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TEAM-3 Processing Trial - Final Report

By

TEAM-3 Steering Committee

Australian Wool Testing Authority Ltd	PO Box 240 North Melbourne Vic 3051
Capronex Services Pty Ltd	PO Box 247 North Carlton Vic 3054

SUMMARY

This report summarises the final analysis of the TEAM-3 database. The TEAM-3 Steering Committee is able to report that the TEAM-2 parameters (SL, SS, MFD, M* and VMB) are still applicable to processing prediction models. It is shown that processing performance has improved since the late 1980's. Mills are producing tops with Hauteur values, on average, 5.1 mm longer than is predicted using the TEAM-2 general formula and greater differences occur as the Hauteur increases above 75 mm. In addition, mills are producing tops with CV of Hauteur values, on average, 2.5% less than predicted by TEAM-2 and Romaine values 2.1% greater than predicted.

Mills also achieve more consistent, predictable results with lower standard deviations between actual and predicted Hauteur than in TEAM-2.

The regression analyses for Hauteur, CV of Hauteur and Romaine have shown that it is possible to calculate new General Formulae for each of these parameters, although they would be very similar to the TEAM-2 General Formulae published in 1988. The addition of CVD and CVL provide small improvements to the prediction. Similarly, the use of M instead of M* makes little change to any prediction model. It has been identified that there is no improvement in processing prediction if MFC is added to the prediction model.

1. INTRODUCTION

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

The introduction of Laserscan in July 2000 as the standard for all Presale Fibre Diameter tests in Australia, and the availability of Staple Length & Staple Strength data on most combing lots in sale catalogues, provided both a catalyst and an opportunity to review the TEAM-2 predictive formulae at minimal cost. It has been suggested that the new measurements provided by Laserscan, such as Coefficient of Variation of Diameter and Mean Fibre Curvature, may influence top making performance. If so, their inclusion in the TEAM formulae may improve the accuracy of predicting such performance. In March 2001, at the Shanghai meeting of IWTO, AWTA Ltd announced the commencement of the TEAM-3 trial.

Four successive reports have been presented to IWTO providing an update on the progress of TEAM-3 (Lindsay *et al*, 2002a; Lindsay *et al*, 2002b; TEAM-3 Steering Committee, 2003; and, Lindsay *et al*, 2003). A commitment was made at these meetings to present the final report on the TEAM-3 processing trial at the Evian 2004 meeting. As such, this will be the final presentation to IWTO documenting the findings of the TEAM-3 processing trial.

2. TEAM-3 CONSIGNMENT CHARACTERISTICS

2.1. Bale and Lot Details

Processing consignments suitable for inclusion in TEAM-3 were accepted until the end of February 2004. At the conclusion of consignment receival, 34 mills had submitted a total of 643 commercial consignments. The composition of the TEAM-3 database, in terms of the number of bales and lots, is shown in Table 2.1 together with a comparison of how these consignments compare with those submitted as part of the TEAM-2 trial. The 603 consignments submitted for the TEAM-2 trial comprised the total database that was used to derive the TEAM-2 General Formulae. This included data from the TEAM-1 and TEAM-2 projects as well as additional mill data (see TEAM-2 report, 1988).

Table 2.1. Composition of the TEAM-2 and TEAM-3 Consignments.

	TEAM-2	TEAM-3
Number of consignments	603	643
Total number of bales	88,000	158,549
Bales/consignment – Average		247
Bales/consignment – Range		44 to 1568
Lots/consignment – Average	17	40
Lots/consignment – Range	3 to 80	3 to 254

The global distribution of the processing mills participating in TEAM-3 is illustrated in Table 2.2. Previous reports indicated that 37 mills had signed an agreement to participate in TEAM-3. However, Table 2.2 lists only 34 participating mills as some of those who signed an agreement were unable to submit consignments. The effects of the 2002/03 drought in many parts of Australia, and general wool market conditions resulted in some participants finding difficulty sourcing consignments that met the requirements for inclusion in the TEAM-3 trial. The number of consignments submitted by each mill or topmaker ranged from 1 to 33 with an average of 19 consignments.

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

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

Table 2.2 TEAM-3 Participants.

Australia

Australian Topmaking Services Ltd

Fletcher International Exports Pty Ltd

Geelong Wool Combing Ltd

GH Michell & Sons (Aust) Pty Ltd

Lempriere (Australia) Pty Ltd

Port Phillip Wool Processing Pty Ltd

Riverina Wool Combing Pty Ltd

Czech Republic

Nejdek Wool Combing, A.S.

China

Australia Harvest Wool Textile Co Ltd

Jiangsu Changzhou Tops Mill

Jiangsu Sunshine Group

Lanzhou Sanmao Textile Group Co Ltd

Reward (Ningbo) Wool Industry Co Ltd

Shanghai No 1 Topmaking Company

Wuxi Xie Xin Group

Zhangjiagang Free Trade Zone – Concord Wool Textile Industrial Co Ltd

Zhangjiagang Free Trade Zone – Tianyu Woollen Textile Co Ltd

Zhangjiagang Yangtse Wool Combing Co Ltd

Zhejiang Xinao Group

France

Peignage de la Tossée

Ets A Dewavrin Fils & Co

India

Global Wool Alliance Pty Ltd

Indorama Group

Indoworth India Limited

Jayashree Textiles Unit

Oswal Woollen Mills Ltd

Raymond Limited

Italy

Pettinatura Europa 90 S.r.l.

Vitale Barberis Canonico S.P.A.

Japan

Nippon Keori Kaisha Ltd

Korea

Cheil Industries Inc

Singapore

Nankai Worsted Spinning Co Ltd

Slovak Republic

Merina j.s.c

Taiwan

Reward Wool Industry Corporation

2.1. Raw Wool and Top Characteristics

A summary of the major raw wool and processing characteristics of the TEAM-2 and TEAM-3 databases are presented in Tables 2.3 and 2.4 respectively. The consignments submitted by TEAM-3 participants represent current commercial processing blends. Apart from the requirement that 95% of the consignment was additionally measured, the selection of consignments for the TEAM-3 trial was entirely at the discretion of the mill (or topmaker). Although participants were encouraged to find consignments with a wide range of raw wool attributes, commercial realities and practicalities limited the ability of mills to process such consignments. The average fleece wool component of the consignments was approximately 90%, however there were a number of 100% skirting wool consignments included in the database.

Histograms of the data depicted in Tables 2 and 3 are shown in Appendix 1.

Table 2.3. Range and Mean of the Average Raw Wool Characteristics of Consignments.

	TEAM-1 & TEAM-2 Total Database			TEAM-3 Database		
	Avg	Min	Max	Avg	Min	Max
Schlumberger Yield (%)	--	--	--	68.81	78.05	56.09
Mean Fibre Diameter (μm)	22.0	17.0	31.0	20.1	16.3	25.1
CV of Diameter (%)	--	--	--	22.0	19.1	28.1
Comfort Factor (%)	--	--	--	97.2	80.7	99.5
Mean Fibre Curvature (deg/mm)	--	--	--	94	74	120
Vegetable Matter Base (%)	2.1	0.1	10.0	1.2	0.3	5.3
Staple Length (mm)	86	59	123	85	64	104
CV Length (%)	19	12	30	18	14	30
Staple Strength (N/ktex)	39	23	60	38	24	51
Tip Breaks (%)	--	--	--	21	2	57
Mid Breaks (%)	--	--	--	52	28	86
Base Breaks (%)	--	--	--	27	5	66

Table 2.4. Range and Mean of the Average Processing Characteristics of Consignments.

	TEAM-1 & TEAM-2 Total Database			TEAM-3 Database		
	Avg	Min	Max	Avg	Min	Max
Hauteur (mm)	67	48	97	72.0	56.3	91.0
CV of Hauteur (%)	49	31	61	44.9	32.5	58.2
Romaine (%)	8	1	21	9.3	2.3	19.5
Top & Noil Yield (%)	64	46	77	69.9	58.2	92.8
Mean Fibre Diameter (μm)	22.1	17	31	20.3	16.3	25.4
CV of Diameter (%)	--	--	--	21.0	17.3	26.3
Comfort Factor (%)	--	--	--	97.1	82.8	99.8

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

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

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

Specific comments on the raw wool characteristics depicted in Table 2.3 are as follows:

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

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

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

- *Vegetable Matter:* During the TEAM-2 project special effort was made to increase the range of vegetable matter blends in order to improve the robustness of the prediction formulae. Commercial decisions being made today clearly indicate that restrictions are placed on maximum vegetable matter levels. This has resulted in a lower range in VM for the TEAM-3 database.

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

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

3.1. Hauteur, CV of Hauteur and Romaine

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

The average differences between actual and predicted (TEAM-2) Hauteur, CV of Hauteur and Romaine are shown in Table 3.1 and graphically in Figures 3.1 to 3.3.

Table 3.1. Comparison between Actual and TEAM-2 Predicted Hauteur, CV of Hauteur and Romaine.

	HAUTEUR (mm)			CV of HAUTEUR (%)			ROMAINE (%)		
	Actual	Predicted*	Diff.	Actual	Predicted*	Diff.	Actual	Predicted*	Diff.
Mean:	72.0	66.9	+ 5.1	44.9	47.4	- 2.5	9.3	7.1	+ 2.1
St Dev:	5.8	5.2	3.7#	4.4	3.0	3.2#	2.6	1.5	1.8#

* Predicted using TEAM-2 General Formulae (1988)

These values are the standard deviations of the differences between actual and predicted Hauteur, CV Hauteur and Romaine.

Using the consignments submitted in this trial, the average difference between actual Hauteur and TEAM-2 predicted Hauteur is + 5.1 mm. Figure 3.1 shows that the differences are larger for Hauteur values in excess of 75 mm. The average difference between actual and predicted Hauteur is 7.3 mm for all those consignments with an actual Hauteur of 75 mm or greater. Approximately 31% of the consignments submitted for TEAM-3 have Hauteur values of 75 mm or greater.

