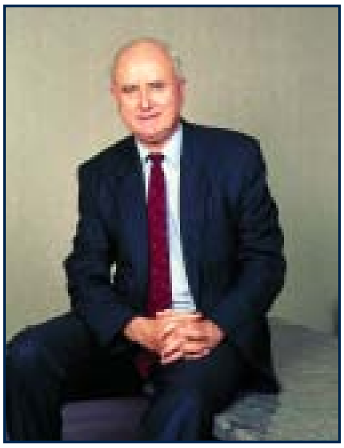
Report on Trials Evaluating Additional Measurements 1981 – 1988

December 1988



This reprint of the TEAM 1 and TEAM 2 reports has been prepared to commemorate the retirement in March 2001 of the Deputy Managing Director of AWTA Ltd, Mr Sas Douglas, after more than 30 years service. Sas is widely recognised in the wool industry all over the world, having developed a significant profile through his activities within Australia and overseas, and his regular participation at IWTO Congresses.

Sas graduated with a Bachelor of Science (Honours II) in Wool Technology from the University of New South Wales in 1964. He was the Officer in Charge of the University's Wool Testing Laboratory from January 1961 to July 1962. Subsequently he worked as a Technical Officer for Agserv Industries Pty Ltd for 3 years, and followed that with a 3-year stint as Technical Manager for one of AWTA Ltd's early competitors, Auscore Testing Pty Ltd, Sydney. He then worked for the Bureau of Agricultural Economics (BAE) in Canberra in the capacity of Principal Research Officer, Wool Marketing Section for 2 years. In September 1970 he joined the then Statutory AWTA in the capacity of Assistant Director. He subsequently served as Deputy Director from 1972 to 1982. When the Statutory Authority was privatised in 1982 he became General Manager - Operations. In 1986 he became Deputy Managing Director.

Sas's Masters Thesis was on the subject of Sale by Objective Measurement, providing an early indication of his special interest in the modernisation of wool selling and marketing systems. While employed by the BAE he was a member of the Australian Objective Measurement Project Technical Committee.

Although Sas's career includes many significant milestones, he will undoubtedly be remembered for his major role in the early development of the IWTO Specification for Staple Length & Strength. Sas was a member of the TEAM 1 Project Management Committee and was the Chairman of the TEAM 2 Project Management Committee. Apart from this important work he also managed AWTA Ltd's internal research effort to develop more efficient sampling systems for staple measurement.

Leaders are remembered for their achievements. Sas has always been a team player and modest in acknowledging his own achievements. To him the TEAM Project was indeed a team effort, and succeeded because of the commitment of the industry organisations, the various companies and individuals who participated in the project. However, while this has to be recognised, Sas's personal contribution must not be understated. Not only within the TEAM Project Management Committee, but also within AWTA Ltd, Sas directed his intellectual capacity, his commercial acumen and his enormous energy and capacity for hard work towards a successful outcome to the project.

The measure of this success is the current uptake of Staple Measurements within Australia. It is now approaching 80% of all bales tested, and has grown continually despite early hiccups in 1986 and 1987. Of all the milestones Sas has achieved, perhaps the most significant is his contribution to the success of TEAM.

TEAM

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

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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.

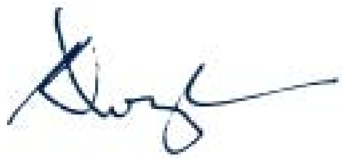
An important aspect of these trials is that they represent actual industrial practice. This means it is possible for immediate industrial application of the findings, as well as demonstrating to individual processors and topmakers the use of prediction techniques for their own applications.

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

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:

$$H = 0.45L + 0.41S + 0.70D - 5.7 \qquad (1)$$

For consignments of skirtings, the formula was:

$$H = 0.40L + 0.32S + 1.53D - 20.1 \qquad (2)$$

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:

$$H = 0.47L + 0.42S + 0.85D - 0.44V - 11.8 \qquad (3)$$

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

CHARACTERISTIC	TEAM-1 MIN	TEAM-1 MAX	TEAM-1 MEAN SD	TEAM-2 MIN	TEAM-2 MAX	TEAM-2 MEAN SD	TOTAL DATABASE MIN	TOTAL DATABASE MAX	TOTAL DATABASE 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

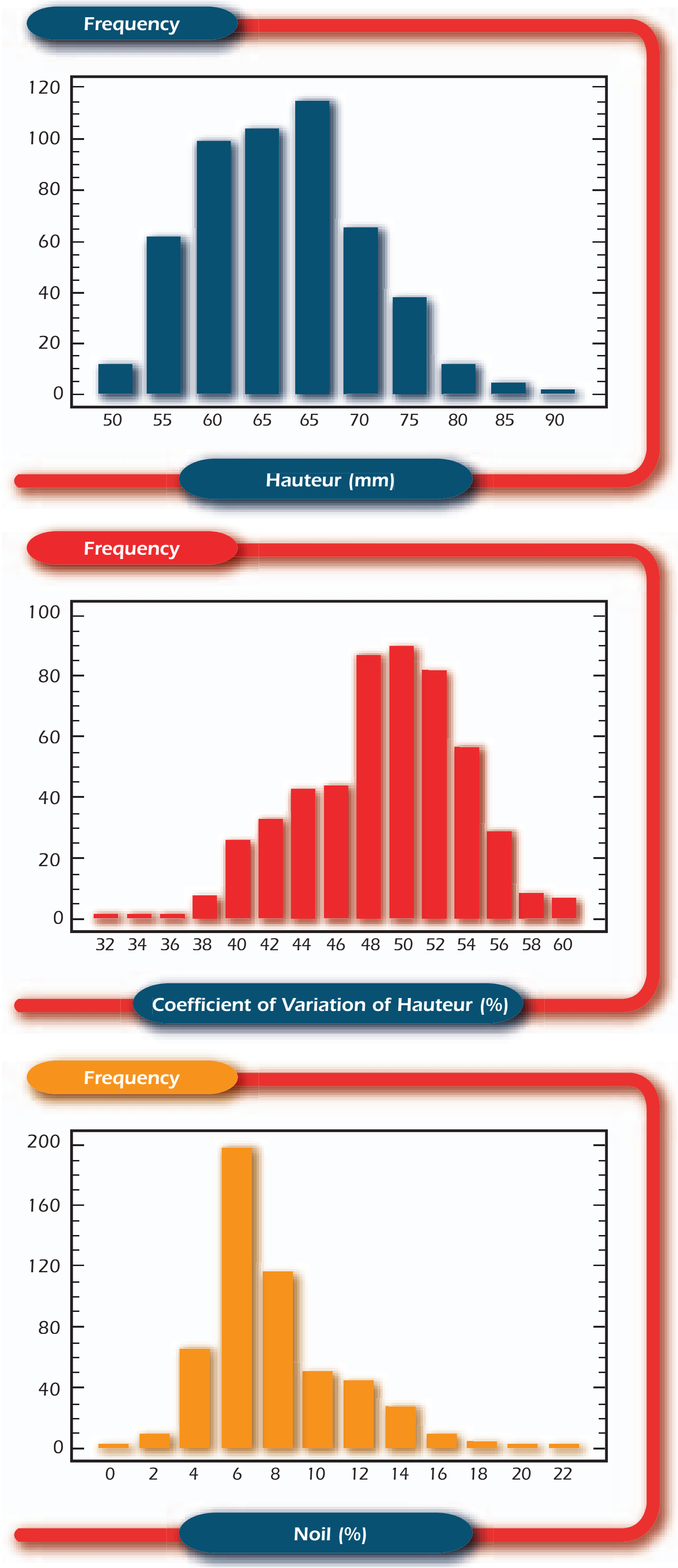
1. Final Report TEAM Project, January, 1985

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.



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.

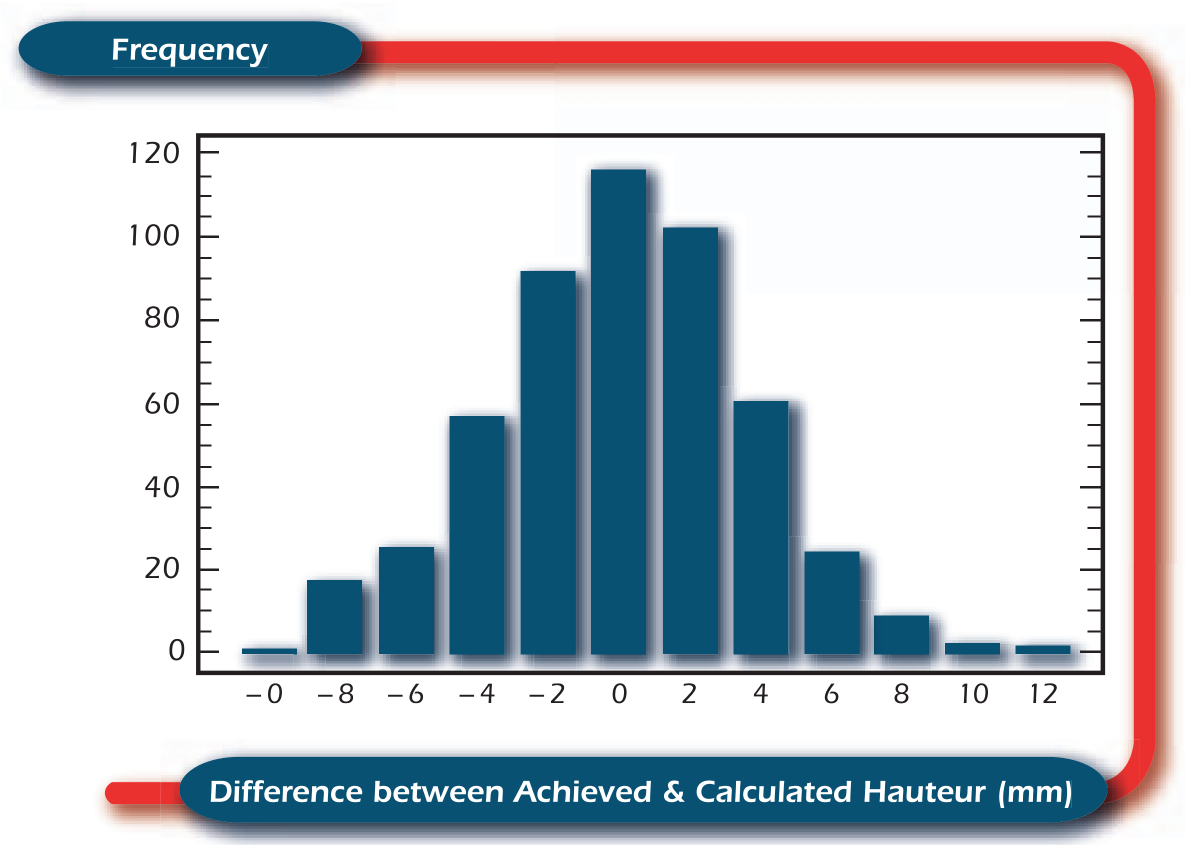
The values of these statistics found for the above general formula (4) are:

