPORTANCE OF THE RAW WOOL PROPERTIES FOR THE PREDICTION OF COEFFICIENT OF VARIATION OF HAUTEUR

CHARACTERISTIC	RELATIVE IMPORTANCE#
Staple Strength (S)	100
Percentage of Middle Breaks (M*)	57
Staple Length (L)	33
Fibre Diameter D	22

 # As judged from the statistical significance of the regression terms.

The analysis has indicated a shift in value since TEAM-1 of about -5.6%. Such a reduction in CVH is compatible with a longer top being achieved since TEAM-1.

Adjustment Constant associated with Individual Mills

Differences between mills have again been identified, and it is necessary to incorporate a mill adjustment to allow for these differences. Adjustments calculated for the participating mills ranged from -3.4% to +4.1%, a spread of 7.5%. While some of this difference will be due to the types of wool being processed in different mills, some will also be due to the different processing performance of mills.

4.3 Prediction of Noil (N)

The raw wool variables of mean fibre diameter and vegetable matter base figured prominently as explanatory variables for Noil in the TEAM-1 analysis. However, in the Total database, staple length and staple strength also play a significant part. Therefore, the general formula, which is considered by the TEAM Management Committee, as being the best general formula that can be achieved from the data available is:

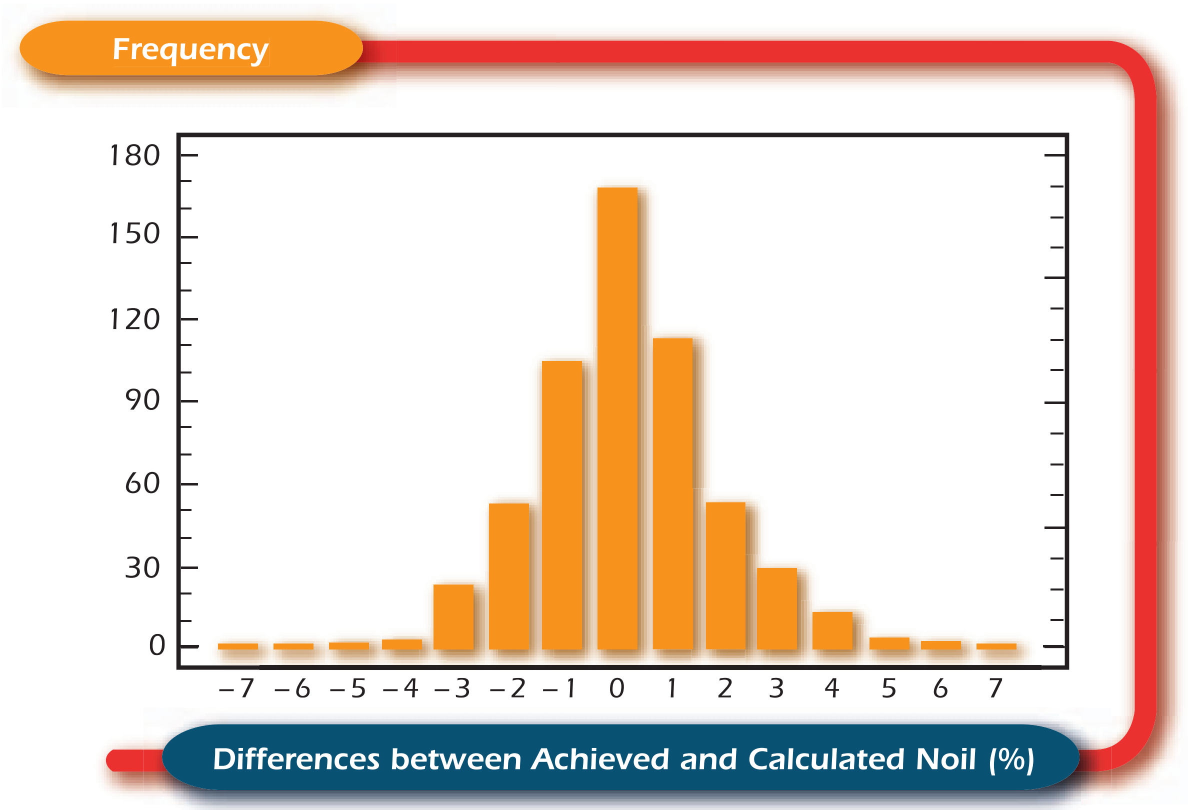
$$\mathbf{N = -0.11L - 0.14S - 0.35D + 0.94v + 27.7} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

with $100R^2 = 76\%$ SD = 1.5%.

Figure 8 demonstrates how this formula fits the TEAM-2 data, with 84% of results falling within ±2.0%. It should be noted that this is a large figure in relation to actual Noil values.

FIGURE 8

HISTOGRAM OF DIFFERENCES BETWEEN ACHIEVED AND CALCULATED NOIL (%)



Relative Importance of Characteristics'

It is important to note that again the relative importance of each variable in prediction is quite different. An estimation of the relative importance is given in Table 10, where the most important variable is given a value of 100. For the prediction of Noil the most important variable is vegetable matter base, but staple strength, staple length and fibre diameter are also important.

TABLE 10

RELATIVE IMPORTANCE OF THE RAW WOOL PROPERTIES FOR THE PREDICTION OF NOIL

CHARACTERISTIC	RELATIVE IMPORTANCE#
Vegetable Matter Base (V)	100
Staple Strength (S)	63
Staple Length (L)	51
Fibre Diameter (D)	41

 # As judged from the statistical significance of the regression terms.

The analysis has indicated a shift since TEAM-1 of about -0.8%.

Adjustment Constant associated with Individual Mills

Again, differences between mills have again been identified, and it is necessary to incorporate a mill adjustment to allow for these differences.

Adjustments calculated for the participating mills ranged from -2.6% to +3.4%, a spread of 6.0%. While some of this difference will be due to the types of wool being processed in different mills, some will also be due to the different processing performance of mills.

Use of the Formulae by Individual Mills or Topmakers

The general formulae (11 & 12) for CVH and Noil, respectively, are suitable only for guidance purposes at this stage. However, there are differences between mills, which arise from differences in machinery, processing procedure and the range of wool types used. Such differences can present themselves as a simple mill adjustment, as indicated above, or can be more complex. For example, the mill either does not perform exactly in accordance with the formula, or there are other factors, variables or identifiable mill practices, which have a significant effect *on* the CVH, or the Noil achieved. The degree of association ($100R^2$) in both cases is lower than for Hauteur and the formulae need further refinement when more data becomes available.

The comments relating to the use of the Hauteur general formula, given in Section 3, and the techniques outlined in Appendices 3 and 4, also apply to the use of the formulae for these top characteristics.

References

1. Final Report TEAM Project, January, 1985.

2. Rottenbury,R.A.,Andrews, M.W., and Brown, G.H. *The Association Between Raw Wool Characteristics and Processing to Top.* Text. Res. J **53**, 29, 1983.

3. Turpie, D.W.F. and Gee, E. *The Properties and Performance During Topmaking and Spinning of a Wide Range of South African Wools*. Proc. 6th Int. Wool Text. Res. Conf. **3**, 293, 1980.

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5. OTHER PREDICTION TECHNIQUES

5.1 Introduction

In Section 3 and 4 the multiple linear regression approach has been used for predicting various processing factors for combinations of the raw wool characteristics. This simple approach has been found to be extremely useful for predicting Hauteur and to a lesser extent other factors such as Noil. It is a suitable approach because of its simplicity of use, and is possible because of the high level of association found between subsets of raw wool characteristics and the processing factors, being predicted ([1]). More complicated regression analyses are possible ([2,3]). For example, these analyses may include squared or cross-product terms derived from the raw wool measurements, or they may include processing factors as regression variables.

As an alternative to the regression approach, there are a number of computer-based methods ([4-9]) being developed, which address the data in a different way. Two such modelling methods for prediction are considered below. One method, SIMTOP, is a simulation modelling approach incorporating processing parameters. Another is the Broken Staple Length Distribution (BSL) model. Both methods draw *on* the knowledge and understanding that has now accrued on the role of raw wool factors, the influence of processing conditions ([10]), and their interaction. A preliminary evaluation of the alternative methods was made using TEAM data from one mill.

5.2 SIMTOP Model

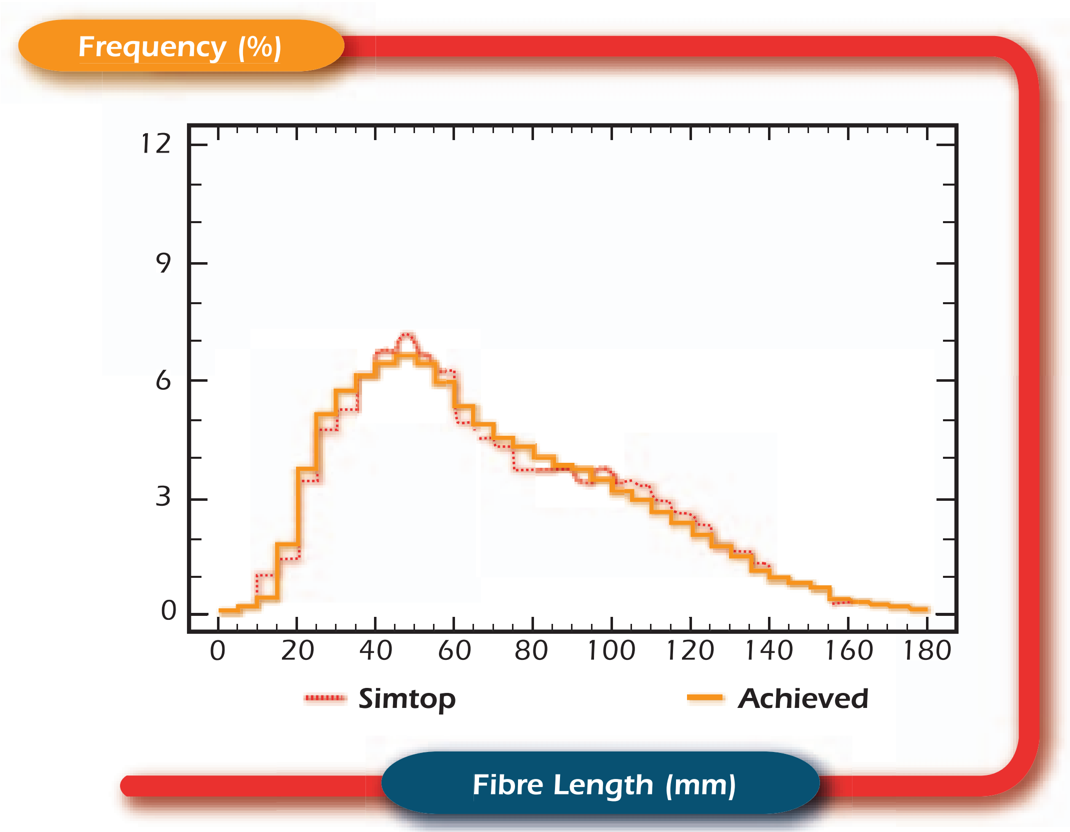
In Belgium, CENTEXBEL has been developing a computer model, which simulates the breakage of fibres during processing, and predicts a complete fibre length distribution of the top ([7]).

This model converts either individual staple measurements (which currently are not reported commercially), or individual sale lot measurements, to a fibre length distribution, and then simulates the processing of the consignment using three basic stages, outlined below:

> **Stage 1** simulates the breaking of each fibre, taking into account its strength (based on the staple strength), its length and the fibre diameter of the wool from which it came. All broken fibres are then allocated into new fibre length groups. This is called the *Weak Point Break* simulation.
>
> **Stage 2** takes the fibres from Stage 1 and applies a *Non-Weak Break* simulation, which depends on length and diameter of the fibres.
>
> **Stage 3** simulates the sorting of the resultant fibre length distribution by the comb, and takes into account the comb setting used. In this manner fibres are allocated to either top or noil, and the final output is in the form of a simulated Almeter diagram, together with the associated calculated parameters of the length distribution, and an estimation of the Noil.

That is a simple explanation. The model is more complicated and requires fitting of up to 12 parameters for each mill or processing line (8 parameters are used for the comparison here) and is designed to enable processors to maintain close control over the operations of their machinery.

FIGURE 9:
SIMTOP OUTPUT



The SIMTOP computer simulations model was designed for application in the mill where the more complete information on the fibre length distribution is required for the optimum adjustment of machine settings. The model used for this comparison can give a good prediction of the form of the Almeter fibre length distribution, as shown in Figure 9.

The SIMTOP model can also be used to simulate CVH and Noil.

5.3 BSL Model

At CSIRO, a broken staple length distribution (BSL) model is under development ([5]). This model aims to derive, from the individual staple measurements, new raw wool parameters that might be potential predictors of the processing results.

This is carried out by applying a weak point break simulation to the individual staples. In its simplest form, each staple is examined and if it is weaker than a selected critical strength, the staple is assumed to be broken at its weak point, thus enabling a broken staple length distribution to be estimated. The critical staple strength is varied depending on the original staple length and the fineness of the sale lot from which it originated, to take into account the tendency for breakage to increase as fibres become longer and finer.

New parameters are then calculated from the BSL distribution for development, by regression techniques, of prediction formulae for the major processing parameters. In a sense, it is a combination of the TEAM formula approach with the simulation breakage approach used by CENTEXBEL. At this stage, the BSL model is only under development for Hauteur prediction.

5.4 Comparison of Prediction Techniques - TEAM, SIMTOP and BSL

The TEAM Project, in cooperation with CENTEXBEL, Belgium, is conducting comparisons of the alternative approaches to prediction, and preliminary results for one mill are given. A report covering a small number of mills is intended to be published for the IWTO Technical Committee in May, 1989. At this stage, only the prediction of Hauteur, CVH and Noil have been examined.

Two techniques used for comparison purposes on this one mill were:

Time Series Analysis

Consignments are considered in the order of processing. Each prediction technique is fitted to earlier results for the same mill and the fitted formula or model is then used to predict the later results. This is very similar to the procedure that would be used in practice for prediction of future results, but suffers from the small number of consignment results currently available in the comparison.

Cross Validation Analysis

This technique consists of randomly splitting the data into 2 groups, one group being used for "fitting" the prediction procedure. The resultant formula or model is then used to predict the other group.

Tables 11 to 13 summarise the results of the analyses for the prediction of Hauteur, CVH and Noil for the three alternative prediction techniques. The TEAM prediction was based on the general formula (10) adjusted for the mill, whilst the SIMTOP and BSL predictions were based on mill specific models.

TABLE 11

RESULTS OF COMPARATIVE ANALYSES OF HAUTEUR PREDICTIONS

Prediction Technique	Time Series Analysis Bias (mm)	Time Series Analysis SD (mm)	Cross-Validation Analysis Bias (mm)	Cross-Validation Analysis SD (mm)
TEAM	1.4	3.6	0.0	3.9
SIMTOP	0.8	3.6	0.1	3.2
BSL	0.1	4.0	0.1	3.6

TABLE 12

RESULTS OF COMPARATIVE ANALYSES OF CVH PREDICTIONS

Prediction Technique	Time Series Analysis Bias (%)	SD (%)	Cross-Validation Analysis Bias (%)	SD (%)
TEAM	-0.4	2.5	0.0	2.8
SIMTOP	-0.1	2.4	-0.1	2.6

TABLE 13

RESULTS OF COMPARATIVE ANALYSES OF NOIL PREDICTIONS

Prediction Technique	Time Series Analysis Bias (%)	SD (%)	Cross-Validation Analysis Bias (%)	SD (%)
TEAM	-0.6	1.1	0.0	1.7
SIMTOP	-0.4	1.9	0.1	1.7

The results presented above should be viewed with some caution as they have been derived from only 28 processing consignments within one mill. Nonetheless, the comparison of the three different analytical techniques does provide some encouragement for further work on simulation and modelling, as there is very little difference between the results for bias and standard deviation.

Conclusions

While these preliminary comparative analyses on one mill do not demonstrate large advantages in the sophisticated computer models, it must be noted that development has only just begun. Future work in this area, and the inclusion of more results and more mills should enable a further improvement in these procedures.

The TEAM regression approach and computer based models are in many ways complementary. The ease of use and simplicity of the TEAM approach makes it ideal as a quick guidance formula for the trade, it requires only a simple pocket calculator. Should the BSL model prove successful, it would result in an even simpler formula for trade purposes, but require more computer calculations by the test house. On the other hand, the extra information calculated by the SIMTOP model, means that it is more suitable for operation in a mill, but requires access to computer facilities.

Both the SIMTOP and the BSL model use the interaction of the measured staple properties, either at the individual staple level or at the individual sale lot level. If either of these approaches is successful it may have the added bonus of being equally applicable to sale lots or consignments. In terms of the technical approach, models such as these have a greater potential for prediction as they better represent the physical realities of the wool processing machinery. The power of computer analysis can be exploited to maximise the potential benefits of these new techniques.

References

1. Rottenbury, R.A., Andrews, M.W., and Brown,G.H., *The Association Between Raw Wool Characteristics and Processing to Top*. Text. Res. J. **53**, 29, 1983.

2. Brown, G.H., Rottenbury, R.A., and Kavanagh, W.J. *Statistical Procedures for the Prediction of Length Characteristics of Top from Raw Wool Measurements.* Text. Res. J. **55**, 143, 1985.

3. Turpie, D.W.F. and Gee, E. *The Properties and Performance During Topmaking and Spinning of a Wide Range of South African Wools.* Proc 6th Int. Wool Text. Res. Conf. **3**, 293, 1980.

4. Carnaby, G.A. *Computer Blends. I. Principles.* WRONZ Commun. No C81, 1983.

5. Elliott, K.H., Carnaby, G.A., and Dent, J.B. *A Computer Model for Simulating the Semi-Worsted Processing of Wool*, J. Text. Inst. **78**, 392, 1987.

6. Turner, T.R. *Applications of Non-Parametric Regression Techniques in the Wool Industry. "The Application of Mathematics. and Physics ,in the Wool Industry*". (eds. G.A. Carnaby, E.J. Wood and L.F. Story), 393, 1988.

7. Delfosse, P., Grignet, J. and Lenoir, J. *Prediction of Fibre Length Distribution and Noil on Top Sliver from Raw Wool Measurements using a Computer Simulation Technique.* Proc IWTO Tech Committee, Report No 5, Paris Meeting, January, 1985.

8. Grignet, J., Miller, J., Galere, H., Godard, P., Delfosse, P. and Lenoir, J., *The "Wooltecs" Software and the "Texlab" System for the Measurement of Wool Fibre Characteristics and their Exploitation in Manufacturing.* Proc IWTO Tech Committee, Report No 1, Paris Meeting, December, 1988.

9. Ainsworth, W.D. *Application of Additional Measurement in Marketing and Processing Wool.* Wool Tech Sheep Breed., December, 1987.

10. Harrowfield, B.V. *Early-stage Worsted Processing from scoured Wool to Top.* Wool Science Review 64, 1988.

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6. ECONOMIC ASPECTS OF STAPLE LENGTH AND STRENGTH MEASUREMENTS

Introduction

An integral part of TEAM-1 was an economic, evaluation which attempted to quantify the benefits which would accrue to processors who used staple measurements. Economic considerations arise in three main areas:

– improved accuracy and reliability of the prediction of top characteristics, processing performance, and the estimation, prior to combing, of the likely cost of a top;

– the potential for improvements in processing productivity; and

– improved control procedures for batching and blending wools to meet a given top specification at least cost.

This Report has specifically examined the prediction aspects.

Formulae are useful if they can be applied to estimate the processing result within acceptable tolerances, and in particular, if they can detect abnormal situations in advance. What is acceptable as a tolerance can differ from mill to mill, but to be useful, a prediction formula must be as reliable as the subjective expectations of the comber or topmaker.

Of nine mills which provided expectation data for comparison with predicted data in TEAM-1, there were less deviations from actual Hauteur with predicted results than with expected results ([1]). In an economic analysis of that data from five mills, the benefit to mills using additional measurements was, in terms of Hauteur prediction, about 6 cents/kg clean top ([2]).

The analysis reported here is an update and extension of the earlier work using the database available from TEAM-2.

Method

The analysis of TEAM-2 data involved comparing, for each consignment, achieved Hauteur and Noil results with both the subjective expectations of topmakers and the predicted result from the new recommended general TEAM formulae, adjusted for each mill. Topmakers. were requested to provide their expectations both before and after access to staple length and strength measurements. For practical reasons, it was difficult to obtain sufficient before and after comparisons for analyses. Consequently, analysis was confined to six mills with 93 expectations provided before staple measurements were known.

Differences in predictive capabilities arising from the alternative approaches were then valued by using an updated version of the premium/discount schedule ([3]) used in the previous economic analysis ([2]).

The basis of the analysis is that if staple length and strength measurements can increase the accuracy with which top results are predicted, then this will have a favourable impact on processors' revenues. The argument is that with increased specification of the raw wool characteristics, topmakers are less likely to over (or under) estimate either Hauteur or Noil. When top Hauteurs exceed specification, topmakers can forgo revenue by delivering a higher valued top against contract price. Conversely, failure to meet specification can lead to spinners applying a price discount or even rejecting the top. Similarly, Noil affects top conversion costs and deviation from expectation impacts on top sales policy and profitability.

Results

Figures 10 and 11 compare the predictions and expectations on the 93 consignments from six mills in the TEAM-2 database. Figure 10 compares the Hauteur expectations and predictions, whilst Figure 11 compares the Noil expectations and predictions for the same consignments. The distributions of the two histograms for Hauteur are very similar, with the adjusted general formula giving slightly better results against topmakers' expectations.

FIGURE 10

HISTOGRAMS OF DIFFERENCES BETWEEN ACHIEVED RESULTS AND CALCULATED AND EXPECTED RESULTS FOR HAUTEUR

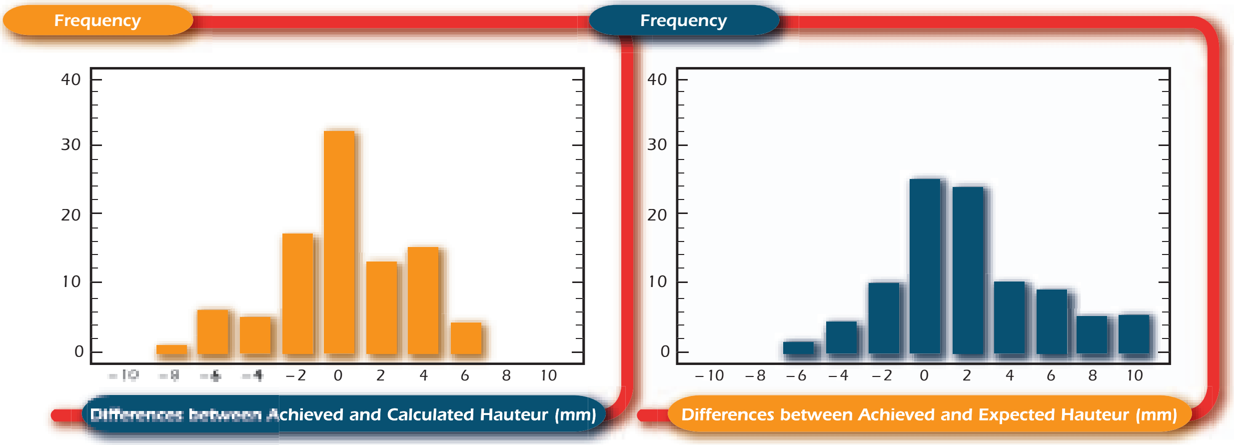
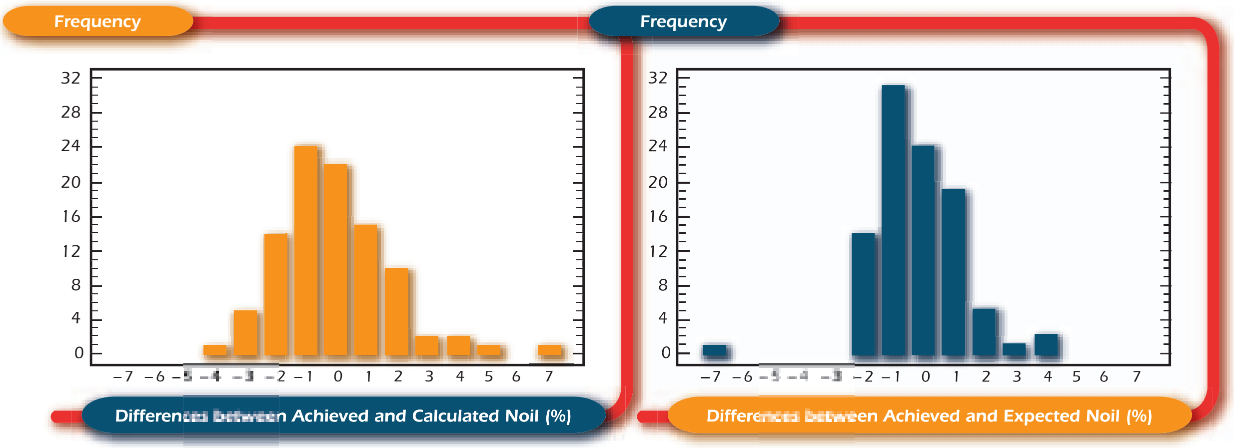


FIGURE 11

HISTOGRAMS OF DIFFERENCES BETWEEN ACHIEVED RESULTS AND CALCULATED AND EXPECTED RESULTS FOR NOIL



The distributions of the two histograms for Noil are also similar, but in this case, the adjusted general formulae gives more variable results than the topmaker expectations.

A comparison for four mills is presented in Tables 14 and 15 for Hauteur and Noil, respectively. The other two mills provided only six comparisons between them.

TABLE 14

COMPARISON OF TOPMAKERS' EXPECTATIONS AND TEAM FORMULAE PREDICTIONS OF HAUTEUR FOR 4 MILLS

Mill	Topmaker Expectation Differences (mm)		TEAM Formula Prediction (mm) Differences (mm)		Number of Comparisons
	Mean	SD	Mean	SD	
A	3.5	3.9	-0.6	3.0	14
B	3.1	2.8	0.0	2.8	23
C	2.1	4.0	-0.1	2.9	21
D	1.2	2.0	0.0	2.9	29
Mean	**2.3**	**3.2**	**0.0**	**2.8**	**87**

TABLE 15

COMPARISON OF TOPMAKER'S EXPECTATION AND TEAM FORMULAE PREDICTION FOR NOIL FOR 4 MILLS

Mill	Topmaker Expectation Differences (mm)		TEAM Formula Prediction (mm) Differences (mm)		Number of Comparisons
	Mean	SD	Mean	SD	
A	-0.8	0.9	0.7	1.2	13
B	-0.1	1.5	-0.6	2.3	22
C	-0.5	1.3	0.9	1.4	21
D	-0.1	0.9	-1.5	1.6	28
Mean	**-0.3**	**1.2**	**-0.3**	**2.0**	**84**

Apart from mill D, the TEAM formula predictions for Hauteur were more accurate than the topmaker's expectations i.e., the standard deviations were lower and negligible bias existed. For all four mills combined, the TEAM formula prediction was also superior. The most obvious difference is the tendency for topmakers to underestimate the achievable Hauteur by about 2 mm. Such a bias for topmakers suggests that they tend to be conservative when formulating their Hauteur expectations.

There is evidence that topmakers expectations have improved since TEAM-1. The mean absolute deviation from the achieved value has reduced from 3.5 mm in TEAM-1, to 2.9 mm in TEAM-2. Whilst staple measurements were not available for individual consignments when expectations were made, experience gained from re-appraisal of expectations and achieved results with the subsequent knowledge of the raw wool measurements, may have contributed to this improvement. The absence of significant drought conditions during TEAM-2 may also be a factor.

As regards the prediction of Noil, the TEAM formula approach appears to be inferior to the current procedures adopted by topmakers. Whilst no bias exists from either procedure, in every instance, the standard deviation of the differences from prediction using the formulae is greater than that for expectations of Noil by topmakers.

The price and revenue effects of the results are reported in Tables 16 and 17.

TABLE 16

BENEFITS (COSTS) OF TEAM FORMULAE PREDICTION OF HAUTEUR FOR 4 MILLS

Mill	Consignment ($)		Cents/Kg of Top	
	Mean	SD	Mean	SD
A	3,878	8,326	30	65
B	3,162	12,017	13	48
C	-1,527	6,726	-10	44
D	-10,534	20,647	-32	64
Mean	-2,419	15,295	-10	66

TABLE 17

BENEFITS (COSTS) OF TEAM FORMULAE PREDICTION OF NOIL FOR 4 MILLS

Mill	Consignment ($)		Cents/Kg Consignment Value (%)
	Mean	SD	
A	-74	1, 670	0.03
B	-3,098	5,233	0.7
C	-663	2,644	0.2
D	-3,726	6,685	0.6
Mean	–2,230	5,085	0.5

For Hauteur, the results are mixed, reflecting differences between topmakers and mills. In two cases, mills A and B, there appears to be a positive benefit from using staple length and strength measurements, whilst for mills C and D there appears to be a negative result. Aggregating across all four mills gives a negative result, with an overall loss of 10 cents/kg of top if these four mills had relied only on staple measurements. However, the large standard deviations around the mean values should indicate caution in drawing conclusions from these results.

An examination of the data suggests that a large portion of the variance in prediction differences occurs amongst finer micron wool categories. Moreover, it appears that the aggregate negative return from length and strength measurement, in this instance, is a direct result of the TEAM formula being a poorer predictor of Hauteur results of fine (less than 21 μm) wool tops. If all observations for tops of less than 21 μm are omitted from the analysis, then the -l0 cents/kg top loss noted in Table 16 becomes +4 cents/kg top profit. Of the 24 observations for wool finer than 21 μm , the TEAM formula prediction was inferior on 14 occasions, better on six, while on four occasions the two procedures had the same prediction. On a mean absolute difference basis for the fine wools, the TEAM formula yielded a value of 2.2 mm, while the topmaker difference was only 1.4 mm. Since a 1 mm Hauteur prediction error for a 19 μm top will incur a discount of about 80 cents, while for 24 μm top it is only about 10 cents, it is apparent why the results are sensitive to the prediction outcomes for fine wool categories.

As regards prediction of Noil, it should be remembered that the Noil formula presented in this Report has not been refined or validated to the same extent as the Hauteur formula. Thus, the results reported here can only be considered preliminary. In all instances there would have been a negative return to processors had they used the TEAM general formula solely to predict Noil results. This suggests that factors other than the currently measured raw wool characteristics have significant bearing on noilage. Future development of the Noil formula is likely to cover the effects of types and settings of machinery, processing conditions and requirements set by the top specifications.

Conclusions

The analysis from the data available suggests that the TEAM formula approach to predicting Hauteur is on average, but not for every mill, superior to the traditional approach. This was not the case for Noil prediction and clearly further development of the Noil formula is required. However, for Hauteur, the improved prediction capability when using the TEAM formula on the data provided did not always translate into a positive price effect. There was a benefit to only two of the four mills. This occurred because the TEAM formula prediction of Hauteur for fine wool top categories did not perform as well as for coarser wool types. Furthermore, the aggregate negative price effect for all mills is influenced by mill D which dominates the total sample. Topmaker predictions are superior to the TEAM formula predictions for this mill.

The analysis also suggests that the greatest potential benefit of staple measurements exists with fine wool categories. To date, TEAM has concentrated on developing a prediction formula, which could be used across all micron counts or wool types. With more data, tailoring the formula for specific wool types or end uses could be expected to improve the formula's prediction capabilities.

It is important to recognise that these findings do not imply that there are no benefits to processors from using staple length and strength measurements as price premiums and discounts must be related to the actual value of the product. Rather it implies that the TEAM general formula approach for predicting Noil and to a lesser extent Hauteur requires further refinement before they could stand on their own in a commercial environment. Furthermore, gains from increased fibre specification will accrue to other sectors of the wool industry, so assessment of the benefits, from improved prediction accruing to topmakers should not be the only criterion for determining the overall economic implications of staple measurements.

References

1. Final Report TEAM Project, January, 1985

2. Spinks, M.L. and Lehmer, C., *An Economic Evaluation of Additional Measurement in Wool Processing.* Aust J. Agric. Econ. **30**(2), 162 (1986).

3. Bell, P.J.M., Personal Communication, 1988

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7. RAW WOOL AND TOP MEASUREMENTS

7.1 Measurement of Fibre Length of Tops

During the TEAM-2 Project, samples of tops were collected for measurement of Hauteur using the CSIRO Almeter and a single operator. This was done in order to eliminate any possible introduction of bias between Almeter instruments, which might affect the selection of variables in the general prediction formula.

Where available, mills were also requested to supply their own Almeter results which, as well as being used as a check that there was no mix-up of top samples, have provided data on the differences between measurements made at the various mills and those made on a single instrument (CSIRO). They also enabled mill specific adjustments to the general formula to be determined based on a mill's own Almeter results.

Table 18 summarises the differences observed between measurements at CSIRO and individual mills. To maintain confidentiality, the mills again have been recoded.

TABLE 18

COMPARISON OF CSIRO AND MILL HAUTEUR MEASUREMENTS: TEAM-2 RESULTS (284 CONSIGNMENTS)

Mill	Difference Mean (mm)	CSIRO-Mill SD (mm)	Statistical significance
A#	-3.0	1.3	***
B	-1.5	3.4	*
C	-0.9	2.7	ns
D	-1.4	1.5	**
E	-0.3	1.1	ns
F	-0.7	0.7	***
G	-0.3	0.6	*
H	-0.9	1.4	*
I	0.0	1.5	ns
J#	-4.1	1.1	ns
K#	-5.9	6.7	ns
L	-1.6	1.5	***
M#	-0.8	1.3	ns
N	-0.6	1.1	*
0#	-0.4	0.7	ns
P	-0.8	2.5	ns
Q#	-0.4	3.2	ns
R#	1.3	1.7	ns
S#	-0.2	0.1	ns
ALL	**-0.8**	**2.0**	***

Significance Levels:

*** = 0.1% ; ** = 1.0% ; * = 5%; ns = not significant
# Mills with less than 10 comparisons

The results in Table 1 indicate that the mill Hauteurs are normally longer than those measured at CSIRO (0.8 mm), with differences ranging from +1.3 to -5.9 mm. For the 11 mills with more than 10 comparisons, the differences ranged from 0.0 to -1.6 mm, with an average difference of -0.7 mm, which is highly significant.