The average difference between actual CV of Hauteur and TEAM-2 predicted CV of Hauteur is – 2.5%. Figure 3.2 shows that for the majority of consignments, the actual CV of Hauteur is lower than that predicted from the TEAM-2 formulae. Only 20% of the consignments received for TEAM-3 have a higher actual CV of Hauteur than predicted CV of Hauteur.

The average difference between actual Romaine and TEAM-2 predicted Romaine is + 2.1%. These differences are shown graphically in Figure 3.3. Only 8% of the consignments received for TEAM-3 have a lower Romaine than that predicted by the TEAM-2 formulae.

Since the TEAM-2 formulae were derived, processing mills have been encouraged to produce tops with lower CV of Hauteur values. This has involved removing more short fibre during combing, which has the effect of reducing CV of Hauteur, increasing Hauteur and increasing Romaine.

On each of Figures 3.1 to 3.3 the trendline from the 1988 TEAM-2 database has been added to the graph as a comparison. These trend lines suggest that although processing performance has changed since 1988, the slopes of the relationship between actual and predicted Hauteur, CV of Hauteur and Romaine are very similar. The observation that longer tops are performing better in comparison to the Hauteur prediction formula is consistent with what was observed in the original TEAM-2 trial.

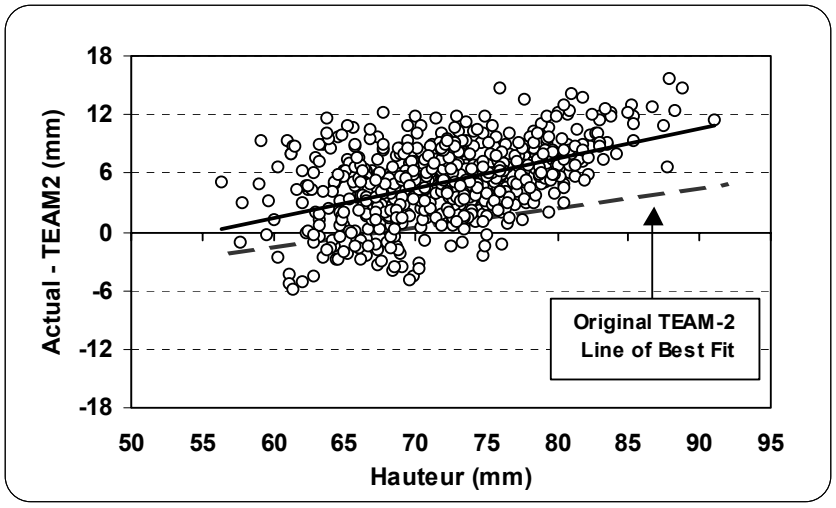

Figure 3.1. Hauteur Differences (Actual – TEAM2).

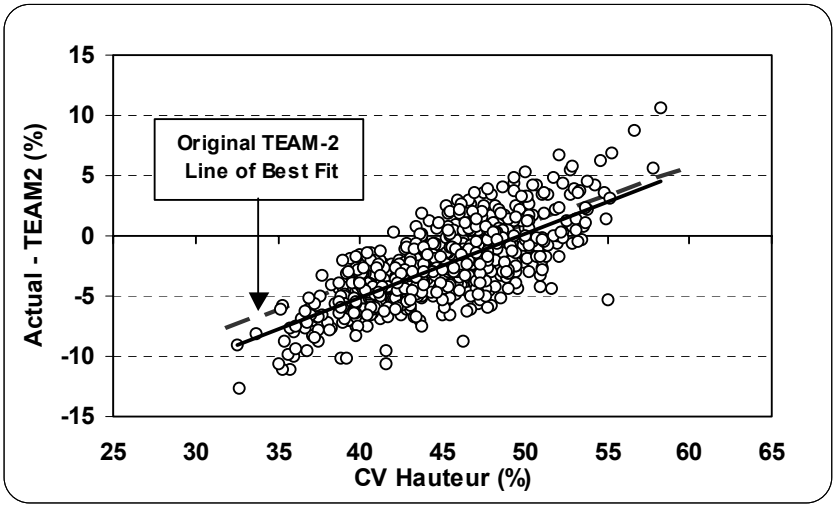

Figure 3.2. CV of Hauteur Differences (Actual – TEAM2).

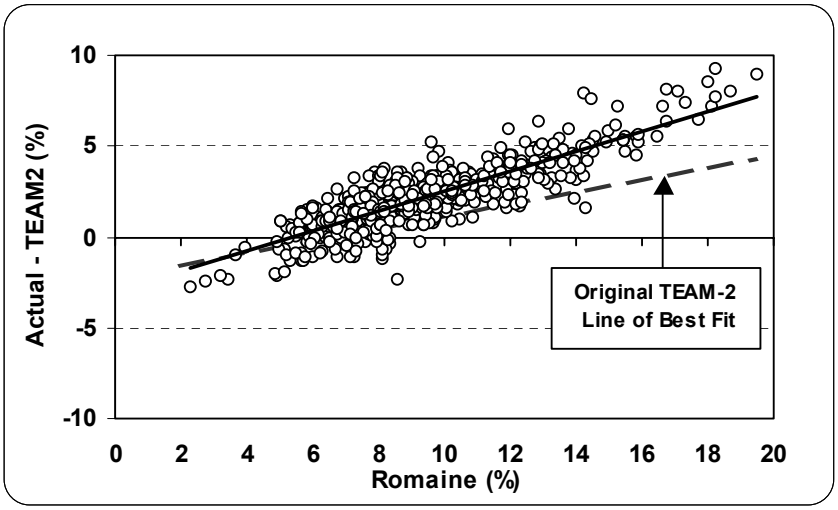

Figure 3.3. Romaine Differences (Actual – TEAM2).

3.2. Comparison of Mill Performance on a Regional Basis

Section 3.1 has shown that, on average, mills produce tops with Hauteur values 5.1 mm longer than predicted by the TEAM-2 General Formulae. However, it is also interesting to examine the differences between actual and predicted Hauteur at a regional level.

As was mentioned earlier, 34 mills from 11 countries participated in TEAM-3. Whilst maintaining the confidentiality of individual mills, the data collected allows a comparison of processing performance on a regional basis. Table 3.1 and Figures 3.4 to 3.6 show the comparison between Actual – Predicted Hauteur, CV of Hauteur and Romaine between the 5 participating regions. The predicted values are derived from the TEAM-2 General Formulae.

Without exception, each of the 6 regions examined are producing tops that have a longer Hauteur, a lower CV of Hauteur and a higher Romaine than predicted by the TEAM-2 General Formulae. Examination of Figures 3.4 to 3.6, indicate a very similar pattern of Residuals regardless of processing region.

Table 3.1. Comparison Between Actual and Predicted Hauteur, CV Hauteur and Romaine for Different Regions Participating in TEAM-3.

Number of:				Actual - Predicted		
Region	Mills	Consignments		Hauteur (mm)	CV Hauteur (%)	Romaine (%)
Australia	6	92	Mean	6.1	-3.0	3.1
			St. Dev (Diff.)	2.5	2.6	2.1
China	11	205	Mean	5.5	-2.8	2.0
			St. Dev (Diff.)	3.6	2.5	1.7
India	5	130	Mean	4.7	-2.4	1.6
			St. Dev (Diff.)	4.0	3.6	1.5
Europe	7	99	Mean	6.6	-3.9	2.3
			St. Dev (Diff.)	3.7	2.9	1.3
Other Asia	4	116	Mean	3.1	-0.4	2.0
			St. Dev (Diff.)	3.5	3.5	1.7

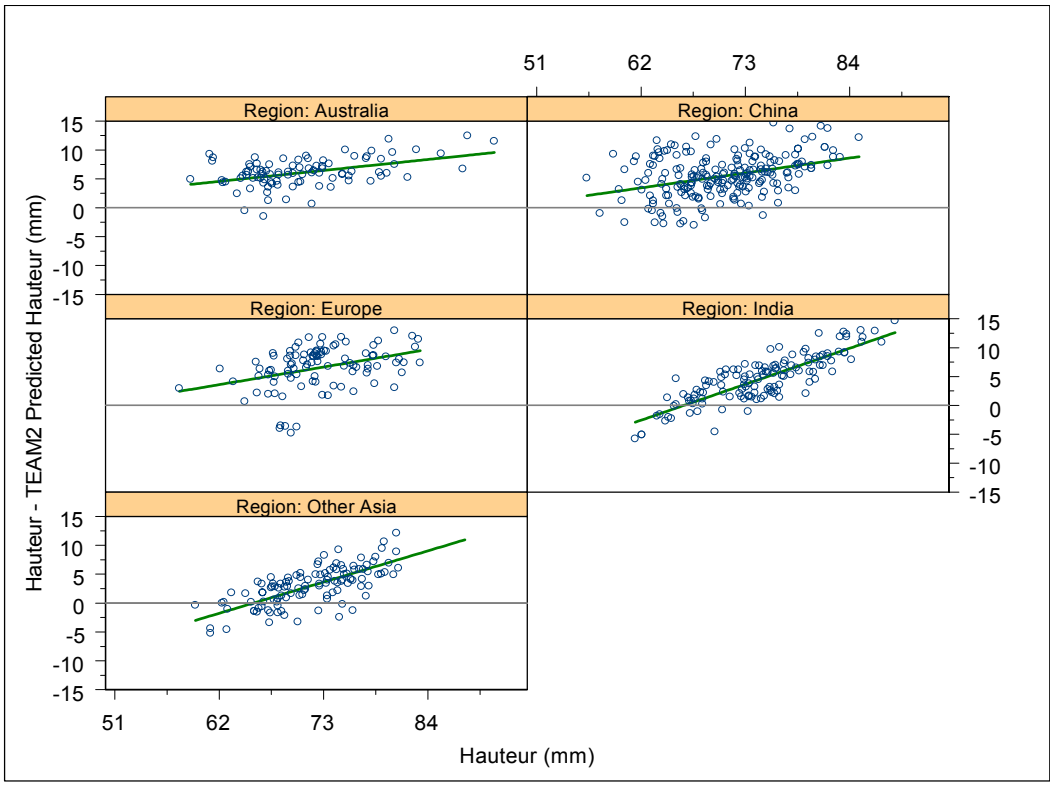

Figure 3.4. TEAM-3 Residual Hauteur against Actual Hauteur: Regional Comparison.