$100R^2 = 81\%$ 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:

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

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:

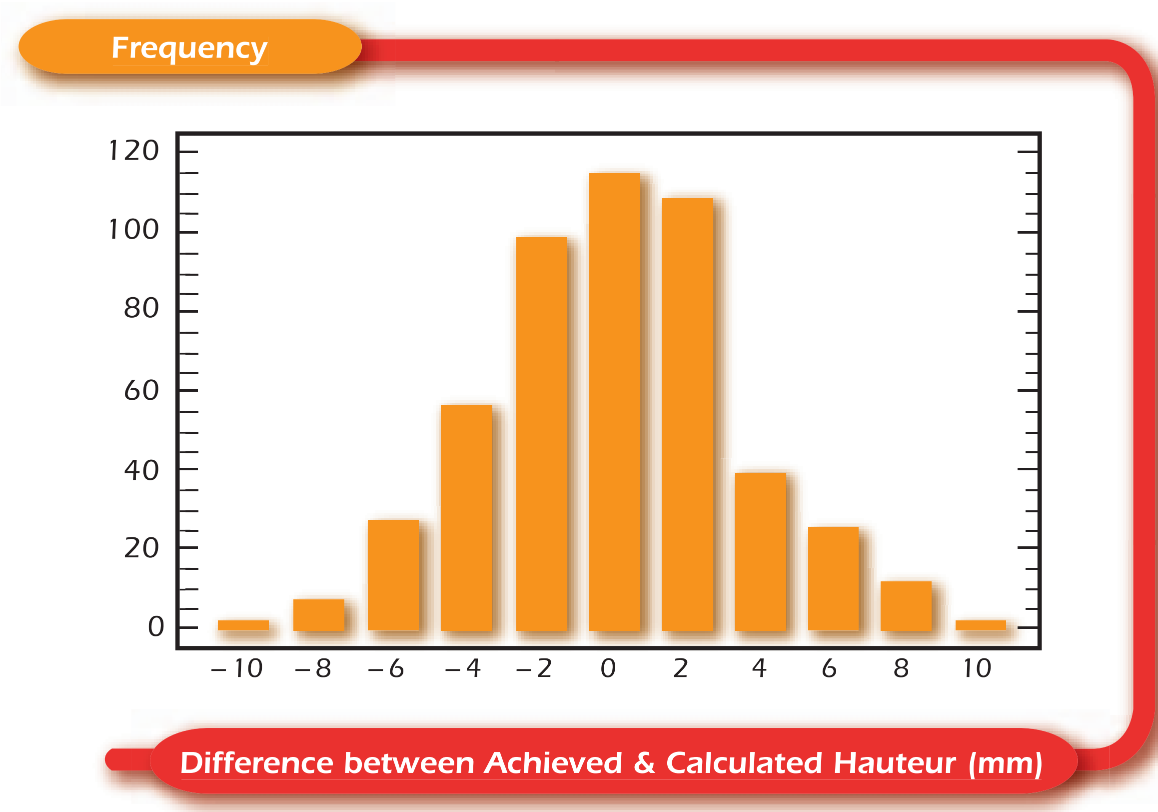
$$H = 0.52L + 0.47S + 0.95D - 0.45V - 0.19M^* + C \quad \text{.................(6)}$$

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.

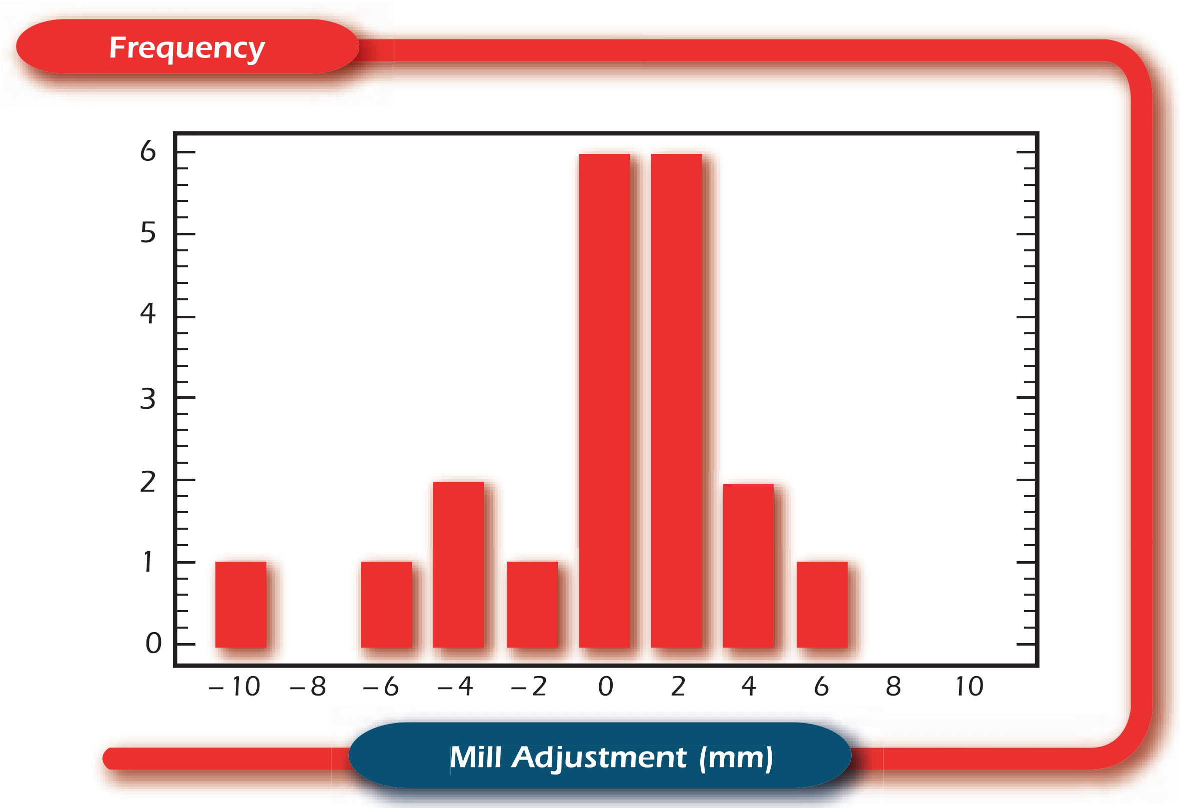
Thus, the complete formula for mill prediction of Hauteur now is:

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

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:

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

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

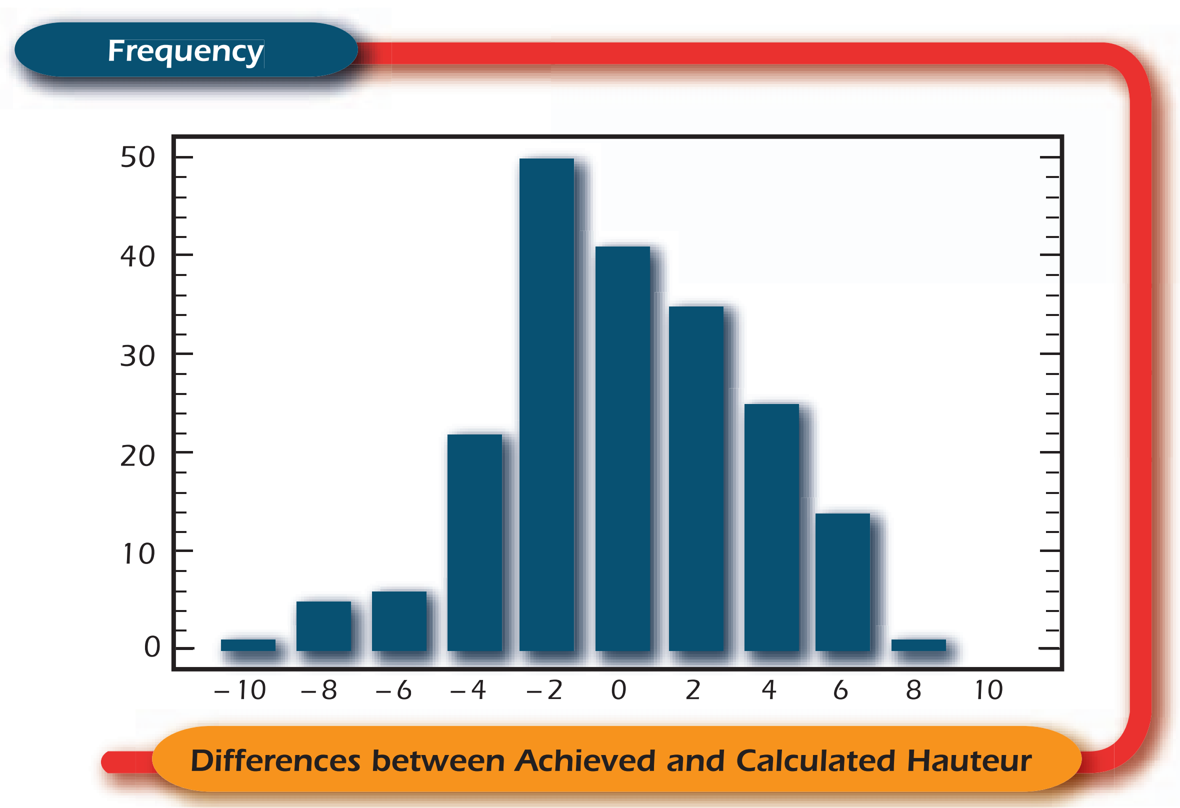
IMPORTANCE OF SELECTED RAW WOOL CHARACTERISTICS RELATIVE TO STAPLE LENGTH FOR THE PREDICTION OF HAUTEUR

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:

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

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:

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

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.

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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:

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

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%.

