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A Review of the Proposed TEAM-3 Formula for Predicting Hauteur.

By

J.W. Marler, R.C. Couchman[#], V.E. Fish and T.J. Mahar

Australian Wool Testing Authority Ltd PO Box 190 Guildford NSW 2161 Australia
[#] Capronex Services Pty Ltd PO Box 247 North Carlton VIC 3054 Australia

SUMMARY

A review of the TEAM-3 formula proposed to the technical and commercial delegates at the IWTO Congress in Evian has been completed. Three options for the coefficient for Vegetable Matter Base were considered:

- Despite its statistical non-significance, use the coefficient derived from the TEAM-3 database;
- Due to its statistical non-significance based on the TEAM-3 database, have no VM term; and
- Due to the much wider VM range in the TEAM-2 database, use the VM coefficient from TEAM-2.

Based on the analyses presented the authors recommend the third option, that is use the VM coefficient from the TEAM-2 formula. The new equation that is proposed to replace the formula for Hauteur presented in Evian is:

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

In addition to reviewing the coefficient for Vegetable Matter in the prediction of Hauteur, the previously reported relationship between the slope of the Hauteur residuals (Actual Hauteur – Predicted Hauteur) and the Actual Hauteur was reviewed. The slope was found to be related to the CV Hauteur of the resultant top. Evidence has been presented that demonstrates that changing machinery settings to balance the requirements of individual customers will have an effect on the differences between what is achieved and the expected outcome from any TEAM formula. On the basis of TEAM-3 one could conclude that, as a rough guide, an increase in Hauteur of 0.5 mm would result from a 1 % decrease in the CVH.

INTRODUCTION

During the presentations of the TEAM-3 Final Report (TEAM-3 Steering Committee, 2004) to the IWTO Raw Wool Group and the Commercial Regulations and Contracts Committee, an offer was made to review the coefficient for Vegetable Matter Base and to report this at the Shanghai Meeting. The coefficient as reported then was positive, contrary to the expectations of most topmakers and the authors, and statistically not significant. It was suggested that this could be due to the relatively small range of Vegetable Matter Base in the consignments that comprised the TEAM-3 database.

To investigate the above suggestion the TEAM-2 database was re-analysed using S-Plus while restricting the range of Vegetable Matter Base to more closely reflect the range in the TEAM-3 database.

In addition to the Vegetable Matter Base the opportunity was taken to review the reasons for the slope on the regression line for the residuals (that is the Actual Hauteur minus the Predicted Hauteur) versus the Actual Hauteur (Lindsay *et al*, 2002a; Lindsay *et al*, 2002b; Lindsay *et al*, 2003; TEAM-3 Steering Committee, 2003; and TEAM-3 Steering Committee, 2004.)

REVIEW OF THE VEGETABLE MATTER BASE COEFFICIENT.

The analysis of the TEAM-3 database returned a coefficient for Vegetable Matter Base (VM) that was both positive and not statistically significant. This would imply that VM has no impact on Hauteur. However, general experience in topmaking would suggest that, all other things being equal, consignments containing high levels of VM will have a lower Hauteur than consignments containing low levels of VM. At the IWTO Meeting in Evian, May 2004, the TEAM-3 Committee Chairman, during his presentation, offered to review this apparent anomaly in the TEAM-3 analysis.

One of the basic underlying assumptions for multiple regression statistics is that there is sufficient variation in each of the input variables, for example VM, to influence the variation in the output result, in this case Hauteur. The range of VM in the TEAM-2 database was much wider (0.1% to 10.2%) than in the TEAM-3 database (0.3% to 5.3%). It is possible that the limited range in the TEAM-3 database is the reason behind the anomaly.

At the IWTO Meeting in Evian the Technology and Standards Committee approved the TEAM-3 formulas as technically correct pending clarification of the role of VM in the equation for Hauteur. The impact of the range in VM on the prediction of Hauteur was examined by re-analysing the TEAM-2 database using restrictions on the range in VM to more closely match the range of VM in the TEAM-3 database. All consignments from the TEAM-2 database that had a VM greater than 3% were removed and a statistical analysis was performed on the remaining 444 consignments. This analysis was repeated on 345 consignments following removal of all consignments with a VM greater than 2%.

The results are presented in Table 1.

Table 1: Analysis of the TEAM-2 Database Following the Removal of Consignments with VM greater than 3% (Regression 1) and greater than 2% (Regression 2).