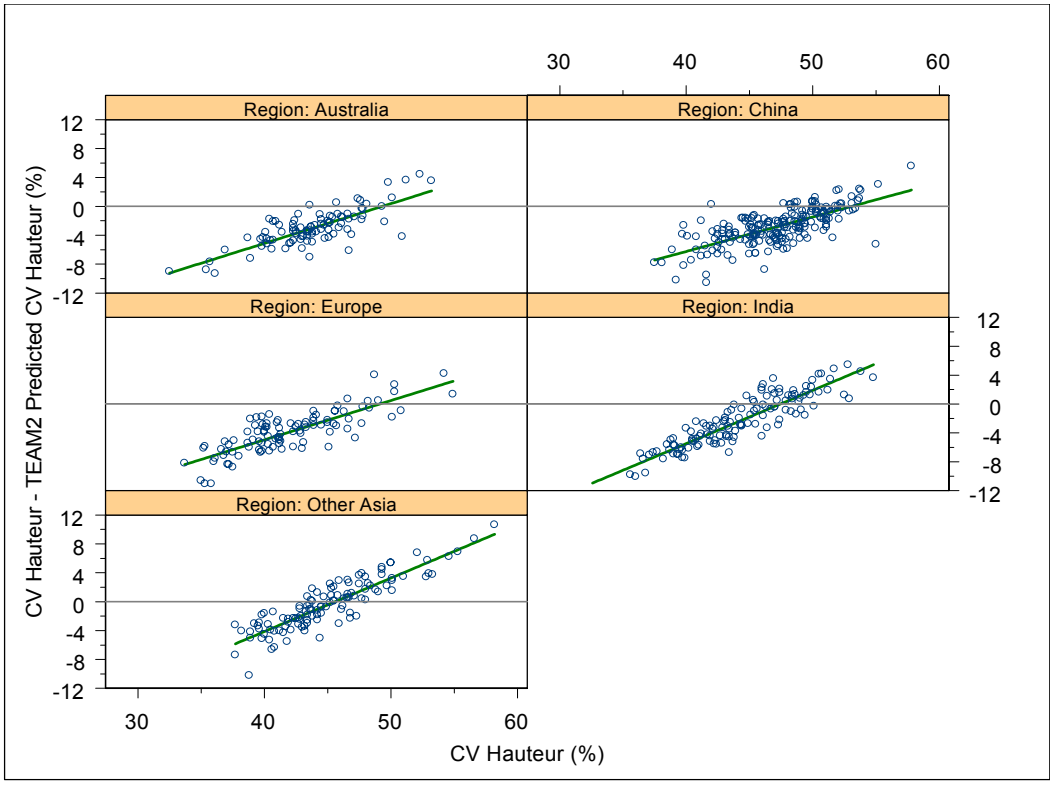

Figure 3.5. TEAM-3 Residual CV of Hauteur against Actual CV of Hauteur: Regional Comparison.

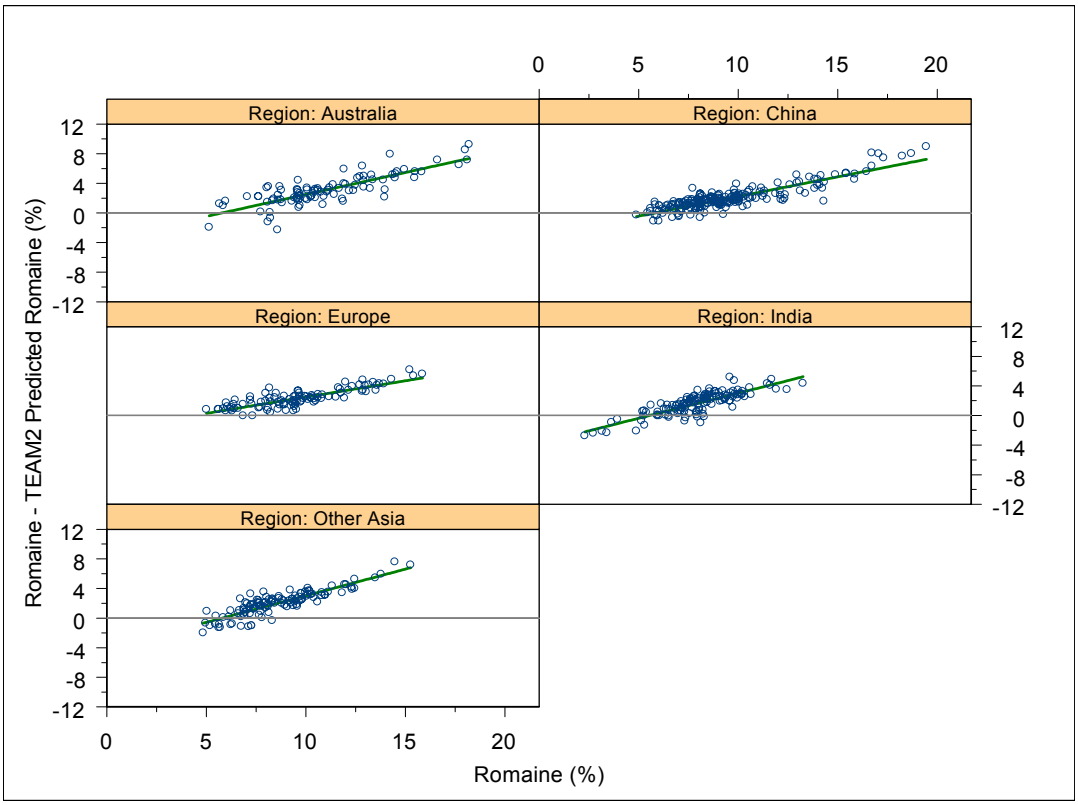

Figure 3.6. TEAM-3 Residual Romaine against Actual Romaine: Regional Comparison.

4. CORE/COMB RELATIONSHIPS

4.1. Mean Fibre Diameter and CV of Diameter

For each processing consignment submitted as part of the TEAM-3 trial, a minimum of five samples of top were provided to AWTA Ltd for analysis. Figure 4.1 shows the relationship between the greasy wool mean fibre diameter and the top mean fibre diameter for the TEAM-3 database. The diameter of the top that is used in this analysis was that measured by AWTA Ltd, using Laserscan. On average, the mean fibre diameter of the top was 0.20 μm coarser than the mean fibre diameter of the greasy wool.

Figure 4.2 compares the CV of Diameter of the greasy wool and the top. It shows that the CV of Diameter was, on average, 0.9% lower in the top than it was in the greasy wool. This is an expected result as processing is understood to remove proportionally more fine fibres than coarse fibres as noil. This has the effect of increasing the fibre diameter in the top (Figure 4.1) as well as decreasing the fibre diameter variation in the top (Figure 4.2).

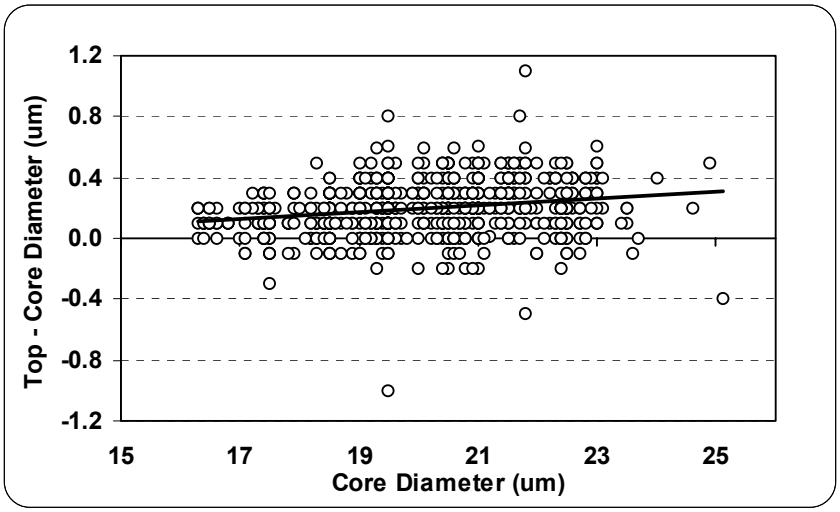

Figure 4.1. Core/Comb Fibre Diameter Comparison.

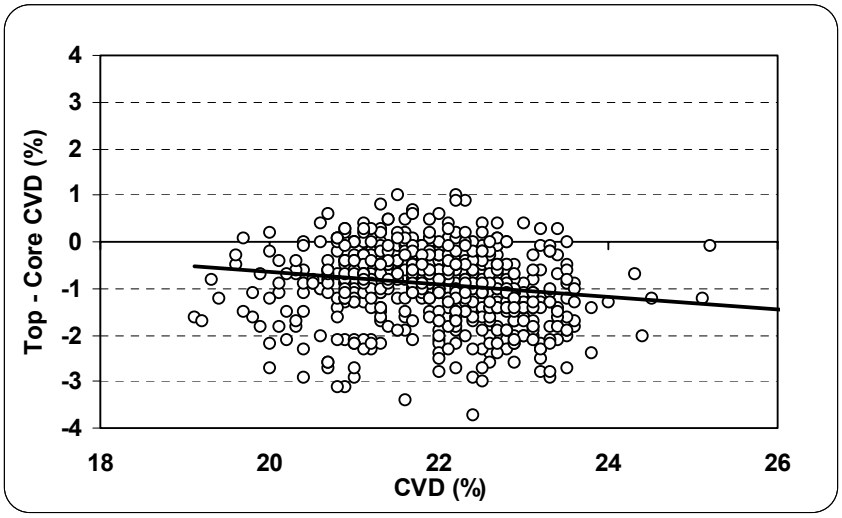

Figure 4.2. Core/Comb CV of Diameter Comparison.

4.2. Processing Yield

A comparison between the actual Top and Noil Yield achieved by the processing mills and the predicted yield using the Schlumberger Dry Top and Noil Yield (SDRY) formula is shown in Figure 4.3. The actual processing yield of the TEAM-3 consignments was, on average, 1.1% higher than the yield predicted by the SDRY formula.