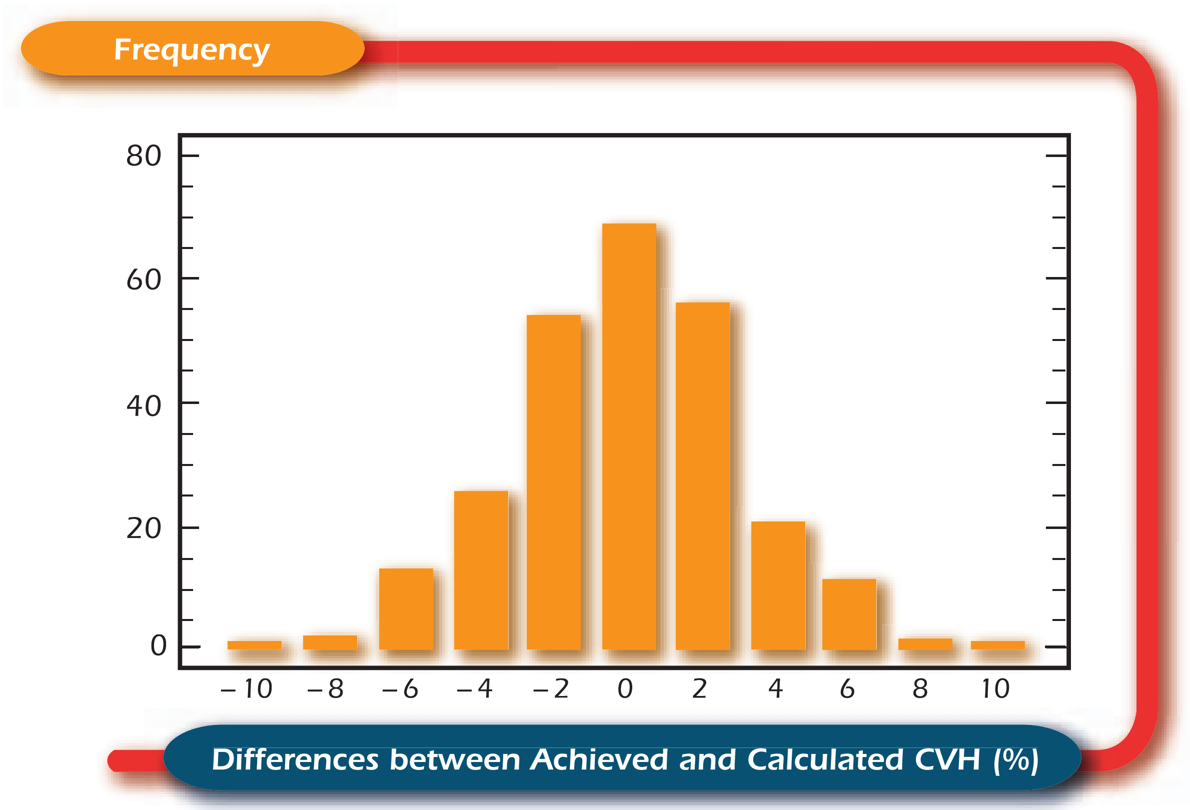
ADDENDUM TO TEAM REPORT

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:

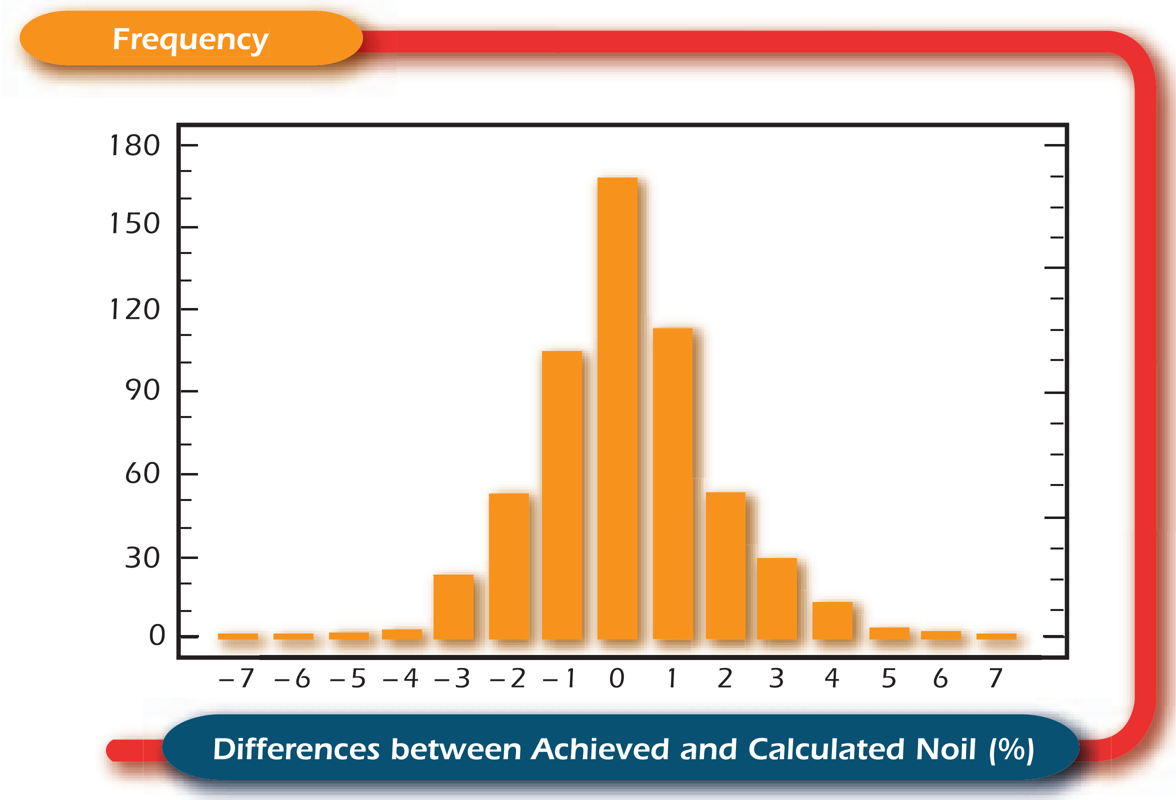
$$N = -0.11L - 0.14S - 0.35D + 0.94v + 27.7 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

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.O%. 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.

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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:

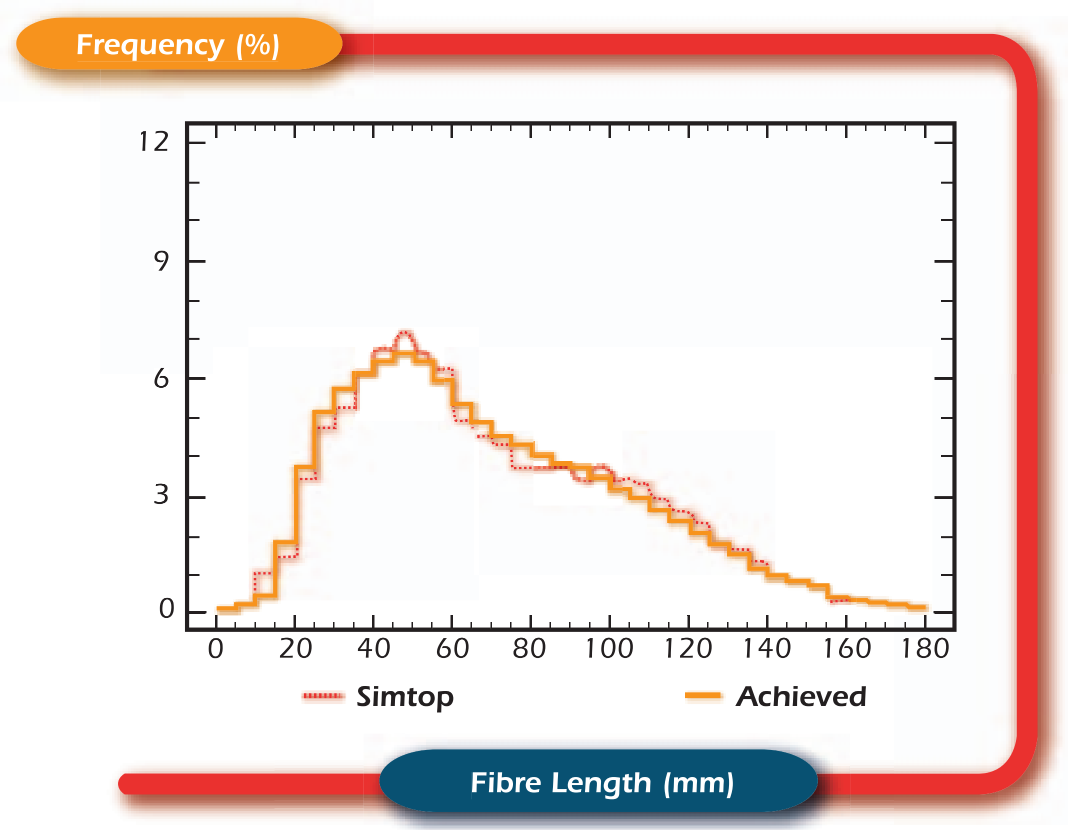
Stage 1 simulates the breaking of each fibre, taking into account its strength (based on the staple strength), its length and the fibre diameter of the wool from which it came. All broken fibres are then allocated into new fibre length groups. This is called the *Weak Point Break* simulation.

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.

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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

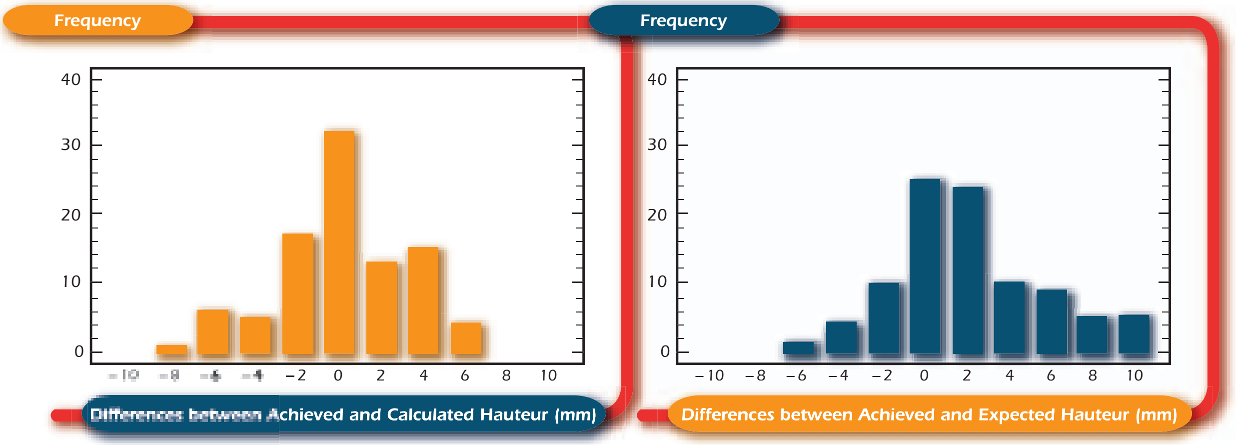
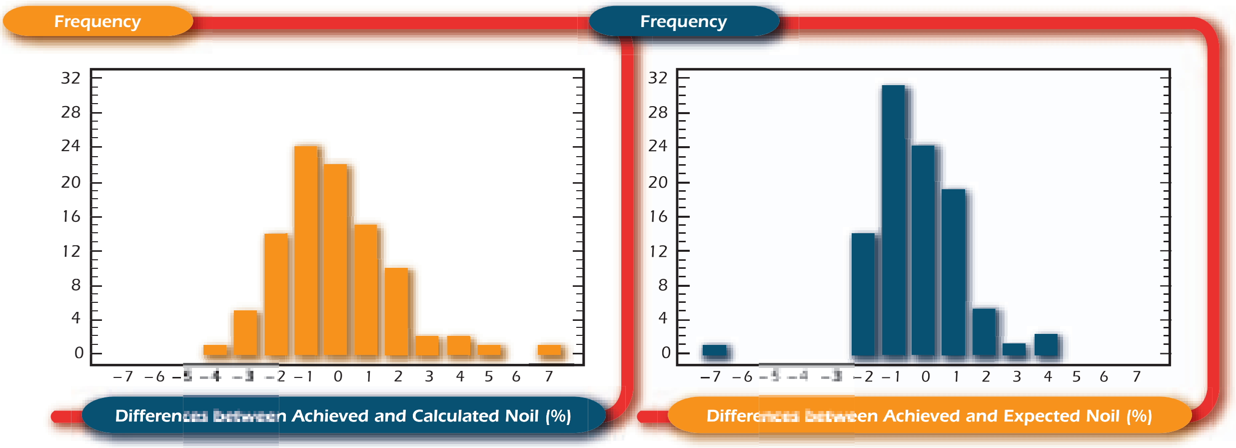


FIGURE 11
HISTOGRAMS OF DIFFERENCES BETWEEN ACHIEVED RESULTS AND CALCULATED AND EXPECTED RESULTS FOR NOIL



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.