During TEAM-1 a similar result from eight mills was noted, with CSIRO Hauteur being consistently lower with an average difference of -1.4 mm. In this present data, the spread of mill differences has been reduced.

The lower Hauteur values measured at CSIRO are probably due to the relaxation of tops during transport and over time. Despite reference to the need for correct sampling and twisting of top samples prior to Almeter measurement, as per IWTO-17 ([1]), some samples were submitted in loose relaxed state.

To put the Almeter comparisons in the TEAM Project in perspective, the tolerance limit adopted for accreditation by Interwoollabs is ±1.8 mm, or a range of 3.6 mm. In terms of commercial trading, such precision is often difficult to accept. However, it is important to recognise such precision, or lack of it, exists and must be taken into account when examining differences between achieved and predicted Hauteurs using TEAM formulae.

7.2 Comparison of Airflow Measurements of Diameter in Top and Raw Wool

The database also provided information regarding the relationship between the airflow mean fibre diameter of the top, as measured by the mill and the airflow mean fibre diameter of the greasy wool, as measured from coretest by AWTA Ltd.

Table 19 summarises the differences between diameter measurements of the greasy wool and top for individual mills for TEAM-1 and TEAM-2. To maintain confidentiality, further recoding of mills has occurred.

TEAM-1 results indicated that, on average, the top fineness was not significantly different from the core test result. However, out of the 12 mills examined, four measured tops coarser than the greasy wool, by 0.13 µm to 0.25 µm, and one was finer, by -0.44 µm. The remaining seven mills did not show any significant differences.

TEAM-2 results indicated that, on average, the top fineness was only slightly coarser, by 0.09 µm, than the greasy core test. Eleven of the 20 mills providing data showed no significant difference between top and core fineness, but all the remaining mills had tops that were, on average, coarser than the greasy core, by 0.11 µm to 0.33 µm.

TABLE 19

DIFFERENCES BETWEEN TOP AND GREASY WOOL MEAN FIBRE DIAMETER (TOP-CORE) (498 CONSIGNMENTS)

MILL CODE	TEAM-1 MEAN (mm)	TEAM-1 SD (µm)	TEAM-1 Stat. Sign	TEAM-2 MEAN (mm)	TEAM-2 SD (µm)	TEAM-2 Stat. Sign.	TOTAL MEAN mm)	TOTAL SD (µm)	TOTAL Stat. Sign.
A	-0.11	0.25	ns	-0.01	0.12	ns	-0.08	0.22	ns
B	-0.02	0.38	ns	-0.00	0.10	ns	-0.01	0.26	ns
C	-0.04	0.19	ns	0.05	0.32	ns	0.00	0.24	ns
D	0.15	0.21	**	0.16	0.24	**	0.16	0.23	***
E	-0.02	0.18	ns	0.14	0.20	**	0.07	0.21	*
F	0.13	0.13	***	0.11	0.17	***	0.12	0.15	***
G#	0.20	0.36	ns						
H#	0.21	0.27	*						
I	0.25	0.22	***						
J	-0.44	0.26	***						
K	-0.01	0.19	ns						
L	-0.15	0.24	ns						
M				0.01	0.22	ns			
N				-0.03	0.14	ns			
0#				0.10	0.14	ns			
P#				-0.12	0.33	ns			
Q				0.16	0.27	*			
R				-0.03	0.27	ns			
S#				0.28	0.13	*			
T				0.31	0.15	***			
U#				0.21	0.23	*			
V				0.18	0.11	***			
W#				0.33	0.30	*			
X#				0.00	0.14	ns			
Y#				-0.41	0.28	ns			
Z#				-0.31	0.30	ns			
ALL	**0.00**	**0.29**	**ns**	**0.09**	**0.23**	*******	**0.05**	**0.26**	*******

Note 1: Significance levels: *** = 0.1%, ** = 1%, * = 5%, ns = not significant
Note 2: Values are all based on weighted means
Note 3: # = Mills with less than 10 comparisons

It is interesting to note that of the six mills with results in both TEAM-1 and TEAM-2 trials, five have no significant change in their mean difference from TEAM-1 to TEAM-2. The remaining mill, has shown a small shift in its relationship over the time period, with the top measurement becoming coarser than the greasy core by 0.16 µm

The overall conclusion is that for some mills the top is tending, on average, to be slightly coarser than the greasy core result. This is expected, due to the removal of generally finer fibres in the noil.

The difference between mills is probably due to very small biases between their laboratories, and in some cases, due to the small number of comparisons available for some mills.

However, it should also be noted that the biases are very small compared to the spread of results, for both TEAM-1 and TEAM-2 results, and there are no large differences between the two time periods.

Standardisation and Harmonisation

Significant variation in the relationships between raw wool and top measurements, or measurements of the same characteristic by different mills or laboratories continues to exist. This highlights the importance of standardisation of instrumentation and procedures, and the harmonisation of testing organisations and mill laboratories.

In the comparison of raw wool and top measurements for similar characteristics, it is quite clear that processing procedures used to convert raw wool to top will influence any comparison. Nevertheless, even with recognised testing procedures, constant vigilance is required to ensure that standards are well defined, unambiguous, and repeatable. In this regard the responsibility given to Interwoollabs and other organisations conducting round trials of test methods cannot be understated.

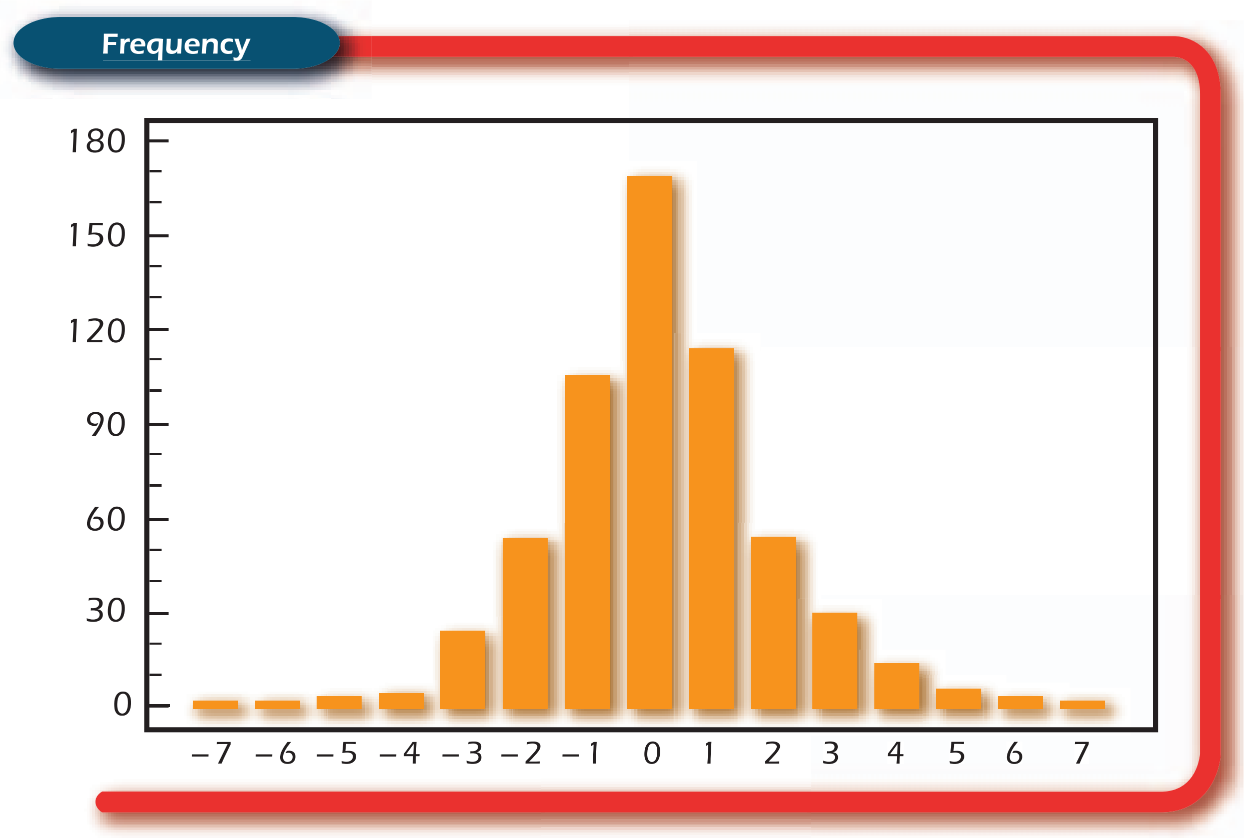
7.3 Comparison of Mill Top and Noil Yield with Coretest

During the trial, details of the conditioned mill top and noil yields, and the Schlumberger dry combed yield, calculated from the core test Certificate, were available for 563 results.

Figure 12 shows the distribution of the differences between the core test yields and the achieved mill yields for the 563 results. There is little difference between the core test yields and the mill yields, with an overall difference of only 0.1%, and a standard deviation of 1.7%. Essentially, the IWTO Schlumberger dry combed top and noil yield is an unbiased predictor of mill top and noil yields at standard regains.

FIGURE 12

HISTOGRAM OF DIFFERENCES - IWTO SCHLUMBERGER DRY COMBED YIELD MINUS CONDITIONED MILL TOP AND NOIL YIELD



The results also indicated that there were no major changes since TEAM-1, with the average difference from the TEAM-1 consignments being 0.0%, with a standard deviation of 1.6%, compared to TEAM-2 values of 0.2% and 1.7%, respectively.

Table 20 gives the differences on a per mill basis, and it can be seen that the mill differences range from -2.3% (an overyield), to +2.6% (an underyield). These differences are related to the types of wool processed in different mills, differing mill practices, particularly with respect to the recycling of card wastes, and possible errors in measurement or procedures leading to the adjustment of yield to standard regains.

TABLE 20

YIELD DIFFERENCES - SCHLUMBERGER DRY (CORE) MINUS MILL TOP AND NOIL YIELD (COMB) (563 CONSIGNMENTS)

Mill	Difference (Core-Comb) Mean (%)	SD (%)	Statistical significance
a	0.4	0.9	*
Z	-1.0	1.1	***
Y	-1.5	1.3	***
X	1.3	1.5	*
W	-0.6	1.9	ns
V	0.2	1.2	ns
U	1.3	1.5	***
T	-0.1	0.9	ns
S	-0.4	2.2	ns
R	0.2	1.6	ns
Q	-0.4	1.7	ns
P	1.0	1.7	***
0#	1.7	1.4	ns
N	0.1	1.0	ns
M#	0.6	0.4	*
L	0.4	1.0	ns
K	-0.1	1.2	ns
J#	0.1	0.4	ns
I	2.6	2.1	***
H#	0.3	1.4	ns
G	-2.3	1.0	***
F	0.8	2.6	ns
E	0.8	0.8	*
D#	0.1	0.4	ns
C#	-0.7	1.0	ns
B#	-0.8	1.3	ns
A#	-0.5	0.1	ns
ALL	**0.1**	**1.7**	*****

Significance Levels:

*** = 0.1%; ** = 1.O%; * = 5%; ns = not significant

Mills with less than 10 comparisons

7.4 Seasonal Effects

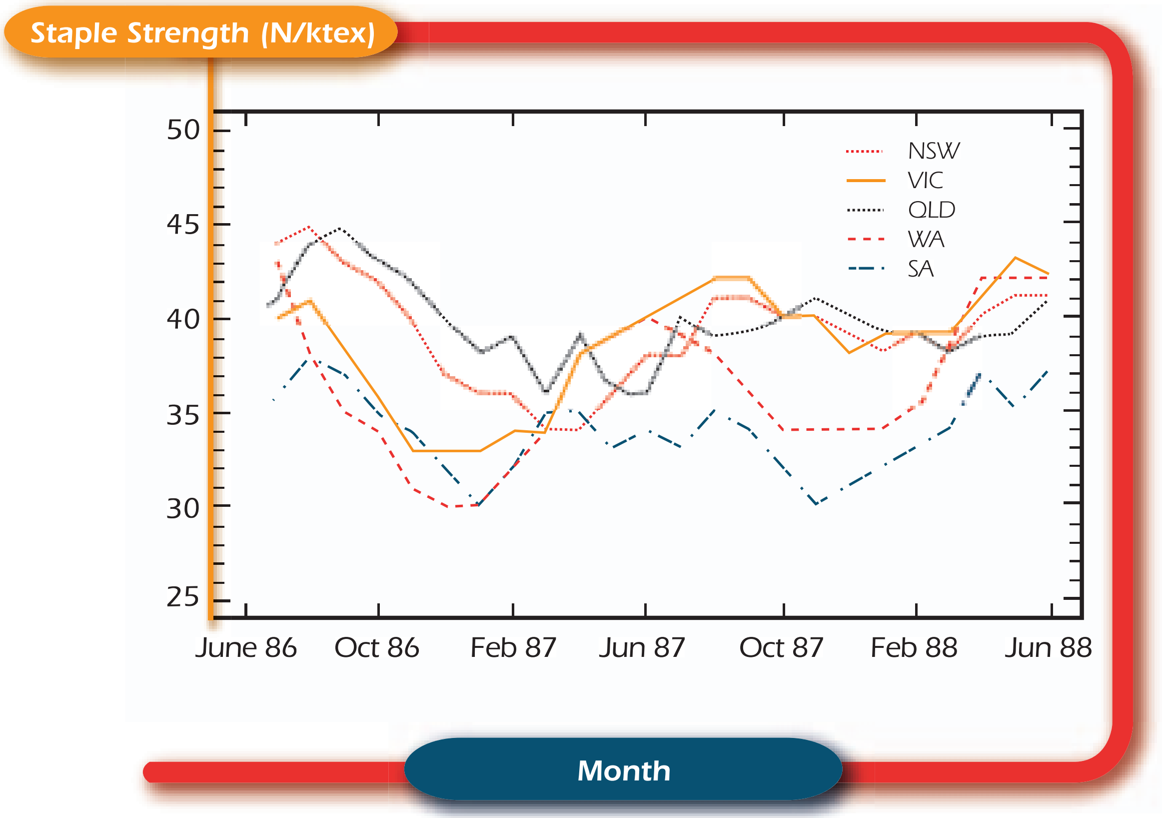
In Australia during 1988/89, more than 20% of all combing wool is expected to be measured for staple length and staple strength before sale. These results, together with the coretest data for yield, vegetable matter base and fibre diameter will be available in auction sale catalogues to assist valuation of sale lots by wool exporters.

With experience, greater use will be made of objective data on seasonal effects of staple measurements, as it is now done for coretest measurements. For example, Figure 13 demonstrates the trends in staple strength measurements of sale lots over the past two wool selling seasons in Australia. At this stage, these trends should be taken as indicative only because of the different uptakes of presale staple testing in each state. However, they could begin to influence topmakers in the selection of their wools for combing blends throughout a season, and may lead to more specification in purchase contracts. Similarly, wool growers can identify periods when supplementary feeding and other farm management practices can beneficially improve the soundness of their clip.

The impact of drought conditions will make it even more important to monitor these trends, so that objective staple measurements and the general formulae developed for individual combing mills should be of particular benefit to them in these circumstances.

FIGURE 13

AVERAGE STAPLE STRENGTH OF PRESALE STAPLE TESTED LOTS BY STATE OF ORIGIN 1986/87, 1987/88 SEASON



References

1. IWTO-17. *Determination of Fibre Length Distribution Parameters by Means of the Almeter.*

2. *Staple Length and Strength Measurements - "What the Growers Say"*, AWC, June, 1988.

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8. ACKNOWLEDGEMENTS

A project such as TEAM involves many companies, organisations and people. The TEAM Management Committee wishes to acknowledge the cooperation of industry, and in particular, those combing mills and topmakers listed in Section 2 of the Report. Without their participation there would not have been a project.

Particular acknowledgement is given to Diana Allen, Jenny Howlett and Andrew Brissett of CSIRO Division of Wool Technology, Ryde, and to Tracey Henwood, Hendrik van Schie and Michael Jackson of AWTA Ltd, Sydney who assisted the Committee and ensured the Report was completed and published on time.

Finally, it is appropriate to recognise the financial support for this Project by the Australian woolgrowers. The TEAM Project was financed by the Wool Research and Development Fund administered by the Australian Wool Research and Development Council.

APPENDIX 1
PROCESSING RESULT PROFORMA

TEAM
TRIALS EVALUATING ADDITIONAL MEASUREMENTS

TEAM PROCESSING REPORT

A. IDENTIFICATION

Combing Mill . . . .

Consignment/Batch Reference . . . .

TEAM Reference Number (allocated by CSIRO) . . . .

Date of combing . . . .

B. WOOL DATA

Total bales . . . .

	INVOICED WEIGHT	REWEIGHT (where possible)
Greasy Weight	. . . . .kg	. . . . .kg
Tare	. . . . .kg	. . . . .kg
Net Weight	. . . . .kg	. . . . .kg
Outsorts (if any)	. . . . .greasy kg	
(AWTA Coretest) Schlum Dry Yield	. . . .%	
Schlum Dry Yield	. . . . .clean kg	

It is preferable that there should be no sorting of wools and/or removal of bales unless considered to be absolutely necessary. If sorting exceeds 1% of the greasy weight, it is unlikely that a valid greasy wool test/combing comparison can be made. So, the amount of any outsorts should be determined accurately and the reasons for removal recorded.

C. PROCESSING DATA

* Please indicate whether cardwastes have been recycled YES/NO

* Results by item (as applicable)

	Nett kg	**%**
- Tops, conditioned (Peignes conditionne)	. . . .	. . . .
- Noils, conditioned (Blousses conditionne)	. . . .	. . . .
- Combable waste (Meches)	. . . .	. . . .
- Second noil (Bloussettes)	. . . .	. . . .
- Stripping (Debourrages)	. . . .	. . . .
- Shoddy, willeyed (Bourres apres battage)	. . . .	. . . .
- Shoddy, unprocessed (Bourres brutes)	. . . .	. . . .
- Burrs, willeyed (Chardons travailles)	. . . .	. . . .
- Burrs, unwilleyed (Chardons brutes)	. . . .	. . . .
- "Floquettes" from shoddy (de Bourres)	. . . .	. . . .
- "Floquettes" from burrs (de Chardons)	. . . .	. . . .

* Romaine (Noil) . . . .%

* Comb Setting . . . . .mm

* Combing Line Reference - Scouring Line: . . . .

- Carding/Combing: . . . .

D. MILL TEST RESULTS (Please attach Certificates where applicable)

Certified

Conditioning — Top moisture regain . . . . %

Noil moisture regain . . . . %

Fatty matter — Top, total fatty matter (on dry fat free weight) . . . . %

Solvent used . . . .

Top Length	Almeter Hauteur	. . . . .mm
	Almeter Barbe	. . . . .mm
	CV Hauteur	. . . . %

Hauteur

% < 25 mm . . . .%	Length (Hauteur) > 5% . . . . .mm
% < 30 mm . . . .%	Length (Hauteur) > l% . . . . .mm
% < 35 mm . . . .%	
% < 40 mm . . . .%	

If Almeter results are not available please provide alternative measurements clearly noting the method used.

Top Fineness

Mean Fibre Diameter Airflow . . . . .micron

Projection Microscope Mean Fibre Diameter (if available) . . . . .micron

<u>Other Tests (if available)</u>

Evenness of top (Uster) . . . . .CV% (short term)

Neps >*...mm* diameter . . . . .per 50g

Vegetable pieces 3-10 mm . . . . .per 50g

Straw & Burrs > lOmm . . . . .per 50g

Other tests (eg. dark fibre, top colour) if available

. . . .

. . . .

E. OTHER TESTS OR PROCESSING INFORMATION (if considered relevant).

. . . .

. . . .

F. SAMPLING TOP FOR TESTING AND FUTURE REFERENCE

Samples of top are required from each processing batch. These samples will be tested by CSIRO for Hauteur and Fibre Length Distribution parameters.

Eight 1.2 metre samples are required per consignment. These should be selected from individual bumps or balls of top on the basis of 2 samples from 4 packages drawn from each quartile of the combing.

Each sample should be identified by the TEAM Reference Number and labelled alphabetically, as follows;

TEAM Number:	. . . . A	} 1st quartile of production samples
TEAM Number:	. . . . B	
TEAM Number:	 C	} 2nd quartile of production samples
TEAM Number:	. . . . D	
TEAM Number:	. . . . E	} 3rd quartile of production samples
TEAM Number:	. . . . F	
TEAM Number:	. . . . G	} 4th quartile of production samples
TEAM Number:	. . . . H	

Each 1.2 meter length of sample sliver should be twisted as per the requirements of Section 6.1.1 (i) of IWTO-17-85 or wrapped onto formers.

THIS IS ABSOLUTELY ESSENTIAL IN ORDER TO OBTAIN ACCURATE TEST RESULTS.

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APPENDIX 2
CLEAN LINEAR DENSITY AND POSITION OF BREAK

Differences between TEAM-1 and TEAM-2 Data

At the time that the TEAM-1 project was undertaken, all staple strength testing was carried out post sale using a CSIRO prototype staple measurement instrument known as the MARK-6. All measurements were conducted at AWTA Ltd under the control of the TEAM-1 Project, with results being forwarded to the topmakers and mills after processing was completed.

TEAM-2 and the AWTA Ltd/AWC schemes were all initiated after AWTA Ltd's introduction, in January 1985, of a commercial staple measurement service based on the fully developed CSIRO-designed ATLAS instrument. Unlike TEAM-1, TEAM-2 relied on the exporter or topmaker to provide the commercial staple testing data on the individual lots in the consignment.

There are some differences in the measurement principles used by ATLAS compared to those used by the earlier MARK-6 prototype. They relate to the method of determining the clean linear density (ktex) and the method of determining the position of break (POB), often referred to as the position of weakness, of individual staples.

Determination of Clean Linear Density (ktex)

The importance-of the clean linear density measurement relates to its role in the calculation of the strength of individual staples. Clean linear density is used in correcting the measured peak force for variations in staple thickness. In the case of the MARK-6 prototype, the clean linear density was measured at one point near the base of the staple using one of the pair of jaws, which had been precalibrated to measure staple thickness([1]). If the thickness at the point of measurement differed greatly from the average linear density of the whole staple, anomalous results were obtained ([2]). While this might have provided some incorrect estimates of linear density on some individual sale lots, a review of data showed that mean staple strength values of consignments were not affected. An alternative system based on the masses of the individual broken staple parts, the average yield of the lot of wool and the length of the staple a being measured, has been incorporated into the design of ATLAS([3,4]) and is now the standard method ([5]).

Determination of Position of Break (POB)

For the MARK-6 prototype, the POB was estimated visually by the operators when the individual staples were broken and the jaws gripping the ends of the staple were well separated from one another. The objective of the operators was to classify the POB of each staple as either a tip, middle or base break. Any break that was estimated to occur from the tip to 1/3 of the staple length was referred to as a tip break. A middle break was a break that was considered to occur between 1/3 and 2/3 of the staple length, while a base break referred to a break in the remaining lower 1/3 of the staple. The operator simply pressed a button to identify either a tip, middle or base break and this was recorded for each individual staple.

For the ATLAS instrument, the POB is objectively determined from the masses of the two broken parts of the staple. The POB for each staple is recorded as a percentage of the broken tip mass to the total mass giving potential values from 0 to 100 percent. A subsequent calculation determines the percentage of staples tested that fall within the 0 to 33 percent range and classifies them as tip breaks. Within the 34 to 66 percent range they are classified as middle breaks and from 67 to 100 percent as base breaks.

The most relevant means of summarising and reporting POB data for predicting processing performance has been under investigation for some time. Options have included:

– the percentage of breaks in either the tip, middle or base region of the staple;

– the average POB referenced from the tip for the staples tested; and

– the average POB referenced from the mid-point of the staple.

For the TEAM Report we have concentrated on the first two options.

Examination of the measurements from the TEAM-1 data compared to the TEAM-2 data, highlighted a major difference between the distributions for the POB of individual staples. The difference is demonstrated in Figure 14 by looking at the percentage of staples that were recorded to have broken in the middle (i.e., from 1/3 of the staple length to 2/3 of the staple length). It now appears that, for the CLARK-6 prototype, the POB was more likely to be designated either tip or base. This is believed to be caused by the method of visual assessment.

2-60 The difference is not as obvious if one calculates the average POB for the consignments. Figure 15 shows the frequency distributions of average POB for the same consignments as were reported in Figure 14.

In the TEAM-1 report, for some mills, the average POB appeared as a significant variable in the prediction of Hauteur. However, it did not appear as significant in the general formulae.

FIGURE 14

FREQUENCY DISTRIBUTIONS OF THE PERCENTAGE OF MIDDLE BREAKS (%M) FOR INDIVIDUAL CONSIGNMENTS ESTIMATED FROM THE MARK-6 PROTOTYPE (TEAM-1 DATA) AND ATLAS (TEAM-2 DATA.

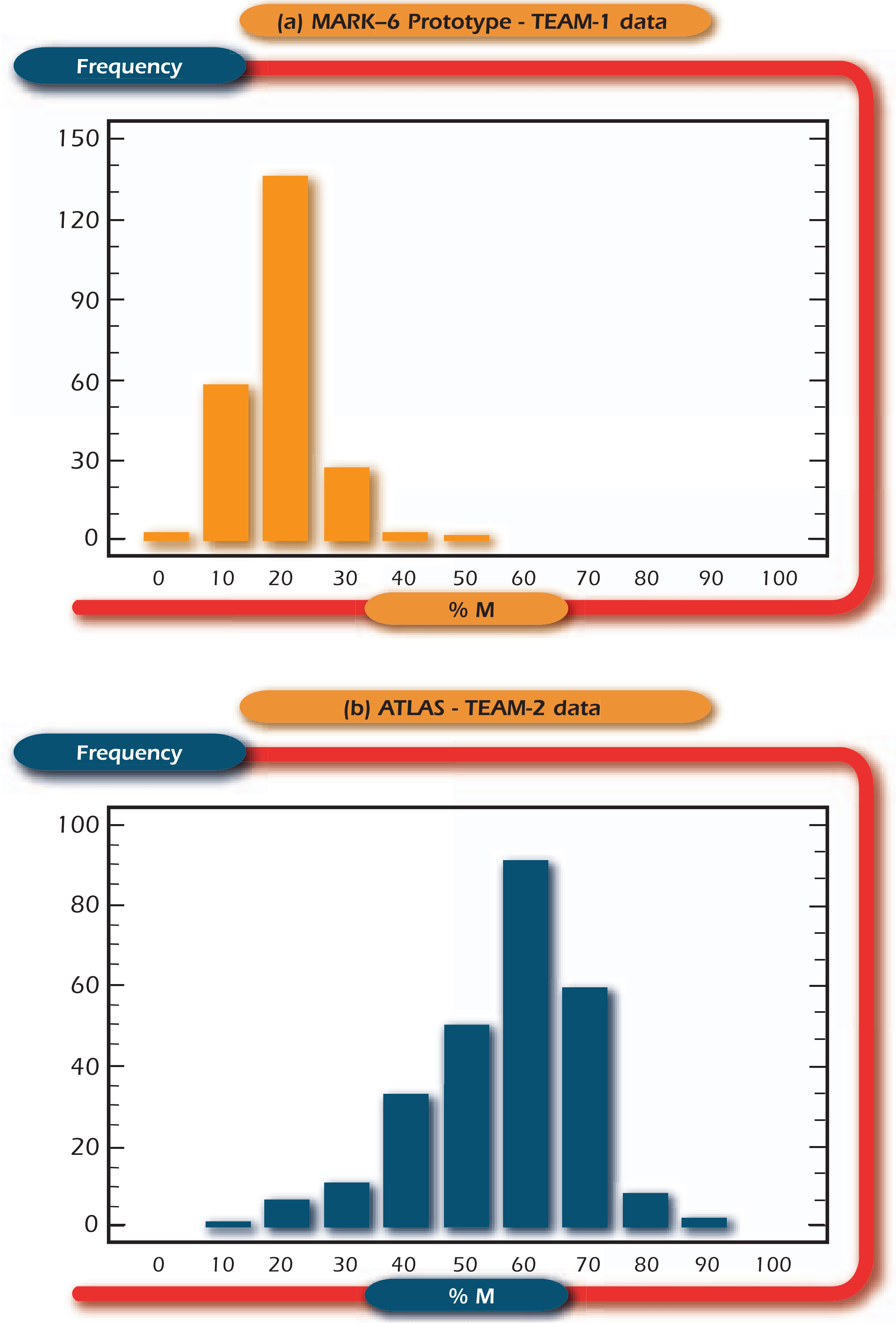
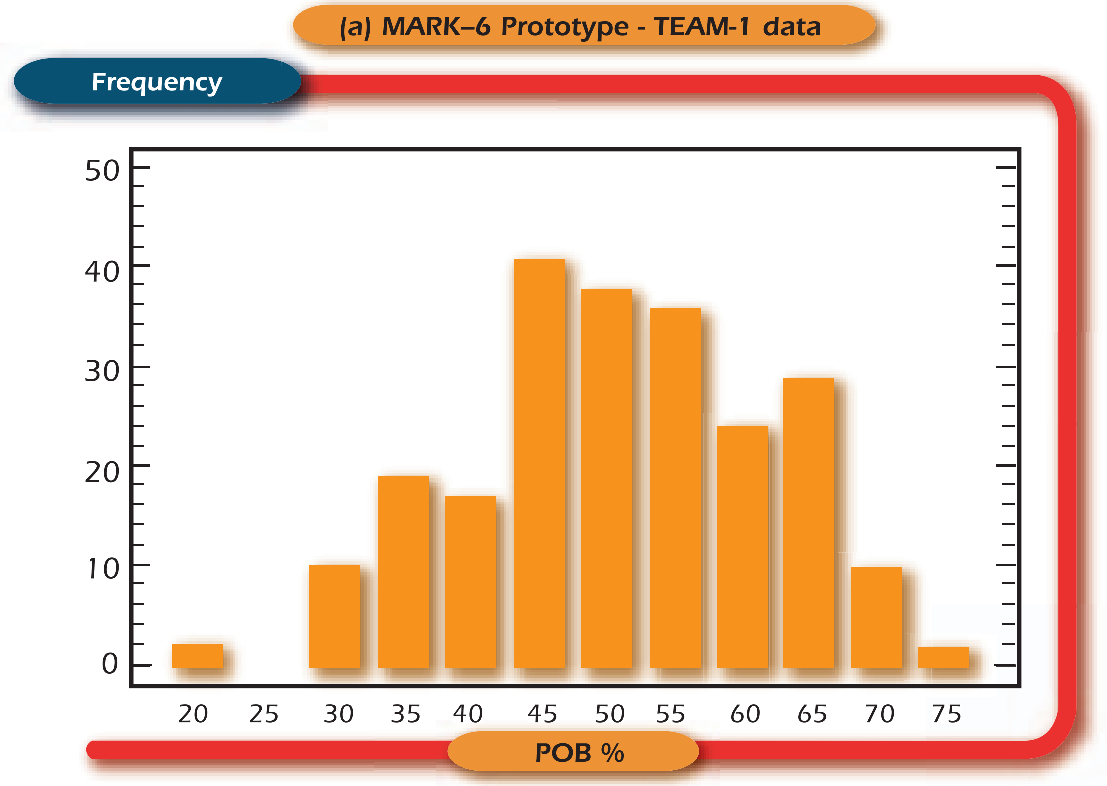
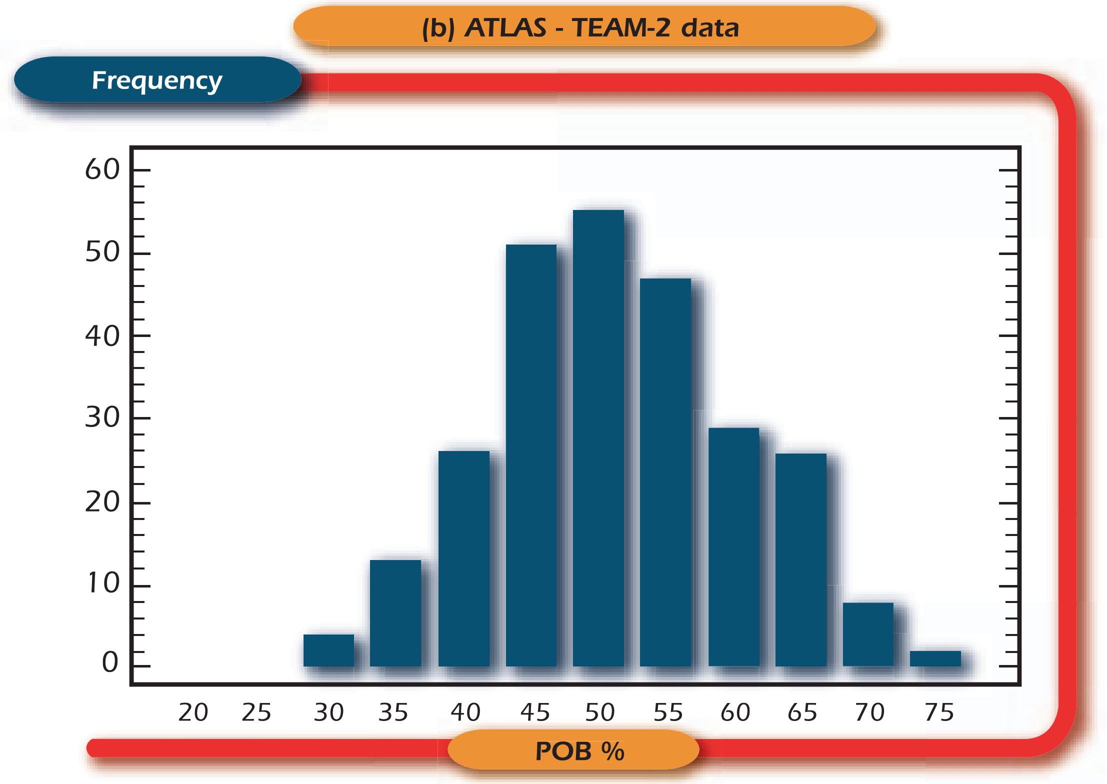


FIGURE 15

FREQUENCY DISTRIBUTIONS OF THE AVERAGE POSITION OF BREAK (POB)
FOR INDIVIDUAL CONSIGNMENTS ESTIMATED FROM
THE MARK-6 PROTOTYPE (TEAM-1 DATA) AND ATLAS (TEAM-2 DATA).