Regression		N	SL	SS	D	M*	VM	SE (mm)	R^2
	TEAM-2 (All Data)	545	0.52	0.47	0.94	-0.19	-0.45	3.41	84%
1	TEAM-2 (VMB<3%)	444	0.54	0.49	0.88	-0.18	(-0.09)	3.48	83%
2	TEAM-2 (VMB<2%)	345	0.50	0.46	0.89	-0.19	(+0.79)	3.42	83%

Note: All Coefficients that were not statistically significant are bracketed and in bold. They relate to the VM coefficients where the range of VM in the analysed data was reduced. As was the case for all TEAM analyses, each individual mill was included as a variable in the regression analysis but, for simplicity, only the coefficients for the greasy wool parameters are presented in the table.

Table 1 shows that the reduced range in VM causes the coefficient for VM to become statistically non-significant and the coefficient also becomes positive in Regression 2 as the range in VM is reduced further.

Using either regressions 1 or 2 in Table 1 to predict the Hauteur of consignments with high VM (greater than 4%) produced poorer results (average difference = 2.5mm) than when the prediction developed from all the data was used for these high VM consignments (average difference = 0.6mm).

A similar situation would exist in respect to Fibre Diameter if, for example, a combing mill was only processing 22.0µm to 22.5µm batches and the mill had developed its own specific Hauteur prediction formula. In such a case, it is likely that diameter would not be included in this mill specific formula and erroneous results could be produced if the mill changed the diameter of the consignments it processed.

For this reason it has always been recommended that the development of any mill specific formula should start with the TEAM General Formula.

This analysis provides three options to account for the influence of VM on the prediction of Hauteur:

1. Despite the statistical non-significance, include the coefficient for VM (+0.03) determined by the analysis of the TEAM-3 data base;

2. In acknowledgement of the statistical non-significance and positive value, exclude a VM term from the model; and

3. As the TEAM-2 database had a much wider range in VM than TEAM-3 database, use the TEAM-2 coefficient for VM (-0.45) in the TEAM-3 prediction model.

The last option is technically feasible as any coefficient is simply an indication of the sensitivity of Hauteur to a change in that particular characteristic. Table 2 provides a comparison of the three alternatives. Regression 1 in Table 2 is the TEAM-3 formula that was proposed in Evian Congress and is provided for comparison. Regression 2 is based on having no VM term, and Regression 3 uses the VM coefficient that was derived from the TEAM-2 database.

Table 2: Statistical Analysis for Different approaches to VM in the Regression Modelling

	Regression	SL	SS	D	M*	V	CVD	CVL	SE (mm)	R^2
1	TEAM-3 + CVD + CVL	0.41	0.33	1.45	-0.18	*(0.08)*	-0.63	-0.32	2.49	83%
2	TEAM-3 + CVD + CVL (No V)	0.41	0.33	1.47	-0.18		-0.65	-0.32	2.49	83%
3	TEAM-3 + CVD + CVL-0.45V	0.42	0.34	1.37	-0.18	-0.45#	-0.55	-0.35	2.50	83%

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

The # indicates that this coefficient was derived from the TEAM-2 analysis and included here due to the lack of range in VM in the TEAM-3 data base. As was the case for all TEAM analyses, each individual mill was included as a variable in the regression analysis but, for simplicity, only the coefficients for the greasy wool parameters are presented in the table.

On the basis of the SE and R^2 values there is no difference between the three alternatives. In addition, there are only small differences in the coefficients for the other wool characteristics. Because it is better able to reflect the sensitivity of Hauteur to the widest range of VM in consignments, including consignments with high levels of VM, Equation 3 from Table 2 is the preferred option.

It should also be recognised that although VM was not a significant variable for the prediction of Hauteur based on the analysis of the TEAM-3 database, its impact was found to be significant in the prediction of Romaine.

In the TEAM-3 Final Report presented at the Evian Meeting the M* was replaced with M, the actual Mid-break percentage, as 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 more easily combine Hauteur values of individual Sale Lots.

Table 3 shows that using the new VM coefficient does not change the conclusion from the TEAM-3 Final Report that the use of M is equivalent to M* in the prediction model. Consequently, the use of M could be considered as a possible replacement for M*.