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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.

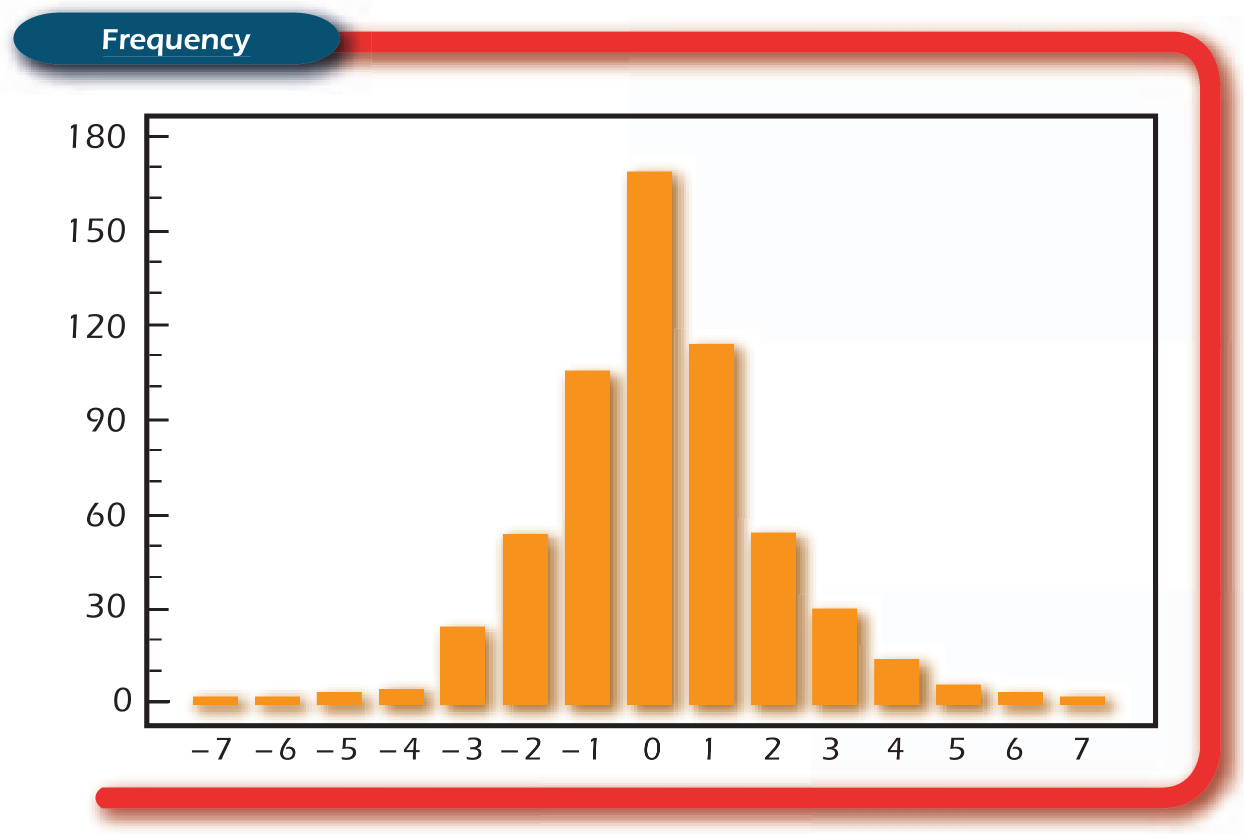
7.3 Comparison of Mill Top and Noil Yield with Coretest

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

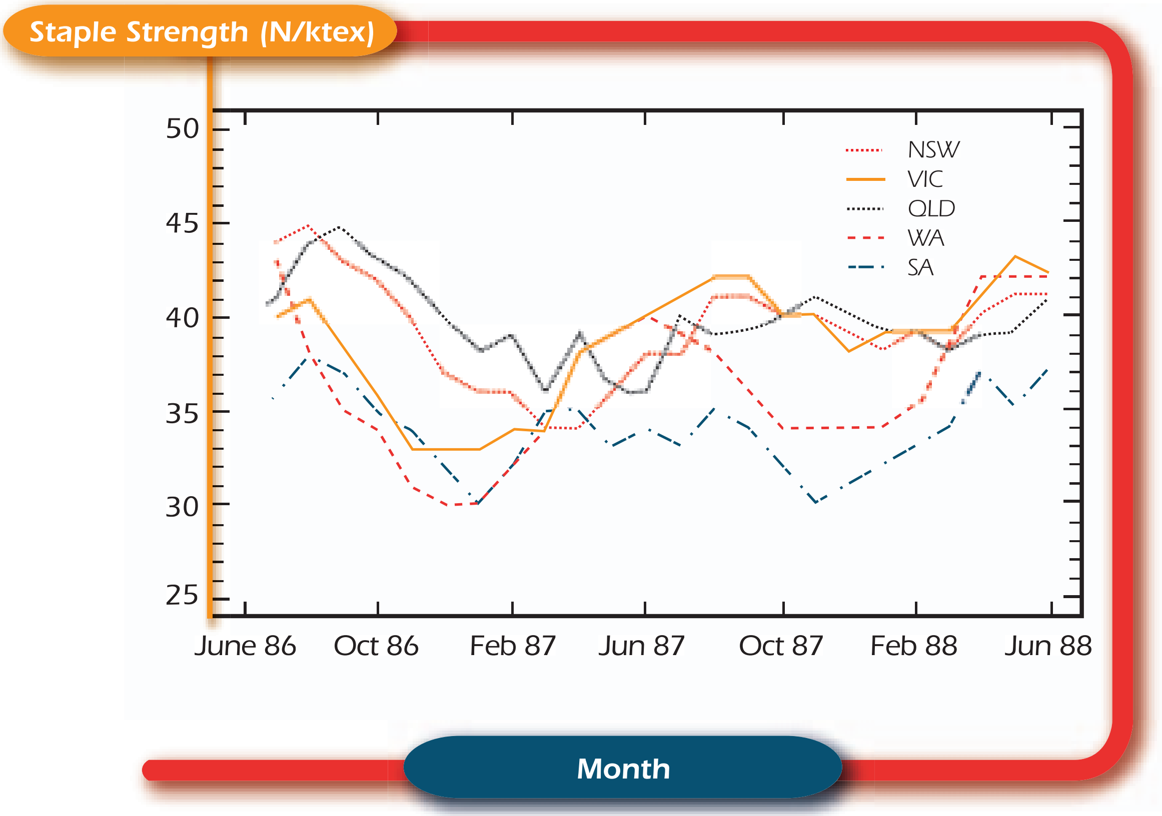
In Australia during 1988/89, more than 20% of all combing wool is expected to be measured for staple length and staple strength before sale. These results, together with the coretest data for yield, vegetable matter base and fibre diameter will be available in auction sale catalogues to assist valuation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

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

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 . . . .%

% < 30 mm . . . .%

% < 35 mm . . . .%

% < 40 mm . . . .%

Length (Hauteur) > 5% . . . . .mm

Length (Hauteur) > I% . . . . .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 > IOmm . . . . .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.

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.

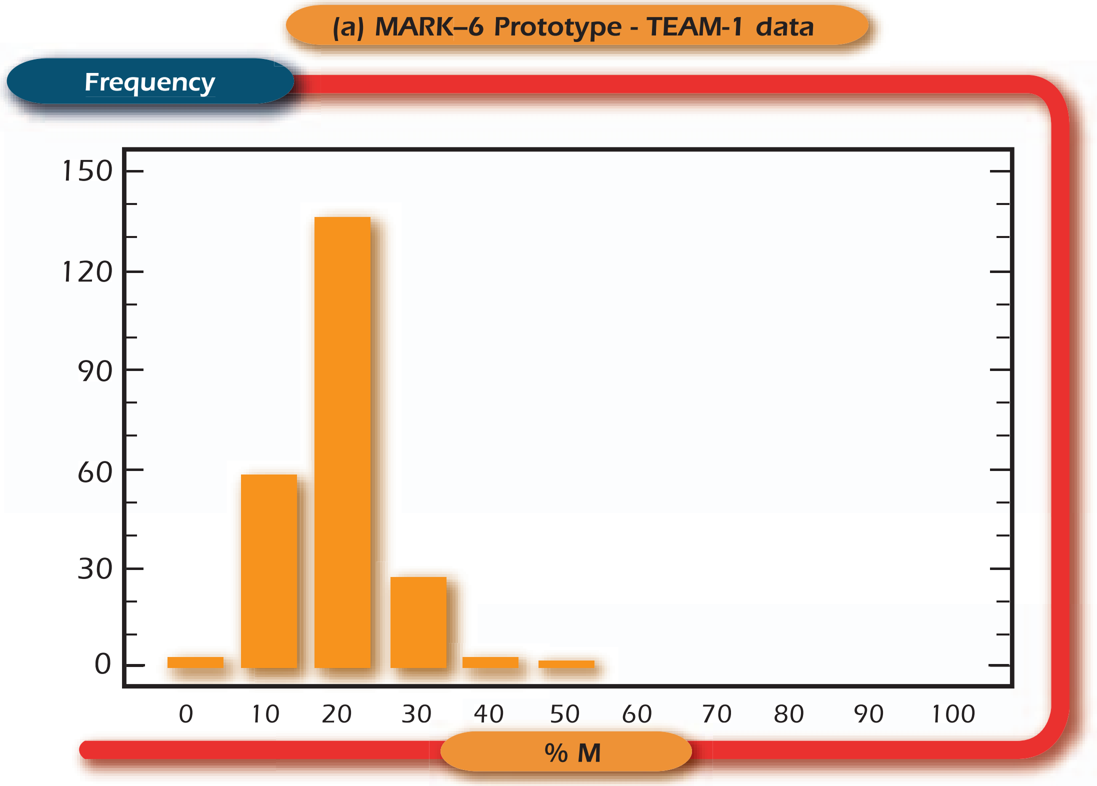
Examination of the measurements from the TEAM-1 data compared to the TEAM-2 data, highlighted a major difference between the distributions for the POB of individual staples. The difference is demonstrated in Figure 14 by looking at the percentage of staples that were recorded to have broken in the middle (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.