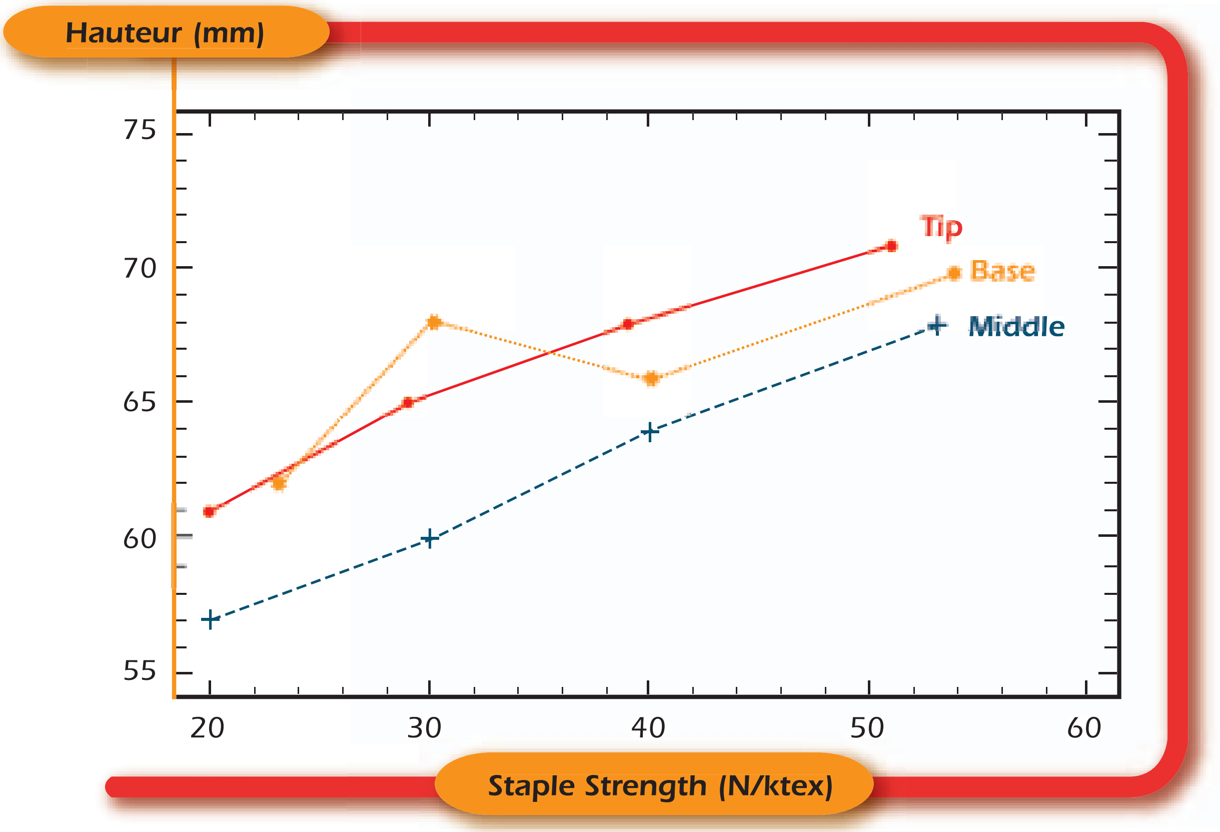




Pilot-trial research ([5]) has also shown that POB has an influence on Hauteur when other raw wool characteristics are controlled. Figure 16 shows that wools selected to have predominantly either base or tip breaks behave almost identically in their relationship between staple strength and Hauteur whereas wools that have predominantly middle breaks behave differently. From the processing point of view, this difference in performance is best quantified by the percentage of middle breaks (%M) rather than average POB.

FIGURE 16

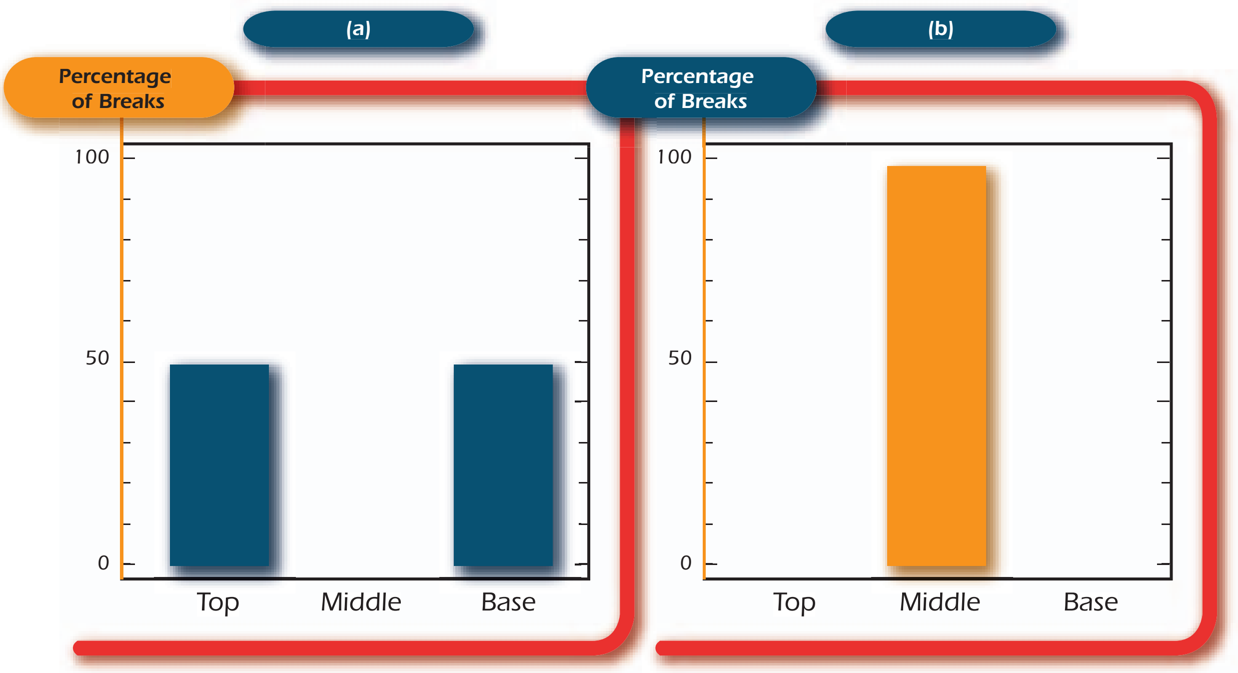
THE INFLUENCE OF POB AND STAPLE STRENGTH ON RESULTANT HAUTEUR (EXTRACTED FROM REFERENCE 5).



It is even more striking if one considers the two hypothetical distributions of POB presented in Figure 17. One distribution has all the breaks in the middle whereas the other has 50% in the tip region and 50% in the base region. Both would have the same average POB of 50%. This together with the results presented in Figure 16 would strongly suggest that average POB is not as good a variable to assist in the prediction of Hauteur as the percentage of middle breaks.

FIGURE 17

COMPARISON OF HYPOTHETICAL DISTRIBUTIONS OF STAPLE BREAKING PATTERNS HAVING AN AVERAGE POB OF 50%



References

1. Caffin, R.N., J. Text. Inst. 1980, **71**, 65-70, 1980.

2. Andrews, M.W., Heuer, P.A. and Bow, M.R. *Linear Density Determination for Staple Strength Measurement,* Report to IWTO Working Group on Length of Raw Wool, Venice, June, 1982.

3. Kavanagh, W.J. and Bow, M.R. *Estimating the Wool Content of Staples Sampled for Staple-Strength Measurement,* Proc IWTO Tech. Cttee. Report No 15, Paris Meeting, January, 1985.

4. Allen, D.J. and Bow, M.R., *Estimation of Loss in Staple Mass During Automatic Staple Strength Testing on CSIRO ATLAS Instrument,* Proc. IWTO Tech. Cttee. Report No 2, Paris Meeting, January, 1986.

5. IWTO(E)-12. *Determination of Staple Length and Staple Strength.*

6. Rottenbury, R.A., Kavanagh, W.J., Eley, J.R. and Andrews, M.W. *The Effect of the Strength Properties of Wool Staples on Worsted Processing. Part II: The Location of Staple Weakness,* J. Text. Inst. **77**, 191, 1986.

APPENDIX 3:
ADJUSTMENT OF THE GENERAL FORMULA FOR HAUTEUR FOR A SPECIFIC MILL

As indicated in Section 3 of this Report, the performance of the general formula is limited by the within-mill variation. The recommended procedure for establishing mill (or even processing line) specific formulae are similar to the procedures already established for making mill adjustments to the constant term of the general formulae reported in TEAM-1, but are now provided in more detail to assist in practical application.

The following techniques for adjusting the general formula can be used by mills using additional measurement data for the first time, as well as those mills who already have a good understanding of the significance of the measurements to monitor processing performance.

Before commencing to make adjustments it should be clear that the mill processing performance is not changing with time. Appendix 4 gives techniques for establishing whether trends are present. If a mill's performance is improving during the adjustment period then it will be continually making adjustments to the formula simply to follow trends that should be resolved before making large changes to the formula.

3.1. Calculation of a mill-specific constant

Select the most recent set of data for the mill where the wool has been coretested, and in addition, sampled and measured for staple length and staple strength. Usually at least 20 processing consignments should be available. As an example, some data from one of the TEAM mills has been used to demonstrate the procedures.

Firstly, calculate the Hauteur (H_i) from the data for each consignment (i) using the TEAM general formula.

$$\mathbf{H_i = 0.52L_i + 0.47S_i + 0.95D_i - 0.19M_i * - 0.45V_i - 3.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

For each consignment, i, determine the difference (C_i) between the achieved Hauteur (H_a) and the calculated Hauteur (H_i).

$$\mathbf{C_i = H_a - H_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

The results for this mill are presented in Table 21 in columns 1 and 2.

The next step is to establish the presence or absence of trends over time by preparing a graph of the differences between the achieved and calculated Hauteurs against either processing order or the actual time when processed (see Figure 18).

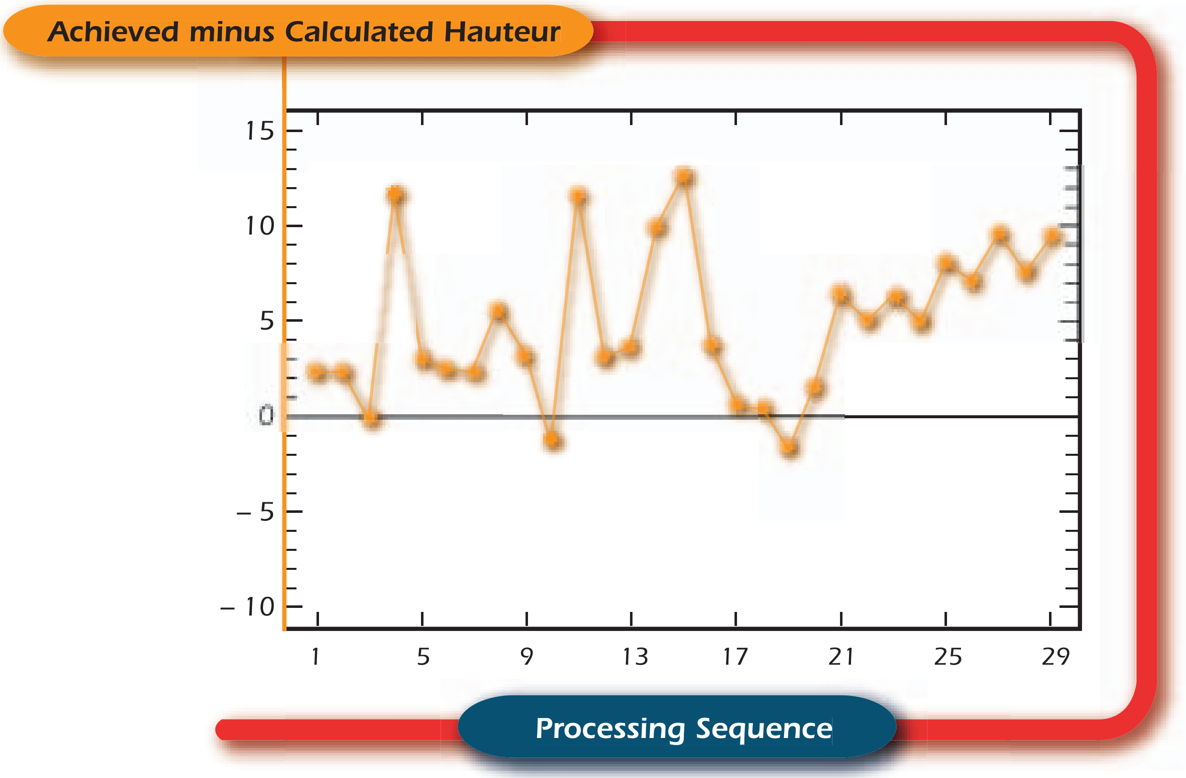
TABLE 21

COMPARISON BETWEEN ACHIEVED AND PREDICTED HAUTEURS FOR AN EXAMPLE MILL

	General Formula		Mill-Adjusted Formula	
Achieved Hauteur (H^a) (mm) (1)	Calculated Hauteur(H^i) (mm) (2)	Deviation From Achieved Hauteur(H^c) (mm) (3)	Calculated Hauteur (mm) (4)	Deviation From Achieved Hauteur (mm) (5)
57.3	54.9	2.4	59.7	-2.4
59.0	56.5	2.5	61 3	-2.3
66.3	66.4	-0.1	71.2	-4.9
82.4	70.7	11.7	75.5	6.9
58.1	55.1	3.0	59.9	-1.8
58.7	56.2	2.5	61.0	-2.3
61.2	58.9	203	63.7	-2.5
58.3	52.8	5.5	57.6	0.7
59.4	56.2	3.2	61.0	-1.6
65.1	66.5	-1.4	71.3	-6.2
83.6	72.0	11.6	76.8	6.8
56.8	53.7	3.1	58.5	-1.7
56.7	53.1	3.6	57.9	-1.2
69.2	59.4	9.8	64.2	5.0
80.6	68.0	12.6	72.8	7.8
66.9	63.2	3.7	68.0	-1.1
61.9	. 61.4	0.5	66.2	-4.3
60.9	60.6	0.3	65.4	-4.5
61.2	63.0	-1.8	67.8	-6.6
64.0	62.5	1.5	67.3	-3.3
68.0	61.7	6.3	66.5	1.5
57.6	52.7	4.9	57.5	0.1
68.0	61.8	6.2	66.6	1.4
70.5	65.6	4.9	70.4	0.1
82.7	74.9	7.8	79.7	3.0
80.0	73.1	6.9	77.9	2.1
75.7	66.3	9.4	71.1	4.6
68.4	61.0	7.4	65.8	2.6
76.3	67.0	9.3	71.8	4.5
66.7	**61.9**	**4.8**	**66.7**	**0.0**

FIGURE 18

HAUTEUR DIFFERENCES - ACHIEVED MINUS CALCULATED FROM GENERAL FORMULA



There is no apparent trend from consignment 1-18 but from 19-29 there is evidence of a trend. It is important to monitor this situation for future batches as if the trend is real, and continues, it may be necessary to adjust the constant term after more data has been collected. However, the best adjustment in the present situation is still the average adjustment based on all the data.

The mill adjustment is calculated by determining the average difference for these 29 results (i.e., 4.8 mm).

The mill-specific constant is then calculated by adding the average difference to the general formula constant (i.e., -3.5 + 4.8 = +1.3). Thus, a specific formula for this mill is written as:

$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.19M^* - 0.45V + 1.3} \quad \text{. . . . .(15)}$$

The recalculated Hauteurs based on the mill specific formula are presented in column 4 of Table 21 and the individual differences from the achieved Hauteur shown in column 5. These are graphed in Figure 19 and presented in histogram format in Figure 20.

This formula should be used initially in conjunction with the monitoring techniques outlined in Appendix 4. Once much more data is available, alternative techniques are possible.

FIGURE 19
HAUTEUR DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER ADJUSTMENT FOR MILL CONSTANT

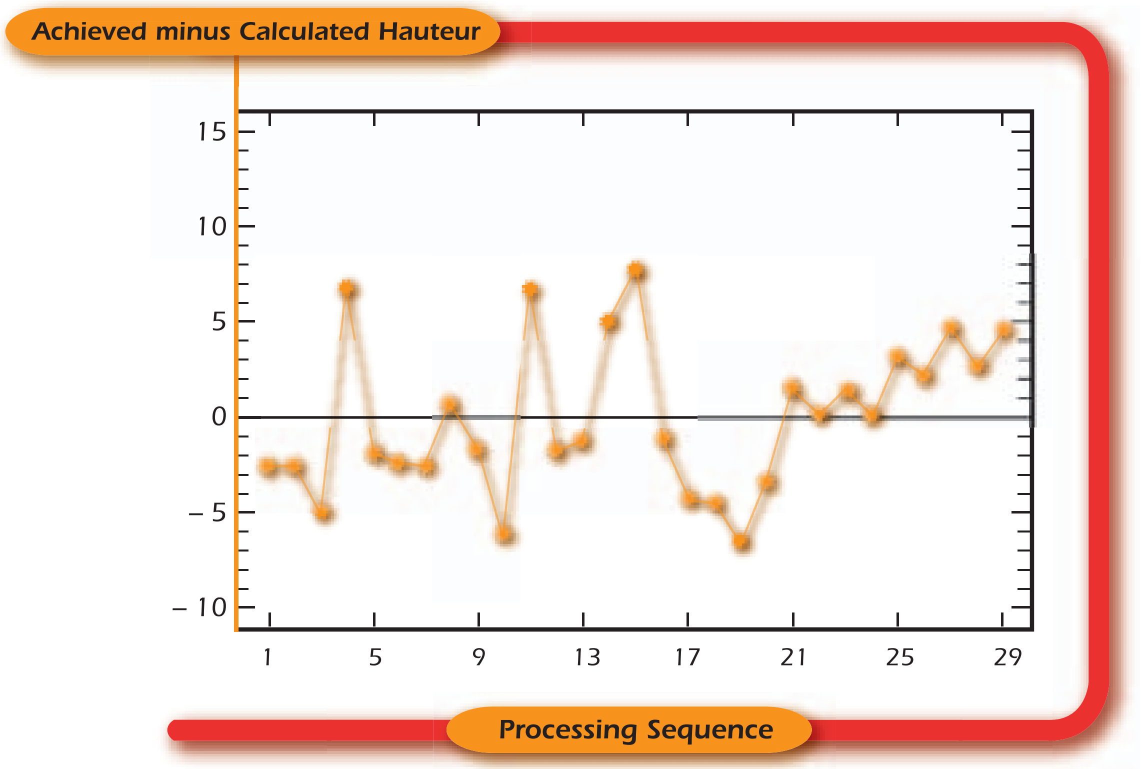
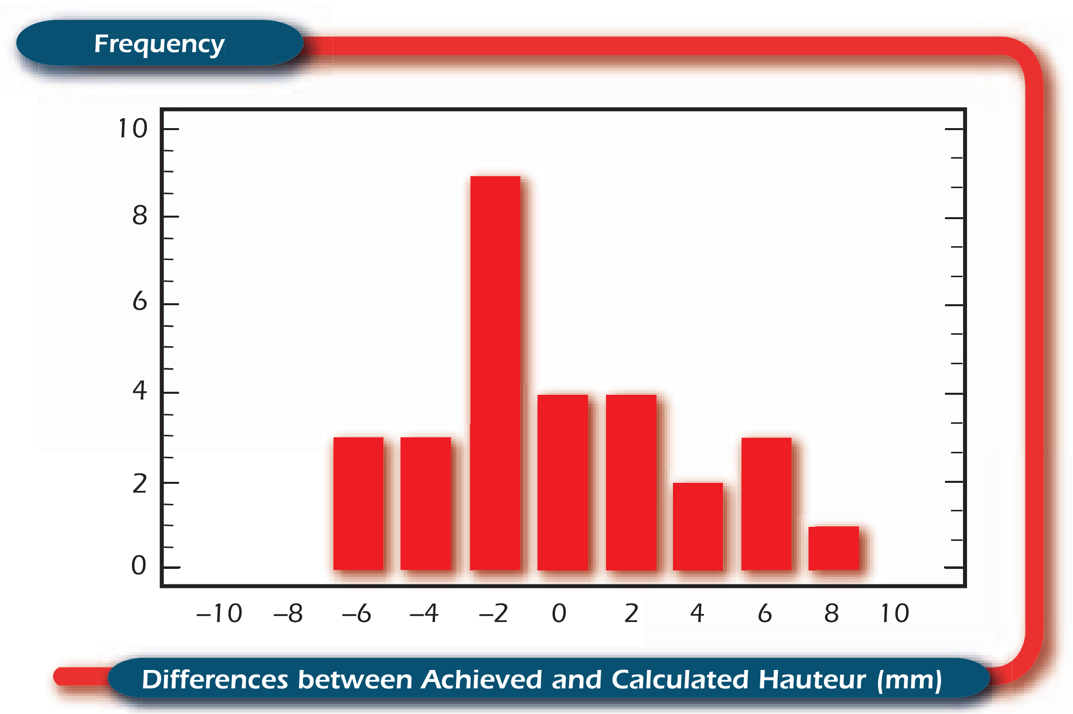


FIGURE 20
HISTOGRAM OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER ADJUSTMENT FOR MILL CONSTANT



3.2 Calculation of mill-specific coefficients and terms

As the Total database used to derive the current general formula consisted of 545 processing consignments from 20 different mills, the best approach in the first stages of modifying the formula beyond a simple adjustment, should be to examine the relationship of the differences between the achieved and calculated Hauteurs, and each raw wool characteristic. This should only be attempted with a stable database of 100 to 200 consignments which cover a range of wools of the type to be processed in the future. To explain this technique, an example is given from the current TEAM database but using less numbers for demonstration purposes.

Firstly, graph the differences between achieved and calculated Hauteurs separately against all measured raw wool characteristics, including those used in the general formula, to see if there are any obvious trends. If a trend is identified, a further appropriate adjustment procedure for trends can be conducted.

For example, the results of graphing the deviations after adjustment listed in Table 21, against coefficient of variation of staple length (CVL) showed an obvious trend, as illustrated in Figure 21.

From Figure 21, it is obvious that as CVL increases the differences between the achieved Hauteur and the calculated Hauteur is decreasing. It would therefore appear that an adjustment to allow for the effect of CVL is needed. One method of doing this is to determine a linear regression equation of the differences against CVL. In this case the equation is:

Differences = 17.5 - 0.71CVL . . . .(16)

This equation can then be added to the previously adjusted formula so that the fully adjusted general formula for this mill would then be expressed as follows:

H = 0.52L + 0.47S + 0.95D - 0.19M* - 0.45V - 0.71CVL + 18.8 . . . .(17)

The improvement in fit achieved by such a technique can be quite large. In this case, the standard deviation of the differences drops from 3.7 min to 2.9 mm and the distribution of differences, as illustrated in the histogram in Figure 22, and graph in Figure 23 is much narrower.

FIGURE 21
GRAPH OF DIFFERENCES (ACHIEVED - CALCULATED HAUTEUR)
AGAINST COEFFICIENT OF VARIATION OF STAPLE LENGTH

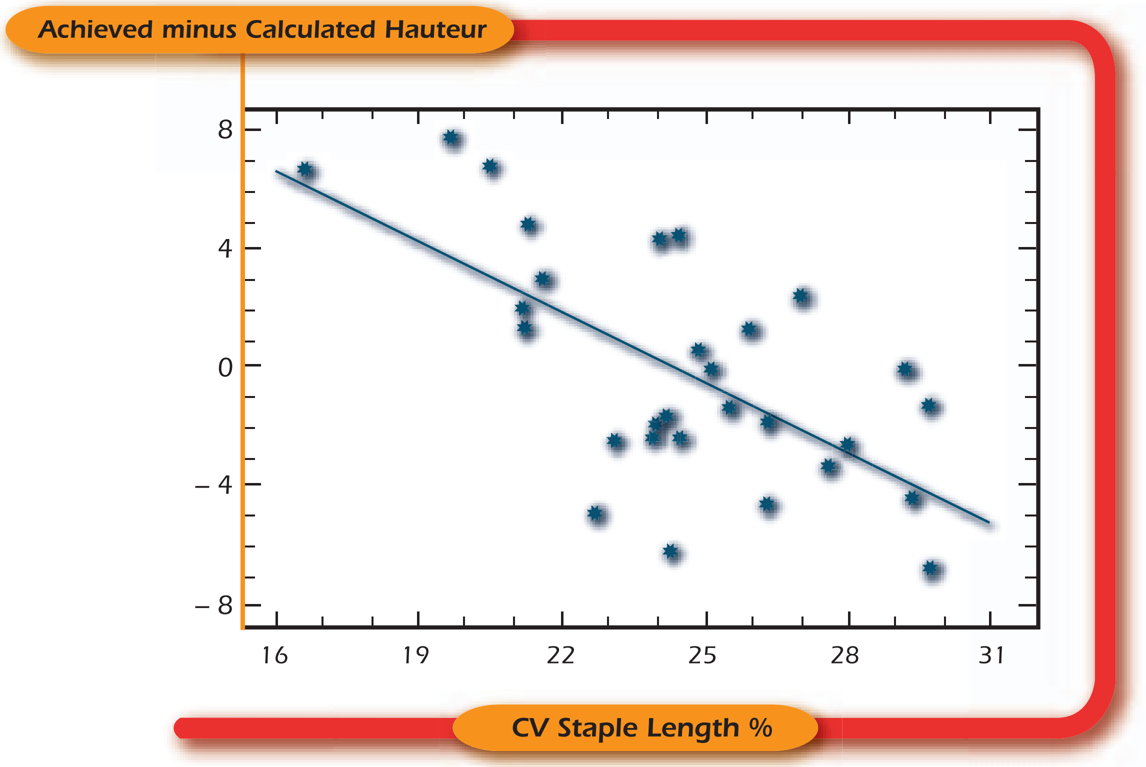


FIGURE 22
HISTOGRAM OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR AFTER ADJUSTMENT FOR
MILL CONSTANT AND COEFFICIENT OF VARIATION OF STAPLE LENGTH

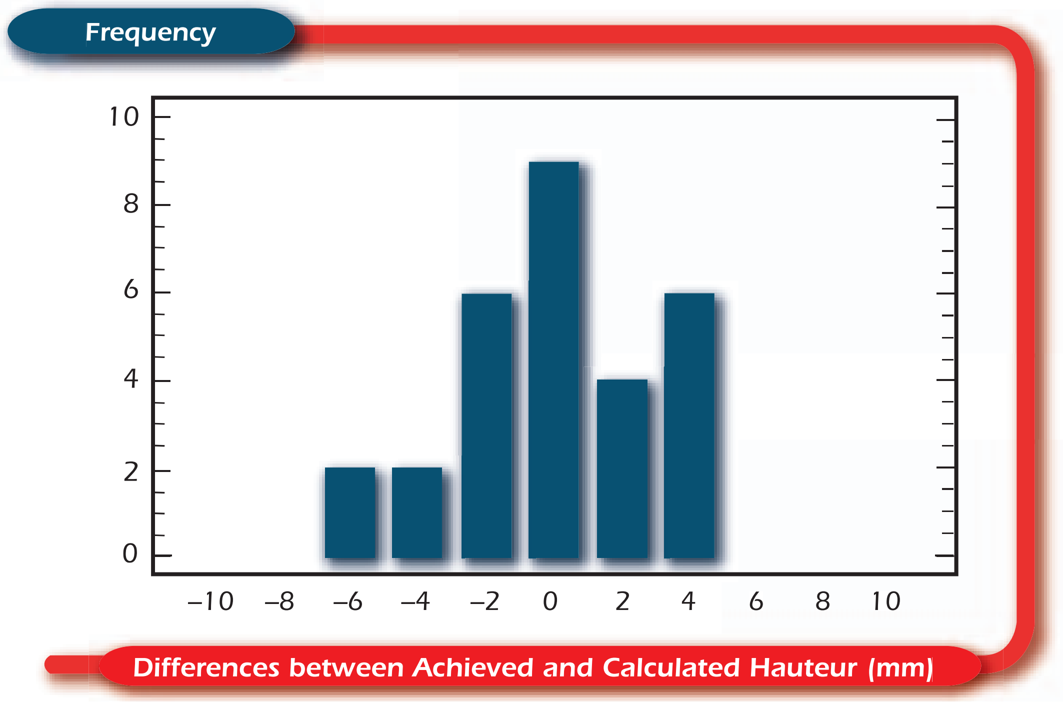
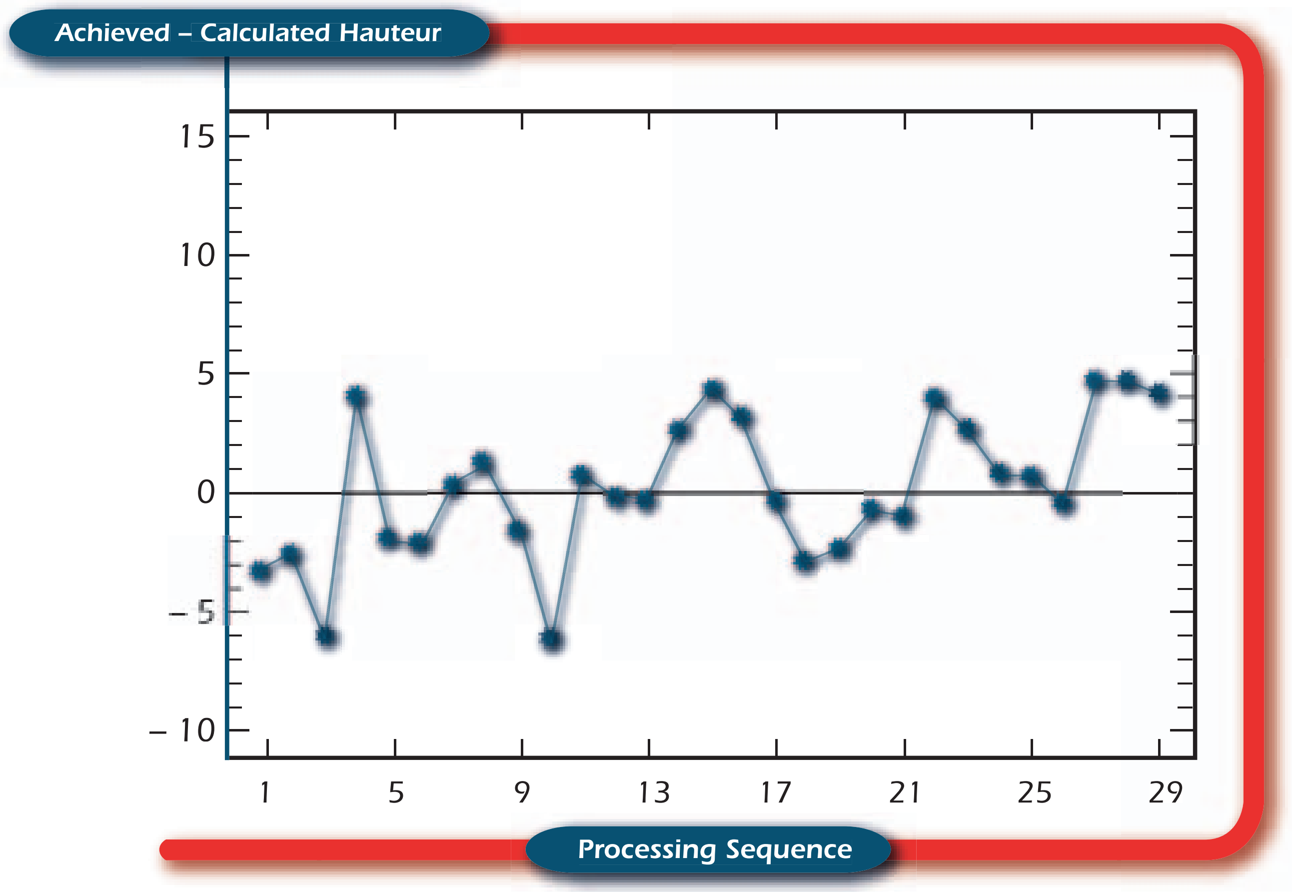


FIGURE 23
GRAPH OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER ALL ADJUSTMENTS



3.3 Adjustment of the Hauteur equation for specific grouping (e.g.,Wool Types, Vegetable Matter Type)

As more data is acquired, alternative techniques can be considered that group the differences between achieved and calculated Hauteur according to any known factor, such as VM Type, Wool Type, etc. This technique can be used as an alternative to that described earlier, when there are a number of non-measurable parameters that might affect the results.

It can also be applied to separate processing lines within mills to establish separate adjustments for each line, and to account for differences between lines. It is recommended that, where possible, separate adjustments be made for separate lines within a mill.

The following example groups the consignments by wool category e.g., fleeces and skirtings. Firstly, calculate the mean and standard deviation of the differences between achieved and calculated Hauteur for each category. This is shown in Table 22.

TABLE 22

GROUPING THE DATA BY WOOL TYPE

Type Category	Number of Results	Differences Mean (mm)	Differences SD (mm)
Fleece	10	2.9	4.2
Skirtings	16	-1.9	1.6
Prems	1	-5.1	*
Mixed	2	3.2	1.3

From this Table it can be seen that there is a large difference between the mean differences for fleece and skirtings types, (although a lot of this difference is accounted for by differences in CVL, with fleeces averaging 22%, and skirtings, 26%).

There are not enough results for “other” types, which includes one prematurely shorn consignment and two fleece/skirtings mixtures, to form any conclusion, and the previous formula should continue to be used for these odd types until more data is obtained.

However, the difference between the fleeces and skirtings is significant. Therefore, an adjustment to formula (17) could be made for all fleece consignments by adding 2.9 min to the calculated Hauteur, and for skirting consignments by subtracting 1.9 mm from the calculated Hauteur.