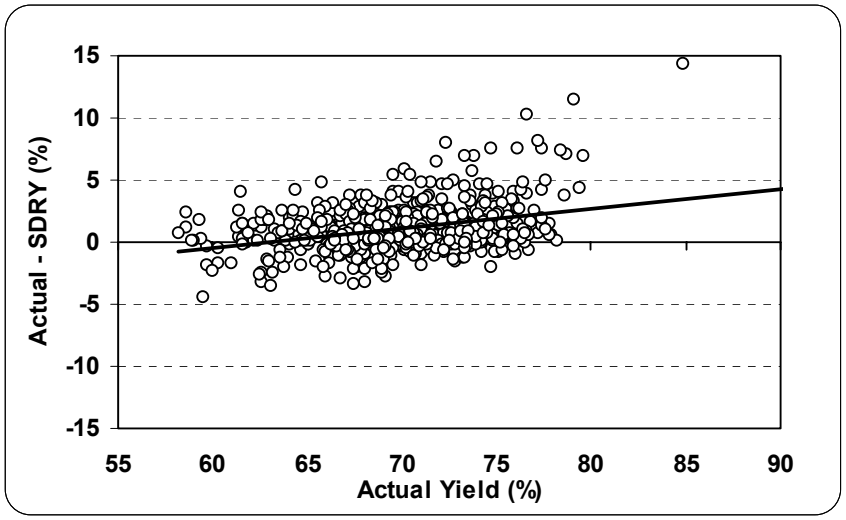

Figure 4.3. Comparison between Actual and Predicted Schlumberger Dry Top and Noil Yield.

5. PREDICTION OF HAUTEUR BASED ON THE TEAM-3 DATABASE

The previous sections have compared the processing performance of consignments submitted as part of the TEAM-3 trial against the TEAM-2 benchmark. However, one of the original aims of the TEAM-3 project was to examine the possibility of creating new processing prediction formulae based on current commercial processing performance.

The authors of the TEAM-2 report (1988) recognised that a feature of the formulae has been their simplicity. A minimum number of raw wool factors with purely additive effects enabled the creation of General Formulae that could be used across various wool types and mills. The formulae used to predict Hauteur were developed using multiple regression techniques. Other more sophisticated approaches were considered by the TEAM-2 committee but these provided no improvement over the simpler approach. The TEAM-3 Steering Committee decided that a similar approach would be taken for the analysis of the TEAM-3 database.

The data from the consignments submitted for the TEAM-3 trial was analysed using the S-Plus (2002) statistical package. The analysis included re-determining the coefficients for the TEAM-2 formula for Hauteur, CV Hauteur and Romaine and then adding new variables to the model. The variables added were Mean Fibre Curvature (MFC), CV of Diameter (CVD), and CV of Length (CVL). Multiple regression analyses were conducted which plotted Hauteur, CV of Hauteur and Romaine against these raw wool factors.

As explained in the TEAM-2 report (1988), the strength of a regression relationship may be measured by two statistics:

- The coefficient of multiple determination (R^2) indicates the fraction of the variation in Hauteur between the consignments which is explained by the raw wool data used in the formula. It reflects the level of association between the raw wool variables and Hauteur and is often called the degree of association and expressed as a percentage.
- The standard error of the differences between actual and predicted Hauteur is a measure of the reliability of the raw wool data as a predictor of Hauteur – the lower the SE the more reliable the formula.

For reference, the TEAM-2 general equation for Hauteur (H), CV of Hauteur (CVH), and Romaine (R), as published in 1988, are as follows:

$$Hauteur = 0.52L + 0.47S + 0.95D - 0.19M^* - 0.45V - 3.5 + [MA1]$$

$$CV\ Hauteur = 0.12L - 0.41S - 0.35D + 0.20M^* + 49.3 + [MA2]$$

$$Romaine = -0.11L - 0.14S - 0.35D + 0.94V + 27.7 + [MA3]$$

Where: L = Staple Length (mm); S = Staple Strength (N/ktex); D = Mean Fibre Diameter (μm); V = Vegetable Matter Base (%); M = Adjusted Mid Breaks; MA = Mill Adjustment Factor (MA1 = Hauteur, MA2 = CV of Hauteur, MA3 = Romaine).*

Table 5.1 presents the results of the regression analysis for the Hauteur prediction based on the TEAM-3 database. Regression 1 in this table is an analysis of the TEAM-3 database using Staple Length (SL), Staple Strength (SS), Fibre Diameter (D), Adjusted Mid Breaks (M*) and Vegetable Matter Base (V) as a function of Hauteur. These are the same parameters that formed the basis of the TEAM-2 equation. It is noticeable that the regression analysis on the TEAM-3 database gives a lower Standard Error (SE) than was reported for TEAM-2. This may suggest improved repeatability.

The coefficients for SS, SL, D and M* are similar between TEAM-2 and Regression 1. The effect of Vegetable Matter Base (V) however is different between TEAM-2 and TEAM-3. In TEAM-2, VMB had a negative effect of Hauteur (-0.45). This was an expected result, however the TEAM-3 analysis shows that VMB has a positive but insignificant influence (0.03) on Hauteur. This is most likely due to the very small range of VMB in the TEAM-3 database. The average VMB of the database was 1.2% with a range from 0.3% to 5.3%. However, of the 643 consignments, 91% of them have a VMB result of 2.0% or less. The narrow range of VMB can be clearly seen in Figure 5.1. With such a narrow range, it would be expected that VMB would have a minimal effect on Hauteur. This may not be the case if consignments of high VMB are processed into top.

Table 5.1. Statistical Analysis using Additional Factors of CVD, MFC and CVL to predict Hauteur.

	Regression	SL	SS	D	M*	V	CVD	MFC	CVL	SE (mm)	R^2
	TEAM-2	0.52	0.47	0.95	- 0.19	- 0.45				3.4	84%
1	TEAM-3	0.58	0.45	1.00	-0.17	*(0.03)*				2.58	82%
2	TEAM-3 +CVD	0.47	0.33	1.37	-0.19	*(-0.12)*	-0.90			2.53	83%
3	TEAM-3 + MFC	0.58	0.45	1.16	-0.17	*(0.05)*		*(-0.04)*		2.58	82%
4	TEAM-3 + CVL	0.46	0.41	1.24	-0.17	*(0.22)*			-0.40	2.51	83%
5	TEAM-3 + CVL + CVD	0.41	0.33	1.45	-0.17	*(0.08)*	-0.63		-0.32	2.49	83%

Note: All coefficients that were not statistically significant are bracketed and in Italics

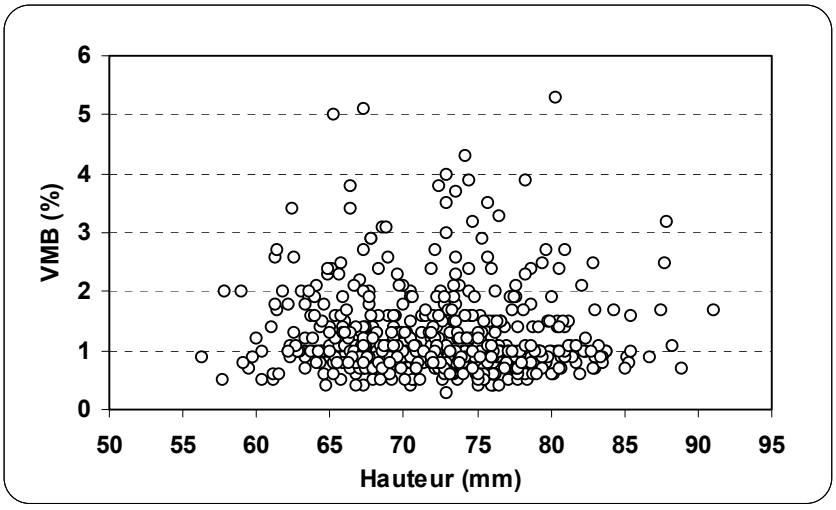

Figure 5.1. Relationship between Vegetable Matter and Hauteur.

5.1. The Addition of CVD and CVL to the TEAM Model

Regressions 2 to 5 in Table 5.1 show a summary of the results from the additional regression analyses that were conducted. Whilst the addition of CVD (Regression 2) and CVL (Regression 4) does reduce the SE slightly over Regression 1, the improvement is small. The coefficients for CVD and CVL are both statistically significant indicating that they can influence processing performance. However, the addition of these parameters does not produce a significant reduction in the SE of the prediction model (F-test, $2.58^2 / 2.49^2 = 1.07$, with 599 degrees of freedom).

It is worth noting that when CVD is added to the model together with the TEAM-3 variables (Regression 2) that the coefficients for both SS and CVD were significant. It has been previously suggested (Lamb, 2000) that CVD could replace SS as a predictor of processing performance. This analysis suggests that SS is still important for the processing prediction of consignments and cannot be replaced by CVD alone.

The addition of CVL to the TEAM-2 Hauteur formulae was considered by the TEAM committee in 1988. Early analysis of the database indicated that CVL did have a small influence on processing performance. However analysis of the total database at the conclusion of the TEAM-2 trial did not confirm the significance of CVL in any prediction formulae. However, it was suggested at the time that CVL may be significant for a mill specific formula. As such, it is not surprising that CVL could be considered as an addition to the processing prediction formulae.

5.2. The Addition of MFC to the TEAM Model

A number of research papers (Haigh, 2002; Peterson, 2002; Stevens and Mahar, 1995; Stevens and Crowe, 1994; Kurdo *et al*, 1984; Marler, 1985; Hunter and Gee, 1980; Turpie and Shiloh, 1973; and, Cilliers and Robinson, 1968) have suggested that wools exhibiting properties of low MFC, low crimp frequency or low Resistance to Compression show a processing benefit in terms of longer Hauteur and lower Romaine. These potential processing advantages have been identified by comparing the extremes of MFC in selected individual fleeces.