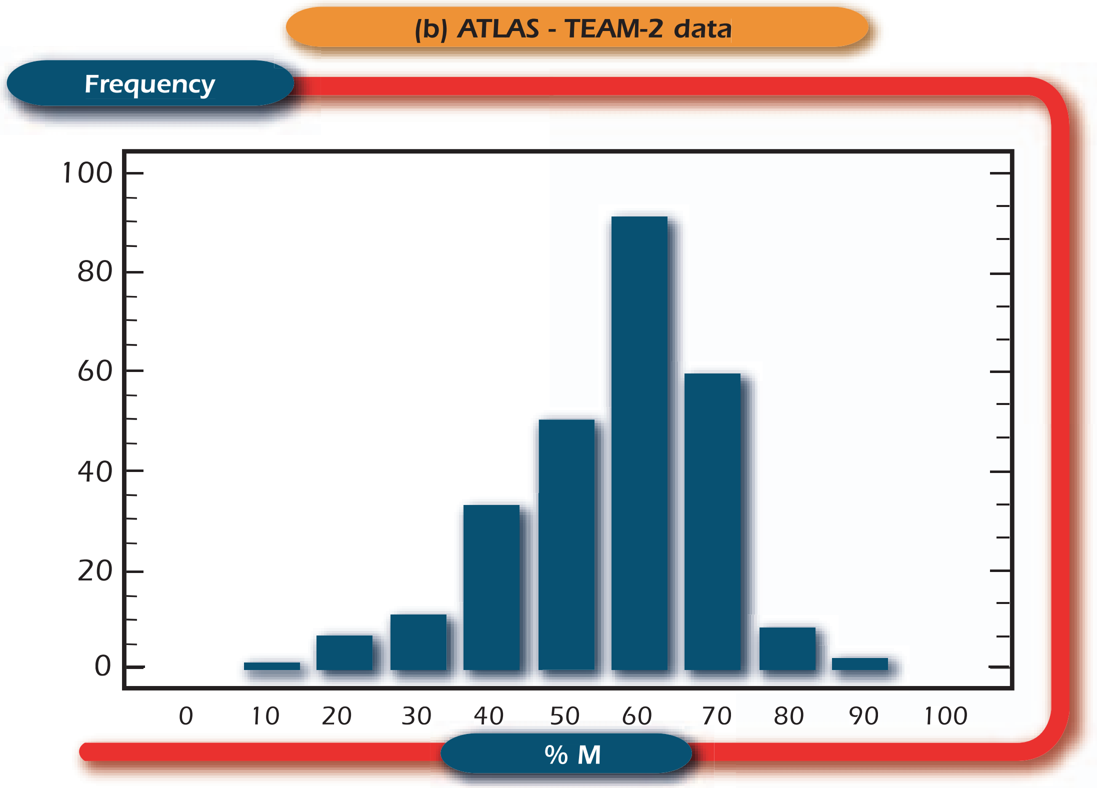
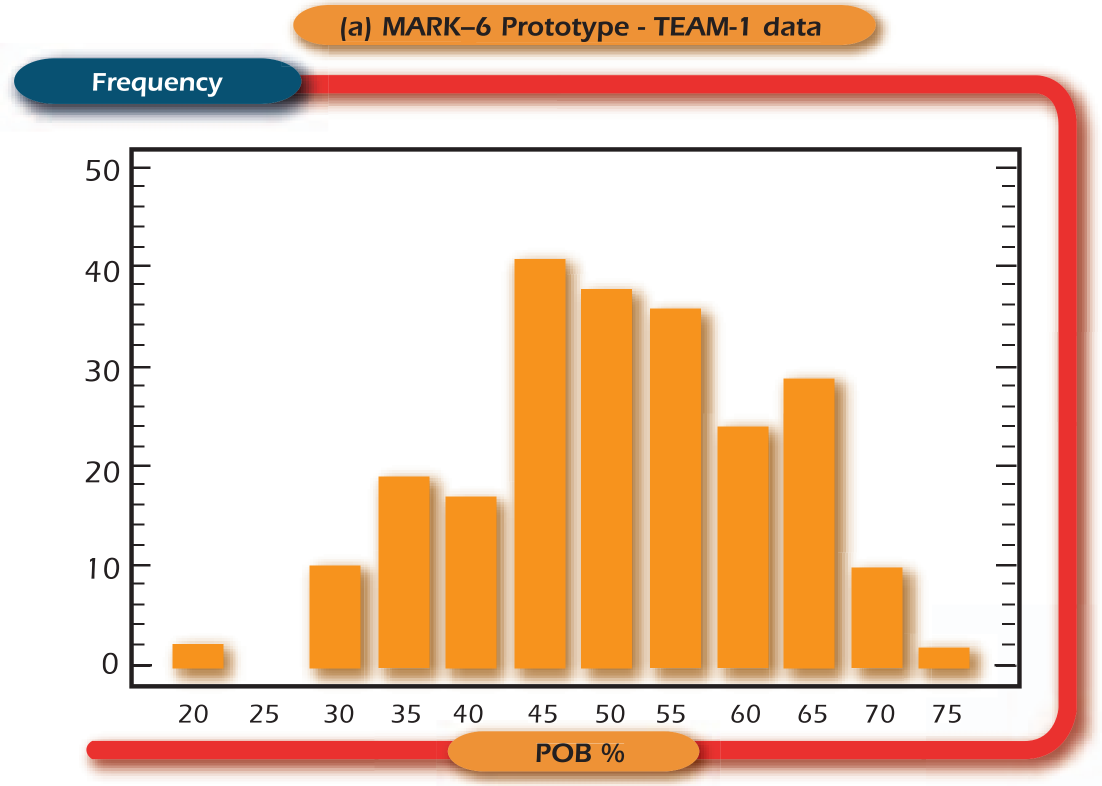
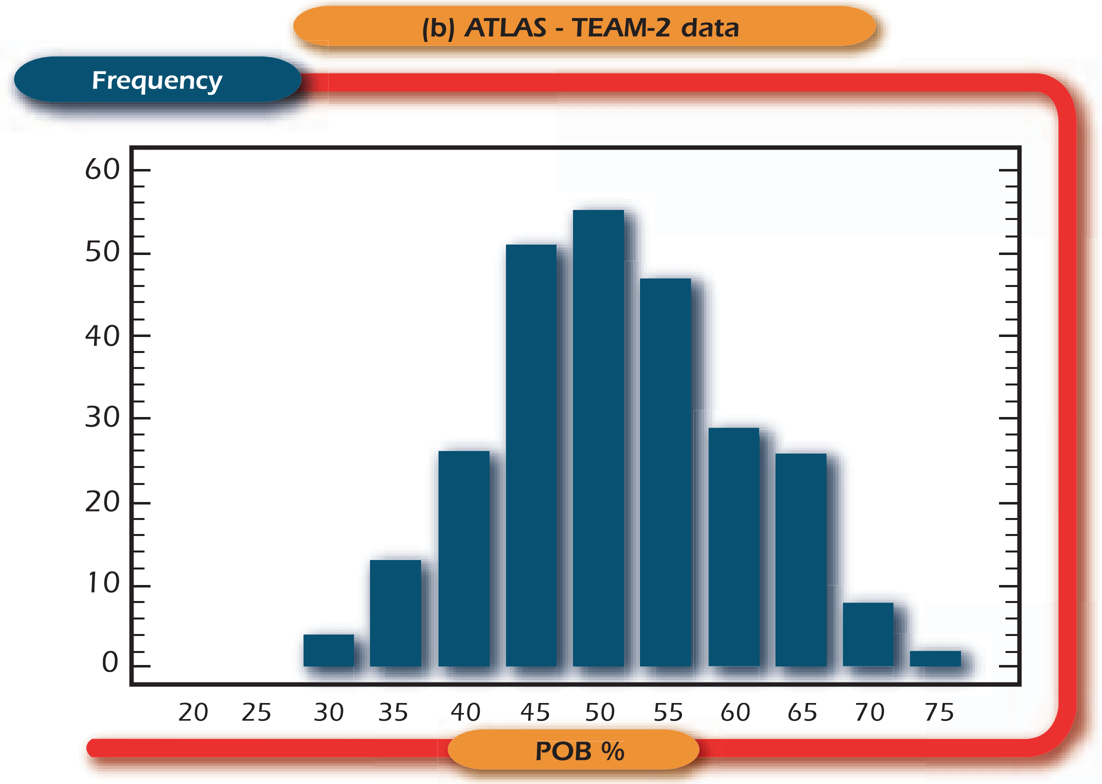


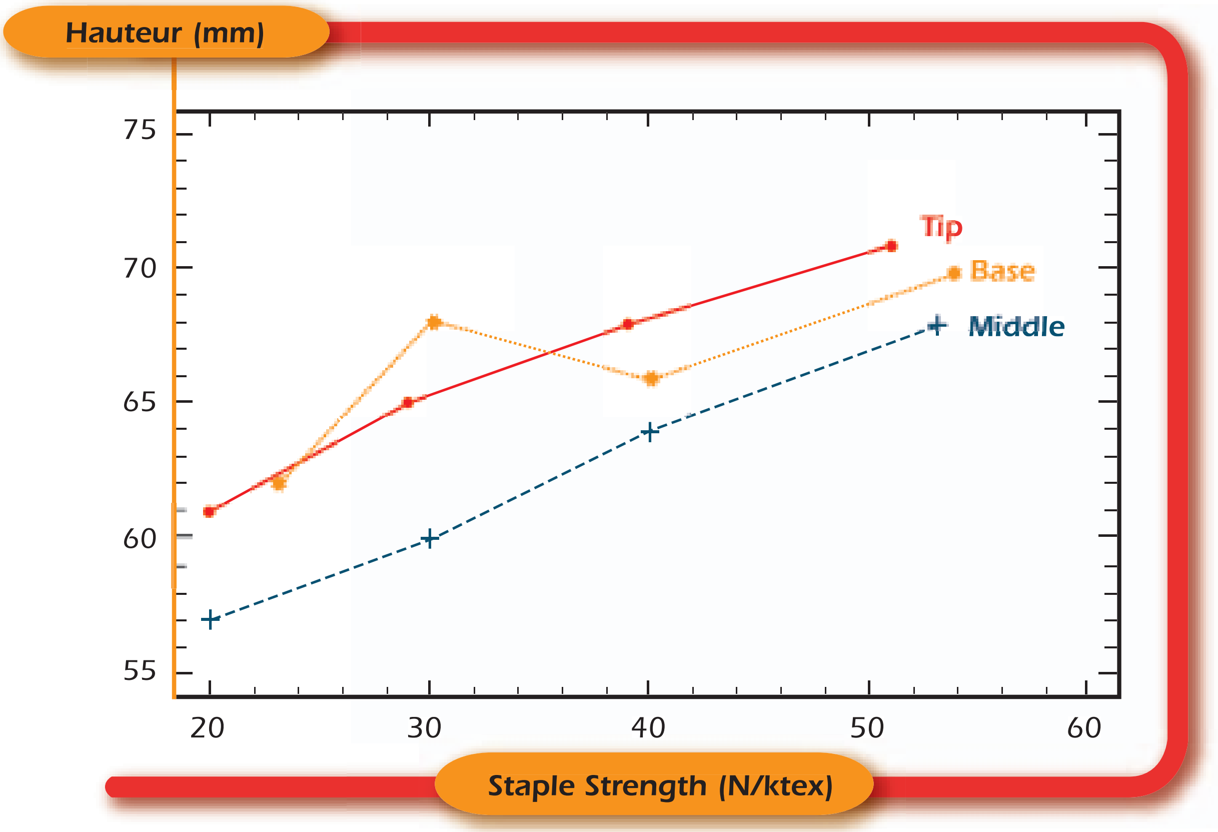
FIGURE 15
FREQUENCY DISTRIBUTIONS OF THE AVERAGE POSITION OF BREAK (POB)
FOR INDIVIDUAL CONSIGNMENTS ESTIMATED FROM
THE MARK-6 PROTOTYPE (TEAM-1 DATA) AND ATLAS (TEAM-2 DATA).