Hence, for this mill only, two possible formulas are:

– for fleece

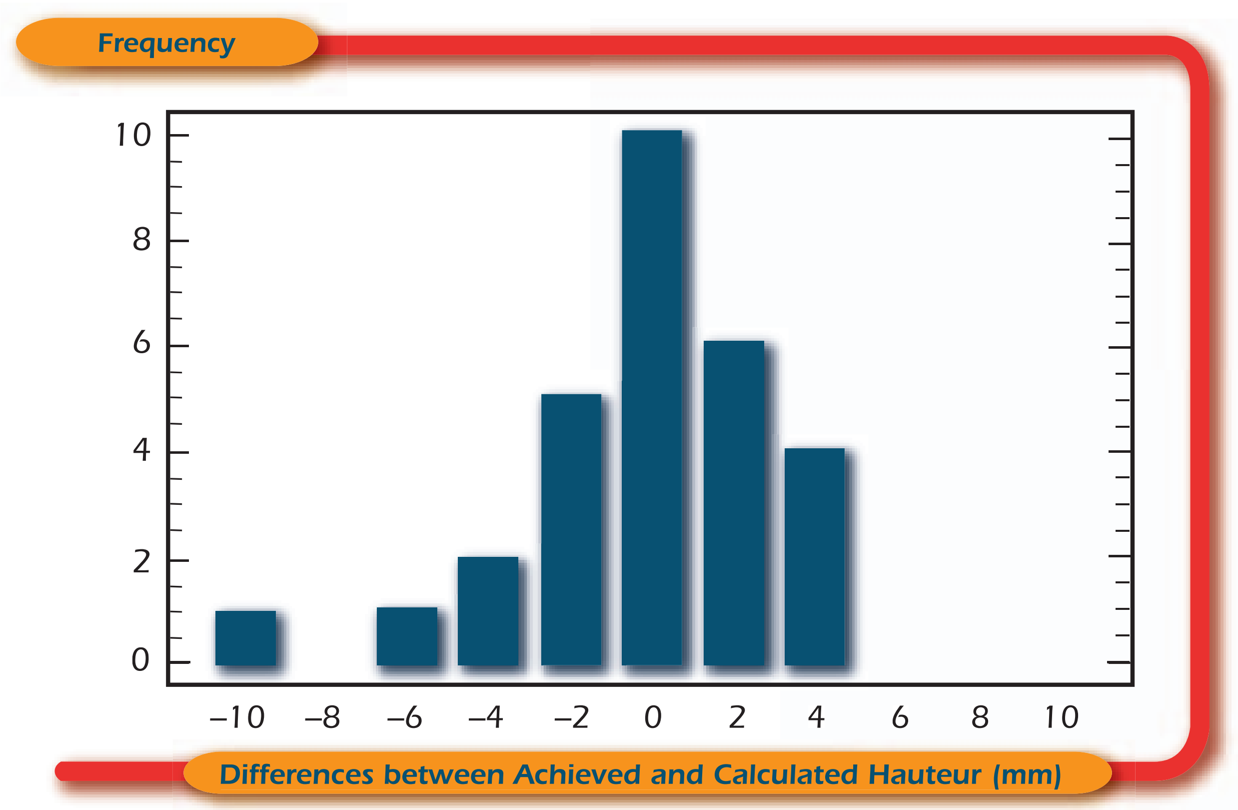
$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.19M^{*} - 0.45V - O.71CVL + 21.7} \quad \ldots\ldots\ldots\ldots\ldots (18)$$

– for skirtings

$$\mathbf{H = 0.52L + 0.47S + 0.95D - 0.19M^{*} - 0.45V - O.71CVL + 16.9} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

As for the CVL alone adjustment formula (17), this procedure reduces the standard deviation of differences to 2.9 mm. Figure 24 illustrates this effect on the differences between achieved and calculated Hauteurs after applying this adjustment.

FIGURE 24
HISTOGRAM OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER GROUPING BY CATEGORY



4. Discussion

The procedures illustrated above demonstrate how the TEAM general formula might be adjusted to allow for individual mill or processing line effects. It should be noted that the results given here are for descriptive purposes only, and while this is actual data from one mill in the Project, it is not suggested that use of Type descriptions or CVL is important for all situations. Yet on the basis of the few results obtained for this mill, adjustment using either CVL or Type are indicated *as* being helpful for this mill.

However, the most important criteria for the acceptability of any adjustment procedure is the ability of an adjusted formula to predict future processing results.

Mills and topmakers need to establish a procedure to continually monitor combing results. For assistance, procedures are described in Appendix 4. These procedures enable processors to ascertain the applicability of their current prediction, as well as providing an indication of when processing is changing and further adjustment of the prediction technique might be warranted.

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APPENDIX 4
USE OF THE GENERAL FORMULA FOR QUALITY CONTROL

Introduction

Once the best prediction technique has been developed for a particular mill, standard quality control procedures can be used to monitor mill performance.

There are essentially three aspects to the use of quality control techniques:

– to indicate when a result is abnormal, so that mill personnel can carry out investigations into the causes, and where possible, undertake corrective action;

– to ascertain if a known alteration to processing, or blend formation, has altered the processing outcome; and

– to check that the current prediction technique being used is working adequately, and to indicate if there are any consistent trends in results. If such trends are perceived, then the prediction technique should be reviewed.

The first aspect is essentially a mill quality control procedure, whereas the other two will be of interest to both mills and topmakers.

Use of Quality Control Charts

The basic technique for the monitoring of results is the Quality Control Chart, the essential features of a which are:

The Target Value

This is the value of the characteristic being measured that would ideally like to be achieved, e.g., for monitoring Hauteur, a target value of zero for the difference between actual and calculated Hauteur is appropriate.

The Inner or Warning Limits

These are the limits, above and below the target value, which indicate that there is a likelihood that something "unusual" may be occurring. If they are exceeded, it is worthwhile carrying out some investigations to see if there is an explanation as to why the results occurred and if corrective action need be taken.

These limits are normally set at twice the standard deviation of the measured characteristic, in this case the difference between actual and predicted Hauteur, which means that values would exceed the limits about 1 in 20 instances. It is essentially an "early warning system" that something may be affecting results. However, it should be realised that values can exceed the limits without any real change in processing having occurred.

The Outer or Action Limits

These are the values, above and below the target value, which are very unlikely to be exceeded unless something specific has occurred to alter the result. These limits are normally set at three times the standard deviation, which means that the values would be exceeded in only 1 in 370 instances. If these values are exceeded it can be reasonably assumed that something has affected the processing.

Setting up a Quality Control Chart

The standard deviation of the differences between actual and predicted Hauteur over all mills of 3.4 mm can be used to set initial limits. However, these may not be suitable for individual mills where direct measurement of the differences may indicate that the standard deviation is either greater or smaller. As prediction techniques are improved the spread of differences should be reduced and tighter limits should be set.

Using the overall standard deviation gives inner (warning) limits of ± 6.8 mm, and outer (action) limits of ± 10.2 mm.

The individual mill standard deviations of differences obtained for TEAM-2 results, varied from 2.7 to 5.2 mm, and limits for individual mills should be based on their own results. The difference in standard deviations indicate that some mills are achieving more reproducible, or less variable, results than others. This may be because of the range of wool types processed or because of mill management practices.

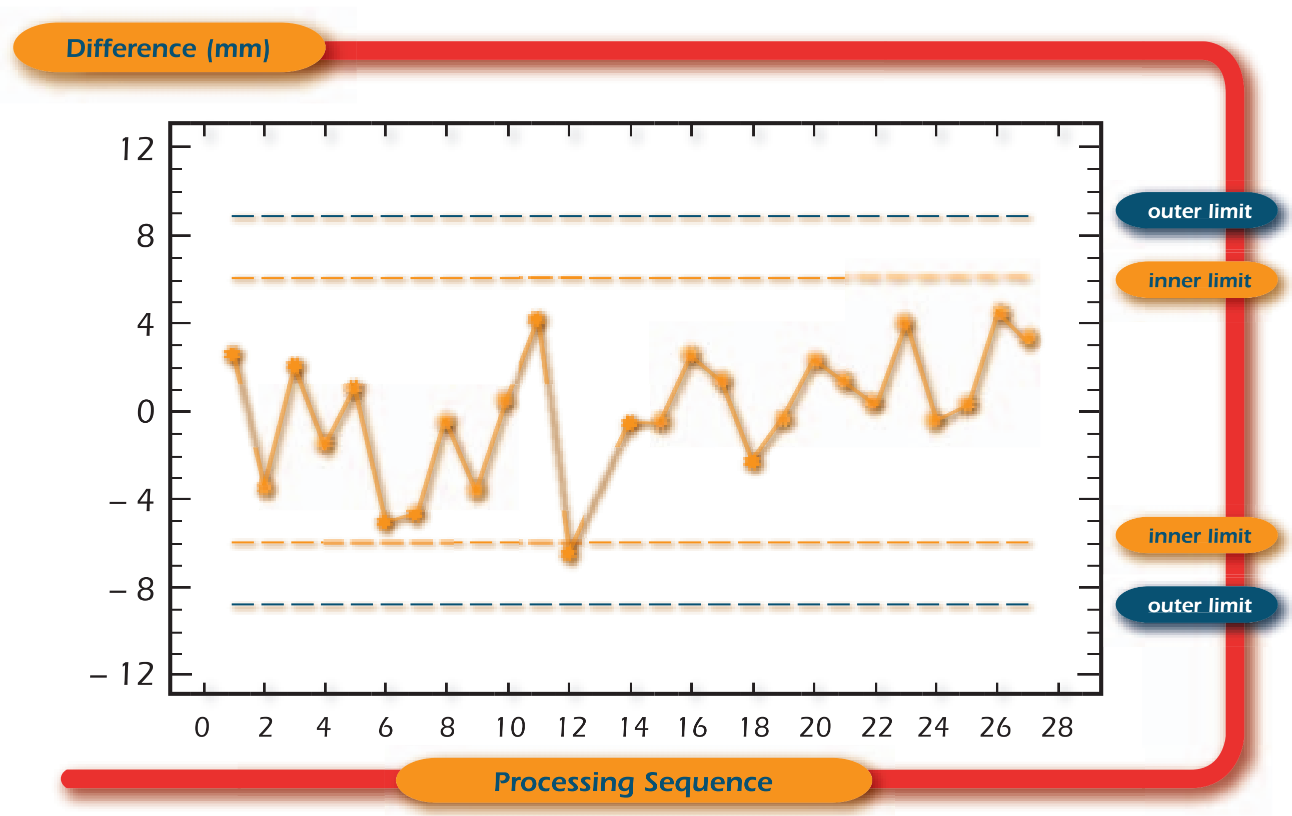
Plotting Results on Charts

The quality control chart is essentially a time-series graph of the difference between the achieved Hauteur and the calculated Hauteur. Figure 25 shows a chart plotted for an example mill, with limits based on the standard deviation of this mill's results only.

The differences are plotted in order of processing and one result (sequence number 12) does fall outside the inner limit. In statistical terms, this is to be expected every 20 or so results.

FIGURE 25

QUALITY CONTROL CHART OF DIFFERENCE (ACHIEVED HAUTEUR MINUS CALCULATED HAUTEUR) FOR AN EXAMPLE MILL



Interpretation of Control Charts

Figure 25 uses the same differences as have been used to determine the prediction formula and to set the limits. This is useful to demonstrate the application of control charts, and will highlight those results, which are unusual.

However, the main purpose of the control chart is to record future differences to ensure that processing results are in "control". It will enable a quick judgement to be made as to whether or not an individual result is likely to be anomalous. In addition, it provides a means for visually assessing if a "trend" is occurring, even when the individual results do not exceed the warning limits.

When interpreting Control Charts both these aspects need to be kept in mind.

Individual Results Falling outside the Limits

Figure 25 has one result that falls outside the inner or warning limit. In a mill situation this should be interpreted as a warning sign and processing conditions should be checked.

A topmaker might also examine data on this particular blend to see if it differed from others of a similar nature.

As there is only one result that exceeds the warning limit, the process is still within control in a statistical sense. If the outer or action limit had been exceeded then it is almost certain that something has occurred to alter the result and careful investigation of all possibilities should be carried out.

It should be remembered that there are many possible reasons why a consignment result could fall outside the limits, such as:

- differences in mill processing conditions (mill accidents?);
- measurement error in either Hauteur or the greasy wool characteristics (has there been a mix-up of lots?);
- an unusual component of the blend has caused the consignment to process differently; or
- normal variation (by chance the 1 in 20 extreme value has been obtained).

Trends

Interestingly, Figure 25 indicates that from result 14 onward there is less variation in the differences, which may indicate that the mill is performing better. Indeed, since result 19, all difference values have been at or greater than zero, and this may indicate that there has been a general improvement in results. This type of behaviour may indicate a trend and if it were to continue then a new prediction formula, or a new adjustment term may need to be determined, using only recent results.

Two types of trends may be observed, a fixed trend, where all the results are shifted by a fixed amount, or a variable or periodic trend, where a pattern of gradual change emerges.

Fixed Trend

If a fixed trend is identified then this indicates that something has caused a change in the processing outcome. The first step would be to try to identify the cause of the change. The same causes as listed for individual results may be responsible for the change. If the change is beneficial then it can continue to be used. For example, if new machinery has been installed, this procedure can indicate whether the processing outcome has changed - for the better or worse.

If the cause of the change cannot be identified or is to be maintained, then an adjustment to the constant term of the prediction formula is required. This can be done by determining the average of the differences, using only those results since the trend was identified, and adding this to the previously determined constant term. If the results since result 19 were considered, the constant term of the prediction formula would need to be adjusted by +1.9mm.

Variable Trend

If a periodic or variable trend is apparent, this is more difficult to account for, and indeed much more information is required to determine if a reproducible pattern can be established. As for the fixed trend, attempts should be made to establish the causes and apply remedies where possible.

Possible causes may be the time since the last major maintenance .of machinery, or seasonal effects of the wool blends used.

If the pattern of the trend can be established, it can be used as a continuous adjustment to predictions. If no fixed pattern emerges but there is a tendency for the mill's performance to vary slowly, then adjustments can be based on "rolling" averages of recent results, for example the last four results.

Alternative Control Charts to Emphasise Trends

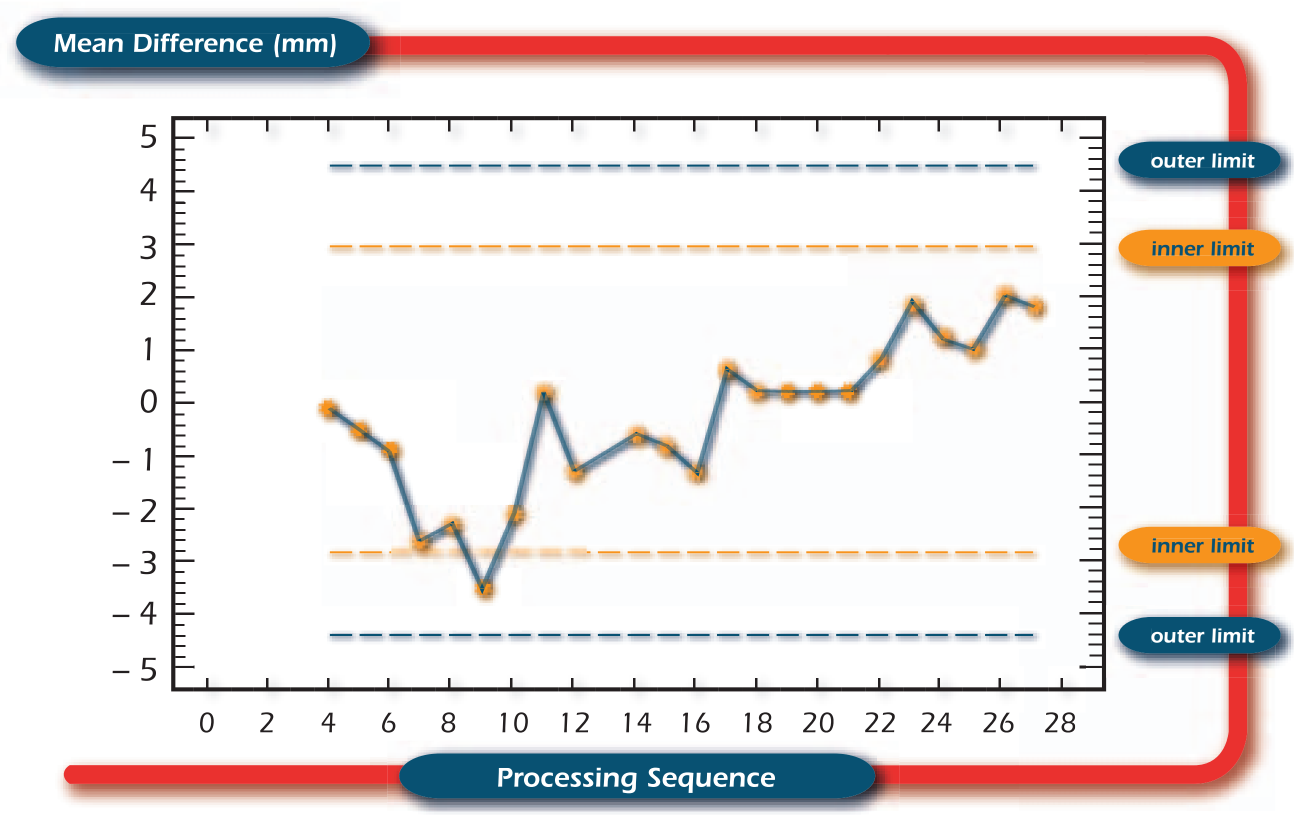
The control chart in Figure 25 uses each individual result to determine a difference for plotting on the chart. If the mill has large fluctuations in differences, this fluctuation may hide any trends that are present.

In order to bring out trends, a modified control chart can be used, which plots the mean difference of a fixed number of recent results, usually four. In this manner the fluctuation of differences is halved, as are the warning and action limits, and trends are more apparent.

Figure 26 shows such a control chart, which has been calculated from the same results as Figure 25.

FIGURE 26

QUALITY CONTROL CHART OF MEAN DIFFERENCE OF LAST 4 RESULTS (ACHIEVED HAUTEUR MINUS CALCULATED HAUTEUR) FOR AN EXAMPLE MILL



From Figure 26 it is apparent that there was a trend for negative differences during the first 9 consignments, which then appears to have been corrected. The more recent results indicate that there is a trend, probably a fixed trend, for differences to be positive, and for future predictions the constant term should be increased.

All these trends exist in Figure 25, but the trends are much easier to see in Figure 26.

Discussion

The above information and examples give a brief idea how the prediction formula can be used for quality control of combing.

Quality control charts can be used for both indicating when an individual result may be in error, and for indicating when there has been a fundamental change in processing results. If a fundamental change is identified, then Appendix 3 outlines procedures that can be used to adjust the general formula for prediction of future results.

However, it is essential that mills and topmakers establish a continual database and regularly monitor the results, using these procedures, if the full benefits, in terms of both mill management and prediction of results, are to be obtained.

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REPORT ON TRIALS EVALUATING ADDITIONAL MEASUREMENTS

March 2001 – March 2004

Printed by
Australian Wool Testing Authority Ltd
Melbourne, July, 2004

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Australian Wool Testing Authority Ltd
July, 2004

TEAM–3 CONTENTS

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1. SUMMARY OF THE REPORT

The TEAM-3 Processing Trial commenced in March 2001 and concluded in March 2004. At the conclusion of the trial, 34 mills had submitted a total of 647 commercial processing consignments. This report summarises the final analysis of the TEAM-3 database.

The principal conclusions of the TEAM-3 Processing Trial are as follows:

- The TEAM-2 parameters (Staple Length, Staple Strength, Mean Fibre Diameter, Vegetable Matter Base, and Adjusted Mid-Breaks) are still applicable to processing prediction models.

- Processing performance has improved since the late 1980's. Mills are producing tops with Hauteur values, on average, 5.1mm longer than is predicted using the TEAM-2 general formula. Greater differences occur as the actual Hauteur increases above 75mm. In addition, mills are producing tops with Coefficient of Variation of Hauteur (CVH) values, on average, 2.5% less than predicted by TEAM-2 and Romaine values 2.1% greater than predicted. These differences were similar for all of the five processing regions examined (Australia, China, India, Europe, and Other Asia).

- The Core/Comb relationships show that the average Mean Fibre Diameter of the processed top is 0.20μm higher than the Mean Fibre Diameter of the greasy wool, whilst the Coefficient of Variation of Diameter is 0.9% lower in the top. The actual processing yield of the TEAM-3 consignments is, on average, 1.1% higher than that predicted by the Schlumberger Dry Top & Noil Yield formula.

- Mills that participated in TEAM-3 achieved more consistent results with lower standard deviations between the actual and predicted Hauteurs than those mills who participated in TEAM-2.

- The regression analyses for Hauteur, CVH and Romaine have shown that it is possible to calculate new General Formulae for these parameters. It is also shown that the raw wool variables from the TEAM-2 General Formulae are still integral to the processing prediction model.

- For Hauteur, the additions of Coefficient of Variation of Diameter (CVD) and Coefficient of Variation of Length (CVL) provide small improvements to the prediction model. The use of Mid-Breaks (M) instead of Adjusted Mid-Breaks (M*) makes little change to the prediction model coefficients and has the benefit of simplifying the formula. It has been observed that there is no improvement in processing prediction if Mean Fibre Curvature (MFC) is included in the prediction model. The analysis of the TEAM-3 database has found that VM does not significantly influence the prediction of Hauteur. However due to the relatively narrow VM range in the TEAM-3 database, the inclusion of the VM coefficient from the TEAM-2 prediction formula for Hauteur is recommended. A revised Hauteur formula is proposed based on the analysis of the TEAM-3 database.

- For CVH, the addition of CVL provides a small improvement to the prediction model. It has been identified that there is no improvement in processing prediction if either MFC or CVD is added to the prediction model. The use of M instead of M* makes little change to the prediction model and has the benefit of simplifying the formula. A revised CVH formula is proposed based on the analysis of the TEAM-3 database.

- For Romaine, it has been identified that there is no improvement in processing prediction if either CVL, CVD or MFC is added to the prediction model. A revised Romaine formula is proposed based on the analysis of the TEAM-3 database.

- As was identified in the TEAM-2 report (1988), significant processing differences were identified between the individual mills participating in TEAM-3. Mills need to establish their own database and develop their own prediction formulae by using the recommended General Formulae and subsequently determining and reviewing an appropriate constant adjustment to the mill factor. Mills should consider fine tuning the formulae for particular categories or types of wool and topmakers who comb at more than one mill should also consider adjustments for each mill.

Based on the analysis of the full TEAM-3 database, the TEAM-3 Steering Committee recommends that the industry consider the following three options:

Option 1. Retain the existing TEAM-2 General Formulae in the IWTO Staple Test Regulations.

Option 2. Introduce new TEAM-3 General Formulae into the IWTO Staple Test Regulations as a replacement for the TEAM-2 General Formulae. The recommended formulae are as follows:

Hauteur = 0.43L + 0.35S + 1.38D – 0.15M – 0.45V – 0.59CVD – 0.32CVL + 21.8

CV Hauteur = 0.30L – 0.37S – 0.88D + 0.17M + 0.38CVL + 35.6

Romaine = – 0.13L – 0.18S – 0.63D + 0.78V + 38.6

Option 3. Include both the TEAM-2 General Formulae and TEAM-3 General Formulae in the IWTO Staple Test Regulations.

2. INTRODUCTION

It is well recognised that the prediction of processing performance is important since it allows individual mills to optimise raw wool inputs to meet desired outcomes in the top and it provides mills with a useful quality management tool.

For many years the Trials Evaluating Additional Measurement (TEAM) formulae, which utilise measurements of Staple Length & Staple Strength, have been the industry benchmark for the prediction of Hauteur (average fibre length in the top), Coefficient of Variation of Hauteur and Romaine (fibre wastage). The TEAM-1 and TEAM-2 projects concluded in 1984 and 1988 respectively and since that time there have been a number of attempts to improve the prediction of processing performance. However, a survey conducted in 1997 (Douglas & Couchman) clearly showed that the TEAM formulae remain the generally recognised world benchmarks. While this survey showed general satisfaction with the current TEAM formulae, it did reveal some limitations. Nevertheless, the use of the TEAM formulae as a benchmark has enabled individual mills to improve processing performance significantly. Due to the shortage of industry funds, research to improve the prediction model has been left to individual topmakers and their customers.

The introduction of Laserscan in July 2000 as the standard for all Presale Fibre Diameter tests in Australia, and the availability of Staple Length & Staple Strength data on most combing lots in sale catalogues, provided both a catalyst and an opportunity to review the TEAM-2 predictive formulae at minimal cost. It has been suggested that the new measurements provided by Laserscan, such as Coefficient of Variation of Diameter (CVD) and Mean Fibre Curvature (MFC), may influence top making performance. If so, their inclusion in the TEAM formulae may improve the accuracy of predicting such performance.

In March 2001, at the Shanghai meeting of the International Wool Textile Organisation (IWTO), the Australian Wool Testing Authority Ltd (AWTA Ltd) announced the commencement of the TEAM-3 trial. The TEAM-3 Processing Trial was co-ordinated by the TEAM-3 Steering Committee. The members of this Committee were as follows:

Michael Jackson	**Managing Director, AWTA Ltd**
Ian Ashman	**General Manager Customer Relations, AWTA Ltd**
Jim Marler	**National Technical Advisor, AWTA Ltd**
Andrew Lindsay	**Sampling Operations Manager NSW/QLD, AWTA Ltd**
Trevor Mahar	**Research Manager, AWTA Ltd**
Bob Couchman	**Capronex Services Pty Ltd**

In addition to the above TEAM-3 Committee members, Victoria Fish and David Crowe, from AWTA Ltd's Research and Development Division, assisted with the statistical analysis of the TEAM-3 database and the interpretation of results.

During the three year duration of the TEAM-3 trial, four successive progress reports were presented to the International Wool Textile Organisation (IWTO) providing an update on its progress (Lindsay et al, 2002a; Lindsay *et al*, 2002b; TEAM-3 Steering Committee, 2003; and, Lindsay *et al*, 2003). A final report was presented to the Raw Wool Group of IWTO on the 10th of May 2004 in Evian, France.

This report is similar to the paper presented at Evian in May 2004, however additional detail has been provided and comments from participants at the Evian Meeting have been incorporated into the report.

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3. TEAM-3 CONSIGNMENT CHARACTERISTICS

3.1 Bale and Lot Details

Processing consignments suitable for inclusion in TEAM-3 were accepted from March 2001 until March 2004. At the conclusion of consignment receival, 34 mills had submitted a total of 647 commercial consignments. The composition of both the TEAM-2 and TEAM-3 databases, in terms of the number of bales and lots, is shown in Table 3.1.

The 603 consignments submitted for the TEAM-2 trial comprised the total database that was used to derive the TEAM-2 General Formulae. This included data from the TEAM-1 and TEAM-2 projects as well as additional mill data (see TEAM-2 report, 1988).

TABLE 3.1

COMPOSITION OF THE TEAM-2 AND TEAM-3 CONSIGNMENTS

	TEAM-2	TEAM-3
Number of consignments	603	647
Total number of bales	88,000	159,000
Bales per consignment – Average	– –	246
Bales per consignment – Range	– –	44 to 1568
Lots per consignment – Average	17	40
Lots per consignment – Range	3 to 80	3 to 254

The global distribution of the processing mills that participated in TEAM-3 is illustrated in Table 3.2. Previous TEAM-3 progress reports have indicated that 37 mills signed an agreement to participate in the trial. However, Table 3.2 lists only 34 participating mills or topmakers because some of those who signed an agreement were unable to submit consignments. The effects of the 2002/03 drought in many parts of Australia, and general wool market conditions resulted in some participants having difficulty sourcing consignments that met the requirements for inclusion in the TEAM-3 trial. The number of consignments submitted by each mill or topmaker ranged from 1 to 33 with an average of 19 consignments.

For a consignment to be accepted as part of the TEAM-3 trial, several requirements had to be met:

- Each consignment contained a minimum of 100 bales of greasy wool (*Note: a small number of specialty superfine consignments were accepted despite being less than 100 bales*);
- Every lot in each consignment was tested for Fibre Diameter using Laserscan technology (IWTO-12);
- 95% of each consignment (by nett weight) had been certified for Staple Length & Staple Strength (IWTO-30);
- The mill provided Test Certificate information and processing information for each consignment submitted (see example proforma in Appendix 1); and
- The mill submitted to AWTA Ltd five (5) lengths of twisted top (as per IWTO-17) which were taken randomly from each processing batch. These samples were tested by AWTA Ltd to provide a common measurement basis for the entire database.

TABLE 3.2

TEAM-3 PARTICIPANTS

Australia
Australian Topmaking Services Ltd
Fletcher International Exports Pty Ltd
Geelong Wool Combing Ltd
GH Michell & Sons (Aust) Pty Ltd
Lempriere (Australia) Pty Ltd
Port Phillip Wool Processing Pty Ltd
Riverina Wool Combing Pty Ltd

Czech Republic
Nejdek Wool Combing, A.S.

Korea
Cheil Industries Inc

Singapore
Nankai Worsted Spinning Co Ltd

Taiwan
Reward Wool Industry Corporation

China
Australia Harvest Wool Textile Co Ltd
Jiangsu Changzhou Tops Mill
Jiangsu Sunshine Group
Lanzhou Sanmao Textile Group Co Ltd
Reward (Ningbo) Wool Industry Co Ltd
Shanghai No 1 Topmaking Company
Wuxi Xie Xin Group
Zhangjiagang Free Trade Zone – Concord Wool Textile Industrial Co Ltd
Zhangjiagang Free Trade Zone – Tianyu Woollen Textile Co Ltd
Zhangjiagang Yangtse Wool Combing Co Ltd
Zhejiang Xinao Group

France
Peignage de la Tossée
Ets A Dewavrin Fils & Co

India
Global Wool Alliance Pty Ltd
Indoworth India Limited
Jayashree Textiles Unit
Oswal Woollen Mills Ltd
Raymond Limited

Italy
Pettinatura Europa 90 S.r.l.
Vitale Barberis Canonico S.P.A.

Slovak Republic
Merina j.s.c

Thailand
Indorama Group

Japan
Nippon Keori Kaisha Ltd

3.2 Raw Wool and Top Characteristics

A summary of the major raw wool and processing characteristics of the TEAM-2 and TEAM-3 databases are presented in Tables 3.3 and 3.4 respectively. The consignments submitted by TEAM-3 participants represent current commercial processing blends. Apart from the requirement that 95% of the consignment was additionally measured, the selection of consignments for the TEAM-3 trial was entirely at the discretion of the mill (or topmaker). Although participants were encouraged to find consignments with a wide range of raw wool attributes, commercial realities and practicalities limited the ability of mills to provide such consignments. The average fleece wool component of the consignments was approximately 90%; however there were a number of 100% skirting wool consignments submitted.

Histograms of the major raw wool and processing characteristics depicted in Tables 3.3 and 3.4 are shown graphically in Figures 3.1 to 3.12.