Table 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 – 0.45V	0.42	0.34	1.37	-0.18		-0.45	-0.55	-0.35	2.50	83%
2	M* replaced by M	0.43	0.35	1.38		-0.15	-0.45	-0.59	-0.32	2.49	83%

As the use of M would simplify the TEAM formula, Regression 2 in Table 3 is the proposed new TEAM-3 prediction formula for Hauteur. It should be noted that this formula contains a constant term which includes an adjustment associated with individual mill differences. For the entire TEAM-3 database, the adjustment equals 23.2. Therefore, the proposed new TEAM-3 formula for Hauteur, which clarifies the role of VM, is as follows:

$$\text{Hauteur} = 0.43L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 21.8$$

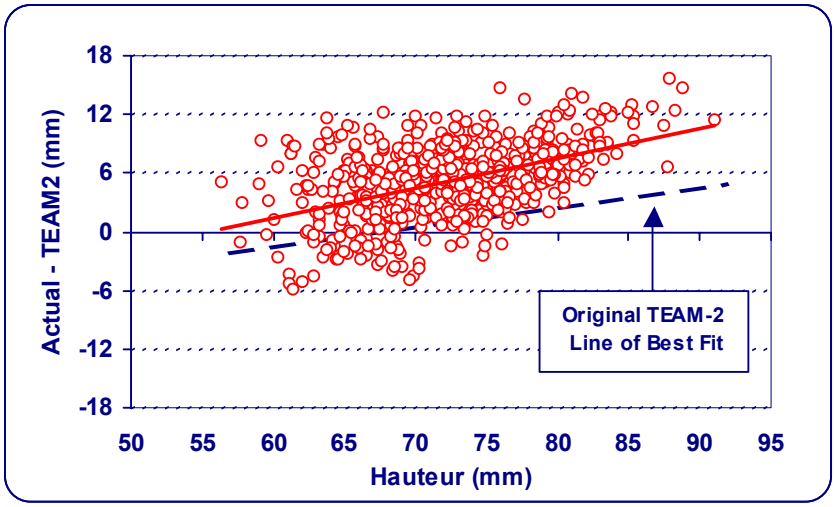
The above formula will be recommended as the replacement formula for the formula proposed in the Evian IWTO Meeting.

REVIEW OF THE RESIDUALS (ACTUAL – PREDICTED) FOR HAUTEUR PREDICTION

Earlier reports to IWTO have reported a relationship between the residuals and the actual Hauteur values. The residual becomes larger as the actual Hauteur increases. The trend was evident in both TEAM-2 and TEAM-3 analyses.

The trend is reproduced from the Final Team-3 Report below as Figure 1.

Figure 1: Hauteur Residuals (Actual – Predicted) for TEAM-2 predictions using the TEAM-3 database.



If all the parameters having an influence on the Hauteur were included in the regression model, the expectation for a relationship of this nature would be a random scatter of data points around zero. The observed trend suggests that a factor is possibly missing.

Figures 2, 3 and 4 show the TEAM-3 Hauteur Residuals (Actual – Predicted) plotted against Actual Hauteur, Romaine and CVH.