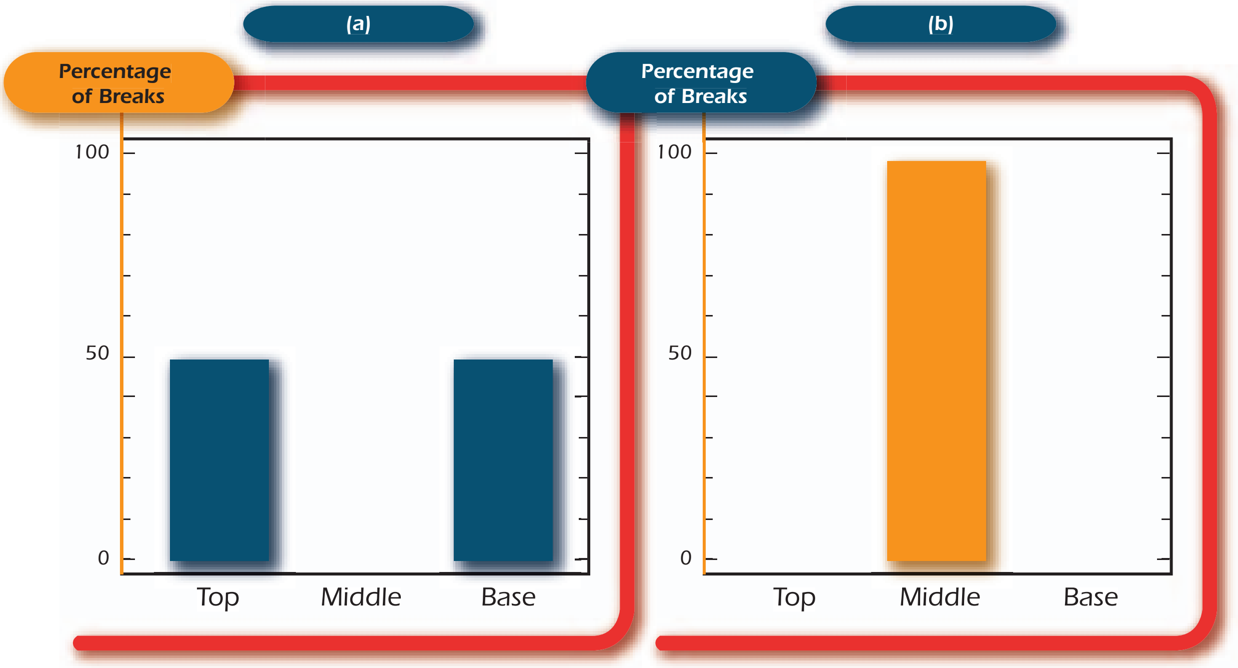
Pilot-trial research ([5]) has also shown that POB has an influence on Hauteur when other raw wool characteristics are controlled. Figure 16 shows that wools selected to have predominantly either base or tip breaks behave almost identically in their relationship between staple strength and Hauteur whereas 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%



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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.

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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.

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

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

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

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

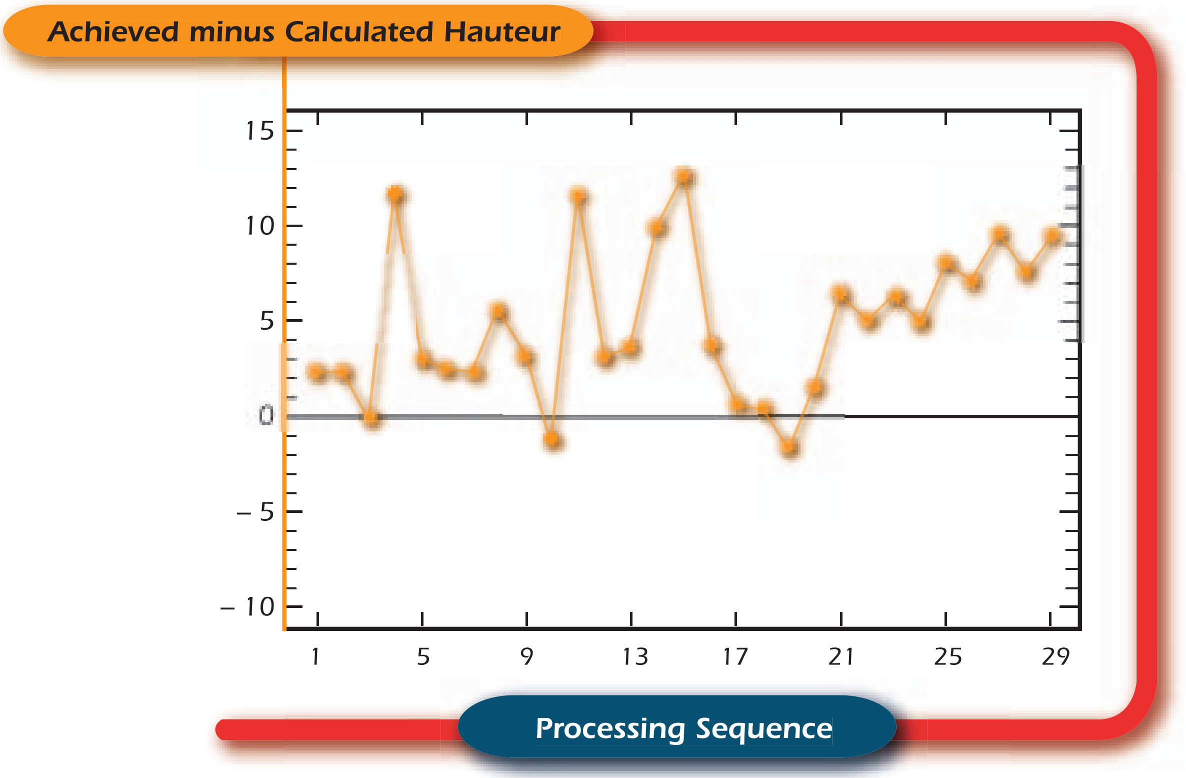
The next step is to establish the presence or absence of trends over time by preparing a graph of the differences between the achieved and calculated Hauteurs against either processing order or the actual time when processed (see Figure 18).

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:

H = 0.52L + 0.47S + 0.95D - 0.19M* - 0.45V + 1.3 . . . .(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

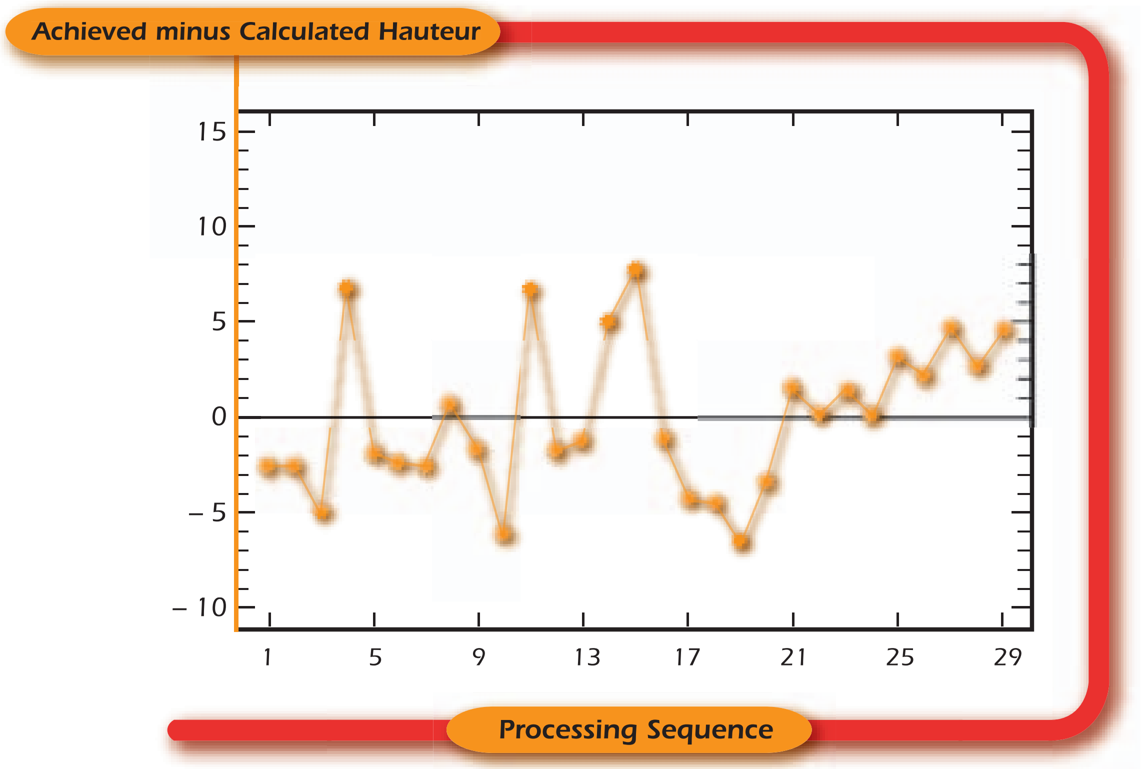
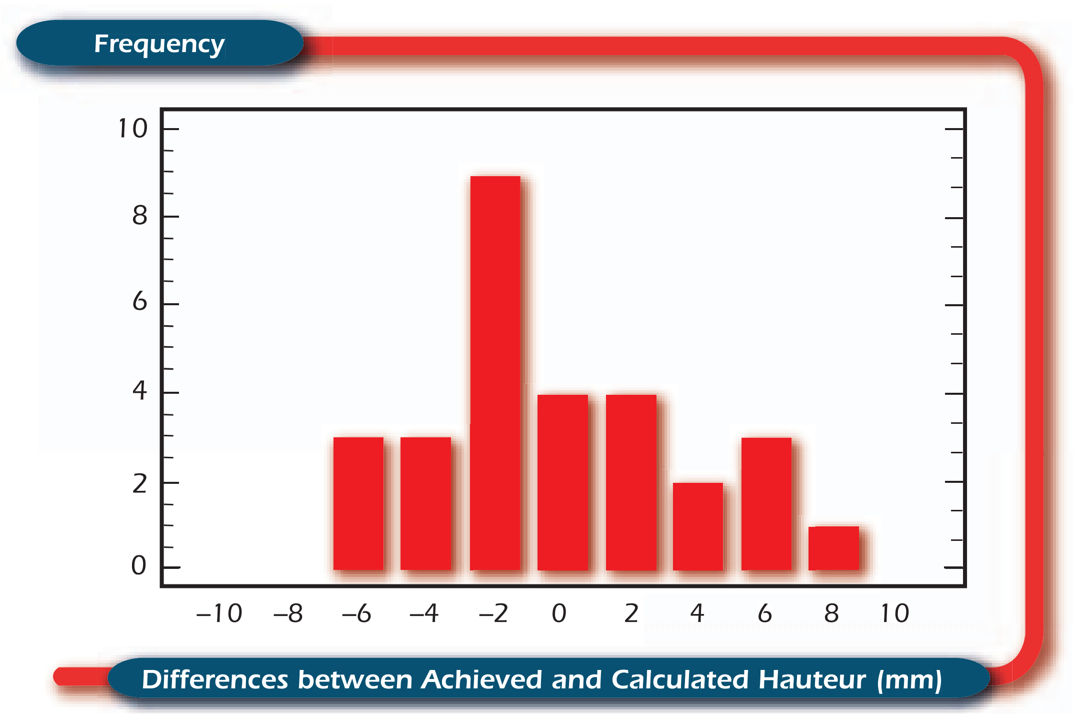