TABLE 3.3

RANGE AND MEAN OF THE AVERAGE RAW WOOL CHARACTERISTICS OF CONSIGNMENTS

	TEAM-1 & TEAM-2 Database			TEAM-3 Database		
	Avg	Min	Max	Avg	Min	Max
Schlum Dry Yield (SDRY) (%)	–	–	–	68.8	56.1	78.1
Mean Fibre Diameter (μm)	22.0	17.4	31.0	20.1	16.3	25.1
CV of Diameter (%)	–	–	–	22.0	19.1	28.1
Comfort Factor (%)	–	–	–	97.2	80.7	99.5
Mean Fibre Curvature (deg/mm)	–	–	–	94	74	120
Vegetable Matter Base (%)	2.1	0.1	10.2	1.2	0.3	5.3
Staple Length (mm)	86	59	123	85	64	104
CV Length (%)	19	12	30	18	14	30
Staple Strength (N/ktex)	39	23	60	38	24	51
Tip Breaks (%)	–	–	–	21	2	57
Mid-Breaks (%)	38	2	88	52	28	86
Base Breaks (%)	–	–	–	27	5	66

TABLE 3.4

RANGE AND MEAN OF THE AVERAGE PROCESSING CHARACTERISTICS OF CONSIGNMENTS

	TEAM-1 & TEAM-2 Database			TEAM-3 Database		
	Avg	Min	Max	Avg	Min	Max
Hauteur (mm)	66.6	48.0	96.8	72.0	56.3	91.0
CVH (%)	48.9	31.1	60.7	44.9	32.5	58.2
Romaine (%)	7.6	1.0	21.0	9.3	2.3	19.5
Top & Noil Yield (%)	64	46	77	69.9	58.2	92.8
Mean Fibre Diameter (μm)	22.1	17	31	20.3	16.3	25.4
CV of Diameter (%)	–	–	–	21.0	17.3	26.3
Comfort Factor (%)	–	–	–	97.1	82.8	99.8

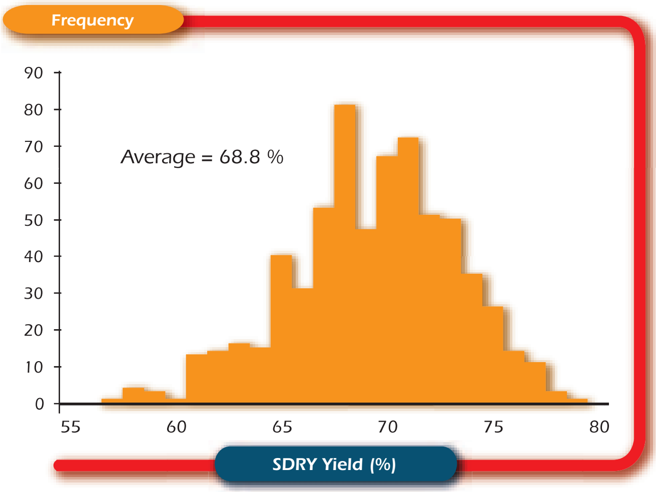

Figure 3.1 SDRY Yield Histogram

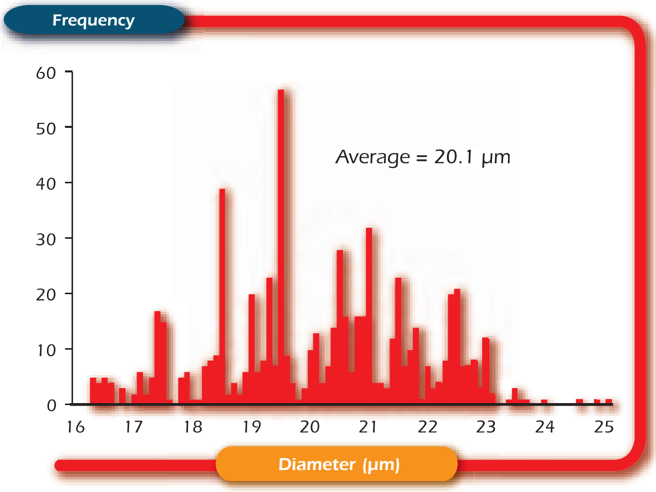

Figure 3.2 Mean Fibre Diameter Histogram

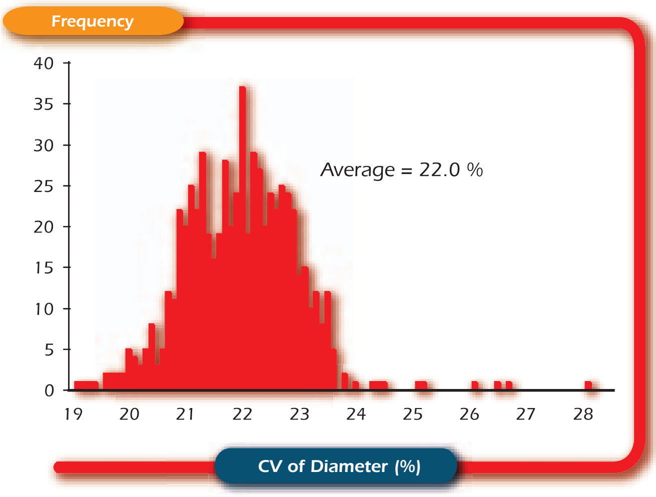

Figure 3.3 CV of Diameter Histogram

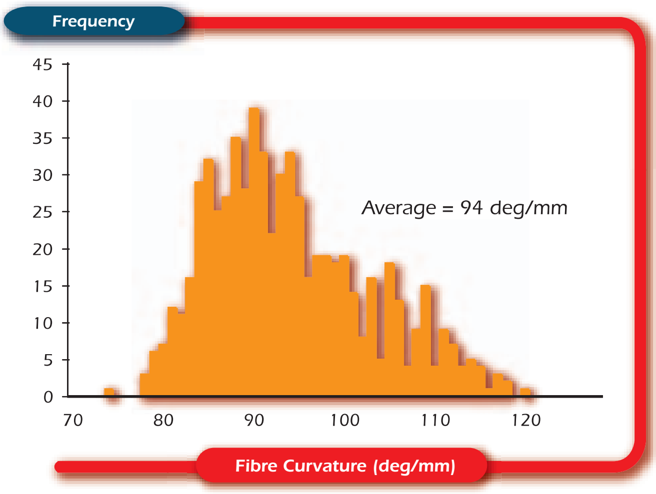

Figure 3.4 Mean Fibre Curvature Histogram

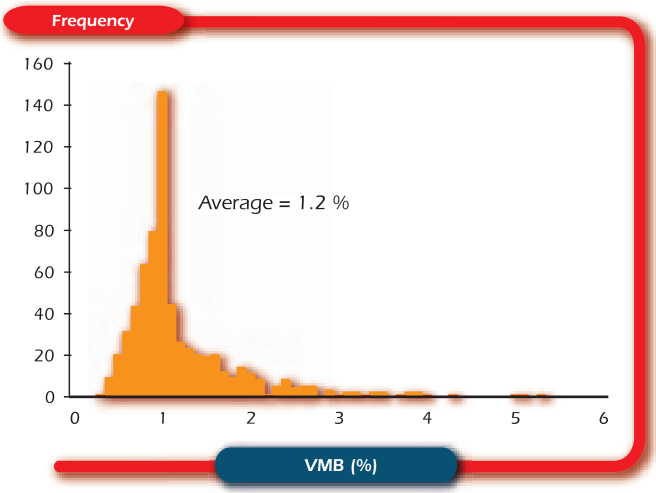

Figure 3.5 Vegetable Matter Base Histogram

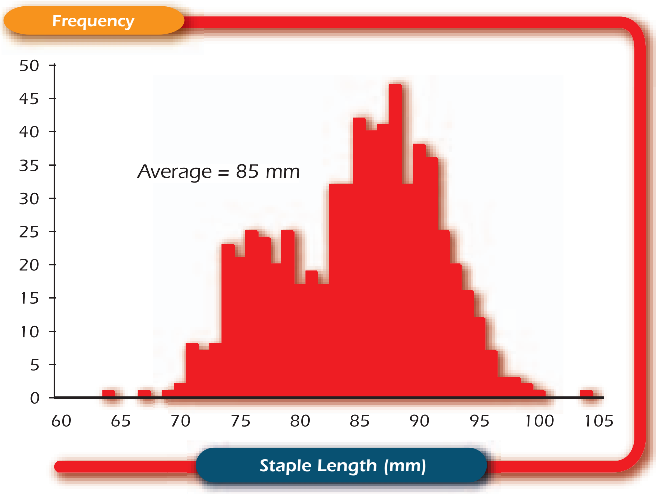

Figure 3.6 Staple Length Histogram

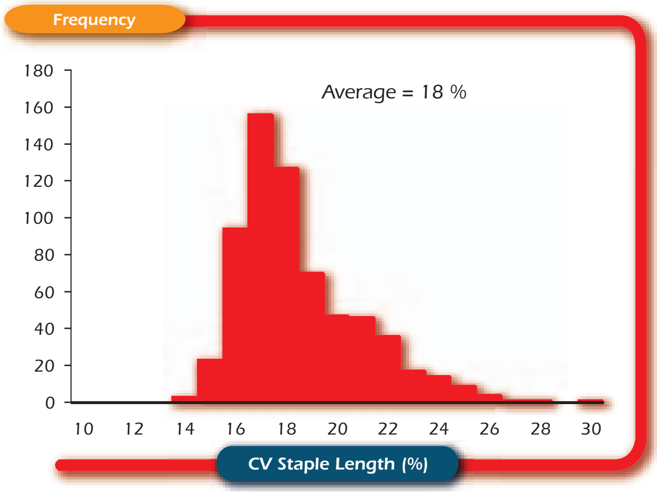

Figure 3.7 CV Staple Length Histogram

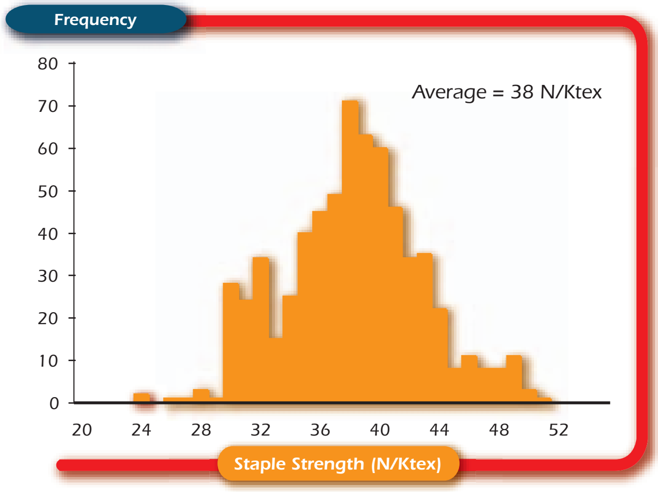

Figure 3.8 Staple Strength Histogram

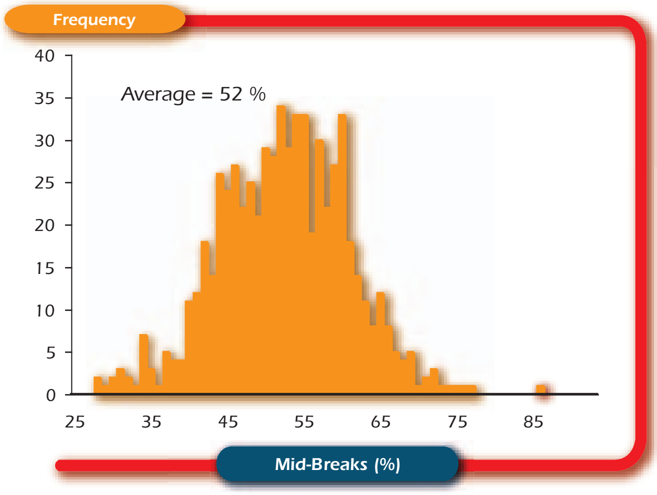

Figure 3.9 Mid-Breaks Histogram

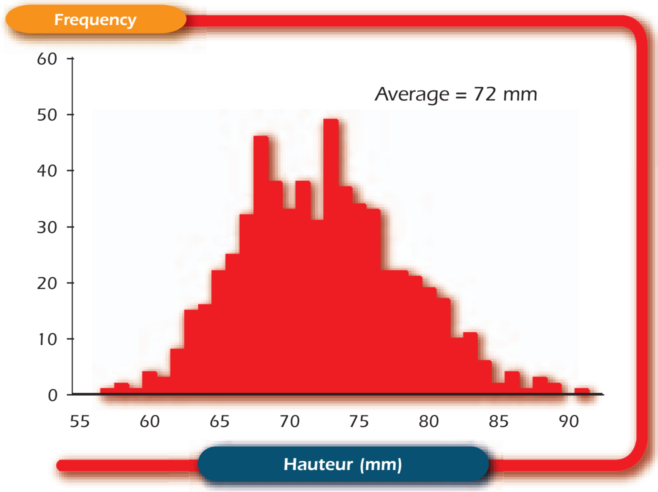

Figure 3.10 Hauteur Histogram

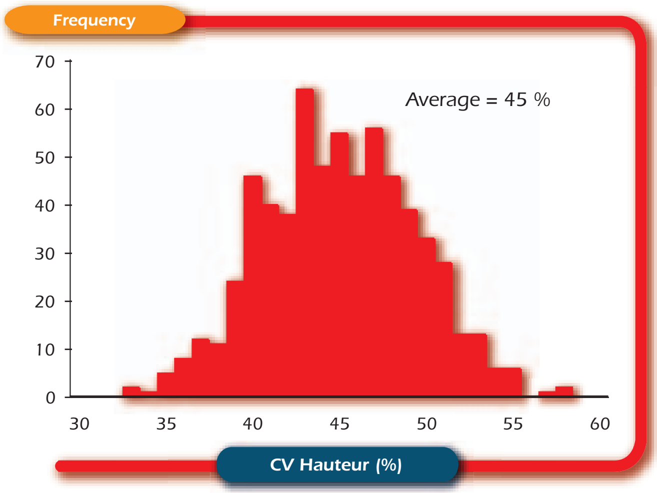

Figure 3.11 TEAM-3 CVH Histogram

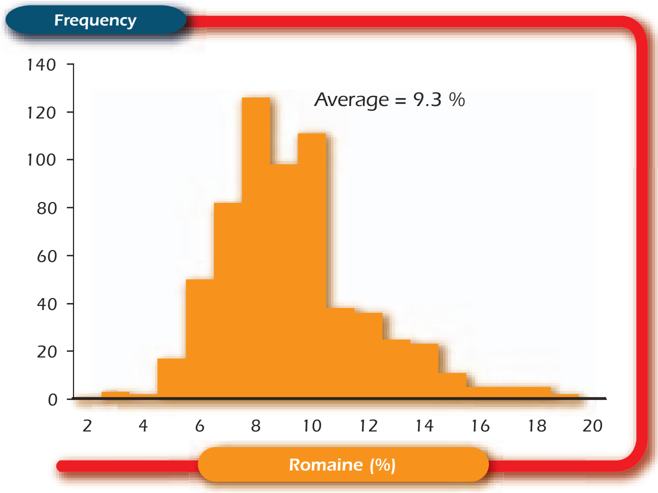

Figure 3.12 TEAM-3 Romaine Histogram

There are some interesting differences between the ranges of the TEAM-2 and TEAM-3 databases. The TEAM formulae are based on multiple regression statistical techniques and, in order to increase the general applicability of predictions, it is important to have as wide a range of inputs (raw wool measurements) as possible. In the development of the TEAM-2 prediction formulae, considerable effort was made to increase the ranges of raw wool properties between the processing consignments to improve the robustness of the formula.

In the original TEAM trials, combing batches were submitted for inclusion in the TEAM project and farm lots that did not have pre-sale staple measurements were sampled and tested post-sale. In effect, this meant that some key raw wool measurements were unknown at the time of blend construction and therefore restrictions could not be placed on inclusion or exclusion of lots from the blend on the basis of the raw wool attributes. As such, it was always likely that the ranges of the raw wool attributes from the TEAM-3 database would be smaller than TEAM-2.

In addition, the understanding of acceptable ranges and specification limits for staple measurements was not as clear in the 1980's as it is today, given the benefit of experience gained with raw wool measurements and prediction over the past 20 years. These trade experiences have resulted in application of greasy wool specifications for blend engineering, based on measurement. Today, for example, typical specifications require mean and range component values for Diameter and Staple Length, mean and minimum component values for Staple Strength and mean and maximum component values for Vegetable Matter. These, along with a TEAM-2 predicted Hauteur, form a common base for raw wool specification. With this in mind, restrictions in the ranges of raw wool attributes observed in the TEAM-3 data set are only to be expected. The inclusion of combing batches into the TEAM-3 program was on the basis of current commercial practice.

Specific comments on the raw wool characteristics depicted in Table 3.3 and Figures 3.1 to 3.9 are as follows:

Diameter: The upper limit in Fibre Diameter is lower in the TEAM-3 database, which is likely to be a reflection of the overall reduction in these types of wool being available, due to the reduction in the average Fibre Diameter of the Australian wool clip over the past 10 to 15 years.

Staple Length: Whilst the mean value is similar in both data sets, the maximum and minimum values have contracted in the TEAM-3 data set. The reduction in the maximum value is partly due to the lower range of diameter and also due to specification restrictions. The slightly higher minimum value may be due to industry experience that suggests shorter wools do not predict as well with the TEAM-2 formulae because they are close to the extremes of the data set used to generate the formulae. Some combers use specific mill based formulae for short wool blends.

Staple Strength: Under the appraisal system used during the TEAM-2 project it was difficult for subjective appraisal to differentiate the actual Staple Strength when it was greater than approximately 30 N/Ktex. Experience, and the use of prediction with TEAM-2, has resulted in topmakers having a better understanding of the available trade-offs between raw wool attributes as well as the cost of high or low strength wool.

Vegetable Matter: During the TEAM-2 project special effort was made to increase the range of Vegetable Matter blends in order to improve the robustness of the prediction formulae. Commercial decisions being made today clearly indicate that restrictions are placed on maximum Vegetable Matter levels. This has resulted in a lower range in Vegetable Matter for the TEAM-3 database. The influence of Vegetable Matter in the TEAM-3 prediction of Hauteur is further discussed in Section 6 of this report.

Other Measurements: The TEAM-3 trials have been designed to determine if improvements to the prediction formulae currently in use (TEAM-2) can be achieved with the addition of measurements that have been introduced since the TEAM-2 formulae were developed.

4. PROCESSING PERFORMANCE AND COMPARISON BETWEEN TEAM-2 AND TEAM-3

4.1 Hauteur, CVH and Romaine

Before examining the potential for new processing prediction formulae, it is worth considering the relationship between the actual processing performance of those consignments submitted and the performance predicted by the TEAM-2 formulae for each of Hauteur, Coefficient of Variation of Hauteur (CVH) and Romaine.

The average differences between actual and predicted (TEAM-2) Hauteur, CVH and Romaine are shown in Table 4.1 and graphically in Figures 4.1 to 4.3.

TABLE 4.1

COMPARISON BETWEEN ACTUAL AND TEAM-2 PREDICTED HAUTEUR, CVH AND ROMAINE

	Hauteur (mm)			CVH (%)			Romaine (%)		
	Actual	Predicted*	Diff.	Actual	Predicted*	Diff.	Actual	Predicted*	Diff.
Mean:	72.0	66.9	+ 5.1	44.9	47.4	- 2.5	9.3	7.1	+ 2.2
St Dev:	5.8	5.2	3.7#	4.4	3.0	3.2#	2.6	1.5	1.8#

* Predicted using TEAM-2 General Formulae (1988)
\# These values are the standard deviations of the differences between actual and predicted Hauteur, CVH and Romaine.

Using the consignments submitted in this trial, the average difference between actual Hauteur and TEAM-2 predicted Hauteur is +5.1mm. Figure 4.1 shows that the differences are larger for those consignments with Hauteur values in excess of 75mm. Approximately 31% of the consignments submitted for TEAM-3 have Hauteur values of 75mm or greater and the average difference between actual and predicted Hauteur for these consignments is 7.3mm.

The average difference between actual CVH and TEAM-2 predicted CVH is -2.5%. Figure 4.2 shows that for the majority of consignments, the actual CVH is lower than that predicted by the TEAM-2 formulae. Only 20% of the consignments received for TEAM-3 have a higher actual CVH than predicted.

The average difference between actual Romaine and TEAM-2 predicted Romaine is +2.2%. These differences are shown graphically in Figure 4.3. Only 8% of the consignments received for TEAM-3 have a lower Romaine than that predicted by the TEAM-2 formulae.

Since the TEAM-2 formulae were derived, processing mills have been encouraged to produce tops with lower CVH values. This has involved removing more short fibre during combing, which has the effect of reducing CVH, increasing Hauteur and increasing Romaine.

On each of Figures 4.1 to 4.3, the trendline from the 1988 TEAM-2 database has been added to the graph as a comparison. These trend lines suggest that although processing performance has changed since 1988, the slopes of the relationship between actual and predicted Hauteur, CVH and Romaine are very similar. The observation that longer tops are performing better in comparison to the Hauteur prediction formula is consistent with what was observed in the original TEAM-2 trial.

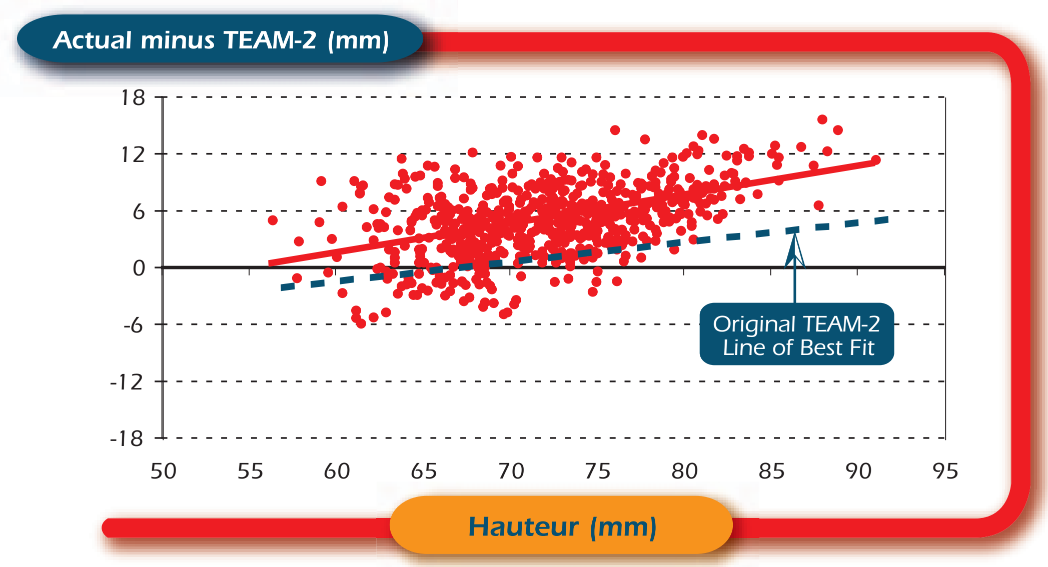

Figure 4.1 Hauteur Differences (Actual minus TEAM-2)

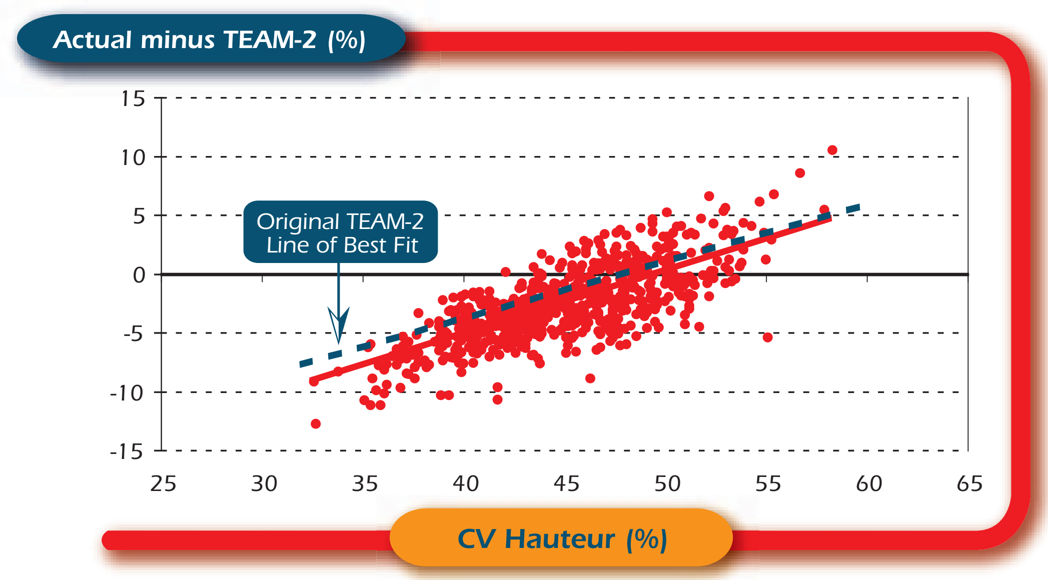

Figure 4.2 CVH Differences (Actual minus TEAM-2)

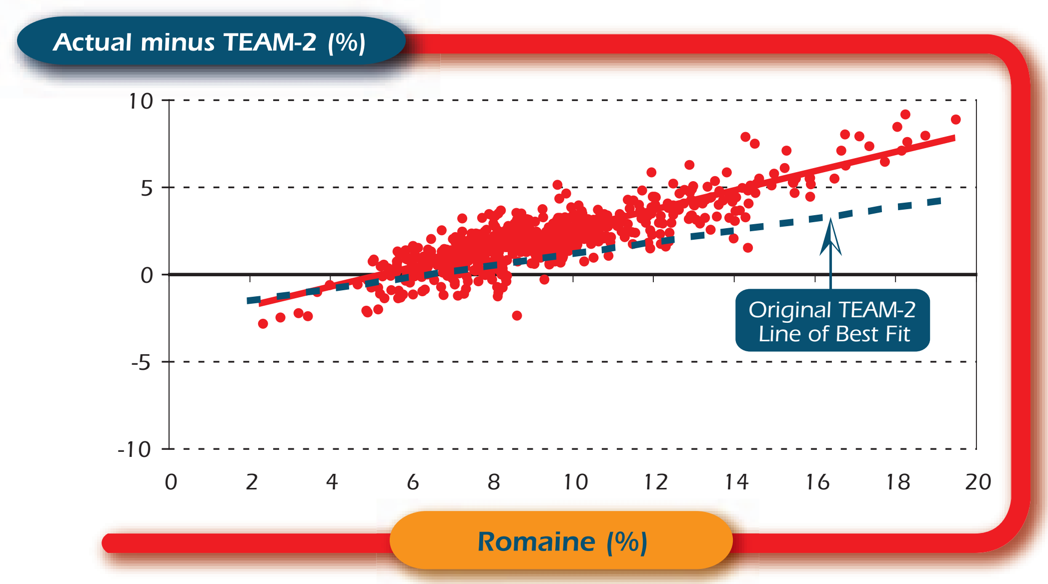

Figure 4.3 Romaine Differences (Actual minus TEAM-2)

3-12

4.2 Comparison of Mill Performance on a Regional Basis

Section 4.1 has shown that, on average, mills produce tops with Hauteur values 5.1mm longer than predicted by the TEAM-2 General Formulae. However, it is also interesting to examine the differences between actual and predicted Hauteur at a regional level.

Whilst maintaining the confidentiality of individual mills, the data collected allows a comparison of processing performance on a regional basis. Table 4.2 and Figures 4.4 to 4.6 compare Actual Hauteur, Predicted Hauteur, CVH and Romaine for the 5 participating regions. The predicted values are derived from the TEAM-2 General Formulae.

Without exception, each of the 5 regions examined are producing tops that have a longer Hauteur, a lower CVH and a higher Romaine than predicted by the TEAM-2 General Formulae. Examination of Figures 4.4 to 4.6 indicate a very similar pattern regardless of processing region.

TABLE 4.2

COMPARISON BETWEEN ACTUAL AND PREDICTED HAUTEUR, CVH AND ROMAINE FOR DIFFERENT REGIONS PARTICIPATING IN TEAM-3

	Number of			Actual – Predicted		
Region	**Mills**	**Consignments**		**Hauteur (mm)**	**CVH (%)**	**Romaine (%)**
Australia	7	97	Mean	6.1	-3.0	3.1
			St. Dev (Diff.)	2.5	2.6	2.1
China	11	205	Mean	5.5	-2.8	2.0
			St. Dev (Diff.)	3.6	2.5	1.7
India	5	130	Mean	4.7	-2.4	1.6
			St. Dev (Diff.)	4.0	3.6	1.5
Europe	7	99	Mean	6.6	-3.9	2.3
			St. Dev (Diff.)	3.7	2.9	1.3
Other Asia	4	116	Mean	3.1	-0.4	2.0
			St. Dev (Diff.)	3.5	3.5	1.7

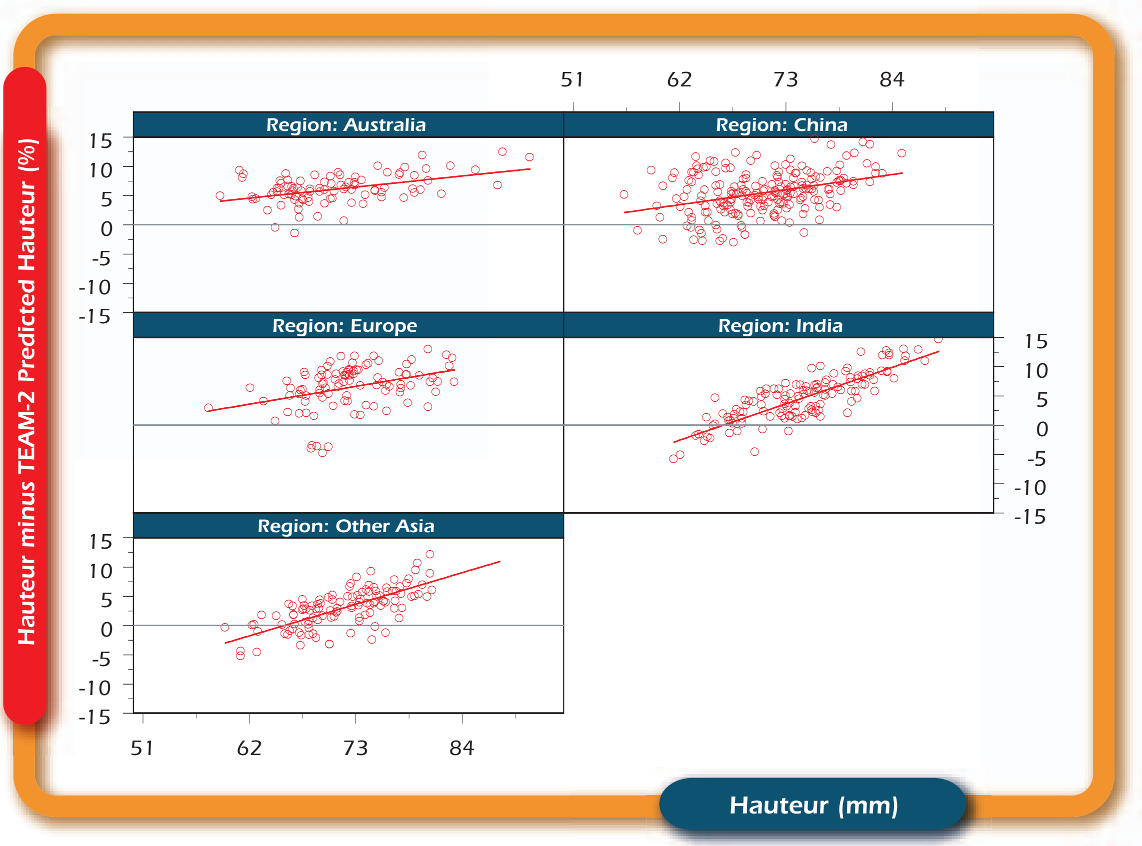

Figure 4.4 TEAM-2 Residual Hauteur against Actual Hauteur: Regional Comparison

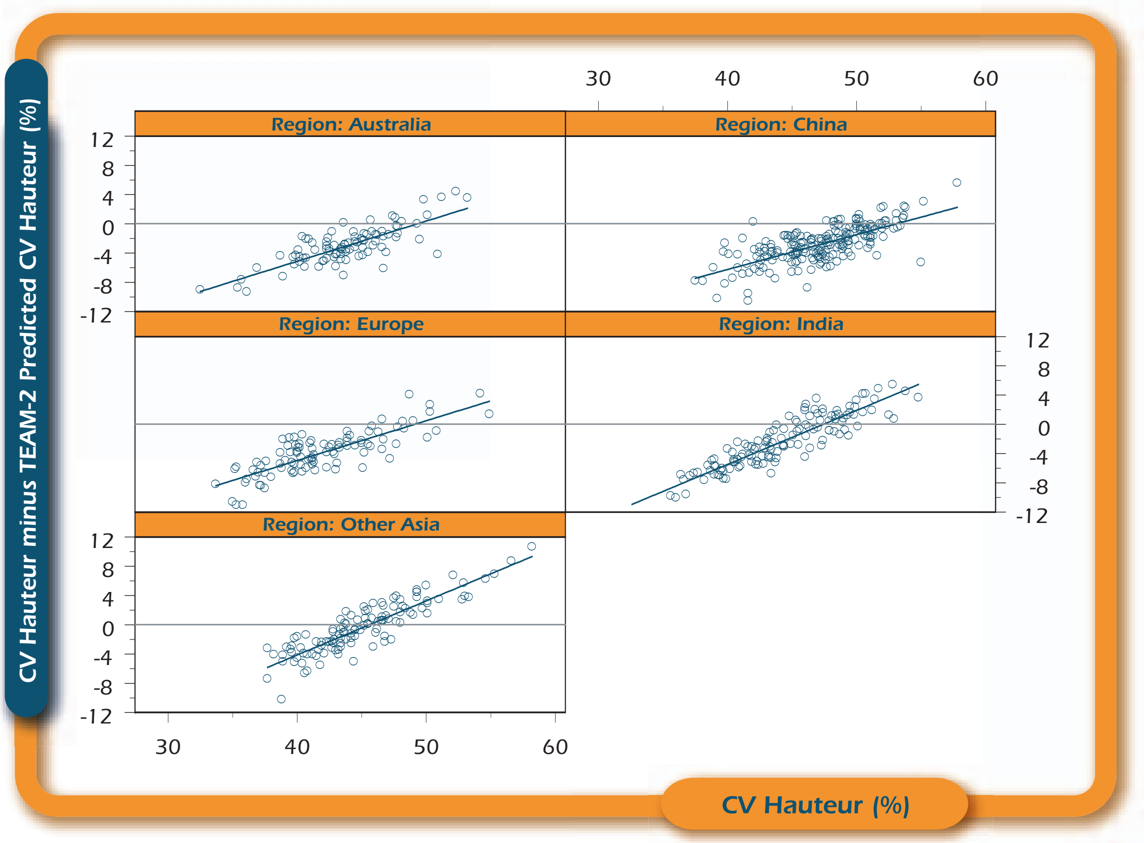

Figure 4.5 TEAM-2 Residual CVH against Actual CVH: Regional Comparison

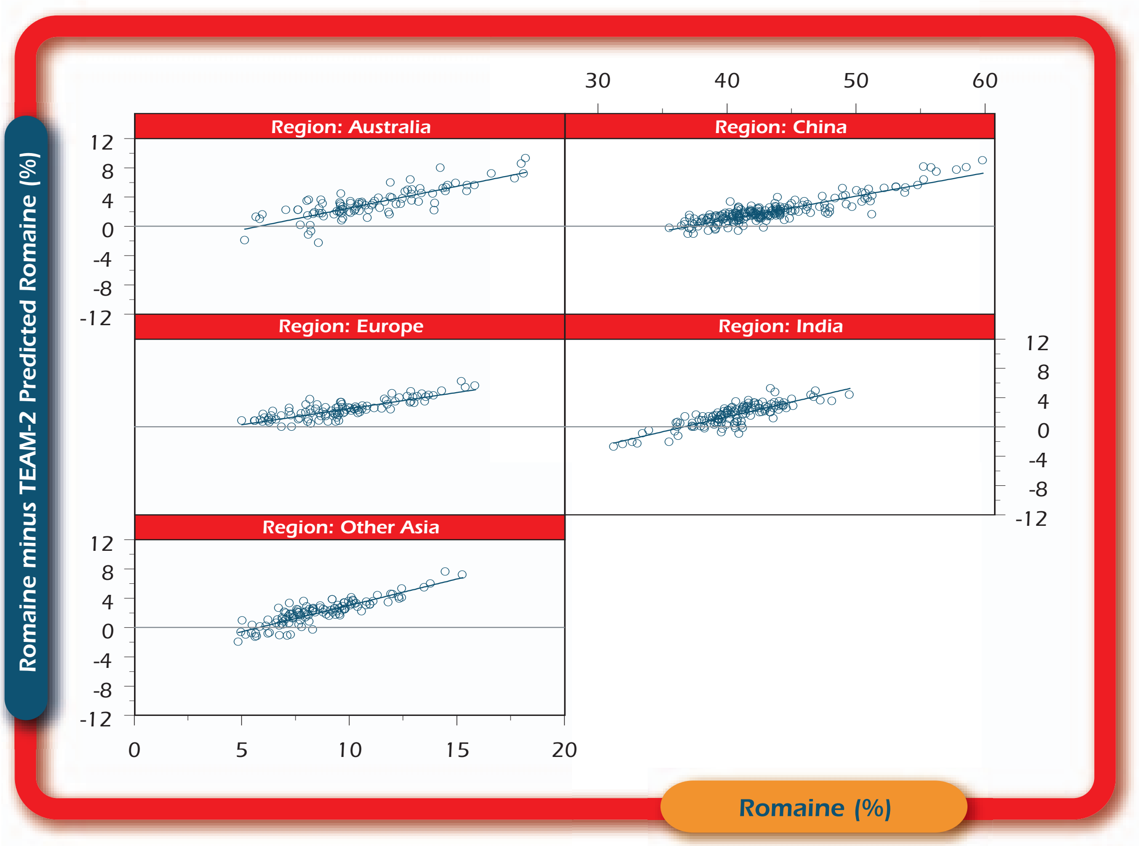

Figure 4.6 TEAM-2 Residual Romaine against Actual Romaine: Regional Comparison

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5. CORE/COMB RELATIONSHIPS

5.1 Mean Fibre Diameter and Coefficient of Variation of Diameter

For each processing consignment submitted as part of the TEAM-3 trial, a minimum of five samples of top was provided to AWTA Ltd for analysis. Figure 5.1 shows the relationship between the greasy wool Mean Fibre Diameter (Core) and the top Mean Fibre Diameter (Comb) for the TEAM-3 database. The diameter of the top measured by AWTA Ltd using Laserscan, was used in this analysis. On average, the Mean Fibre Diameter of the top was 0.20μm coarser than the Mean Fibre Diameter of the greasy wool.