Figure 2: Team-3 Residual (Actual – Predicted) versus Actual Hauteur

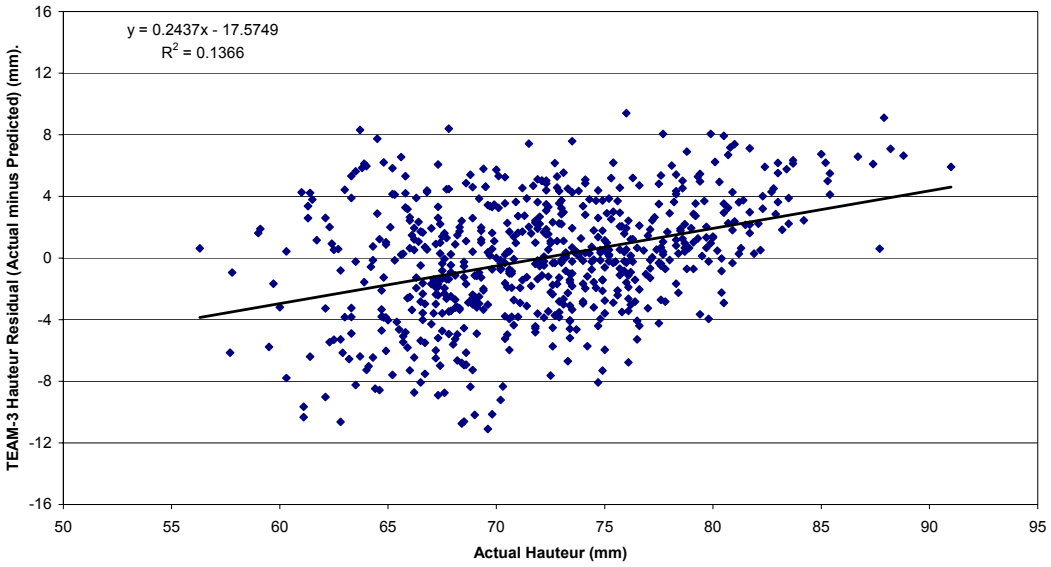


Figure 3: Team-3 Residual (Actual – Predicted) versus Actual Romaine

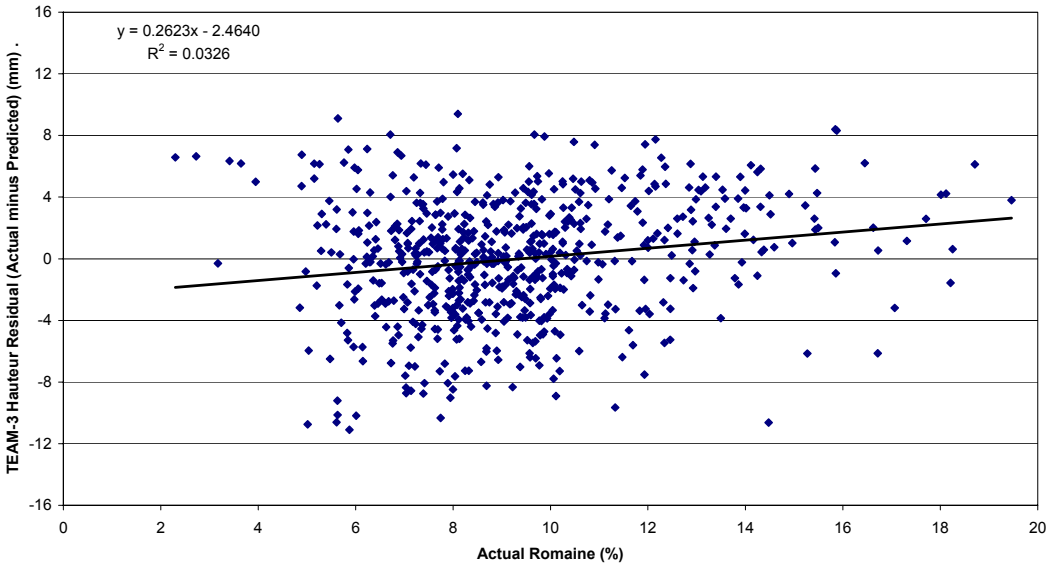
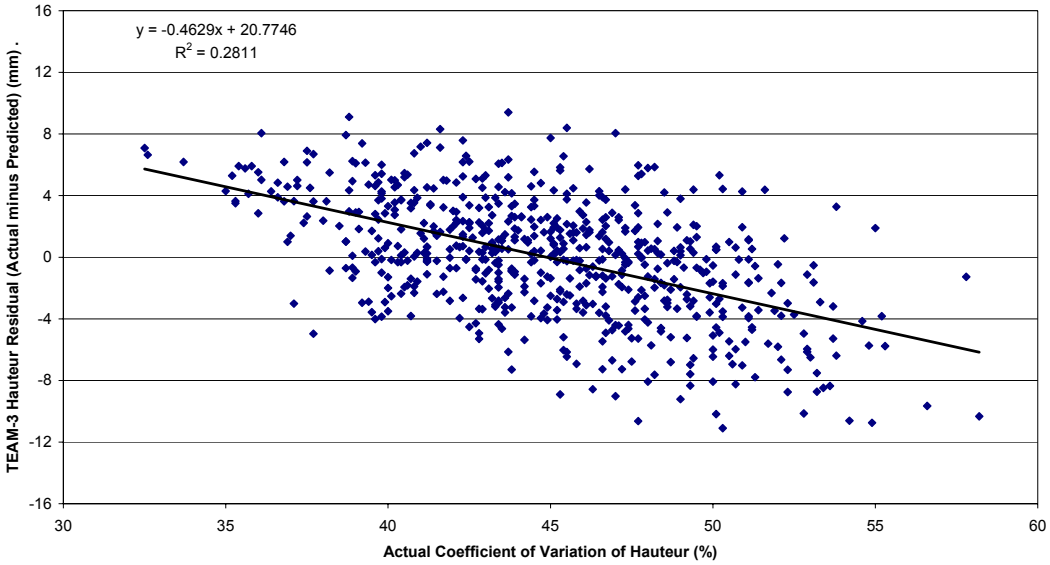


Figure 4: Team-3 Residual (Actual – Predicted) versus Actual CV Hauteur (CVH)



The TEAM-3 Residual Hauteur shows a positive slope with respect to Hauteur and Romaine and a negative slope with respect to CV Hauteur. This combination of trends is consistent with a greater than normal removal of short fibre. The scatter around the line of best fit is smaller for CVH than for Romaine.