TEAM-3 relates to the processing results for consignments rather than sale lots or fleeces, hence the range in MFC is likely to be less than reported in these research trials. The range in MFC for each micron level in TEAM-3 is approximately 10 to 15 degrees/mm (Figure 5.2). All reports to date on the TEAM-3 trial (Lindsay *et al*, 2002a; Lindsay *et al*, 2002b; TEAM-3 Steering Committee, 2003; and, Lindsay *et al*, 2003) have been unable to demonstrate any processing advantage of low MFC when examining commercial consignments.

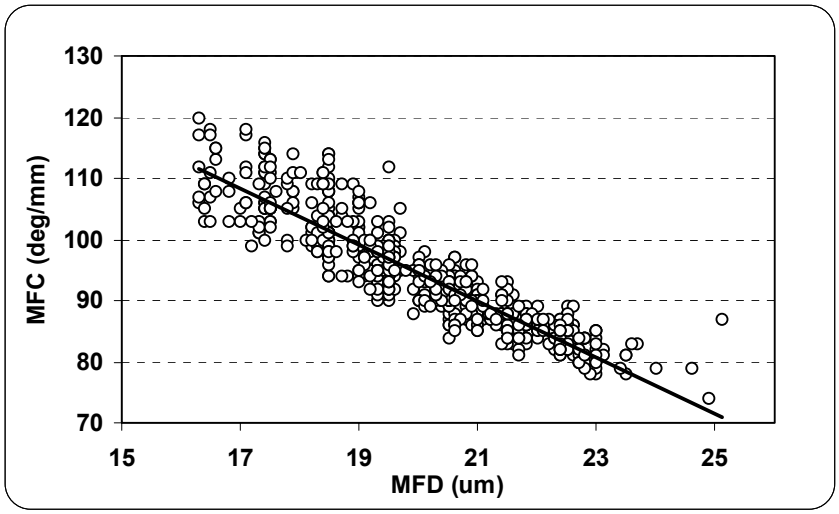

Figure 5.2. Fibre Diameter and Fibre Curvature Relationships.

Figure 5.3 is a plot of Mean Fibre Curvature against the TEAM-3 Residual Hauteur (i.e. Actual Hauteur – TEAM3 Predicted Hauteur, where Regression 5 in Table 5.1 is used to calculate predicted values). If the inclusion of MFC in any processing prediction model resulted in an improvement in processing prediction, then it would be expected that Figure 5.3 would exhibit a significant slope effect. However it is clear from this plot that MFC does not influence processing prediction based on the commercial consignments processed as part of the TEAM-3 trial.

In addition, the trend line on Figure 5.3 shows that as MFC decreases, the difference between Actual and Predicted Hauteur also decreases. Based on the MFC research studies this is not the expected result. If consignments of low MFC did exhibit a processing advantage then the differences between Actual and Predicted Hauteur would increase with decreasing MFC.

Although not reported in this paper, Figure 5.3 has been dissected further to compare the relationships for consignments of similar fibre diameter. For example, the MFC relationship of all consignments with a diameter of 16-18 μm was examined. This was repeated for wools of diameter 18-20μm, 20-22μm etc. No relationships were evident in any of these analyses.

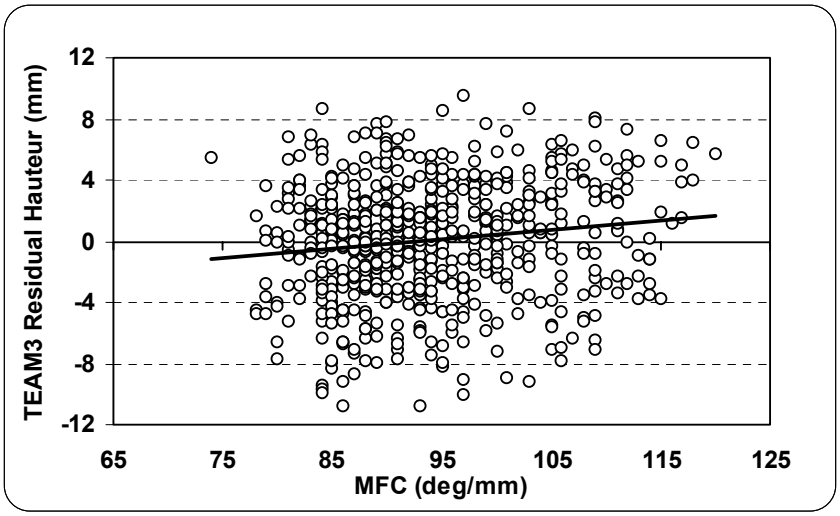

Figure 5.3. Relationship between MFC and TEAM-3 Residual for the TEAM-3 Database.

5.3. Validation of the TEAM-3 Calibration

The statistics presented in Section 5 are based on using the entire TEAM-3 database to derive a regression equation to predict processing performance. This regression equation has not been validated with additional consignments. A similar approach was taken by the TEAM-2 committee in 1988.

This section examines the validation of the TEAM-3 database by splitting the database into two based on a random allocation of consignments. The first set of consignments was allocated to the prediction model and the second set of consignments was used to validate the prediction model. This is therefore a true model development and validation process rather than just a data fitting process.

Using the consignments allocated to the prediction model, the S-Plus (2002) statistical package was used to determine a prediction equation. The coefficients that were determined by this regression analysis are shown in Table 5.3. It is clear that the coefficients are very similar to those obtained when the entire TEAM-3 database was used to derive a calibration equation (Regression 1, Table 5.1).

Table 5.2. Calibration of a Random Subset of the TEAM-3 Database.

Regression	SL	SS	D	M*	V
TEAM-3 (Calibration)	**0.60**	**0.45**	**0.83**	**-0.20**	*(-0.25)*

Once the regression was derived, the equation was used to predict the Hauteur of the remaining validation consignments. The differences between the predicted and actual Hauteur of these validation consignments were then analysed. The average difference between actual and predicted Hauteur was 0.30 mm and the standard deviation of these differences was 3.67 mm. Given that the mean residual was only 0.30 mm and the SD of the differences was relatively low, it can be concluded that the calibration equation is an effective predictor of processing performance. As a comparison, the SD of the differences when the entire TEAM-3 database was used to calculate the prediction equation was 3.70 mm.

5.4. The Use of M* in the TEAM Model

Since the TEAM-2 report was published in 1988, there has been some conjecture over the use of M* (adjusted mid breaks) in the TEAM-2 general equation. M* is the adjusted percentage of middle breaks and all values of M up to 45% are replaced by a value of 45% for M* in the TEAM-2 formula. For values of M greater than 45%, the measured value itself is used as M* in the formula. The TEAM-2 Committee included M* rather than M in their formula as it was evident on scatter plots that there was no obvious trend between the Hauteur residuals and Mid Breaks for values of M to 45%, however for mid break values in excess of 45% a trend was evident.

The use of M rather than M* would simplify the TEAM formulae. In addition, the current formulae do not allow additivity of Hauteur and CV of Hauteur at the sale lot level. Due to the use of M* in the TEAM-2 formulae, it is not possible to easily calculate an average Hauteur or CVH when using simple weighted averages for the combination of a number of Sale Lots. A new formula with M rather than M* would allow buyers to easily combine Hauteur values of individual Sale Lots.

Using the TEAM-3 database, the use of M* was compared to the use of the actual mid break percentage (M). Table 5.2 shows that the use of M is equivalent to M* in the prediction model. Consequently, the use of M could be considered as a possible replacement for M*.

The previous sections have used Regression 5 from Table 5.1 as the TEAM-3 prediction equation for Hauteur. This equation had coefficients for CVD and CVL but contained M* rather than M. As the use of M would simplify the TEAM formula, **Equation 2 in Table 5.3 is the proposed TEAM-3 prediction equation for Hauteur.**

Table 5.3. Statistical Analysis using M instead of M*.

Regression	SL	SS	D	M*	M	V	CVD	CVL	SE (mm)	R^2
1 TEAM-3 + CVD + CVL	0.41	0.33	1.45	-0.17		*(0.08)*	-0.63	-0.32	2.49	83%
2 M* replaced by M	0.41	0.34	1.46		-0.15	*(0.06)*	-0.68	-0.29	2.48	83%
Note: All coefficients that were not statistically significant are bracketed and in Italics										

Figure 5.4 plots the differences between actual and predicted Hauteur when Regression 2 from Table 5.3 is used to derive the predicted Hauteur values for the TEAM-3 database. Approximately 76% of the consignments fall within a narrow range of ± 4mm of the achieved Hauteur. This was similar to the results achieved in the TEAM-2 trial when 77% of the consignments fell within 4mm of the achieved Hauteur.

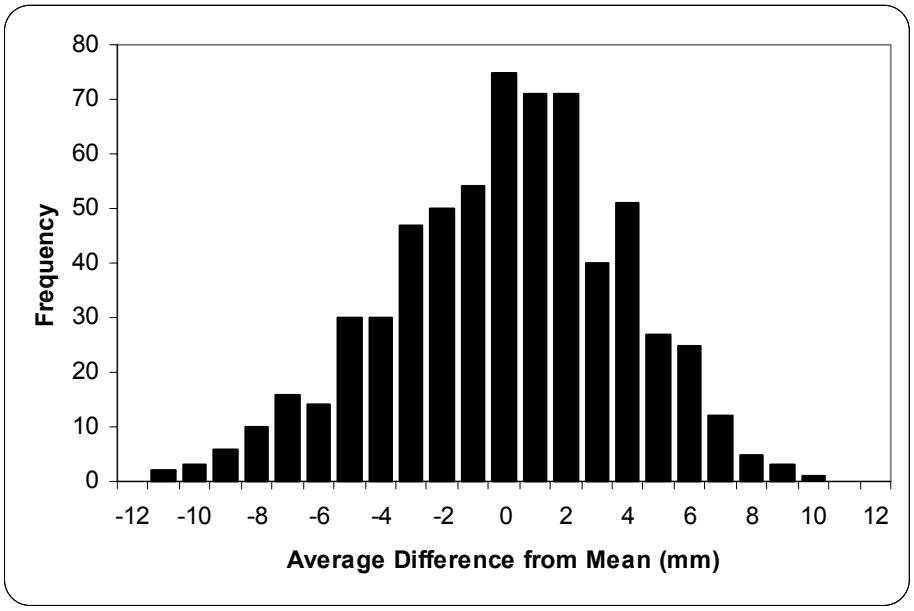

Figure 5.4. Histogram of Differences Between Actual and Predicted (TEAM-3) Hauteur.