Figure 5.2 compares the Coefficient of Variation of Diameter (CVD) of the greasy wool and the top. It shows that the average CVD was 0.9% lower in the top than it was in the greasy wool. This is an expected result because processing is understood to remove proportionally more fine fibres than coarse fibres as noil. This has the effect of increasing the Fibre Diameter in the top (Figure 5.1) and decreasing the Fibre Diameter variation in the top (Figure 5.2).

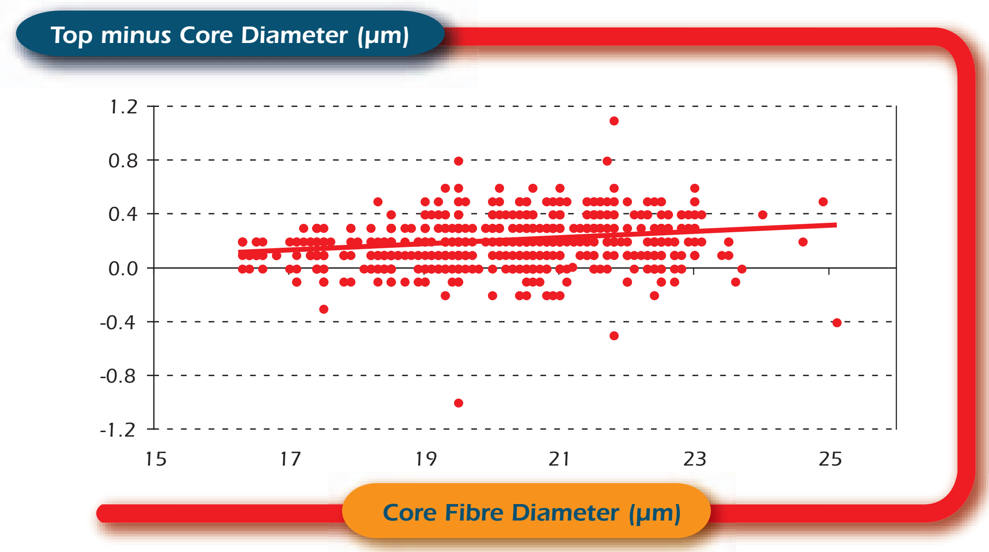

Figure 5.1 Core/Comb Fibre Diameter Comparison

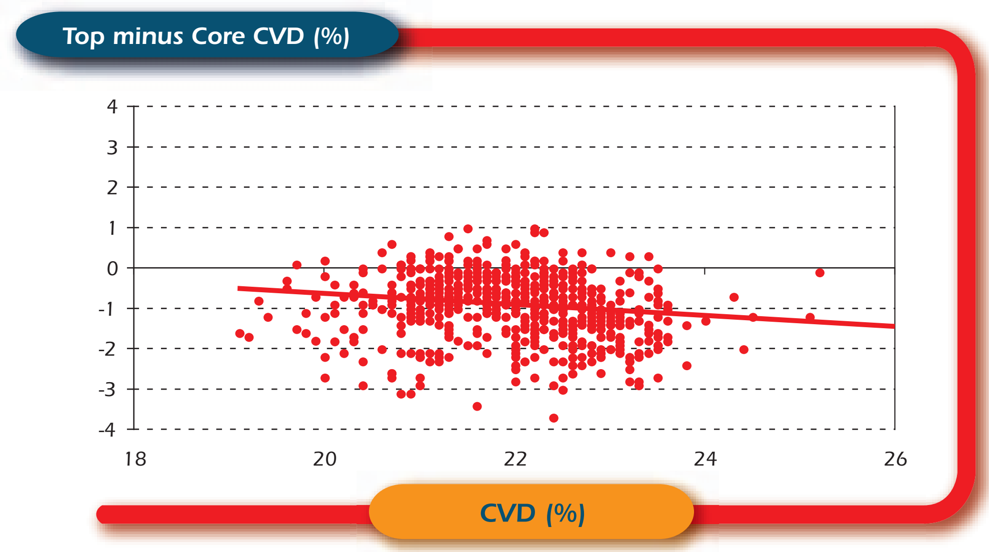

Figure 5.2 Core/Comb CVD Comparison

5.2 Processing Yield

A comparison between the actual Top & Noil Yield achieved by the processing mills and the predicted yield using the Schlumberger Dry Top & Noil Yield (SDRY) formula is shown in Figure 5.3. The actual processing yield of the TEAM-3 consignments was, on average, 1.1% higher than the yield predicted by the SDRY formula.

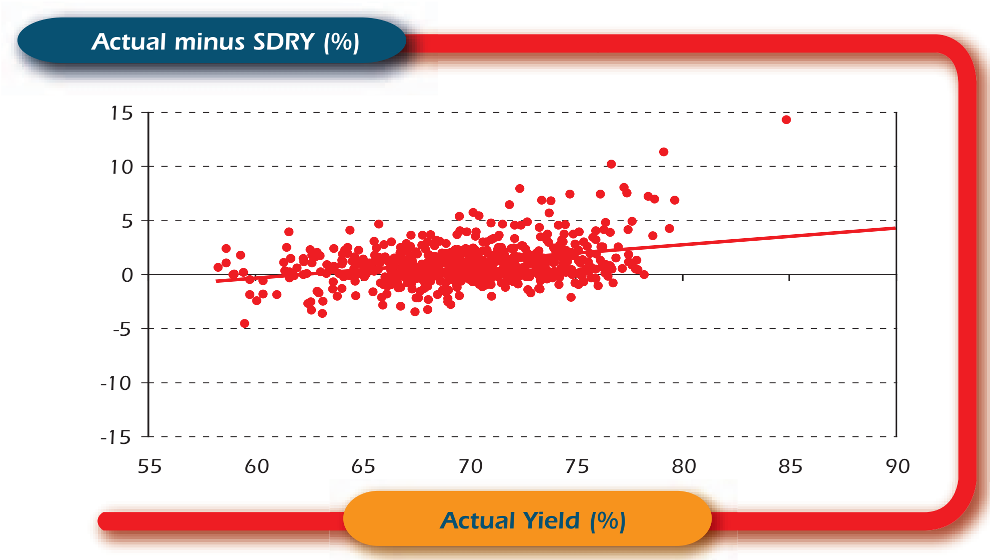

Figure 5.3 Comparison between Actual and Predicted Schlumberger Dry Top & Noil Yield

6. TEAM-3 DATABASE - PREDICTION OF HAUTEUR

Section 4 of this report compared the processing performance of consignments submitted as part of the TEAM-3 trial against the TEAM-2 benchmark. However, one of the original aims of the TEAM-3 project was to examine the possibility of creating new processing prediction formulae based on current commercial processing performance.

The authors of the TEAM-2 report (1988) recognised that a feature of the formulae was their simplicity. A minimum number of raw wool factors with purely additive effects enabled the creation of General Formulae that could be used across various wool types and mills. The formulae used to predict Hauteur were developed using multiple regression techniques. Other more sophisticated approaches were considered by the TEAM-2 committee but these provided no improvement over the simpler approach. The TEAM-3 Steering Committee decided that a similar approach would be taken for the analysis of the TEAM-3 database.

The data from the consignments submitted for the TEAM-3 trial was analysed using the S-Plus (2002) statistical package. The analysis included re-determining the coefficients for the TEAM-2 formula for Hauteur, CVH and Romaine and then adding new variables to the model. The variables added were Mean Fibre Curvature (MFC), Coefficient of Variation of Diameter (CVD) and Coefficient of Variation of Length (CVL). Multiple regression analyses were conducted, which plotted Hauteur, CVH and Romaine against these raw wool factors.

As explained in the TEAM-2 report (1988), the strength of a regression relationship may be measured by two statistics:

- The coefficient of multiple determination (R^2) indicates the fraction of the variation in Hauteur between the consignments which is explained by the raw wool data used in the formula. It reflects the level of association between the raw wool variables and Hauteur, and is often called the degree of association. The R^2 is expressed as a percentage.

- The standard error (SE) of the differences between actual and predicted Hauteur is a measure of the reliability of the raw wool data as a predictor of Hauteur. The lower the SE the more reliable the formula. The SE is expressed in the units of measurement of the variable being considered (i.e. as mm for Hauteur and as a percentage for CVH and Romaine).

For reference, the TEAM-2 General Formulae for Hauteur (H), CV Hauteur (CVH), and Romaine (R), as published in 1988, are as follows:

Hauteur = 0.52L + 0.47S + 0.95D – 0.19M* – 0.45V – 3.5 + [MA1]

CV Hauteur = 0.12L – 0.41S – 0.35D + 0.20M* + 49.3 + [MA2]

Romaine = -0.11L – 0.14S – 0.35D + 0.94V + 27.7 + [MA3]

Where:	L	=	Staple Length (mm)
	S	=	Staple Strength (N/ktex)
	D	=	Mean Fibre Diameter (μm)
	V	=	Vegetable Matter Base (%)
	M*	=	Adjusted Mid-Breaks
	MA	=	Mill Adjustment Factor (MA1 = Hauteur, MA2 = CVH, MA3 = Romaine)

Table 6.1 presents the results of the regression analysis for the Hauteur prediction based on the TEAM-3 database. Regression 1 in this table is an analysis of the TEAM-3 database using Staple Length (SL), Staple Strength (SS), Fibre Diameter (D), Adjusted Mid-Breaks (M*) and Vegetable Matter Base (V) as a function of Hauteur. These are the same parameters that formed the basis of the TEAM-2 formula. It is noticeable that the regression analysis on the TEAM-3 database gives a lower Standard Error (SE) than was reported for TEAM-2, possibly suggesting improved reliability of prediction. The coefficients for SS, SL, D and M* for Regression 1 are similar to the TEAM-2 coefficients.

The effect of Vegetable Matter Base (VM) however is different between TEAM-2 and TEAM-3. It is expected that as the level of VM in a consignment increases, the Hauteur will decrease. This was the case in TEAM-2 where VM had a negative effect on Hauteur (–0.45). However the TEAM-3 analysis shows that VM has a positive but insignificant influence on Hauteur (+0.03). This is most likely due to the very small range of VM in the TEAM-3 database. The average VM of the database was 1.2% with a range from 0.3% to 5.3%. However, of the 647 consignments, 91% have a VM result of 2.0% or less. The narrow range of VM can be seen clearly in Figure 6.1. With such a narrow range, it would be expected that VM would have a minimal effect on Hauteur. This may not be true if consignments of high VM are processed into top. In addition to the relatively low range of VM, mill management decisions may also contribute to the insignificant influence of VM on Hauteur. This comment was also made by the authors of the TEAM-2 report (1988).

One of the reasons for conducting the TEAM-3 Processing Trial was to examine the impact of additional measurements, such as Coefficient of Variation of Diameter (CVD) and Mean Fibre Curvature (MFC), on the prediction of processing performance. Regressions 2 to 8 in Table 6.1 show the results when various combinations of CVD, MFC and Coefficient of Variation of Length (CVL) are added to the TEAM-3 variables.

TABLE 6.1

STATISTICAL ANALYSIS USING ADDITIONAL FACTORS OF CVD, MFC AND CVL TO PREDICT HAUTEUR

REGRESSION	SL	SS	D	M*	VM	CVD	MFC	CVL	SE(mm)	R^2
TEAM-2	0.52	0.47	0.95	-0.19	-0.45				3.4	84%
1 TEAM-3	0.58	0.45	1.00	-0.17	(0.03)				2.58	82%
2 TEAM-3 +CVD	0.47	0.33	1.37	-0.19	(-0.12)	-0.90			2.53	83%
3 TEAM-3 + CVL	0.46	0.41	1.24	-0.17	(0.22)			-0.40	2.51	83%
4 TEAM-3 + MFC	0.58	0.45	1.16	-0.17	(0.05)		(-0.04)		2.58	82%
5 TEAM-3 + CVL + CVD	0.41	0.33	1.45	-0.18	(0.08)	-0.63		-0.32	2.49	83%
6 TEAM-3 + CVD + MFC	0.47	0.33	1.41	-0.19	(-0.12)	-0.89	(0.01)		2.53	83%
7 TEAM-3 + CVL + MFC	0.46	0.41	1.31	-0.17	(0.23)		(0.02)	-0.40	2.51	83%
8 TEAM-3 + CVD + CVL + MFC	0.41	0.33	1.45	-0.18	(0.08)	-0.63	(0.00)	-0.32	2.49	83%

Note: All coefficients that were not statistically significant are bracketed.

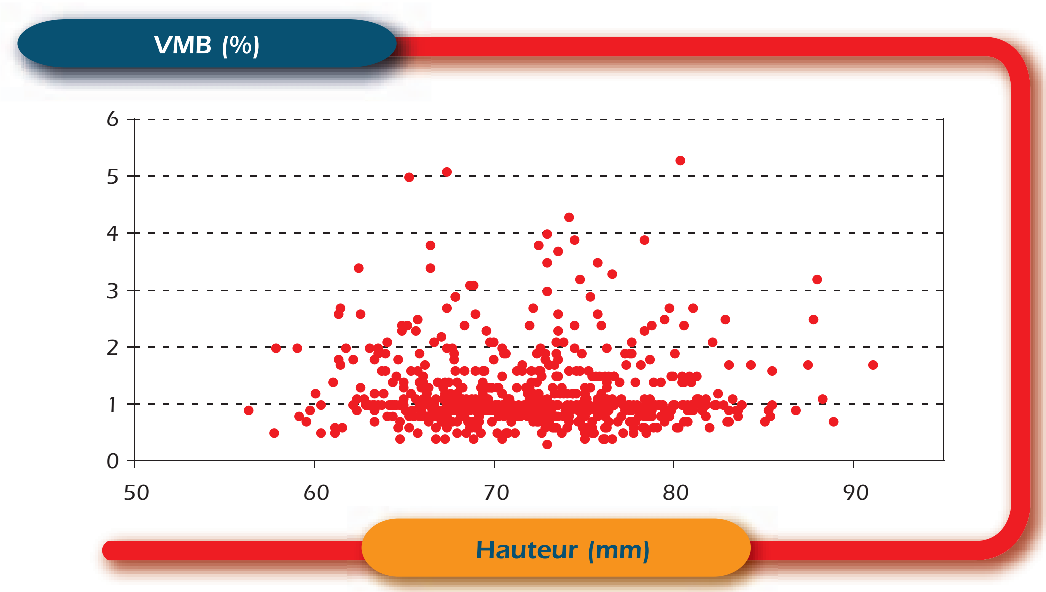

Figure 6.1 Relationship between Vegetable Matter and Hauteur

6.1 The Addition of CVD and CVL to the TEAM Model

Regressions 2, 3 and 5 in Table 6.1 show the impact when CVD and CVL are added to the basic TEAM regression model. The addition of CVD (Regression 2) and CVL (Regression 3) provides a small reduction in the SE over Regression 1. The coefficients for CVD and CVL are both statistically significant indicating that they can influence processing performance. The combination of CVL and CVD with the TEAM variables (Regression 5) provides another small reduction in the SE. However, the addition of these parameters does not produce a significant reduction in the SE of the prediction model.

It is worth noting that when CVD is added to the model together with the TEAM-3 variables (Regression 2) that the coefficients for both SS and CVD are significant. It has been previously suggested (Lamb, 2000) that CVD could replace SS as a predictor of processing performance. This analysis suggests that SS is still important for the processing prediction of consignments and cannot be replaced by CVD alone.

The addition of CVL to the TEAM-2 Hauteur formula was considered by the TEAM committee in 1988. Early analysis of the database indicated that CVL did have a small influence on processing performance. However, analysis of the total database at the conclusion of the TEAM-2 trial did not confirm the significance of CVL in any prediction formulae. It was suggested at the time that CVL may be significant for a mill-specific formula. As such, it is not surprising that CVL could be considered as an addition to the processing prediction formulae following the TEAM-3 analysis.

Based on the regression analysis of the TEAM-3 database to this point, Regression 5 from Table 6.1 is considered the most appropriate equation for further evaluation.

6.2 The Addition of MFC to the TEAM Model

A number of research papers (Haigh, 2002; Peterson, 2002; Vizard and Hansford, 1999; Stevens and Mahar, 1995; Stevens and Crowe, 1994; Kurdo *et al*, 1984; Marler, 1985; Hunter and Gee, 1980; Turpie and Shiloh, 1973; and, Cilliers and Robinson, 1968) have suggested that wool exhibiting properties of low MFC, low crimp frequency or low Resistance to Compression shows a processing benefit in terms of longer Hauteur and lower Romaine. These potential processing advantages have been identified by comparing the extremes of MFC in selected individual fleeces. TEAM-3 relates to the processing results for consignments rather than sale lots or fleeces, hence the range in MFC is likely to be less than reported in these research trials. The range in MFC for each micron level in TEAM-3 is approximately 10 to 15 degrees/mm (Figure 6.2).

All reports to date on the TEAM-3 trial (Lindsay *et al*, 2002a; Lindsay *et al*, 2002b; TEAM-3 Steering Committee, 2003; and, Lindsay *et al*, 2003) have been unable to demonstrate any processing advantage of low MFC when examining commercial consignments. The final analysis of the TEAM-3 database has shown that the inclusion of MFC does not improve the processing prediction model (Regression 4 in Table 6.1).

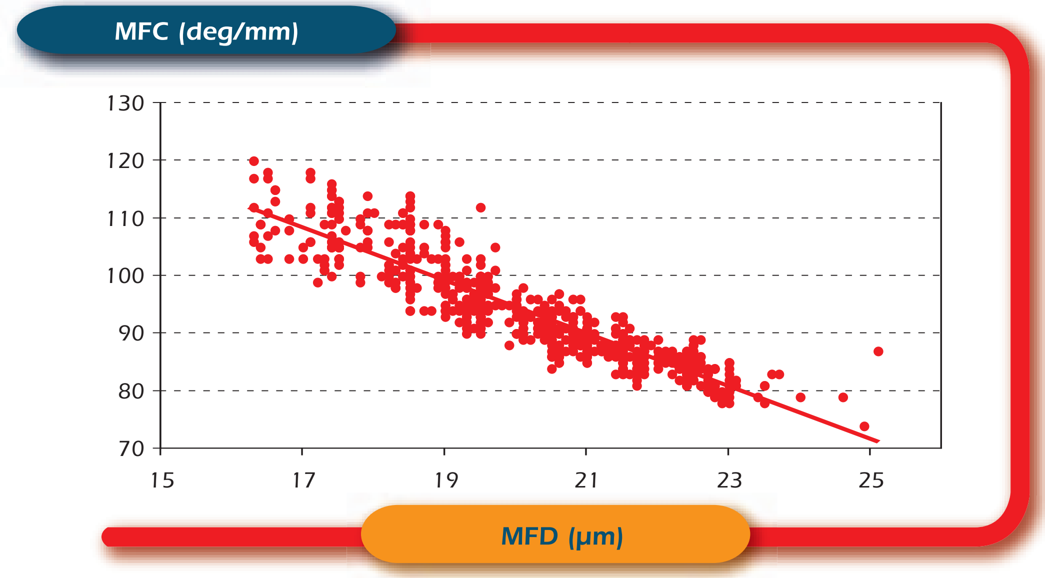

Figure 6.2 Fibre Diameter and Fibre Curvature Relationships

Figure 6.3 is a plot of Mean Fibre Curvature against the TEAM-3 Residual Hauteur (i.e. Actual Hauteur minus TEAM3 Predicted Hauteur, where Regression 5 in Table 6.1 is used to calculate the predicted values). If the inclusion of MFC in any processing prediction model resulted in an improvement in processing prediction, then it would be expected that Figure 6.3 would exhibit a significant slope effect. However it is clear from this plot that MFC does not influence processing prediction based on the commercial consignments processed as part of the TEAM-3 trial.

In addition, the trend line on Figure 6.3 shows that as MFC decreases, the difference between Actual and Predicted Hauteur also decreases. Based on the MFC research studies this is not the expected result. If consignments of low MFC did exhibit a processing advantage then the differences between Actual and Predicted Hauteur would increase with decreasing MFC.

Figure 6.3 has been dissected further to compare the relationships for consignments of similar Fibre Diameter. The MFC relationship of all consignments with a diameter of 16.0µm to 18.0µm was examined. This was repeated for wool of diameter 18.1µm to 20.0µm, and 20.1µm and greater. The plots of these comparisons appear in Appendix 2. Once again, no relationships are evident in these analyses.

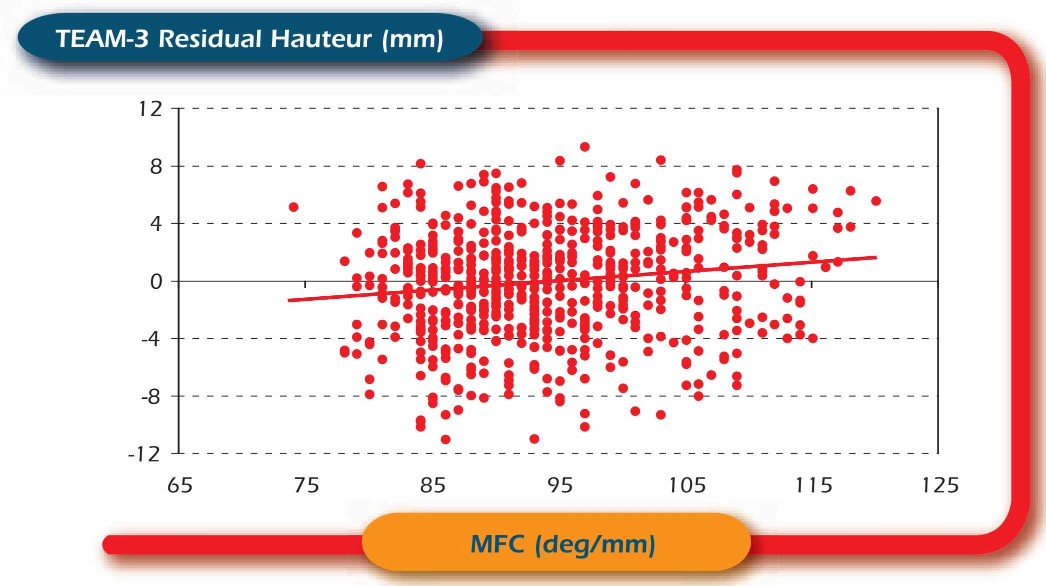

Figure 6.3 Relationship between MFC and TEAM-3 Residual Hauteur for the TEAM-3 Database

6.3 Review of the Impact of Vegetable Matter Base on the TEAM Prediction of Hauteur

As shown in Table 6.1 and in earlier discussions, the analysis of the TEAM-3 database has indicated that the coefficient for Vegetable Matter Base (VM) was both positive and not significant, from a statistical point of view. This would imply that VM has no impact on the prediction of Hauteur. However, general experience in topmaking would suggest that, all other things being equal, consignments containing high levels of VM will have a lower Hauteur than consignments containing low levels of VM. At the IWTO Meeting in Evian, May 2004, the TEAM-3 Committee Chairman offered to review this apparent anomaly in the TEAM-3 analysis.

One of the basic underlying assumptions for multiple regression statistics is that there is sufficient variation in each of the input variables, for example VM, to influence the variation in the output result, in this case Hauteur. As mentioned earlier, the range of VM in the TEAM-2 database was much wider (0.1% to 10.2%) than in the TEAM-3 database (0.3% to 5.3%). It is possible that the limited VM range in the TEAM-3 database is the reason behind the anomaly.

Following the IWTO Meeting in Evian, the impact of the range in VM on the prediction of Hauteur was further examined by re-analysing the TEAM-2 database using restrictions on the range in VM to more closely match the range of VM in the TEAM-3 database. All consignments from the TEAM-2 database which had a VM greater than 3% were removed and a statistical analysis was performed on the remaining 371 consignments. This analysis was repeated on 283 TEAM-2 consignments following removal of all consignments with a VM greater than 2%.

The results are presented in Table 6.2.

TABLE 6.2

ANALYSIS OF THE TEAM-2 DATABASE FOLLOWING REMOVAL OF CONSIGNMENTS WITH VM GREATER THAN 3% (REGRESSION 1) AND GREATER THAN 2% (REGRESSION 2)

Regression		No.	SL	SS	D	M*	VM	SE (mm)	R^2
	TEAM-2 (All Data)	464	0.52	0.47	0.94	-0.19	-0.45	3.41	84%
1	TEAM-2 (VM ≤ 3%)	371	0.54	0.49	0.88	-0.18	(-0.09)	3.48	83%
2	TEAM-2 (VM ≤ 2%)	283	0.50	0.46	0.89	-0.19	(+0.79)	3.42	83%

Note: All coefficients that were not statistically significant are bracketed. They relate to the VM coefficients where the range of VM in the analysed data was reduced.

Table 6.2 shows that the reduced range in VM causes the coefficient for VM to become statistically non-significant and the coefficient also becomes positive in Regression 2 as the range in VM is reduced further. Using either Regression 1 or 2 in Table 6.2 to predict the Hauteur of consignments with high VM (greater than 4%) produced poorer results (average difference = 2.5mm) than when high VM consignments were included in the development of the prediction model (average difference = 0.6mm.

A similar situation would, for example, exist in respect to Fibre Diameter if a combing mill was only processing 22.0µm to 22.5µm batches and the mill had developed its own specific Hauteur prediction formula. In such a case, it is most likely that diameter would not be included in the mill specific formula and erroneous results could be produced if the mill changed the diameter of the consignments it processed. For this reason it has always been recommended that the development of any mill specific formula should start with the TEAM General Formula (see Appendix 3).

This analysis provides three options to account for the influence of VM on the prediction of Hauteur:

1. Despite the statistical non-significance, include the coefficient for VM (+0.03) determined from the analysis of the TEAM-3 database;

2. In acknowledgement of the statistical non-significance and positive value, exclude the VM term from the model; or

3. As the TEAM-2 database had a much wider range in VM than the TEAM-3 database, use the TEAM-2 coefficient for VM (–0.45) in the TEAM-3 prediction model.

The last option is technically feasible as any coefficient is simply an indication of the sensitivity of Hauteur to a change in that particular characteristic. Table 6.3 provides a comparison of the three alternatives. Regression 1 in Table 6.3 is the same equation as Regression 5 from Table 6.1 which was deemed to be the most appropriate model for further evaluation.

TABLE 6.3

STATISTICAL ANALYSIS FOR DIFFERENT APPROACHES TO VM IN THE REGRESSION MODELLING

Regression	SL	SS	D	M*	VM	CVD	CVL	SE (mm)	R^2
1 TEAM-3 + CVD + CVL	0.41	0.33	1.45	-0.18	(0.08)	-0.63	-0.32	2.49	83%
2 TEAM-3 + CVD + CVL (No VM)	0.41	0.33	1.47	-0.18		-0.65	-0.32	2.49	83%
3 TEAM-3 + CVD + CVL – 0.45VM	0.42	0.34	1.37	-0.18	-0.45#	-0.55	-0.35	2.50	83%

Note: All coefficients that were not statistically significant are bracketed.
The # indicates that this coefficient was derived from the TEAM-2 analysis and included here due to the lack of range in VM in the TEAM-3 database.

On the basis of the SE and R^2 values, there is no difference between the three alternatives. In addition there are only small differences in the coefficients for the other raw wool characteristics. Therefore, Equation 3 from Table 6.3 is the preferred option as it is better able to reflect the sensitivity of Hauteur to the widest range of VM in the consignments, including consignments with high levels of VM.

It should also be recognised that although VM was not a significant variable for the prediction of Hauteur based on the analysis of the TEAM-3 database, its impact was found to be significant in the prediction of Romaine (see Section 8).

6.4 The Use of M* in the TEAM Model

Since the TEAM-2 report was published in 1988, there has been some conjecture over the use of M* (adjusted Mid-Breaks) in the TEAM-2 general formula. M* is the adjusted percentage of Mid-Breaks (M) and all M values of up to 45% are replaced by a value of 45% for M* in the TEAM-2 formula. For values of M greater than 45%, the measured value itself is used as M* in the formula. The TEAM-2 Committee included M* rather than M in their formula because it was evident on scatter plots that there was no obvious trend between the Hauteur residuals and Mid-Breaks for values of M to 45%. However for Mid-Break values in excess of 45% a trend was evident.

The use of M rather than M* would simplify the TEAM formulae. In addition, due to the use of M* in the TEAM-2 formulae, it is not possible to easily calculate an average Hauteur or CVH when using simple weighted averages for the combination of a number of Sale Lots. A new formula with M rather than M* would allow buyers to easily combine the Hauteur values of individual Sale Lots.

Using Regression 3 from Table 6.3 as the benchmark, the TEAM-3 database was analysed to compare the use of M* with the use of the actual mid break percentage (M). Table 6.4 shows that the use of M is equivalent to M* in the prediction model. Consequently, the use of M could be considered as a possible replacement for M*.

TABLE 6.4

STATISTICAL ANALYSIS USING M INSTEAD OF M*

Regression	SL	SS	D	M*	M	VM	CVD	CVL	SE(mm)	R^2
1 TEAM-3 + CVD + CVL – 0.45VM	0.42	0.34	1.37	-0.18		-0.45#	-0.55	-0.35	2.50	83%
2 M* replaced by M	0.43	0.35	1.38		-0.15	-0.45#	-0.59	-0.32	2.49	83%

Note: The # indicates that this coefficient was derived from the TEAM-2 analysis and included here due to the lack of range in VM in the TEAM-3 database.

As the use of M would simplify the TEAM formula, **Regression 2 in Table 6.4 is the proposed TEAM-3 prediction formula for Hauteur.** It should be noted that this formula contains a constant term which includes an adjustment associated with individual mill differences. For the entire TEAM-3 database, the adjustment equals 21.8. Therefore, the proposed TEAM-3 formula for Hauteur is as follows:

$$\textbf{Hauteur} = 0.43L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 21.8$$

With the exception of the VM, the relative importance of the remaining variables in Table 6.4 has been estimated from the statistical significance of the regression terms. Table 6.5 provides an estimate for the relative importance of each variable with the most significant factor, Mean Fibre Diameter, given a rating of 100. The next most important variable after MFD is Staple Length (96) followed by Mid-Breaks (91). Table 6.5 provides a comparison to the TEAM-2 (1988) results where Staple Length had a rating of 100, followed by Staple Strength (88).

The fact that the importance of Staple Strength has decreased from TEAM-2 to TEAM-3 is likely to be a reflection of the fact that the TEAM-3 regression formula includes CVD, which has been suggested as a potential indicator of Staple Strength. It is important to note however that, based on this analysis, Staple Strength has a much greater influence on Hauteur than does CVD.

TABLE 6.5

THE RELATIVE IMPORTANCE OF RAW WOOL CHARACTERISTICS FOR THE PREDICTION OF HAUTEUR

Characteristic	Relative Importance TEAM-3	Relative Importance TEAM-2
Diameter	100	46
Staple Length	96	100
Mid-Breaks	91	NA
Adjusted Mid-Break	NA	40
Staple Strength	72	88
CV Length	40	NA
CV Diameter	28	NA
Vegetable Matter	–	19

Figure 6.4 compares the actual Hauteur values with the Residual Hauteur. The Residual Hauteur was calculated by subtracting the predicted Hauteur values from the actual Hauteur values. The predicted Hauteur was calculated using the proposed TEAM-3 formula listed above.

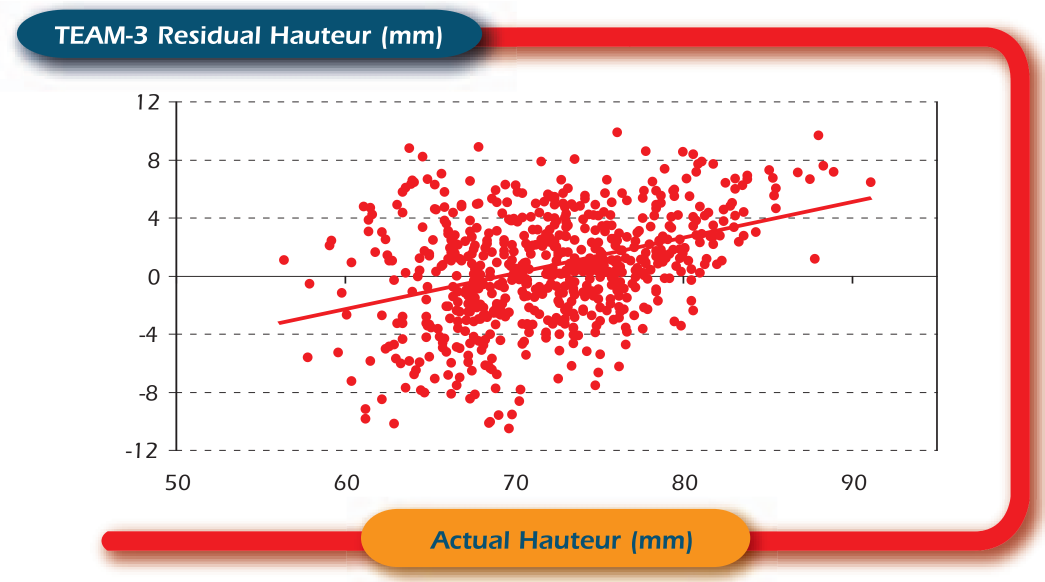

Figure 6.4 Relationship between Actual Hauteur and TEAM-3 Residual Hauteur

The existence of a slope on the TEAM-3 residuals in Figure 6.4 is indicative of some factor, that can have influence on the Hauteur, being absent from the formula. This same phenomenon was also evident in the TEAM-2 analysis. It is generally acknowledged that there will be a strong interaction between the Hauteur, the CVH and the Romaine of any top for any given consignment. Allen (1991) demonstrated the influence of CVH (over the 34% to 60% range) and the shape of the Hauteur diagram on the prediction of Hauteur. Market forces to produce a low CVH or less Romaine will clearly influence the Hauteur of the top produced.

One approach to investigate the impact of the above interactions is to examine the inclusion of both the actual CVH and the actual Romaine into the Hauteur prediction formula. Their inclusion is not to develop a formula per se, as they are clearly not known until the wool has been processed, but rather to quantify the impact that they are having on the data. In part they are a reflection of the machine settings, the processing conditions and other mill variables that are often difficult to quantify.