The samples with low CVH values have positive residuals (that is they have processed longer than predicted) and those with high CVH values tend to have negative residuals (that is they have processed shorter than predicted).

To investigate this further, the Hauteur Diagrams for consignments with CVH values less than 37% and greater than 53% were compared and found to show consistent differences as depicted in Figures 5 and 6.

Figure 5: A Typical Hauteur Diagram for a consignment with a CVH less than 37%.

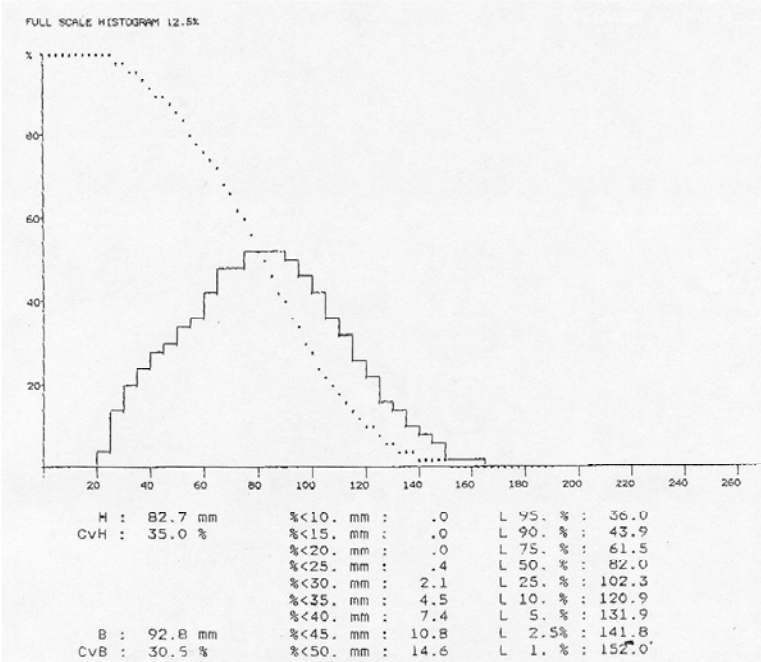
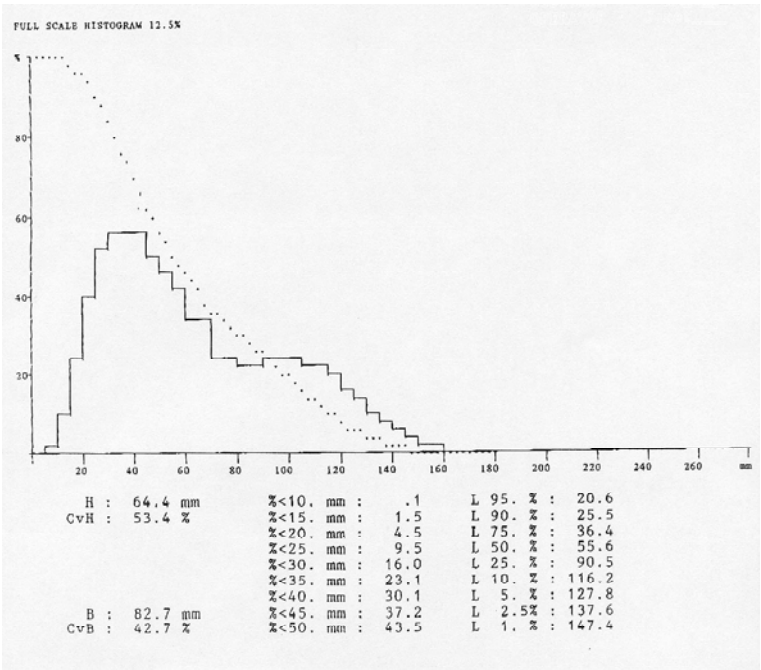


Figure 6: A Typical Hauteur Diagram for a consignment with a CVH greater than 53%.



The clear differences between the two Hauteur diagrams above relate to the short fibre content. Those consignments with low CVH values appear to have been combed with the aim to remove as much short

fibre as possible, whereas those with high CVH values appear to be the opposite with an abundance of short fibres present (see the high frequency count at about 30mm in Figure 6 which is absent in Figure 5).

Throughout the TEAM Projects mills were at liberty to change machine settings to satisfy the needs of their customers. It was hypothesised that changing machine settings would influence Hauteur, CV Hauteur (CVH) and Romaine. Despite the CVH and Romaine values being unavailable before the wool is processed, it was considered advantageous to examine their impact on the Hauteur prediction model in order to help to explain the observed trends.

Table 4 below summarises the regressions.