5.5. Variation Between and Within Individual Mills

As in TEAM-2, processing differences between mills have been identified and therefore an important aspect to be emphasised in using the prediction formula is the adjustment of the calculated value of Hauteur to allow for mill differences. Individual mills can comb consistently longer or shorter tops than the values for Hauteur calculated from a general formula. Figure 5.5 plots the distribution of the average differences (i.e. the mill corrections) when the data is analysed on a mill by mill basis. In Figure 5.5, only mills that submitted 10 or more consignments were included, and Equation 2 from Table 5.3 was used to calculate predicted Hauteur values.

The average mill adjustment has decreased from 4.4 mm in TEAM-2 to 0.4 mm in TEAM-3. The range in mill adjustments was 15.4 mm in TEAM-2 (–11.7 mm to 3.7 mm) but has decreased to 10.1 mm in TEAM-3 (– 4.9 mm to 5.3 mm).

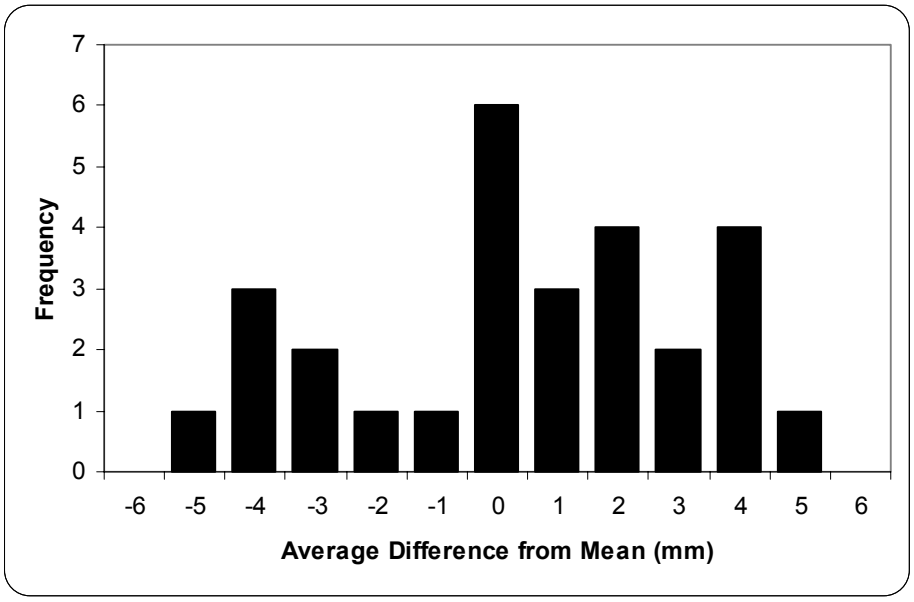

Figure 5.5. Histogram of Differences Between Actual and Predicted Hauteur for Individual Mills.

The variability within a mill is largely related to mill quality management. The availability of the TEAM-2 database allowed a comparison between the average predictability of Hauteur for the individual mills in TEAM–2 and the average predictability for the individual mills in TEAM-3. For each mill, the data was analysed so that the variability within that mill could be considered in conjunction with the average mill adjustments.

The statistical method that is used is the calculation of the standard deviation of 'Actual – Predicted' Hauteur for each mill. There was a marked (41%) reduction from 4.1 mm to 2.4 mm between the two trials (Table 5.4).

These results demonstrate that there has been a significant improvement in the predictability of Hauteur based on Raw Wool measurements for individual mills in the 16-year period since the publication of the TEAM-2 formulae. The lower SD of the prediction differences implies better mill quality management, further illustrating the benefits of using prediction technology. In addition, improvements in mill quality management may include tighter control of the variation of the raw wool properties in the component Sale Lots.

Table 5.4. Comparison of SD of Prediction Differences and Mill Factors for TEAM-2 and TEAM-3 Databases.

	Mill Adjustment (mm)		SD of Prediction Differences (mm)	
	TEAM-2	TEAM-3	TEAM-2	TEAM-3
Average	4.4	0.4	4.1	2.4
Minimum	-11.7	-4.9	2.3	1.4
Maximum	3.7	5.3	6.2	3.7
No. Mills	20	28	20	28

6. PREDICTION OF CV OF HAUTEUR BASED ON TEAM-3 DATABASE

The same statistical methods used in Section 5 to analyse the TEAM-3 database for Hauteur were used for CV of Hauteur. Table 6.1 shows that the coefficients obtained when a regression was conducted on the TEAM-3 database are similar to those obtained in TEAM-2. The main difference is that diameter has a bigger influence on predicted CVH in the TEAM-3 analysis.

The addition of CVD or MFC to the model resulted in little improvement to the prediction of CVH. However, the addition of CVL (Regression 4) did impact on the prediction with the SE decreasing from 2.70 to 2.60. The TEAM variables together with various combinations of CVL, CVD and MFC were also examined. They are not reported in Table 6.1 as they did not improve the prediction model.

Table 6.1. Statistical Analysis using CVD, MFC and CVL to predict CV of Hauteur.

	Regression	SL	SS	D	M*	CVD	MFC	CVL	SE (mm)	R^2
	TEAM-2	0.12	-0.41	-0.35	0.20				2.8	63%
1	TEAM-3	0.18	-0.40	-0.61	0.20				2.69	65%
2	TEAM-3 +CVD	0.23	-0.34	-0.78	0.21	*(0.44)*			2.68	65%
3	TEAM-3 + MFC	0.18	-0.40	-0.59	0.20		*(0.01)*		2.69	65%
4	TEAM-3 + CVL	0.31	-0.35	-0.90	0.20			0.42	2.62	67%

Note: All coefficients that were not statistically significant are bracketed and in Italics.

6.1. The Replacement of M* with M in the Prediction of CVH

As with the TEAM-2 formula for Hauteur, the TEAM-2 prediction formula for CVH contains an adjusted mid break (M*) parameter. As was examined earlier with Hauteur, the use of M* was compared to the use of the actual mid break percentage (M) for the prediction of CVH. Table 6.2 shows that the use of M instead of M* results in a minor improvement to the prediction model. As with Hauteur, the use of M can be considered as a possible replacement for M* for the prediction of CVH.

Equation 2 in Table 6.2 is proposed as the TEAM-3 prediction equation for CVH.

Table 6.2. Statistical Analysis using M instead of M*.

	Regression	SL	SS	D	M*	M	CVL	SE (mm)	R^2
1	TEAM-3 + CVL	0.31	-0.35	-0.90	0.20		0.42	2.62	67%
2	M* replaced by M	0.30	-0.37	-0.88		0.17	0.38	2.58	68%

Figure 6.1 compares the actual CV of Hauteur values with the CV Hauteur Residual. The CVH Residual was calculated by subtracting the predicted CVH from the actual CVH. The predicted CVH was calculated using Regression 2 in Table 6.2. Figure 6.2 plots the differences between actual and predicted CVH and shows that 86% of the consignments fell within ± 4% of the mean. This was comparable with the 83% that fell within this range in the TEAM-2 trial.

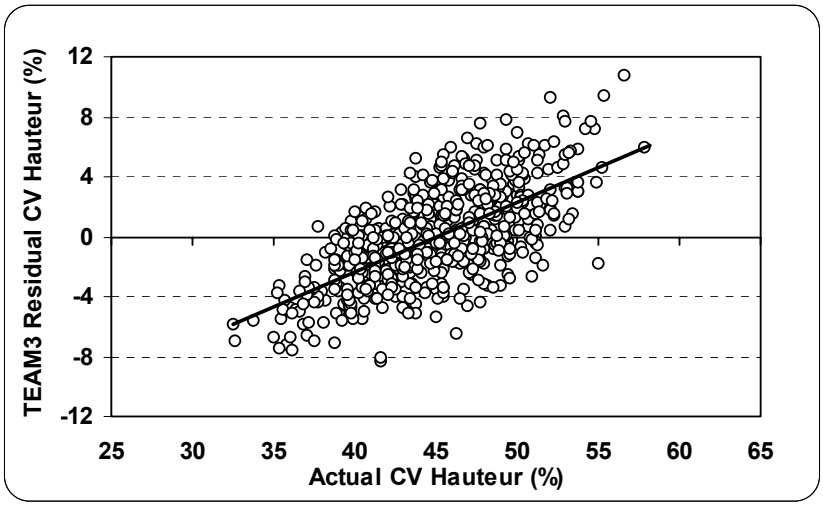

Figure 6.1. Relationship between Actual CV of Hauteur and TEAM-3 Residual CV of Hauteur.

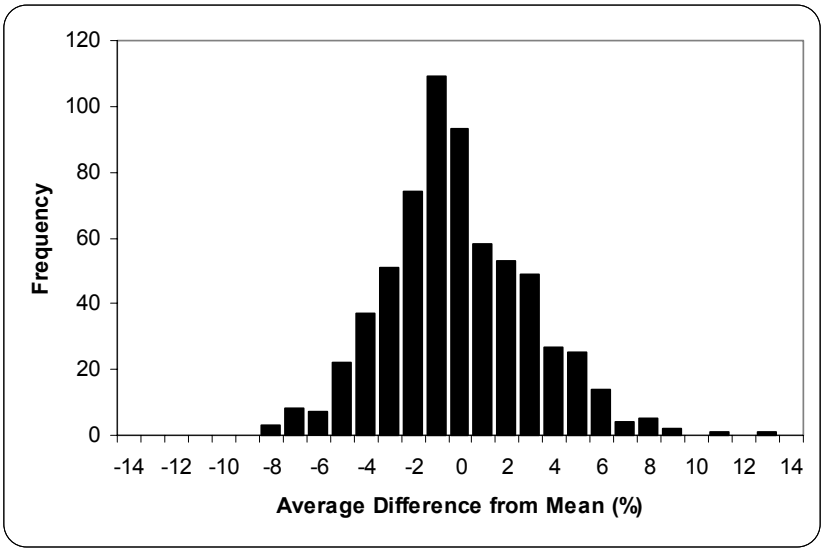

Figure 6.2. Histogram of Differences Between Actual and Predicted (TEAM-3) CV Hauteur.