An analysis of the TEAM-3 residuals shown in Figure 6.4 indicated that most of the slope effect was related to the CVH of the top with Romaine having a marginal effect. The inclusion of the actual CVH into the regression reduced the SE from 2.5mm to 1.6mm and increased the R^2 from 83% to 93%. To improve the prediction of topmaking outcomes beyond the normal regression approach will require a clearer understanding and accounting of this interaction.

On the basis of the above analysis, the use of actual CVH, post processing, or the predicted CVH from a general TEAM formula, prior to processing, could provide valuable information to individual mills on how their processing performance differs or is likely to differ from the general formula for predicted Hauteur.

Further analysis of the residuals shows that approximately 75% of the consignments fall within a narrow range of ±4mm of the achieved Hauteur (Figure 6.5). This was similar to the results achieved in the TEAM-2 trial when 77% of the consignments fell within ±4mm of the achieved Hauteur.

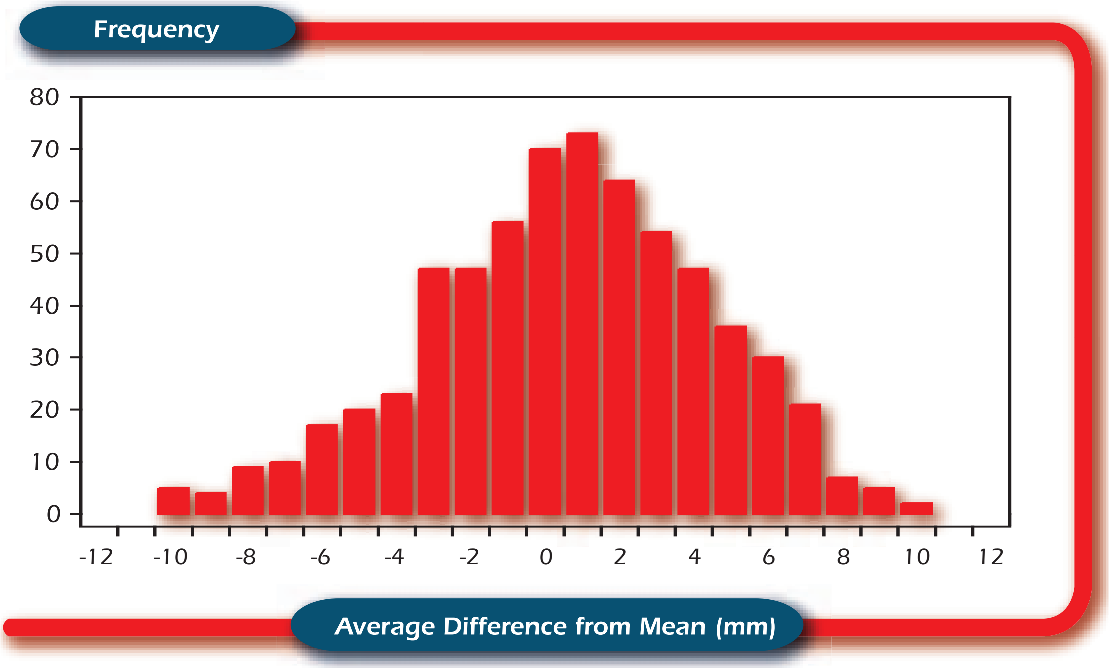

Figure 6.5 Histogram of Differences Between Actual and Predicted (TEAM-3) Hauteur

6.5 Variation Between and Within Individual Mills

As was done in TEAM-2, processing differences between mills have been identified and therefore an important aspect to be emphasised in using the prediction formula is the adjustment of the calculated value of Hauteur to allow for mill differences. Individual mills can comb consistently longer or shorter tops than the values calculated for Hauteur using a general formula. Figure 6.6 plots the distribution of the average differences (i.e. the mill corrections) when the data is analysed on a mill by mill basis. In Figure 6.6, only mills that submitted 10 or more consignments were included, and the proposed TEAM-3 Hauteur formula (Regression 2 from Table 6.4) was used to calculate predicted Hauteur values.

The average of all mill adjustments, 0.2mm, is the same for both TEAM-2 and TEAM-3. The range in mill adjustments was 14.2mm in TEAM-2 (-9.2mm to +5.0mm) but has decreased to 10.8mm in TEAM-3 (-5.2mm to +5.6mm).

As was the case in TEAM-2, the TEAM-3 Steering Committee recommends that mills continually monitor the prediction of Hauteur. As mills collect data on processing consignments, methods to adjust the prediction formula should be implemented. Appendix 3 provides methods by which individual mills can calculate these adjustments and use them as a mill monitoring technique. This Appendix is very similar to Appendix 3 in the TEAM-2 report (1988).

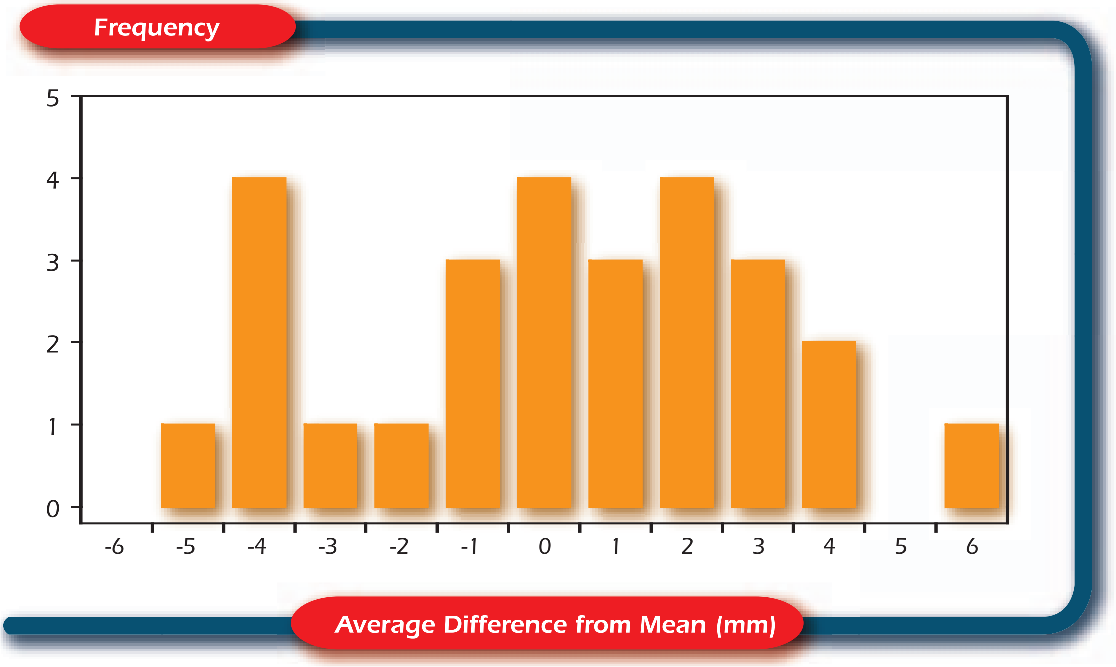

Figure 6.6 Histogram of Differences Between Actual and Predicted Hauteur for Individual Mills

The variability within a mill is largely related to mill quality management. The availability of the TEAM-2 database allowed a comparison between the average predictability of Hauteur for the individual mills in TEAM–2 and the average predictability for the individual mills in TEAM-3. For each mill, the data was analysed so that the variability within that mill could be considered in conjunction with the average mill adjustments.

The statistical method that was used was the calculation of the standard deviation of 'Actual minus Predicted' Hauteur for each mill. There was a marked (30%) reduction from 3.5mm to 2.4mm between the two trials (Table 6.6).

These results demonstrate that there has been a significant improvement in the predictability of Hauteur based on Raw Wool measurements for individual mills in the 16-year period since the publication of the TEAM-2 formulae. The lower SD of the prediction differences implies better mill quality management, further illustrating the benefits of using prediction technology. In addition, improvements in mill quality management may include tighter control of the variation of the raw wool properties in the component Sale Lots.

TABLE 6.6

COMPARISON OF WITHIN-MILL SD OF PREDICTION DIFFERENCES AND MILL FACTORS FOR TEAM-2 AND TEAM-3 DATABASES

	Mill Adjustment (mm)		SD of Prediction Differences (mm)	
	TEAM-2	TEAM-3	TEAM-2	TEAM-3
Average:	0.2	0.2	3.5	2.4
Minimum:	-9.2	-5.2	2.3	1.3
Maximum:	5.0	5.6	4.6	3.7
No. of Mills:	20	27	20	27

6.6 Validation of the TEAM-3 Calibration

The statistics presented in Section 5 are based on using the entire TEAM-3 database to derive a regression formula to predict processing performance. This regression formula has not been validated with additional consignments. A similar approach was taken by the TEAM-2 committee in 1988.

This section examines the validation of the TEAM-3 database by dividing the database into two sets based on a random allocation of consignments. The first set of consignments was allocated to the prediction model and the second set of consignments was used to validate the prediction model. This is therefore a true model development and validation process rather than just a data fitting process.

Using the consignments allocated to the prediction model, the S-Plus (2002) statistical package was used to determine a prediction equation. The coefficients that were determined by this regression analysis are shown in Table 6.7. It is clear that the coefficients are very similar to those obtained when the entire TEAM-3 database was used to derive a calibration equation (Regression 2, Table 6.4).

TABLE 6.7

CALIBRATION OF A RANDOM SUBSET OF THE TEAM-3 DATABASE

Regression	SL	SS	D	VM	M	CVD	CVL
TEAM-3 (Calibration)	0.41	0.26	1.60	- 0.45#	- 0.17	-0.80	-0.35

The # indicates that this coefficient was derived from the TEAM-2 analysis and included here due to the lack of range in VM in the TEAM-3 database.

Once the regression was derived, the equation was used to predict the Hauteur of the remaining validation consignments. The differences between the predicted and actual Hauteur of these validation consignments were then analysed. The average difference between actual and predicted Hauteur was 0.25mm and the standard deviation of these differences was 3.97mm. Given that the mean residual was only 0.25mm and the SD of the differences was relatively low, it can be concluded that the calibration equation is an effective predictor of processing performance. As a comparison, the SD of the differences when the entire TEAM-3 database was used to calculate the prediction equation was 3.84mm. This value includes both within-mill and between-mill effects.

It should be noted that the SD of differences (3.84) is larger than the regression SE (2.49 from Table 6.4). The former represents the error around the average difference whereas the latter represents the error around the regression line. The difference arises from the observed slope between the TEAM-3 residuals and the Actual Values (see Figure 6.4).

6.7 Application of Formulae to Sale Lots

As with TEAM-2, the formulae proposed for TEAM-3 are based on analysis of results from commercial processing consignments. The TEAM-3 consignments contained an average of 40 sale lots with a range from 3 to 254 lots. As the raw wool characteristics of individual sale lots can be outside the average raw wool characteristics of the consignments processed in TEAM-3, application of General Formulae to these sale lots may lead to misleading results. Despite this, the use of the formulae for prediction at the sale lot level can offer mills a useful tool for quality management, as long as results are interpreted in the knowledge that the formulae are based on the performance of consignments, not sale lots.

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7. TEAM-3 DATABASE - PREDICTION OF COEFFICIENT OF VARIATION OF HAUTEUR

The same statistical methods used in Section 6 to analyse the TEAM-3 database for Hauteur were used for the Coefficient of Variation of Hauteur (CVH). Table 7.1 presents the results of the regression analyses for the CVH prediction based on the TEAM-3 database. Regression 1 in Table 7.1 is an analysis using SL, SS, D and M* as a function of CVH. These are the same parameters that formed the basis of the TEAM-2 formula. The coefficients obtained when a regression was conducted on the TEAM-3 database are similar to those obtained in TEAM-2. The main difference is that diameter has a bigger influence on predicted CVH in the TEAM-3 analyses.

The addition of either CVD or MFC to the model resulted in little improvement to the prediction of CVH. However, the addition of CVL (Regression 3) did impact on the prediction with the SE decreasing from 2.69 to 2.62. The TEAM variables together with various combinations of CVL, CVD and MFC were also examined (Regressions 5 to 8).

TABLE 7.1

STATISTICAL ANALYSIS USING CVD, MFC AND CVL TO PREDICT CVH

	Regression	SL	SS	D	M*	CVD	MFC	CVL	SE (%)	R^2
	TEAM-2	0.12	-0.41	-0.35	0.20				2.80	63%
1	TEAM-3	0.18	-0.40	-0.61	0.20				2.69	65%
2	TEAM-3 +CVD	0.23	-0.34	-0.78	0.21	(0.44)			2.68	65%
3	TEAM-3 + CVL	0.31	-0.35	-0.90	0.20			0.42	2.62	67%
4	TEAM-3 + MFC	0.18	-0.40	-0.59	0.20		(0.01)		2.69	65%
5	TEAM-3 + CVL + CVD	0.32	-0.33	-0.95	0.20	(0.14)		0.40	2.62	67%
6	TEAM-3 + CVD + MFC	0.23	-0.34	-0.70	0.21	(0.45)	(0.63)		2.68	65%
7	TEAM-3 + CVL + MFC	0.31	-0.36	-0.77	0.20		(0.03)	0.42	2.62	67%
8	TEAM-3 + CVD + CVL + MFC	0.32	-0.34	-0.80	0.20	(0.16)	(0.04)	0.41	2.62	67%

Note: All coefficients that were not statistically significant are bracketed.

7.1 The Replacement of M* with M in the Prediction of CVH

The TEAM-2 prediction formula for CVH contains an adjusted Mid-Break (M*) parameter. As was examined earlier with Hauteur, the use of M* was compared to the use of the actual Mid-Break percentage (M) for the prediction of CVH. For this analysis Regression 3 from Table 7.1 was used as a benchmark. Table 7.2 shows that the use of M instead of M* results in a minor improvement to the prediction model. As with Hauteur, the use of M can be considered as a possible replacement for M* for the prediction of CVH.

TABLE 7.2

STATISTICAL ANALYSIS USING M INSTEAD OF M*

Regression		SL	SS	D	M*	M	CVL	SE (%)	R^2
1	TEAM-3 + CVL	0.31	-0.35	-0.90	0.20		0.42	2.62	67%
2	M* replaced by M	0.30	-0.37	-0.88		0.17	0.38	2.58	68%

As the use of M would simplify the TEAM formula, **Regression 2 in Table 7.2 is proposed as the TEAM-3 prediction formula for CVH.** It should be noted that this formula contains a constant term which includes an adjustment associated with individual mill differences. For the entire TEAM-3 database, the adjustment equals 35.6. Therefore, the proposed TEAM-3 formula for CVH is as follows:

$$\textbf{CV Hauteur} = 0.30L - 0.37S - 0.88D + 0.17M + 0.38CVL + 35.6$$

The relative importance of each variable in the above table has been estimated from the statistical significance of the regression terms. Table 7.3 provides an estimate for the relative importance of each variable with the most significant factor, Mid-Breaks, given a rating of 100. The next most important variable after Mid-Breaks is Staple Strength (82) followed by Staple Length (66). Table 7.3 also provides a comparison to the TEAM-2 (1988) results where Staple Strength had a rating of 100, followed by Adjusted Mid-Breaks (57).

TABLE 7.3

THE RELATIVE IMPORTANCE OF RAW WOOL CHARACTERISTICS FOR THE PREDICTION OF CVH

	Relative Importance	
Characteristic	**TEAM-3**	**TEAM-2**
Mid-Breaks	100	NA
Adjusted Mid-Breaks	NA	57
Staple Strength	82	100
Staple Length	66	33
Diameter	66	22
CV Length	46	NA

Figure 7.1 compares the actual CVH values with the residual CVH. The residual CVH was calculated by subtracting the predicted CVH from the actual CVH. The predicted CVH was calculated using the TEAM-3 CVH regression formula which has been proposed above.

Figure 7.2 plots the differences between actual and predicted CVH and shows that 86% of the consignments fell within ±4% of the mean. This was comparable with the 83% that fell within this range in the TEAM-2 trial.

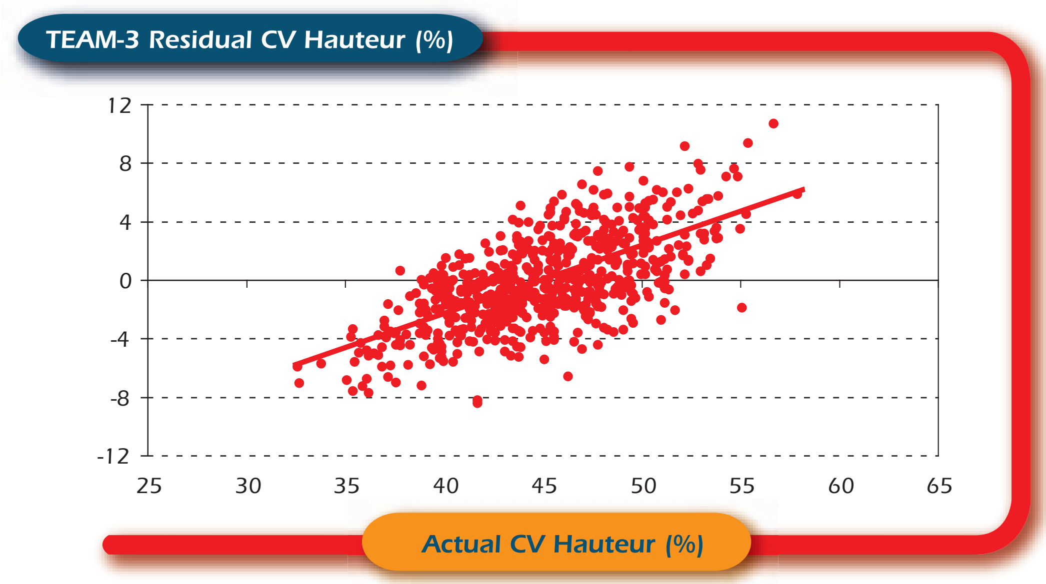

Figure 7.1 Relationship between Actual CVH and TEAM-3 Residual CVH

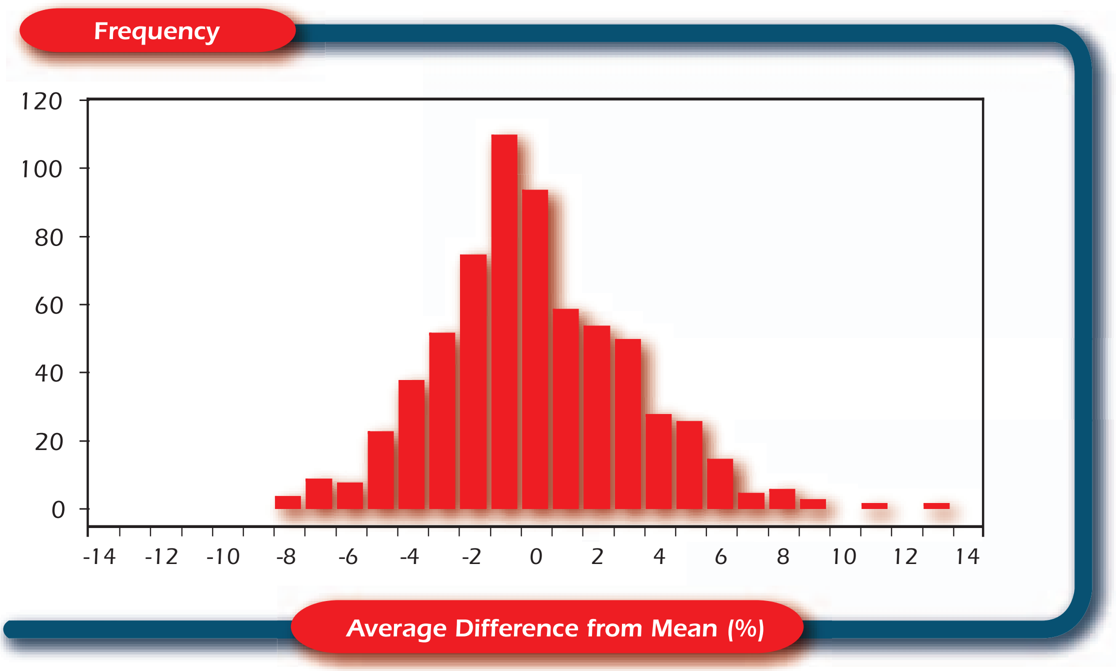

Figure 7.2 Histogram of Differences Between Actual and Predicted (TEAM-3) CVH

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8. TEAM-3 DATABASE - PREDICTION OF ROMAINE

The same statistical methods used in Sections 6 and 7 to analyse the TEAM-3 database for Hauteur and CVH were used for Romaine. Table 8.1 presents the results of the regression analyses for the Romaine prediction based on the TEAM-3 database. Regression 1 in Table 8.1 is an analysis using SL, SS, D and VM as a function of Romaine. These are the same parameters that formed the basis of the TEAM-2 formula. The coefficients obtained when a regression was conducted on the TEAM-3 database are similar to those obtained in TEAM-2. The main differences are that diameter has a bigger influence on predicted Romaine in the TEAM-3 analysis and VM has less impact. The reduced influence of VM may be a reflection of the relatively narrow range of VM in the TEAM-3 database. This was discussed for Hauteur in Section 6. Despite the reduced influence, it is important to note that VM does have a statistically significant influence on the TEAM-3 processing prediction model for Romaine. This was not the case for Hauteur.

The addition of CVD, MFC or CVL to the model resulted in little improvement to the prediction of Romaine. The TEAM variables together with various combinations of CVL, CVD and MFC were also examined.

TABLE 8.1

STATISTICAL ANALYSIS USING CVD, MFC AND CVL TO PREDICT ROMAINE

	Regression	SL	SS	D	VM	CVD	MFC	CVL	SE (%)	R^2
	TEAM-2	-0.11	-0.14	-0.35	0.94				1.50	76%
1	TEAM-3	-0.13	-0.18	-0.63	0.78				1.31	77%
2	TEAM-3 +CVD	-0.10	-0.14	-0.73	0.82	(0.23)			1.31	77%
3	TEAM-3 + CVL	-0.08	-0.16	-0.74	0.69			0.17	1.29	78%
4	TEAM-3 + MFC	-0.13	-0.17	-0.80	0.77		(-0.04)		1.31	77%
5	TEAM-3 + CVL + CVD	-0.07	-0.14	-0.77	0.72	(0.10)		0.16	1.29	78%
6	TEAM-3 + CVD + MFC	-0.10	-0.14	-0.86	0.81	(0.20)	(-0.03)		1.31	77%
7	TEAM-3 + CVL + MFC	-0.08	-0.15	-0.86	0.69		(-0.03)	0.17	1.29	78%
8	TEAM-3 + CVD + CVL + MFC	-0.07	-0.17	-0.88	0.71	(0.08)	(-0.03)	0.16	1.29	78%

Note: All coefficients that were not statistically significant are bracketed.

As the addition of CVD, CVL or MFC did not impact on the prediction model for Romaine, **Regression 1 in Table 8.1 is proposed as the TEAM-3 prediction formula for Romaine.** It should be noted that this formula contains a constant term which includes an adjustment associated with individual mill differences. For the entire TEAM-3 database, the adjustment equals 38.6. Therefore, the proposed TEAM-3 formula for Romaine is as follows:

$$\textbf{Romaine} = -0.13L - 0.18S - 0.63D + 0.78V + 38.6$$

The relative importance of each variable in the above table has been estimated from the statistical significance of the regression terms. Table 8.2 provides an estimate for the relative importance of each variable with the most significant factor, Mean Fibre Diameter, given a rating of 100. The next most important variable is Staple Strength (79) followed by Staple Length (69). Table 8.2 also provides a comparison to the TEAM-2 (1988) results where Vegetable Matter Base had a rating of 100, followed by Staple Strength (63).

TABLE 8.2

THE RELATIVE IMPORTANCE OF RAW WOOL CHARACTERISTICS FOR THE PREDICTION OF ROMAINE

	Relative Importance	
Characteristic	**TEAM-3**	**TEAM-2**
Diameter	100	41
Staple Strength	79	63
Staple Length	69	51
Vegetable Matter	66	100

Figure 8.1 provides a comparison of the actual Romaine and the Residual Romaine. The Residual Romaine was calculated by subtracting the predicted Romaine from the actual Romaine. The predicted Romaine was calculated using the above proposed TEAM-3 Romaine regression formula.

Figure 8.2 plots the differences between actual and predicted Romaine and shows that 88% of the consignments fell within ±2% of the mean. This was comparable with the 84% that fell within this range in the TEAM-2 trial.

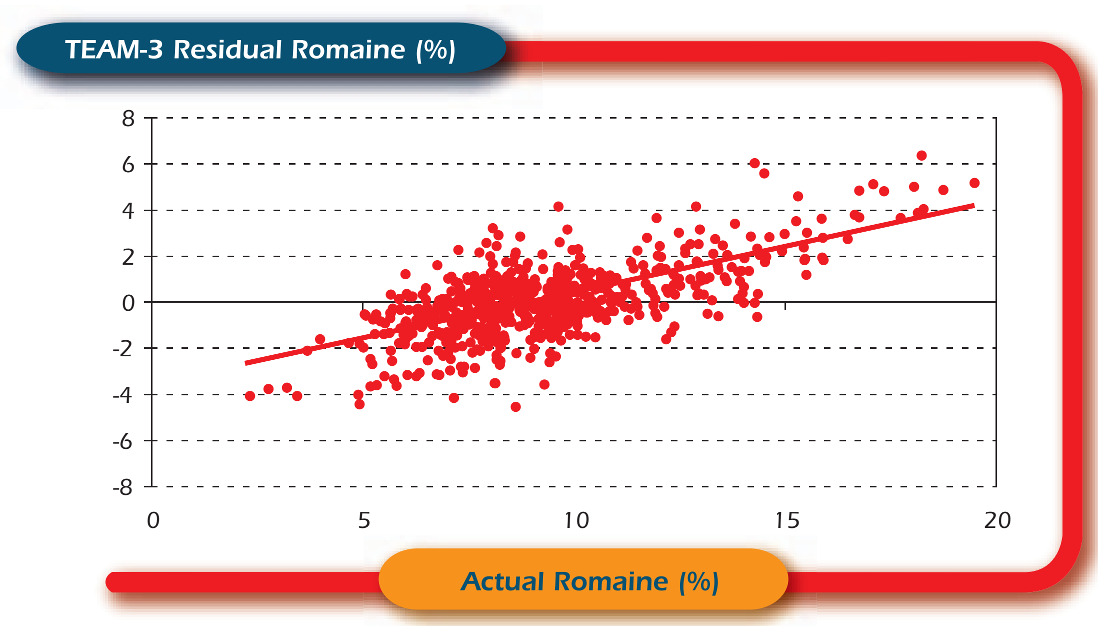

Figure 8.1 Relationship between Actual Romaine and TEAM-3 Residual Romaine

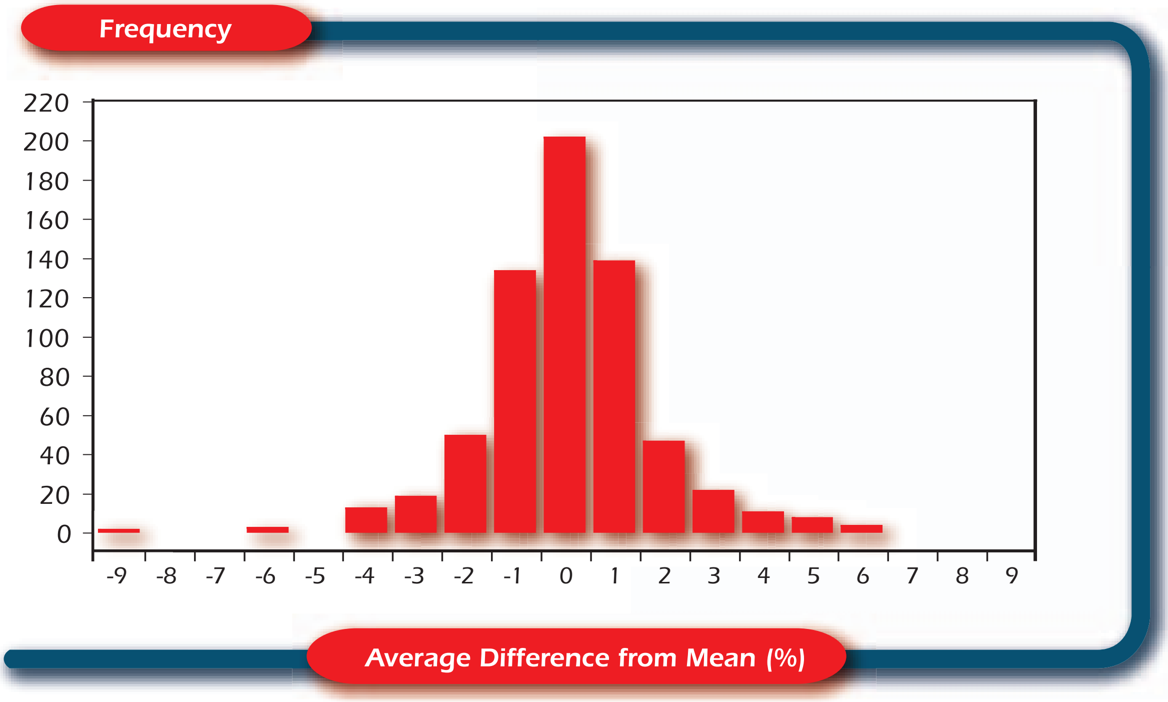

Figure 8.2 Histogram of Differences Between Actual and Predicted (TEAM-3) Romaine

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9. CONCLUSIONS AND RECOMMENDATIONS

This report summarises the final analysis of the TEAM-3 database. The TEAM-3 Steering Committee is able to report that, with the exception of VM, the TEAM-2 parameters (SL, SS, MFD, and M*) are still applicable to processing prediction models. It is shown that processing performance has improved since the late 1980's. Mills are producing tops with Hauteur values, on average, 5.1mm longer than is predicted using the TEAM-2 general formula and greater differences occur as the Hauteur increases above 75mm. In addition, mills are producing tops with CVH values, on average, 2.5% less than predicted by TEAM-2 and Romaine values 2.1% greater than predicted.

Mills also achieve more consistent, predictable results with lower standard deviations between actual and predicted Hauteur than in TEAM-2.

The regression analyses for Hauteur, CVH and Romaine have shown that it is possible to calculate new General Formulae for each of these parameters, although they would be similar to the TEAM-2 General Formulae published in 1988. The addition of CVD and CVL provides small improvements to the prediction of Hauteur and the addition of CVL provides a small improvement to the prediction of CVH. Similarly, the use of M instead of M* makes little change to any prediction model. Based on the regression analysis of the TEAM-3 database and the additional analyses on the influence of VM Base, the inclusion of the TEAM-2 coefficient for VM in a TEAM-3 prediction model for Hauteur is recommended. It has also been identified that there is no improvement in processing prediction if MFC is added to the prediction model.

The TEAM-3 Steering Committee recommends that the industry consider the following three options:

Option 1. Retain the existing TEAM-2 formulae in the IWTO Staple Test Regulations.

Advantages of Option 1:

- The TEAM-3 trial has shown that the TEAM-2 formula is robust, and if changes were made to the formulae they would be small and would not improve processing predictability significantly.
- The observed differences can be easily accommodated with the TEAM-2 recommended techniques for calculating and applying mill adjustment factors.
- It is the easiest solution to implement with minimal disruption.
- The TEAM-2 formulae are simple to apply and understand.
- No changes are required to existing databases and computer programs around the world.
- No changes are required for Letters of Credit, specifications and contract limits.

Disadvantages of Option 1:

- General processing conditions have changed and actual processing performance will differ from predicted processing performance (eg. average of +5.1mm for Hauteur).
- A database as comprehensive as that complied for TEAM-3 is unlikely to be available in the near future due to the cost of assembling it.
- The use of M* in the TEAM-2 formulae makes it difficult to calculate an average Hauteur when a number of sale lots are combined.

Option 2. **Introduce the following TEAM-3 formulae into the IWTO Staple Test Regulations as a replacement for the TEAM-2 formulae.**

Hauteur = 0.43L + 0.35S + 1.38D – 0.15M – 0.45V – 0.59CVD – 0.32CVL + 21.8

CV Hauteur = 0.30L – 0.37S – 0.88D + 0.17M + 0.38CVL + 35.6

Romaine = – 0.13L – 0.18S – 0.63D + 0.78V + 38.6

Advantages of Option 2:

- The new formulae will better reflect current commercial processing conditions.
- The new formulae includes additional measurement data (CVL and CVD) that provide a small benefit to the prediction model.
- New formulae would better facilitate any future adjustments (eg 'Atypical' Sale Lots) without the need to repeat a processing trial of this magnitude.
- New formulae would remove the complications caused by the use of M* rather than M.

Disadvantages of Option 2:

- The introduction of new formulae would cause significant disruption to current systems in terms of databases, software, contract limits, Letters of Credit etc.
- There would be a requirement for an extensive education campaign.
- The use of more 'minor' terms may encourage the use of inappropriately tight specifications for these measurements. This may lead to more difficulty in purchasing for only very small gains in processing prediction.

Option 3. **Include both the TEAM-2 formulae and TEAM-3 formulae in the IWTO Staple Test Regulations.**

Advantages of Option 3:

- Will allow mills to choose the formulae that best suit their requirements.
- Is consistent with the IWTO Core Tests Regulations which provide different formulae for calculating Commercial Yield.

Disadvantage of Option 3:

- Two sets of processing prediction formulae is likely to create some confusion.
- The use of M* in the TEAM-2 formulae makes it difficult to calculate an average Hauteur when a number of sale lots are combined.

10. REFERENCES

Allen, D.J. (1991). Variability of Fibre Length in Tops. *International Wool Textile Organisation. Commercial Technology Forum.* Nice Meeting, November 1999 Report CTF 11.

Cilliers, W.C., Robinson, G.A. and Slinger, R.I. (1968). The Processing Characteristics of South African Wools. Part IV: High Crimp Wools. SAWTRI Tech. Rep. No 110.

Douglas, S.A.S. and Couchman, R.C. (1997). Industry Review of the TEAM Prediction Formulae. *International Wool Textile Organisation. Woolgrowers, Traders & Early Processors Committee.* Nice Meeting, December 1997.

Haigh, M. (2002). Fibre to fabric. Fibre Crimp and Fibre Curvature: Fibre to Fabric Seminar, February 2002.