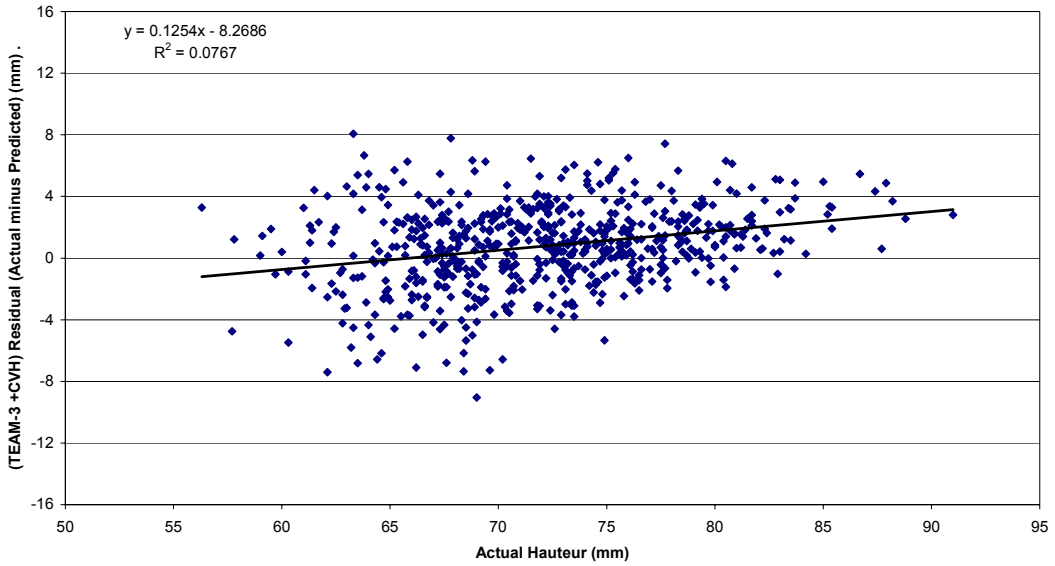
Table 4: Including Romaine (ROM) and CV Hauteur (CVH) in the new proposed TEAM-3 Formula.

	Regression	SL	SS	D	M	V	CVD	CVL	ROM	CVH	SE (mm)	R^2
1	New TEAM-3	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32			2.49	83%
2	New TEAM-3 + ROM	0.38	0.28	1.10	-0.14	-0.45	-0.59	-0.23	-0.45		2.41	84%
3	New TEAM-3 + CVH	0.65	0.11	0.70	-0.02	-0.45	-0.43	*(-0.07)*		-0.72	1.66	92%
4	New TEAM-3 + ROM + CVH	0.61	*(0.06)*	0.50	*(-0.02)*	-0.45	-0.44	*(0.00)*	-0.35	-0.70	1.60	93%

It is clear from the regressions that adding CVH on its own had a significant impact on the SE and R^2, more so than adding Romaine on its own. The addition of both Romaine and CVH (Regression 4) provided no real improvement over CVH by itself (Regression 3) but their addition reduced the statistical significance of the coefficients for Staple Strength (SS), Mid breaks (M) and Coefficient of Variation of Staple Length (CVL) because of their relationship with CVH.

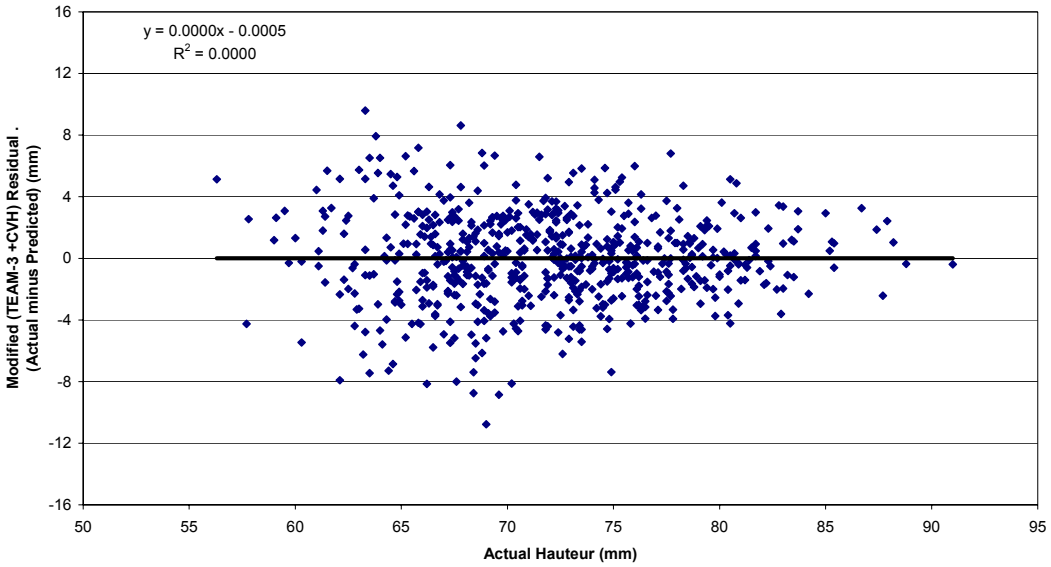
Figure 7 shows the Hauteur residuals, derived from Regression 3 in Table 4, plotted against the actual Hauteur.