FIGURE 20
HISTOGRAM OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER ADJUSTMENT FOR MILL CONSTANT



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

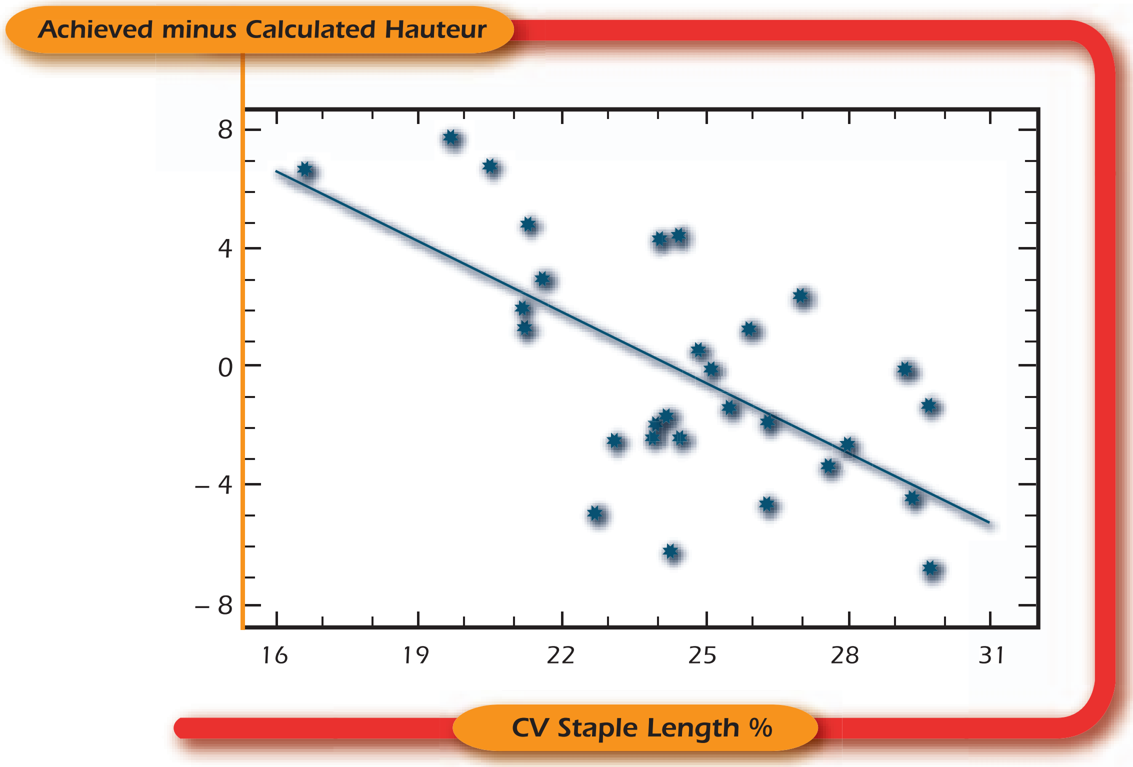


FIGURE 22
HISTOGRAM OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR AFTER ADJUSTMENT FOR MILL CONSTANT AND COEFFICIENT OF VARIATION OF STAPLE LENGTH

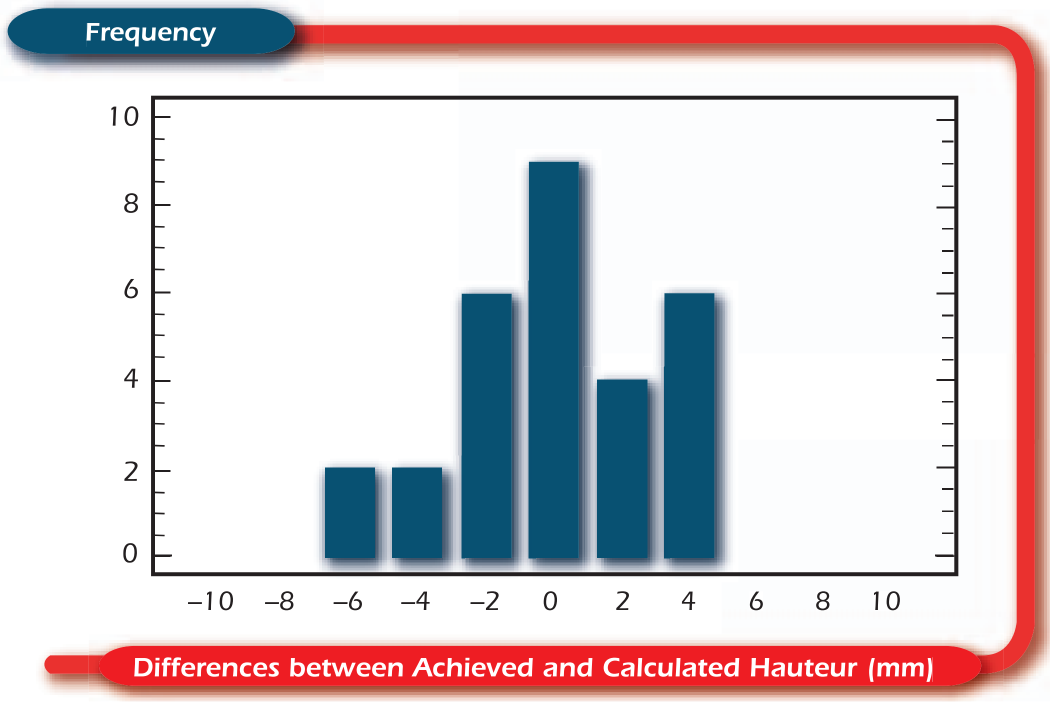
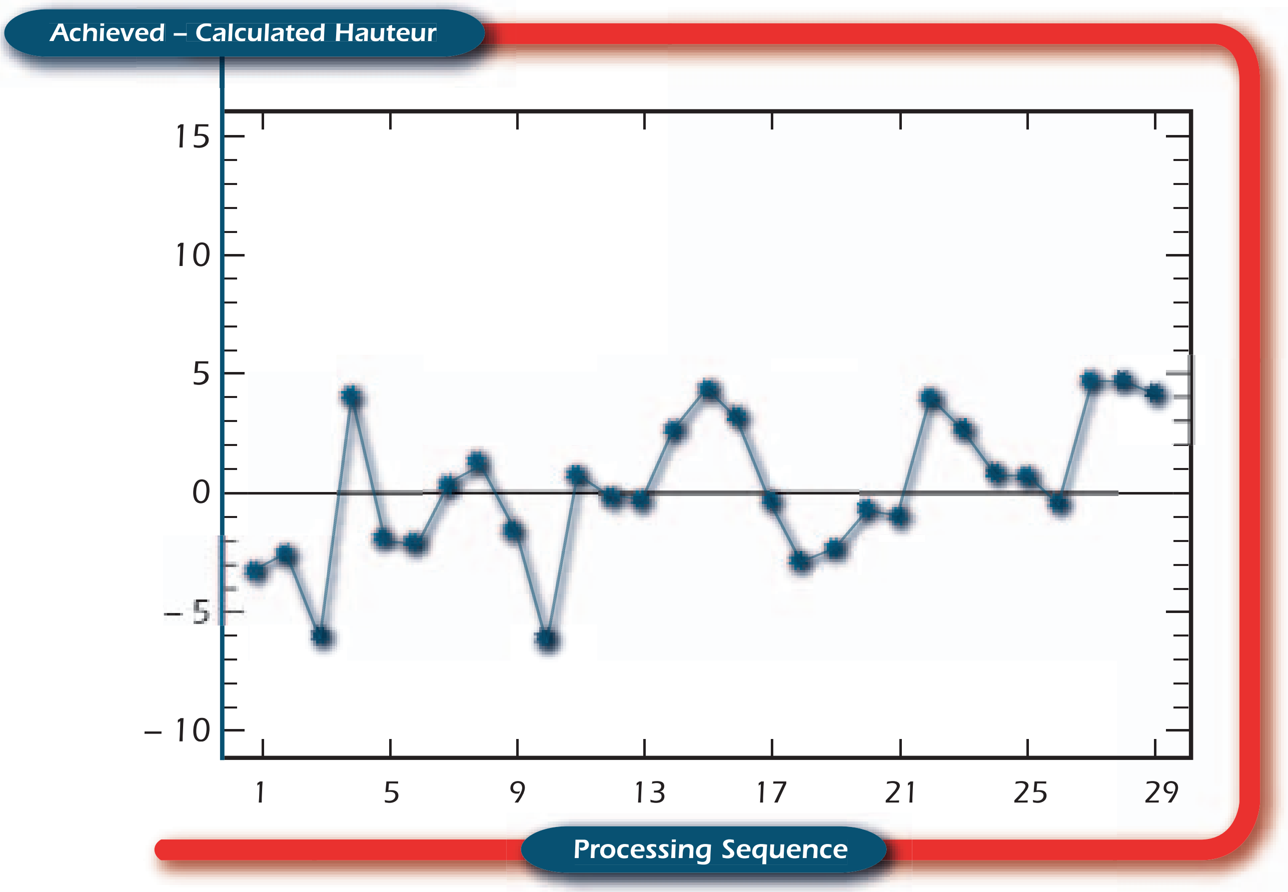