Hunter, L. and Gee, E. (1980), The Effect of Staple Crimp, Resistance to Compression and Fibre Diameter and Length Characteristics on the Physical Properties of Wool Worsted Yarns. *Proc. 6th Quinquennial Int. Wool Textile Res. Conf.*, Pretoria, 1980, Vol II.

IWTO-DTM-60-01, The Woolmark Company, UK.

Kurdo, K.O.A., Whiteley, K.J. and Smith, L.J. (1984) The Influence of Resistance to Compression on the Processing Performance of Superfine Wools Part 1: Topmaking, *International Wool Textile Organisation. Technical Committee.* Tokyo Meeting, May 1984 Report 12.

Lamb, P. R. (2000). The Impact of CV(D) and Crimp or Curvature on Hauteur and Romaine. International *Wool Textile Organisation. Commercial Technology Forum.* Christchurch Meeting, May 2000 Report CTF 02.

Lindsay, A.R., Marler, J.W., and Jackson, M.A. (2003). TEAM-3 Processing Trial – November 2003 Update. *International Wool Textile Organisation. Commercial Technology Forum.* Dubrovnik Meeting, November 2003.

Lindsay, A.R., Marler, J.W., and Jackson, M.A. (2002a). Preliminary Analysis of TEAM-3 Database. *International Wool Textile Organisation.* Raw Wool Group. Barcelona Meeting, May 2002 Report 4.

Lindsay, A.R., Marler, J.W., and Jackson, M.A. (2002b). TEAM-3 Progress Report (December 2002). *International Wool Textile Organisation. Commercial Technology Forum.* Nice Meeting, December 2002 Report CTF 02.

Marler, J.W. (1985), The Influence of Resistance to Compression on Early Stage Processing , Standards Association of Australia, TX12/85-25, 1.

Peterson, A. (2002). What is fibre curvature? Fibre Crimp and Fibre Curvature: Fibre to Fabric Seminar, February 2002.

S-Plus for Windows (2002). Professional Edition, Insightful Corp.

Stevens, D and Mahar, T.J. (1995), The Beneficial Effects of Low Crimp in Worsted Processing and on Fabric Properties and Fabric Handle, 9th International Wool Textile Research Conference, Biella, V,134.

Stevens, D. and Crowe, D.W. (1994), Style and Its Processing Effects, WoolSpec 94, E1.

TEAM-3 Steering Committee (2004). TEAM-3 Processing Trial – Final Report. *International Wool Textile Organisation. Raw Wool Group.* Evian Meeting, May 2003 Report RWG 02.

TEAM-3 Steering Committee (2003). TEAM-3 Processing Trial – May 2003 Update. *International Wool Textile Organisation. Commercial Technology Forum.* Buenos Aries Meeting, May 2003 Report CTF 04.

Trials Evaluating Additional Measurement (1988). Report to the Raw Wool Measurement Research Advisory Committee of the Australian Wool Corporation, December 1988.

Turpie, D.W.F., and Shiloh, M. (1973). The Processing Characteristics of South African Wools. Part V: Properties of Merino Wool Types Varying in Staple Crimp. SAWTRI Tech. Rep. No 189.

Vizard, A.L., and Hansford, K.A. (1999). Use of Objective Measurements in Breeding Programs for Merino Sheep Leads to Improved Topmaking Performance. *International Wool Textile Organisation. Commercial Technology Forum.* Florence Meeting, June 1999 Report CTF 01.

APPENDIX 1
STANDARD PROFORMA FOR COLLECTION OF CONSIGNMENT DATA

TEAM-3 PROJECT: CONSIGNMENT NOMINATION

A. IDENTIFICATION

Participating Company Name ....

Consignment / Batch Reference ....

Date of Combing ....

Processing Mill ....

B. GREASY WOOL TEST RESULTS

Test Number of IWTO Combined Certificates* – Yield/Micron...

– Length/Strength..

* Where an IWTO Combined Certificate has not been created for the consignment by AWTA Ltd, **please attach a list of the individual AWTA Ltd Test Numbers** for both Core Test and Staple Measurement Certificates comprising the consignment. Or, for wool of non- Australian origin, attach copies of the relevant NZWTA Ltd or WTB-SA Certificates.

C. CONSIGNMENT WEIGHT AND OUTSOURCED WOOL

Total Bales	....	Bales
Greasy Weight	....	Kg
Tare	....	Kg
Net Weight	....	Kg
Outsorts (if any)	....	Greasy kg

NOTE: It is preferable that there should be no sorting of wools and/or removal of bales unless considered to be absolutely necessary. If sorting exceeds 1% of the greasy weight, it is unlikely that a valid greasy wool test/combing comparison can be made. So, the amount of any outsorts should be determined accurately and the reasons for removal noted below.

Reason for Outsorts:..

Please attach the Processing Report (either the Mills own combing report, or the proforma TEAM-3 Processing Report) to this Nomination form, then despatch it and the required top samples to:

AWTA Ltd
Attn: Andrew Lindsay, Sampling Operations Manager – NSW & Qld
Cnr Byron and Military Roads
GUILDFORD, NSW 2161
AUSTRALIA

Fax number: +61 (0)2 9892 3195
E-mail address: andrew.lindsay@awta.com.au

TEAM-3 PROJECT: PROCESSING REPORT

Note: The Mill Combing Report and Top Test Results can be used instead of this proforma, if they provide the equivalent information.

A. IDENTIFICATION

Participating Company Name ....

Consignment / Batch Reference ....

Date of Combing ....

Processing Mill ....

B. PROCESSING DATA

* Please indicate whether cardwastes have been recycled YES / NO

Results by item (as applicable)		Nett kg	%
- Tops, conditioned		....	....
- Noils, conditioned		....	....
- Other wastes		....	....
Romaine (Noil)		..................%	
IF AVAILABLE Combing Line Reference	- Scouring Line: - Carding / Combing:	....	

C. MILL TEST RESULTS

Conditioning:	Top moisture regain	.... %
	Noil moisture regain	.... %
Fatty Matter:	Top, total fatty matter (on dry fat free weight)	.... %
	Solvent used	....
Top Length:	Almeter Hauteur	.... mm
	CV Hauteur	.... %
	% < 25mm	.... %
	Length (Hauteur) > 5%	.... mm

NOTE: If Almeter results are not available, please provide alternative measurements clearly noting the method used.

Top Fineness: *(Please supply all available results)*

	LASERSCAN	OFDA	Airflow	
Mean Fibre Diameter	....	....	....	micron (µm)
Coefficient of Variation of Diameter	....	....		%
Fibres <30 micron	....	....		%

D. OTHER TESTS OR PROCESSING INFORMATION (if considered relevant):

....

....

....

E. SAMPLING FOR TESTING AND FUTURE REFERENCE

Tops:

A minimum of 5 samples of top, each 1.2 metres in length, are required from each processing batch. These samples will be retained by AWTA Ltd and used as a reference sample should there be any discrepancy in results. Each top sample should be taken sequentially throughout combing so that they are representative of the whole consignment. The most practical method of sampling is to take 2 lengths of top when sampling for in-house mill testing.

Each sample should be identified by the name of the participant, the consignment reference number and a suffix to indicate the production sequence.

NOTE:
1. The sampling requirements are based on those set out in the IWTO Regulations for the testing of Wool Slivers for Mean Fibre Diameter & Mean Fibre Length.
2. Each 1.2 metre length of sample sliver should be twisted as per the requirements of Section 6.1.1 (i) of IWTO-17-85 or wrapped onto formers.

APPENDIX 2
RELATIONSHIP BETWEEN MEAN FIBRE CURVATURE AND RESIDUAL HAUTEUR FOR CONSIGNMENTS OF DIFFERENT MEAN FIBRE DIAMETER

In an attempt to remove any potential influence due to the strong correlation (R = -0.91) between MFC and MFD (see Appendix 4), the MFC relationship of all consignments with a diameter of 16.0µm to 18.0µm was examined (see Figure A2.1). This was repeated for wool of diameter 18.1µm to 20.0µm (see Figure A2.2), and 20.1µm and greater (see Figure A2.3).

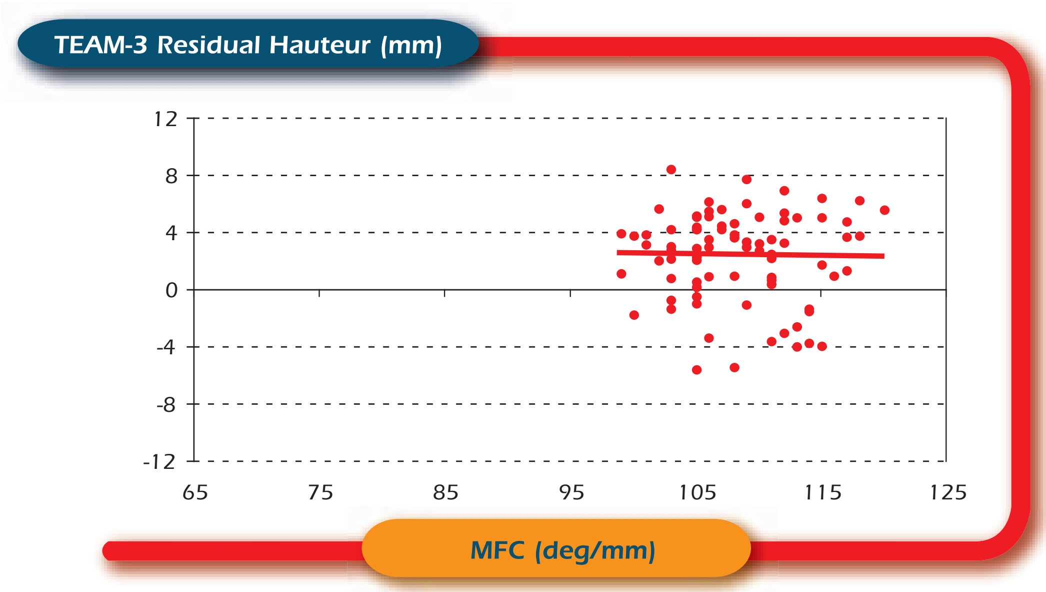

Figure A2.1 Relationship between MFC and TEAM-3 Residual Hauteur for Consignments 16.0µm to 18.0µm

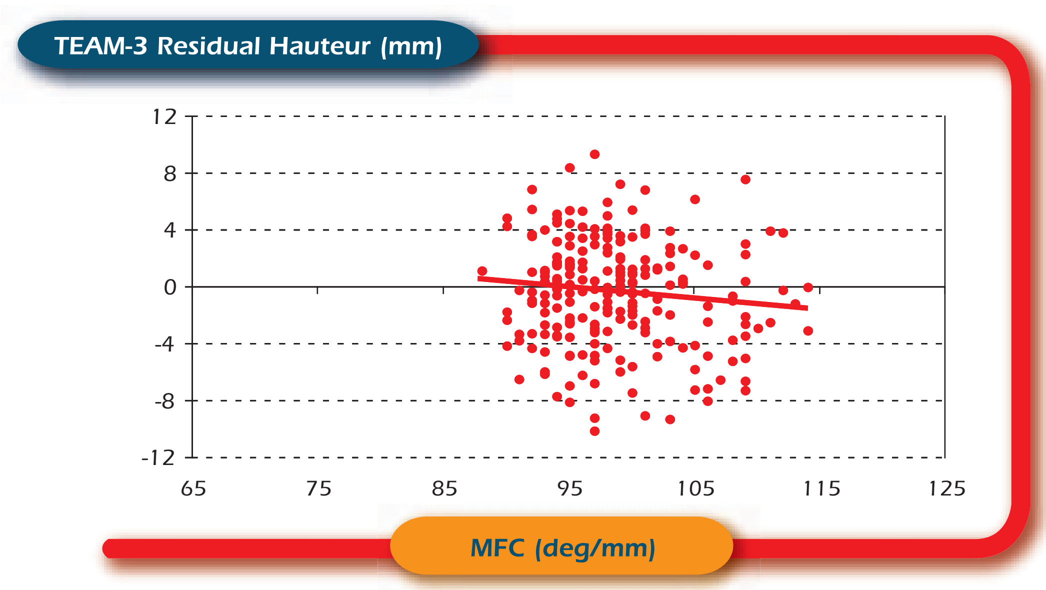

Figure A2.2 Relationship between MFC and TEAM-3 Residual Hauteur for Consignments 18.1µm to 20.0µm

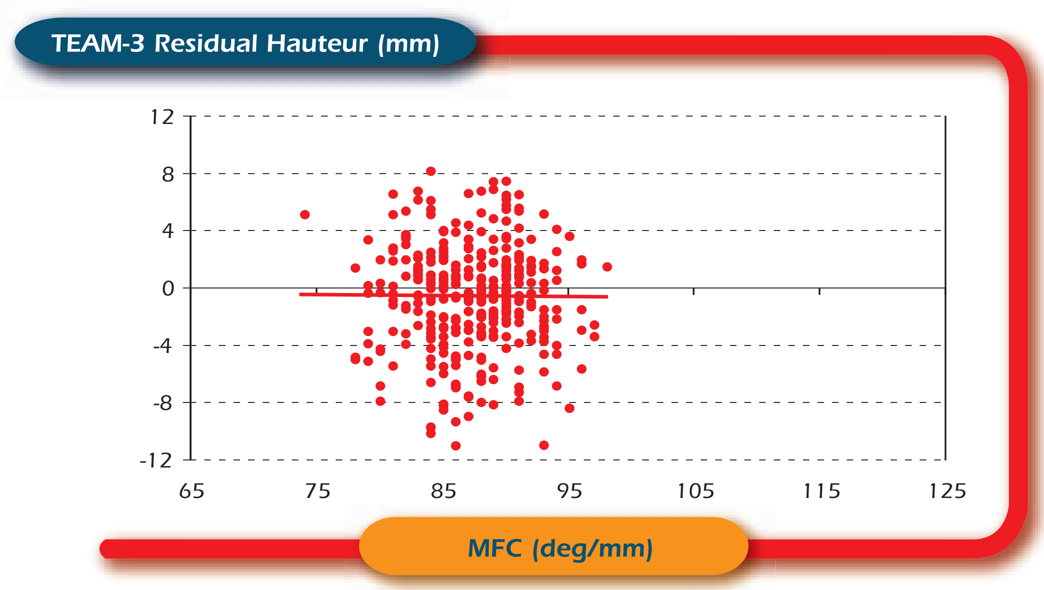

Figure A2.3 Relationship between MFC and TEAM-3 Residual Hauteur for Consignments 20.1μm and greater

The three figures above show that there is no relationship between the TEAM-3 Residual Hauteur and MFC. This gives further weight to the conclusion that, for the processing consignments submitted as part of the TEAM-3 trial, the inclusion of MFC does not improve the prediction of Hauteur.

APPENDIX 3
ADJUSTMENT OF THE GENERAL FORMULAE FOR A SPECIFIC MILL

As indicated in Section 6.4 of this report, the performance of a general formula is influenced by both within and between mill variation. This Appendix provides techniques for mills to adjust the General Formulae to suit their individual situation. It is important that before making an attempt to adjust the TEAM General Formulae, the mill's processing performance is stable. If a mill's performance is changing during the adjustment period then it will be continually making adjustments to the formulae to simply follow the trends.

This appendix provides an example of how to calculate a mill specific formula for Hauteur. The same techniques can be used to create mill specific formulae for CVH and Romaine.

A3.1 Calculation of a Mill-Specific Constant

A mill should select the most recent batch of processing consignments that are available. This will preferably be a minimum of 20 consignments, of which the individual sale lot components should all have been tested for Yield & Micron and Length & Strength.

The first step is to calculate the Hauteur (H_i) from the data for each consignment (i) using the prediction formula. In this example, we have used the proposed TEAM-3 formula for Hauteur:

$$H_i = 0.43L_i + 0.35S_i + 1.38D_i - 0.15M_i - 0.45V_i - 0.59CVD_i - 0.32CVL_i + 21.8$$

For each consignment (i), the difference (C_i) between the actual Hauteur (H_a) and the predicted Hauteur (H_i) should be calculated:

$$C_i = H_a - H_i$$

The results for a theoretical mill are presented Table A3.1 where the average difference between actual and predicted Hauteur is 1.7mm. This is referred to as the mill adjustment.

The next step is establish the presence or absence of trends over time by preparing a graph of the differences between the actual and predicted Hauteur against processing order (Figure A3.1). During the processing time period for these 20 consignments, no obvious trend is evident.

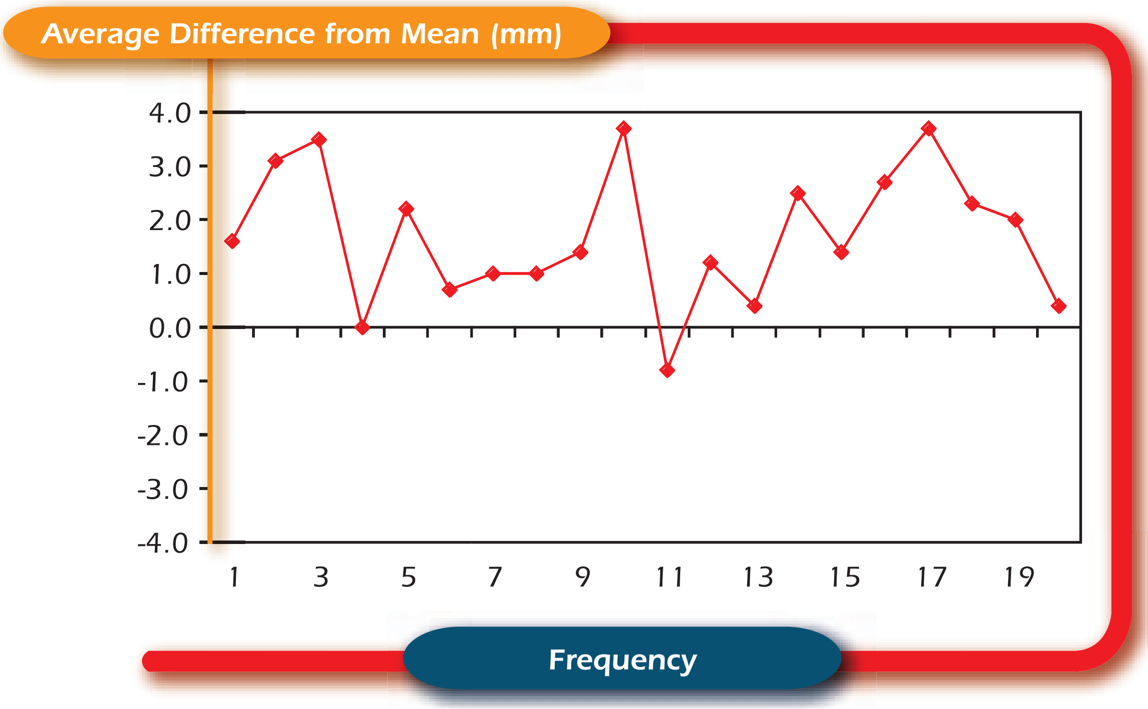

Figure A3.1 Hauteur Differences: Actual Predicted Hauteur

TABLE A 3.1

COMPARISON BETWEEN ACTUAL AND PREDICTED HAUTEUR FOR A THEORETICAL MILL

Actual Hauteur (H_a) (mm)	Predicted Hauteur (H_m) (mm)	$C_i = H_a - H_i$ (mm)
61.6	60.0	1.6
79.1	76.0	3.1
61.5	58.0	3.5
80.8	80.8	0.0
64.2	62.0	2.2
68.2	67.5	0.7
77.5	76.5	1.0
79.3	78.3	1.0
62.6	61.2	1.4
59.0	55.3	3.7
66.0	66.8	-0.8
73.9	72.7	1.2
58.1	57.7	0.4
66.5	64.0	2.5
71.4	70.0	1.4
70.7	68.0	2.7
67.3	63.6	3.7
74.3	72.0	2.3
67.0	65.0	2.0
77.9	77.5	0.4
69.3	**67.6**	**1.7**

The mill adjustment shown in Table A3.1 is 1.7mm. The TEAM-3 formula for Hauteur contains a constant of 21.8. A mill specific constant can be calculated by adding the average mill adjustment to the general formula constant (i.e. 21.8 + 1.7 = +23.5). Therefore, the specific Hauteur (H_m) formula for this theoretical mill can be written as:

$$H_m = 0.43L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 23.5$$

The recalculated Hauteurs based on the mill specific formula are compared to the actual Hauteurs in Table A3.2. The average difference between actual and predicted Hauteur based on the adjusted mill Hauteur formula is 0.0mm. These differences are presented in Figure A3.2 and A3.3.

TABLE A 3.2

COMPARISON BETWEEN ACTUAL AND PREDICTED HAUTEUR USING MILL SPECIFIC FORMULA

Actual Hauteur (H_a) (mm)	Predicted Hauteur (H_m) (mm)	$C_i = H_a - H_m$ (mm)
61.6	61.7	-0.1
79.1	77.7	1.4
61.5	59.7	1.8
80.8	82.5	-1.7
64.2	63.7	0.5
68.2	69.2	-1.0
77.5	78.2	-0.7
79.3	80.0	-0.7
62.6	62.9	-0.3
59.0	57.0	2.0
66.0	68.5	-2.5
73.9	74.4	-0.5
58.1	59.4	-1.3
66.5	65.7	0.8
71.4	71.7	-0.3
70.7	69.7	1.0
67.3	65.3	2.0
74.3	73.7	0.6
67.0	66.7	0.3
77.9	79.2	-1.3
69.3	**69.3**	**0.0**

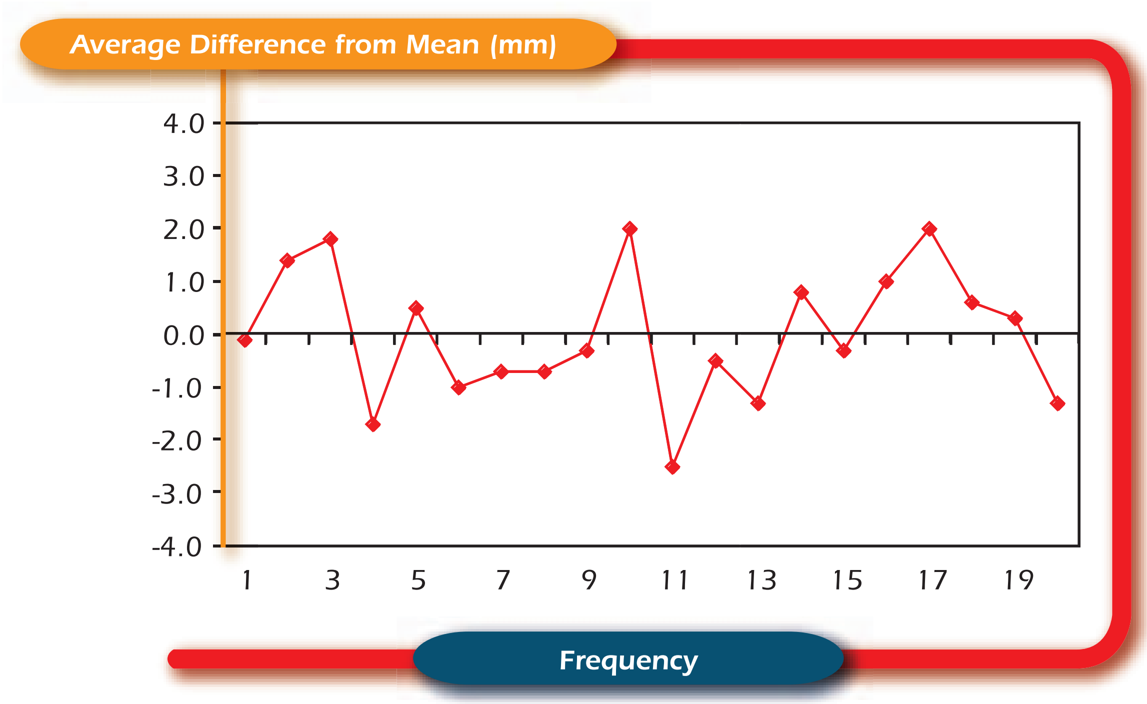

Figure A3.2 Hauteur Differences: Actual Predicted Hauteur when Mill Adjusted Formula is Applied

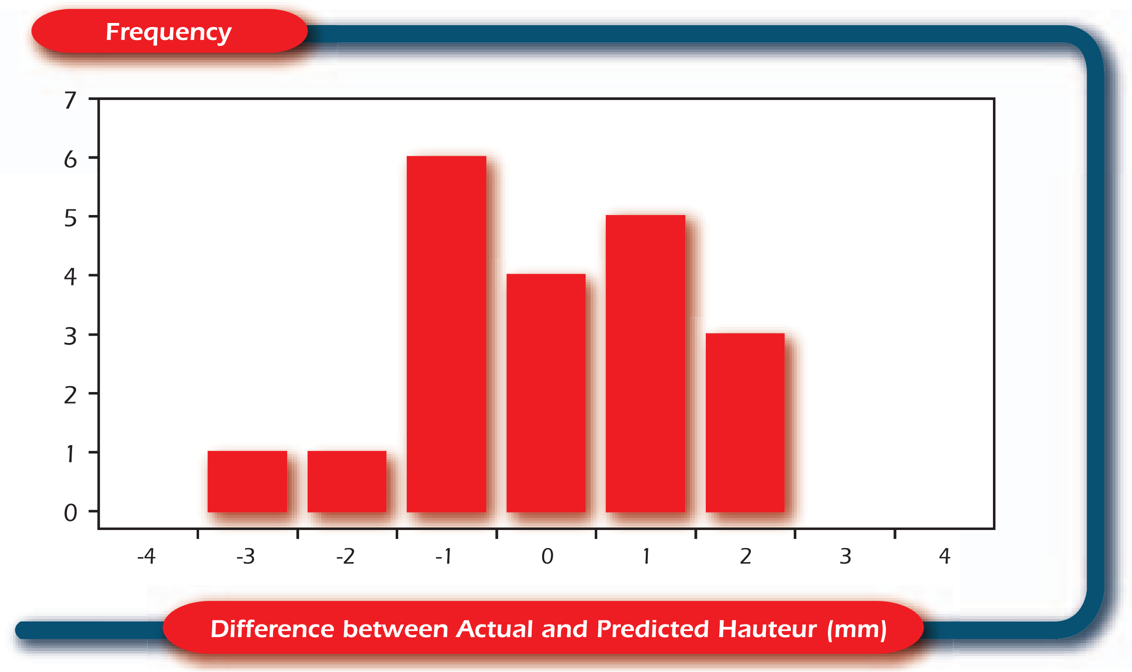

Figure A3.3 Histogram of Differences: Actual Predicted Hauteur when Mill Adjusted Formula is Applied

A3.2 Calculation of Mill-Specific Coefficients and Terms

Once more data is available, alternative techniques can be used to create a mill specific Hauteur formula. The first step to modify the formula beyond a simple adjustment is to examine the relationship of the differences between the actual and predicted Hauteurs for each of the major raw wool characteristics. This should only be attempted when a database of 100 to 200 consignments is obtained. This database should be representative of the wool types the mill expects to process in the future.

The first step is to identify obvious trends by graphing the differences between actual and predicted Hauteur for the measured raw wool characteristics, including those used in the general formula. If a trend is identified, a further adjustment procedure can be conducted.

As an example from a theoretical mill, Figure A3.4 shows the differences between actual and predicted Hauteur plotted against Staple Length (mm). An obvious trend is evident in this graph in that as SL increases, the differences between actual and predicted Hauteur become larger. It would appear that an adjustment to the formula is required for this mill based on these results. One technique that can be used to achieve this is to determine a linear regression equation of the differences. This equation is shown on Figure A3.4. This equation can be added to the previously adjusted Hauteur formula so that the fully adjusted general formula for this mill would be:

$$H_m = 0.43L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 21.8 + (0.15L - 10.7)$$

$$H_m = 0.58L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 11.1$$

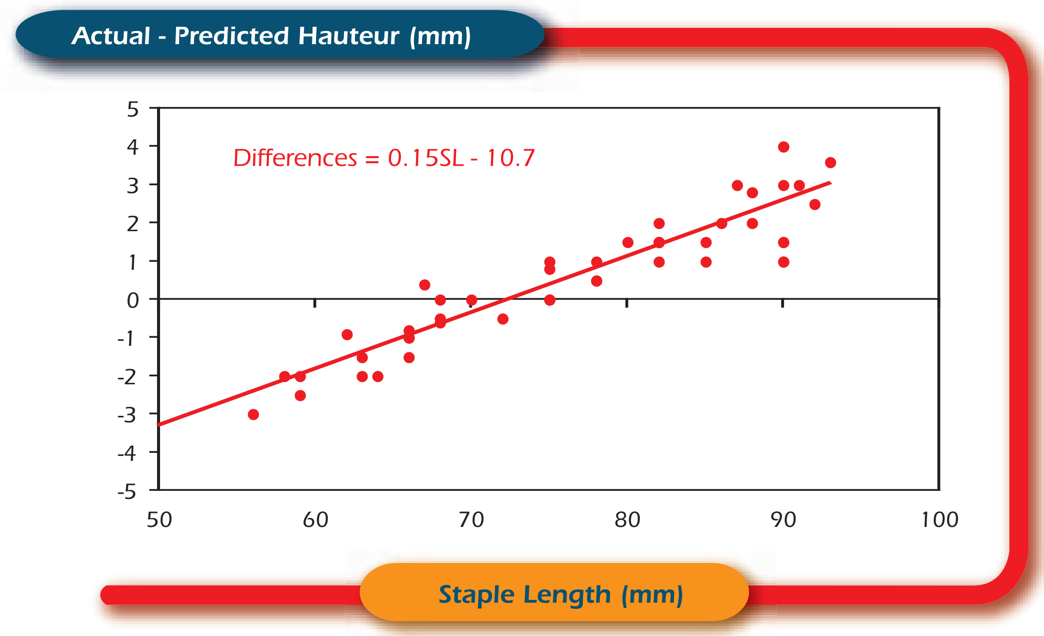

Figure A3.4 Hauteur Differences as a Function of Vegetable Matter Base

A3.3 Adjustment of the Hauteur Formula for Specific Requirements

As more data is obtained, alternative techniques can be considered that group the differences between actual and predicted Hauteur according to a variety of different factors. These factors may include wool type, Vegetable Matter type etc. This technique can be used as an alternative to that described above when there are a number of non-measurable parameters that may influence processing results.

It can also be applied to separate processing lines within the same mill to establish separate adjustments for each line and to account for differences between the lines.

Appendix 4

Correlation Matrix for TEAM-3 Data Base

	WB	MFD	CVD	CF	MFC	VMB	SL	CVL	SS	MID	Romaine	FEFD	FECF	Top MFD	Top CVD	Top CF	Hauteur	CVH
WB	1.00	-0.18	-0.75	0.29	0.33	-0.43	0.11	-0.50	0.48	-0.04	-0.24	-0.21	-0.01	-0.17	-0.58	0.25	0.14	-0.03
MFD	-0.18	1.00	0.16	-0.89	-0.91	0.05	0.73	-0.13	0.04	-0.09	-0.68	0.97	-0.02	0.99	0.43	-0.91	0.65	-0.01
CVD	-0.75	0.16	1.00	-0.34	-0.29	0.15	-0.05	0.51	-0.54	-0.02	0.16	0.20	0.03	0.14	0.77	-0.27	-0.18	0.14
CF	0.29	-0.89	-0.34	1.00	0.77	-0.10	-0.55	-0.03	0.01	0.10	0.51	-0.87	0.03	-0.88	-0.47	0.97	-0.52	0.04
MFC	0.33	-0.91	-0.29	0.77	1.00	-0.08	-0.70	0.03	0.15	0.01	0.57	-0.90	0.00	-0.91	-0.57	0.80	-0.55	-0.09
VMB	-0.43	0.05	0.15	-0.10	-0.08	1.00	-0.21	0.43	0.01	0.05	0.29	0.04	-0.01	0.06	0.12	-0.10	-0.01	-0.19
SL	0.11	0.73	-0.05	-0.55	-0.70	-0.21	1.00	-0.47	-0.22	0.07	-0.67	0.73	0.02	0.73	0.25	-0.59	0.57	0.29
CVL	-0.50	-0.13	0.51	-0.03	0.03	0.43	-0.47	1.00	-0.11	0.12	0.44	-0.10	0.03	-0.13	0.30	0.02	-0.34	0.04
SS	0.48	0.04	-0.54	0.01	0.15	0.01	-0.22	-0.11	1.00	-0.27	-0.20	-0.02	-0.07	0.05	-0.49	0.00	0.29	-0.53
MID	-0.04	-0.09	-0.02	0.10	0.01	0.05	0.07	0.12	-0.27	1.00	0.10	-0.04	0.03	-0.10	-0.02	0.10	-0.33	0.54
Romaine	-0.24	-0.68	0.16	0.51	0.57	0.29	-0.67	0.44	-0.20	0.10	1.00	-0.67	0.02	-0.68	-0.14	0.55	-0.65	0.06
FEFD	-0.21	0.97	0.20	-0.87	-0.90	0.04	0.73	-0.10	-0.02	-0.04	-0.67	1.00	-0.03	0.97	0.46	-0.88	0.63	0.03
FECF	-0.01	-0.02	0.03	0.03	0.00	-0.01	0.02	0.03	-0.07	0.03	0.02	-0.03	1.00	-0.02	0.00	0.03	-0.05	0.04
Top MFD	-0.17	0.99	0.14	-0.88	-0.91	0.06	0.73	-0.13	0.05	-0.10	-0.68	0.97	-0.02	1.00	0.43	-0.91	0.65	-0.02
Top CVD	-0.58	0.43	0.77	-0.47	-0.57	0.12	0.25	0.30	-0.49	-0.02	-0.14	0.46	0.00	0.43	1.00	-0.49	0.04	0.19
Top CF	0.25	-0.91	-0.27	0.97	0.80	-0.10	-0.59	0.02	0.00	0.10	0.55	-0.88	0.03	-0.91	-0.49	1.00	-0.55	0.05
Hauteur	0.14	0.65	-0.18	-0.52	-0.55	-0.01	0.57	-0.34	0.29	-0.33	-0.65	0.63	-0.05	0.65	0.04	-0.55	1.00	-0.50
CVH	-0.03	-0.01	0.14	0.04	-0.10	-0.19	0.29	0.04	-0.53	0.54	0.06	0.03	0.04	-0.02	0.19	0.05	-0.50	1.00

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