Figure 7: 'TEAM-3 plus CVH' model (Regression 3, Table 4) residuals plotted against Hauteur.



The slope on the regression line of best fit has been reduced. The regression model was recalculated to provide a correction for the slope and bias. The residuals for this Modified Regression model are presented in Figure 8.

Figure 8: Hauteur Residuals for the Modified 'TEAM-3 + CVH' regression model.



In this case the residuals show the expected relationship of random scatter around the zero line, with no trend.

The two issues that have impacted on the regression analysis for the original TEAM-3 Formula have been:

- The absence of any terms to account for possible machine setting differences used between different consignments and different mills; and
- The potential limitations associated with the regression model assumptions that the independent variables are without error or variance.

It is not uncommon for mills to alter comb settings to achieve different outcomes. There are two major reasons for doing this:

- to improve sliver cleanliness; and/or
- to remove more short fibre and improve the actual Hauteur and CV Hauteur values.

The latter of course has a cost penalty in respect to increased Romaine.

CSIRO research in the late 1970's (Andrews (1979)) clearly showed the effect of comb settings on Hauteur and Romaine. Two figures from the Proceedings of a Seminar on "Staple Length and Strength of Greasy Wool: Measurement and Effects on Worsted Processing" are reproduced in this report as Figures 9 and 10 to demonstrate the effects.

Figure 9: Reproduction of the Effect of Comb Settings on Hauteur.

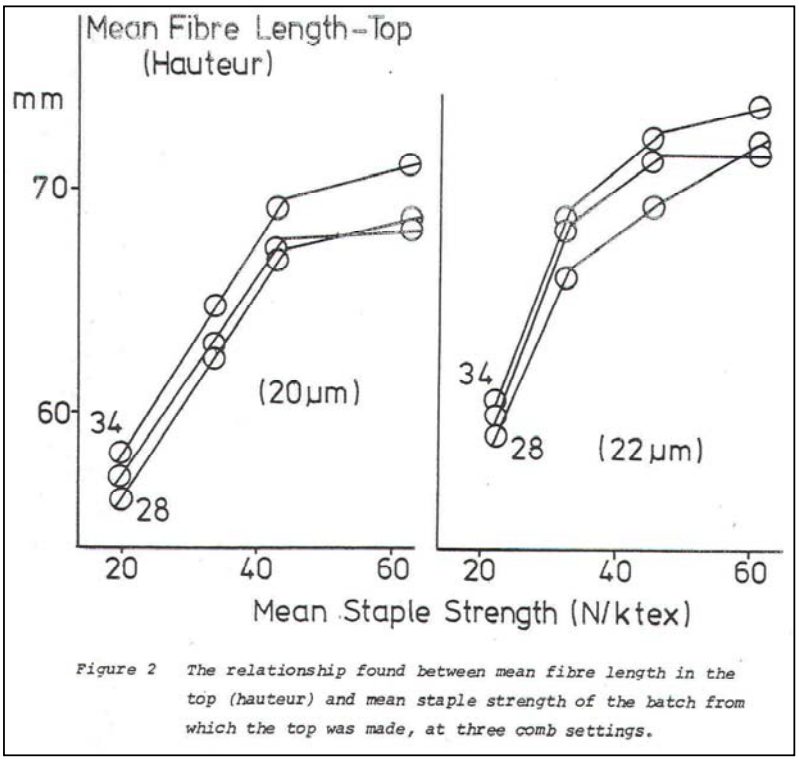


Figure 2 *The relationship found between mean fibre length in the top (hauteur) and mean staple strength of the batch from which the top was made, at three comb settings.*

Figure 10: Reproduction of the Effect of Comb Settings on Romaine.