FIGURE 23
GRAPH OF DIFFERENCES - ACHIEVED MINUS CALCULATED HAUTEUR
AFTER ALL ADJUSTMENTS



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)	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

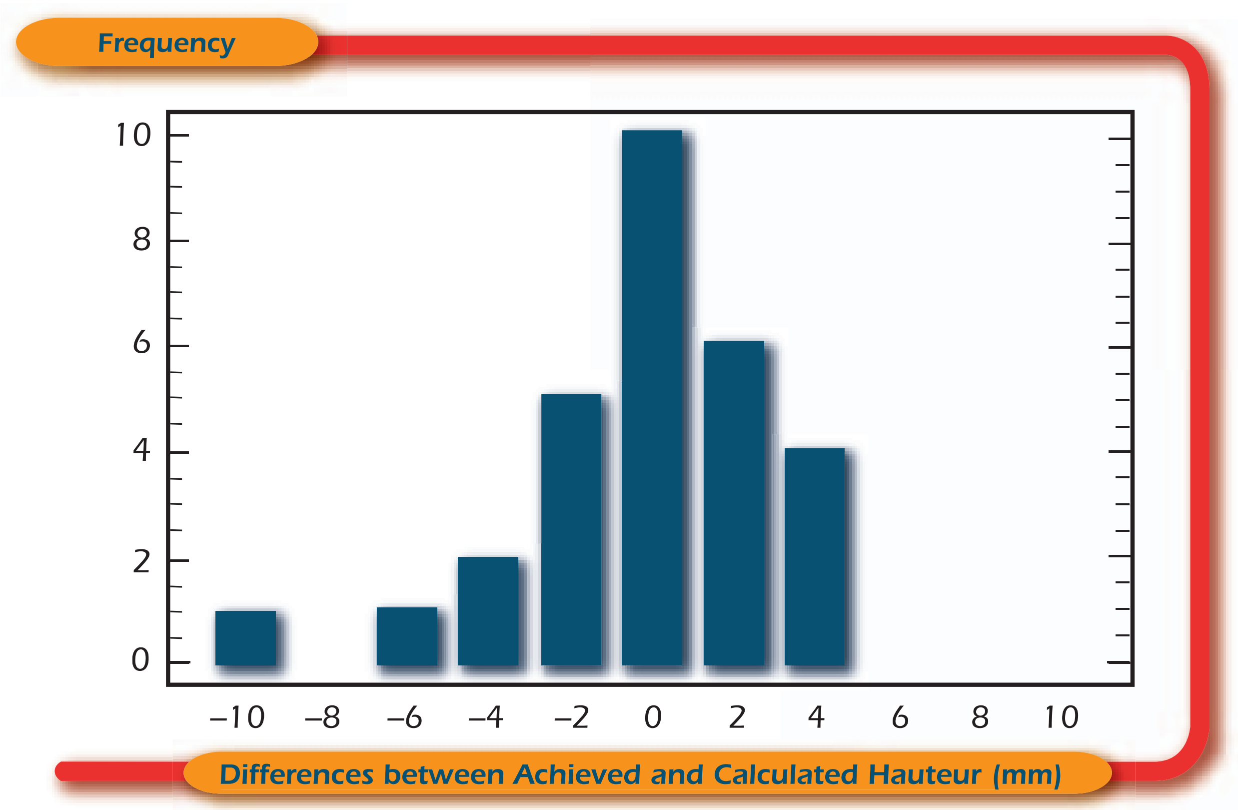
H = 0.52L + 0.47S + 0.95D - 0.19M* - 0.45V - O.71CVL + 21.7 . . . .(18)

– for skirtings

H = 0.52L + 0.47S + 0.95D - 0.19M* - 0.45V - O.71CVL + 16.9 . . . .(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.

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.

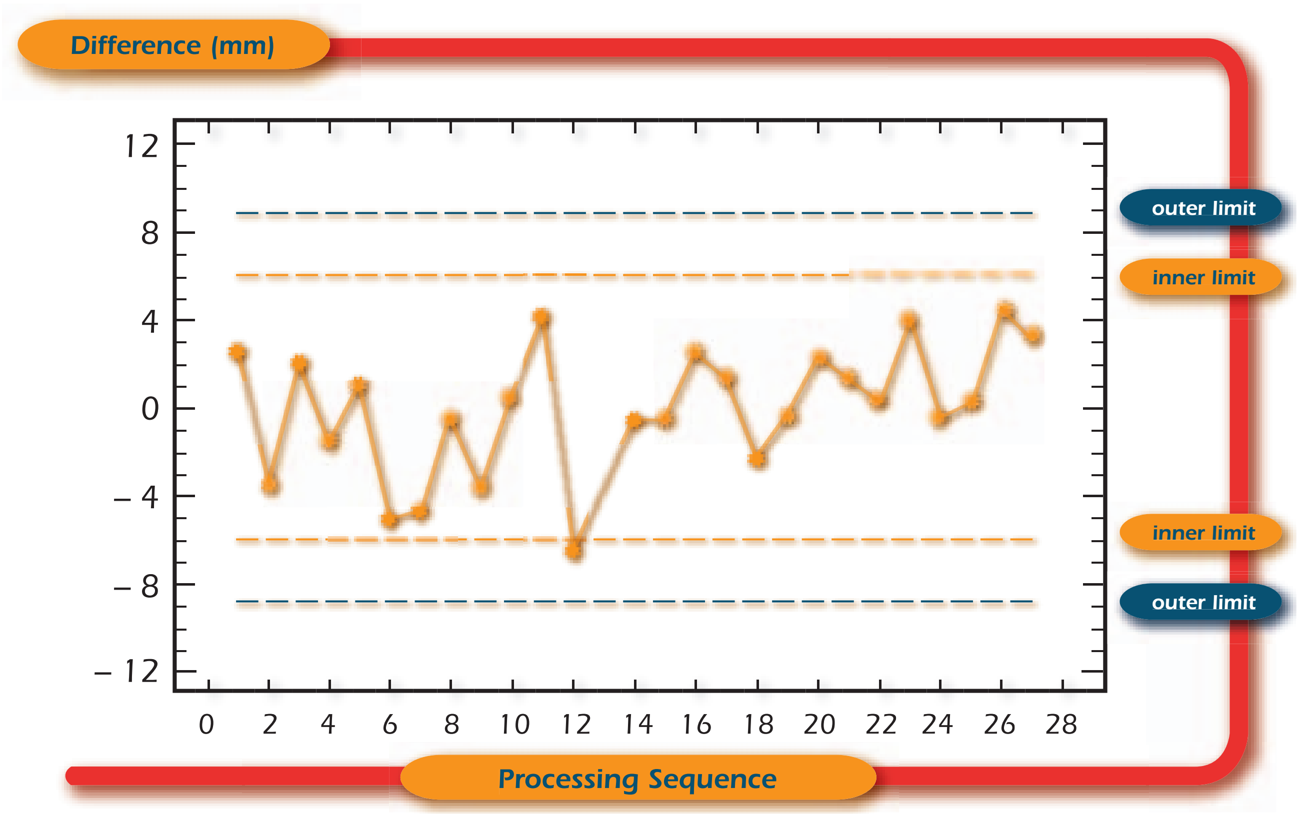
The individual mill standard deviations of differences obtained for TEAM-2 results, varied from 2.7 to 5.2 mm, and limits for individual mills should be based on their own results. The difference in standard deviations indicate that some mills are achieving more reproducible, or less variable, results 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

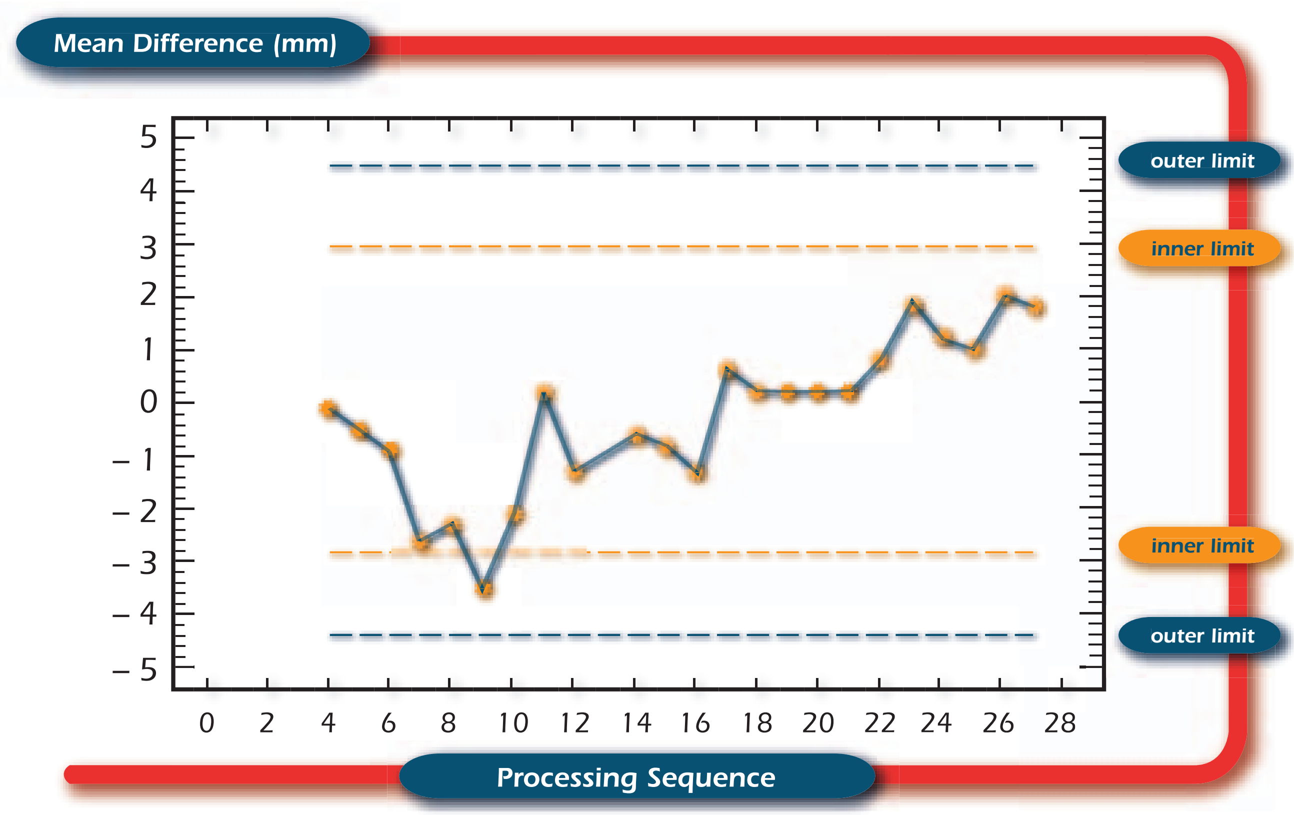
The control chart in Figure 25 uses each individual result to determine a difference for plotting on the chart. If the mill has large fluctuations in differences, this fluctuation may hide any trends that are present.

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.