7. PREDICTION OF ROMAINE BASED ON TEAM-3 DATABASE

The same statistical methods used in Section 5 to analyse the TEAM-3 database for Hauteur were used for Romaine. Table 7.1 shows that the coefficients obtained when a regression is conducted on the TEAM-3 database are similar to those obtained in TEAM-2. The main difference is that diameter has a bigger influence on predicted Romaine in the TEAM-3 analysis and VMB has less impact. The reduced influence of VMB may be a reflection of the relatively narrow range of VMB in the TEAM-3 database. This was discussed for Hauteur in Section 5.

The addition of CVD, MFC or CVL to the model resulted in little improvement to the prediction of Romaine. The TEAM variables together with various combinations of CVL, CVD and MFC were also examined. They are not reported in Table 7.1 as they did not improve the prediction model.

Figure 7.1 compares the actual Romaine values with the Romaine Residual. The Residual Romaine was calculated by subtracting the predicted Romaine from Regression 1 in Table 7.1 from the actual Romaine. Figure 7.2 plots the differences between actual and predicted Romaine and shows that 88% of the consignments fell within ± 2% of the mean. This was comparable with the 84% that fell within this range in the TEAM-2 trial.

Table 7.1. Statistical Analysis using CVD, MFC and CVL to predict Romaine.

Regression		SL	SS	D	V	CVD	MFC	CVL	SE (mm)	R^2
	TEAM-2	-0.11	-0.14	-0.35	0.94				1.50	76%
1	TEAM-3	-0.13	-0.18	-0.63	0.78				1.31	77%
2	TEAM-3 +CVD	-0.10	-0.14	-0.73	0.82	*(0.23)*			1.31	77%
3	TEAM-3 + MFC	-0.13	-0.17	-0.80	0.77		*(-0.04)*		1.31	77%
4	TEAM-3 + CVL	-0.08	-0.16	-0.74	0.69			0.17	1.29	78%

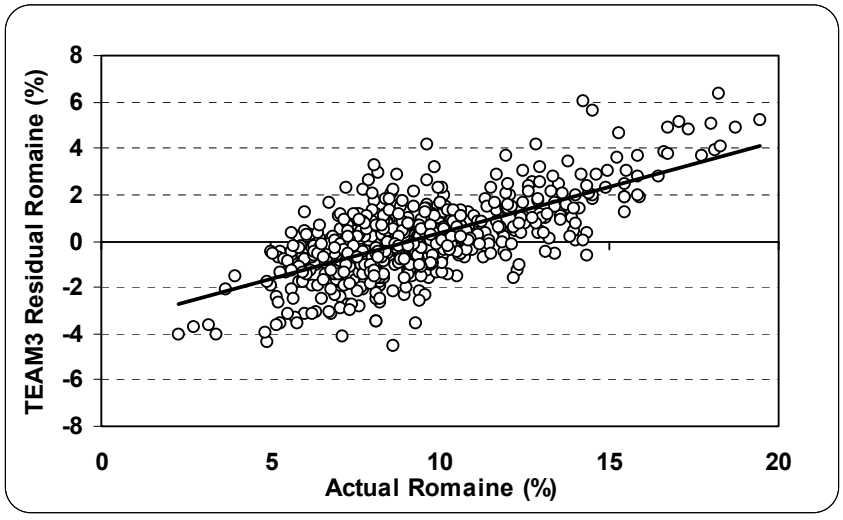

Figure 7.1. Relationship between Actual Romaine and TEAM-3 Residual Romaine.

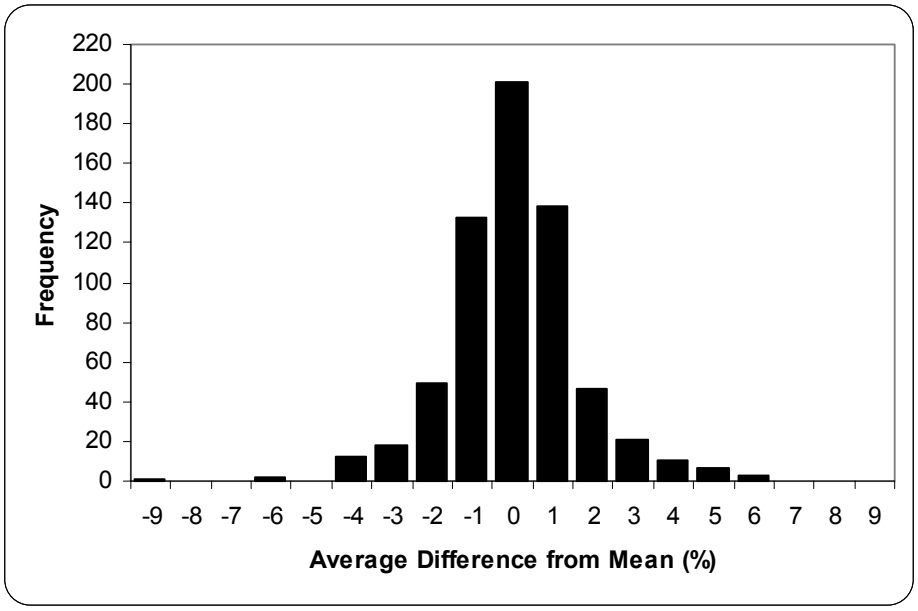

Figure 7.2. Histogram of Differences Between Actual and Predicted (TEAM-3) Romaine.

8. SUMMARY

This report summarises the final analysis of the TEAM-3 database. The TEAM-3 Steering Committee is able to report that the TEAM-2 parameters (SL, SS, MFD, M* and VMB) are still applicable to processing prediction models. It is shown that processing performance has improved since the late 1980's. Mills are producing tops with Hauteur values, on average, 5.1 mm longer than is predicted using the TEAM-2 general formula and greater differences occur as the Hauteur increases above 75 mm. In addition, mills are producing tops with CV of Hauteur values, on average, 2.5% less than predicted by TEAM-2 and Romaine values 2.1% greater than predicted.

Mills also achieve more consistent, predictable results with lower standard deviations between actual and predicted Hauteur than in TEAM-2.

The regression analyses for Hauteur, CV of Hauteur and Romaine have shown that it is possible to calculate new General Formulae for each of these parameters, although they would be very similar to the TEAM-2 General Formulae published in 1988. The addition of CVD and CVL provide small improvements to the prediction. Similarly, the use of M instead of M* makes little change to any prediction model. It has been identified that there is no improvement in processing prediction if MFC is added to the prediction model.

9. RECOMMENDATIONS

The TEAM-3 Steering Committee recommends that the industry consider the following three options:

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

Advantages of Option 1:

- The TEAM-3 trial has shown that the TEAM-2 formula is robust, and if changes were made to the formulae they would be small and would not improve processing predictability significantly.
- The observed differences can be easily accommodated with the TEAM-2 recommended techniques for calculating and applying mill adjustment factors.
- It is the easiest solution to implement with minimal disruption.
- The TEAM-2 formulae are simple to apply and understand.
- No changes are required to existing databases and computer programs around the world.
- No changes are required for Letters of Credit, specifications and contract limits.

Disadvantages of Option 1:

- General processing conditions have changed and actual processing performance will differ from predicted processing performance (eg average of + 5.1 mm for Hauteur).
- A database as comprehensive as that complied for TEAM-3 is unlikely to be available in the near future due to the cost of assembling it.
- The use of M* in the TEAM-2 formulae makes it difficult to calculate an average Hauteur when a number of sale lots are combined.

Option 2. Introduce the following TEAM-3 formulae into the IWTO Staple Test Regulations as a replacement for the TEAM-2 formulae.

Hauteur = 0.41L + 0.34S + 1.46D – 0.15M + 0.06V – 0.68CVD – 0.29CVL

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

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

Advantages of Option 2:

- The new formulae will better reflect current commercial processing conditions
- The new formulae includes additional measurement data (CVL and CVD) that provide a small benefit to the prediction model.

- New formulae would better facilitate any future adjustments (eg 'Atypical' Sale Lots) without the need to repeat a processing trial of this magnitude.
- New formulae would remove the complications caused by the use of M* rather than M.

Disadvantages of Option 2:

- The introduction of new formulae would cause significant disruption to current systems in terms of databases, software, contract limits, Letters of Credit etc.
- The new formulae may not be the best predictor of consignments containing high levels of VM.
- There would be a requirement for an extensive education campaign
- The use of more 'minor' terms may encourage the use of inappropriately tight specifications for these measurements. This may lead to more difficulty in purchasing for only very small gains in processing prediction.

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

Advantages of Option 3:

- Will allow mills to choose the formulae that best suit their requirements.
- Is consistent with the IWTO Core Tests Regulations which provide different formulae for calculating Commercial Yield.

Disadvantage of Option 3:

- Two sets of processing prediction formulae is likely to create some confusion.

The TEAM-3 analysis has resulted in the derivation of prediction formulae for the calculation of Hauteur, CV of Hauteur and Romaine. It is recommended that, from a technical perspective, the Raw Wool Group endorse the TEAM-3 formulae presented by the TEAM-3 Steering Committee in this paper.

However, the advantages and disadvantages of the three options presented here are of a more commercial nature than a technical nature. Therefore, it is recommended that this paper be discussed by the Commercial Regulations Committee and then circulated to all National Committees prior to any decision being made to change the IWTO Staple Test Regulations.

10. TEAM-3 STEERING COMMITTEE MEMBERS AND ACKNOWLEDGEMENTS

The TEAM-3 Processing Trial was co-ordinated by the TEAM-3 Steering Committee. The Committee included:

Michael Jackson	AWTA Ltd
Ian Ashman	AWTA Ltd
Jim Marler	AWTA Ltd
Andrew Lindsay	AWTA Ltd
Trevor Mahar	AWTA Ltd
Bob Couchman	Capronex Services Pty Ltd

The TEAM-3 Steering Committee would particularly like to acknowledge the hard work of Victoria Fish and David Crowe, from AWTA Ltd's Research and Development Department, for their statistical analysis of the TEAM-3 database. Final acknowledgement goes to all the participating mills and topmakers (See Table 2.2). Their support of this industry project is very much appreciated.