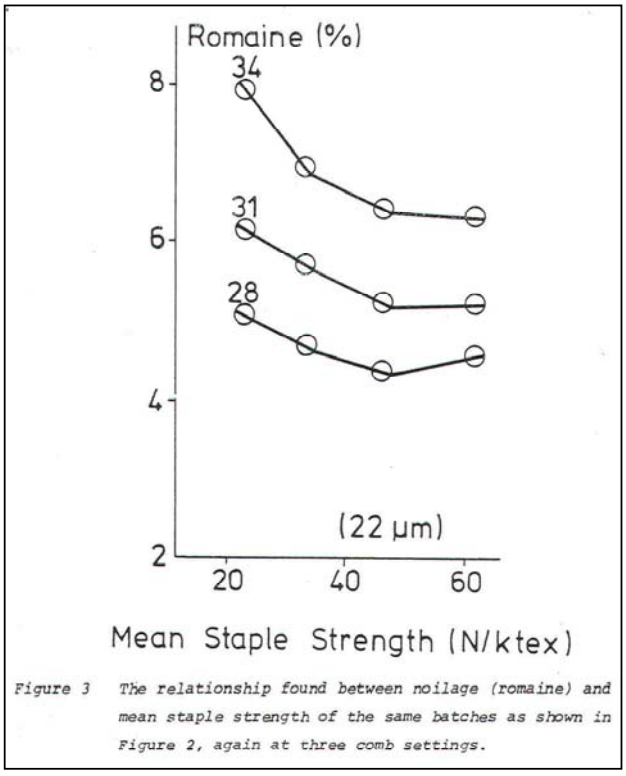


Figure 3 *The relationship found between noilage (romaine) and mean staple strength of the same batches as shown in Figure 2, again at three comb settings.*

If different comb settings are used for the same greasy wool input the residual (Actual – Predicted) values obtained would be affected. This can occur either within the same mill, to meet an individual customer's requirements, or between different mills. Other processing factors such as choice of lubricant, loading on the card during processing, number of gill passes etc will also have an influence if they differ between processing batches.

The net result will be to increase the variation experienced in attempting to predict processing outcomes if they are not incorporated into the formula. For example, the Standard Error of the TEAM-3 model for predicting Hauteur was 2.49 mm without the inclusion of CVH and dropped to 1.66 mm when it was included. This drop is much larger than that achieved by adding additional greasy wool terms and highlights the importance of processing conditions in limiting what can be achieved in prediction.

The possibility exists to provide some indication of the potential deviation from the TEAM-3 Hauteur result as a function of Hauteur and CVH. On the basis of the slope of the relationship presented in Figure 4 for the residual (Actual minus Predicted) Hauteur versus actual CV Hauteur, one would conclude that, as a rough guide, an increase in Hauteur of 0.5 mm would result from a 1 % decrease in the CVH. Clearly the Romaine would also rise. Hence, the conversion costs would also rise. Whether the conversion costs are offset by the added value in the top is a matter between the buyer and seller of the top and noil.

CONCLUSIONS

A review of the TEAM-3 formula proposed to the technical and commercial delegates at the IWTO Congress in Evian has been completed. Three options for the coefficient for Vegetable Matter Base were considered:

- Despite its statistical non-significance, use the coefficient derived from the TEAM-3 database;
- Due to its statistical non-significance based on the TEAM-3 database, have no VM term; and
- Due to the much wider VM range in the TEAM-2 database, use the VM coefficient from TEAM-2.

Based on the analyses presented in this report, the authors recommend the third option, that is use the VM coefficient from the TEAM-2 formula. The new equation that is proposed to replace the formula for Hauteur presented in Evian is:

$$\text{Hauteur} = 0.43L + 0.35S + 1.38D - 0.15M - 0.45V - 0.59CVD - 0.32CVL + 21.8 + MA$$

In addition to reviewing the coefficient for Vegetable Matter in the prediction of Hauteur, the previously reported relationship between the slope of the Hauteur residuals (Actual Hauteur – Predicted Hauteur) and the Actual Hauteur was reviewed. The slope was related to the CV Hauteur of the resultant top.

Evidence has been presented that demonstrates that changing machinery settings to balance the requirements of individual customers will have an effect on the differences between what is achieved and the predicted outcome from any formula. On the basis of TEAM-3 one could conclude that as a rough guide an increase in Hauteur of 0.5 mm would result from a 1 % decrease in the CVH.

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APPENDIX 1

RECOMMENDATION

The TEAM-3 formula for Hauteur prediction that was accepted as "technically correct pending clarification of the role of VM" at the IWTO Evian Meeting as:

Hauteur = 0.41L + 0.34S + 1.46D – 0.15M + 0.06V – 0.68CVD – 0.29CVL + 24.8 + MA

and as a consequence of the clarification provided in this report, it be replaced with the following formula:

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