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APPENDIX 1

Histograms of Raw Wool and Top Characteristics

Figure A1: TEAM-3 SDRY Yield Histogram

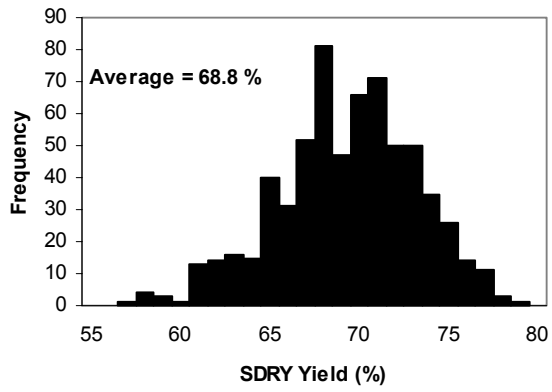

Figure A2: Team-3 VMB Histogram

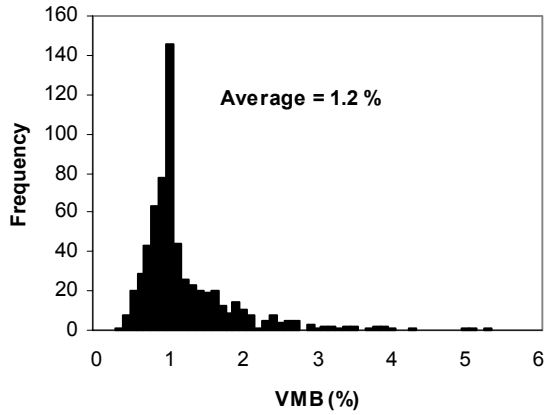

Figure A3 : TEAM-3 Mean Fibre Diameter Histogram

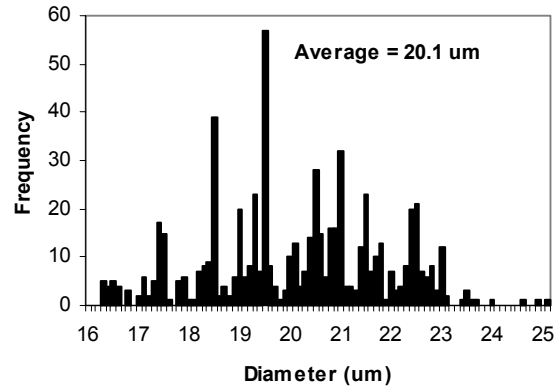

Figure A4: TEAM-3 CV of Diameter Histogram

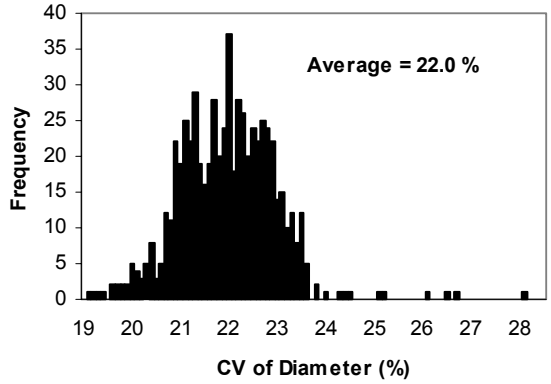

Figure A5: TEAM-3 Fibre Curvature Histogram

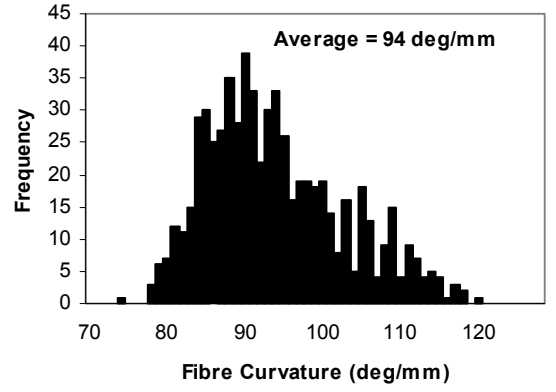

Figure A6: TEAM-3 Staple Length Histogram

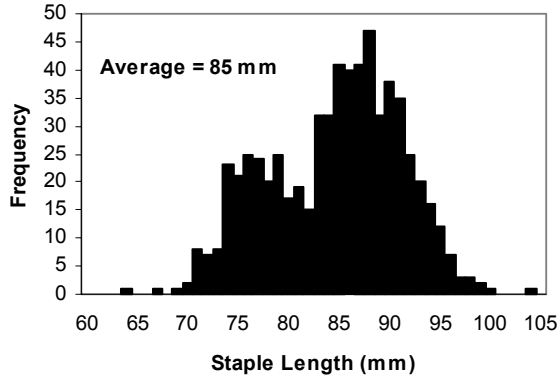

Figure A7: TEAM-3 CV Staple Length Histogram

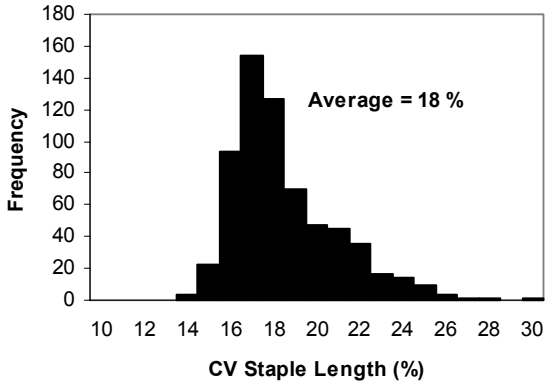

Figure A8: TEAM-3 Staple Strength Histogram

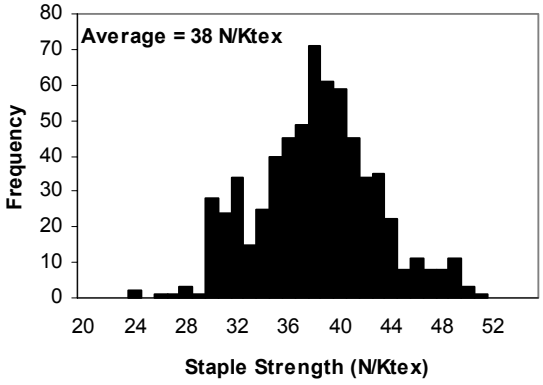

Figure A9: TEAM-3 Tip Break Histogram

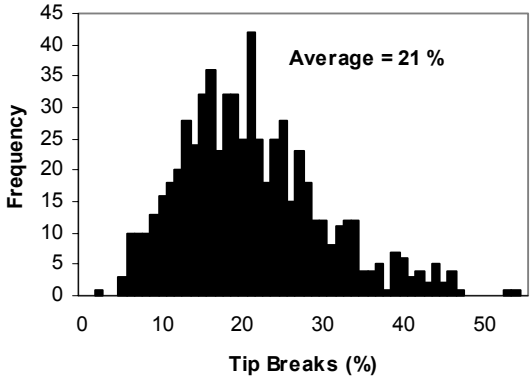

Figure A10: TEAM-3 Mid Break Histogram

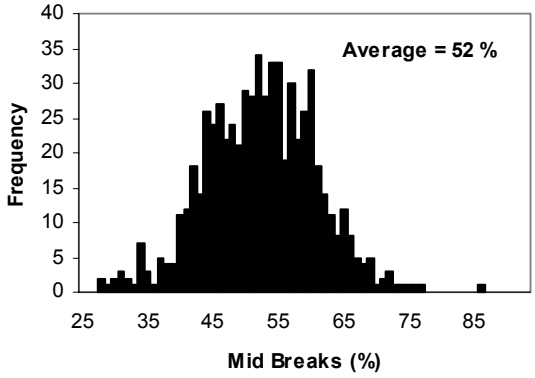

Figure A11: TEAM-3 Base Break Histogram

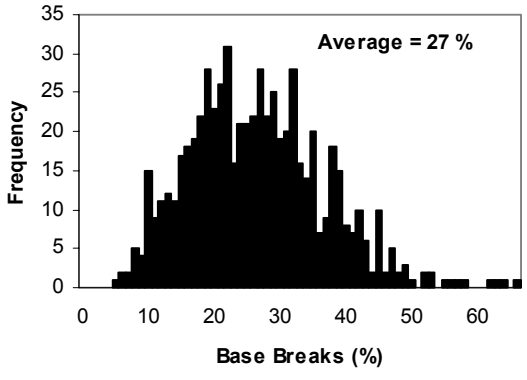

Figure A12: TEAM-3 Hauteur Histogram

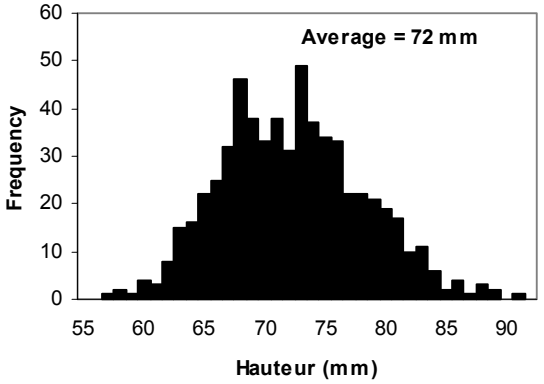

Figure A13: TEAM-3 CV Hauteur Histogram

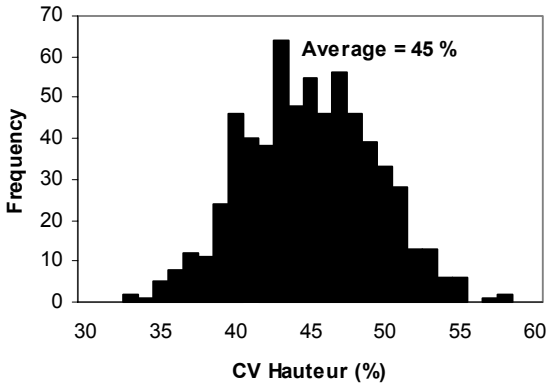

Figure A14: TEAM-3 Romaine Histogram