The *Journal of Cotton Science 6:133–142 (2002)*
http://journal.cotton.org, © The Cotton Foundation 2002

TEXTILE TECHNOLOGY

Sensitivity of the Shirley Developments Ltd. Micromat Tester to Operators and Sample Preparations

Joseph G. Montalvo, Jr.*, Sherman E. Faught, and Steven M. Buco

INTERPRETIVE SUMMARY

The fineness of cotton is important because yarn made from fine fibers is generally stronger and more uniform than yarn from coarse fibers. Fiber maturity is important because mature fibers, those with well-developed cell walls, absorb dye better and are less prone to cause defects of various sorts in the finished product. Micronaire measurements are considered to be a combination of fiber fineness and maturity (Thibodeaux et al., 2000).

Improved reference methods to measure fineness and maturity are needed to calibrate the faster, high-volume instruments that grade cotton for these properties. A substantially improved high-volume instrument is also needed because millions of samples must be analyzed each year, but the accuracy of the data must not be compromised in order to attain speed. Work is being conducted at the Southern Regional Research Center (SRRC) to develop a more reliable reference method and a high-volume instrument to measure fineness and maturity. Emphasis is on analyzing a large sample, especially with the high-volume device, to more closely represent bale values. The improved reference method analyzes a 4-g sample in about 30 s; the faster device analyzes a 40-g sample in <1 s.

The reference method for fineness and maturity is based on the analysis of fineness and maturity by the resistance to air flowing through cleaned cotton that an operator has placed in a short cylinder. This machine is called a “Fineness and Maturity Tester” (FMT). The high-volume instrument that we have been developing measures the reflectance of different wavelengths of near infrared light. Our prototype near infrared high-volume instrument can measure other properties, as well as fineness and maturity, while the slower FMT only assesses the fineness and maturity of fiber.

The strategy is to use fundamental reference methods (e.g., image analysis) to develop a moderately small set of calibration cottons that can subsequently be used to convert the air pressure readings of the FMT into fineness and maturity values. These instruments are then to be used to develop a much larger set of cottons with known fineness and maturity values that can then be used to calibrate the near infrared high-volume instrument system. The improvements to both the FMT and the near infrared device have gained recognition, but important gaps must be filled before the technology is widely used. The focus of this research was to develop techniques to minimize the variations that occur when the cotton is mechanically cleaned (prepared) for FMT analysis and when the operator puts the specimen in the sample chamber.

This research consists of several major thrusts: 1) the development of an appropriate theory to guide the work, 2) the collection of experimental data, 3) interpretation of data, and 4) correction of data to eliminate adverse changes in mean values. The theory is needed to guide the work because a literature review confirms that this is the first attempt in identifying and eliminating operator and preparation errors in order to generate more consistent data. Several operators and mechanical cleaners are used to generate fineness and Maturity Tester experimental data. Data interpretation is straightforward. Sensitivity of the instrument to an operator is detected as random “spikes” or outliers in the data. Sensitivity to preparation is recognized as “biases” or persistent shifts in the data. Correcting data for operator influence is achieved by using statistics and for preparation effects is achieved by checking for improper settings in mechanical cleaners or by avoiding the use of a specific cleaner.

Joseph G. Montalvo, Jr., and Sherman E. Faught, USDA-ARS, Southern Regional Research Center, P.O. Box 19687, New Orleans, LA 70179: Steven M. Buco, Statistical Resources, Inc., 11505 Perkins Rd., Suite H, Baton Rouge, LA 70810
* Corresponding author (montalvo @srrc.ars.usda.gov)

The performance of the FMT with and without data correction was compared to determine accuracy and repeatability. Three operators analyzed three cottons, which had been cleaned by six different mechanical cleaners. This produced a database of more than 650 observations. Sensitivity to both operators and sample preparations were found in the database. After data correction, results were more consistent. The expected outcome is the adoption of the technology by organizations that need to assess cotton fineness and maturity.

ABSTRACT

Protocols were developed to identify operator and preparation effects in the analysis of cotton (*Gossypium hirsutum* L.) samples by the Micromat model of the Shirley Developments Fineness and Maturity Tester. The instrument measures fineness and maturity based on air permeability through a fixed mass of compressed fibers. Differential pressures are the quantities measured, and are related to maturity and fineness by appropriate equations. The specimens are placed manually into the sample chamber so there is the potential for sensitivity to different operators. Mechanically cleaned cottons are analyzed so there is also the potential for sensitivity to different mechanical cleaners. Operator effects lead to random outliers in the data, while preparation effects give rise to persistent biases. Three cottons that span the range of micronaires were analyzed by three operators, and cleaned on six cleaners at four laboratories. There was a negative correlation between operator experience with the instrument and number of outliers. A negative correlation was also found between micronaire and the number of outliers. After removing operator outliers from the data sets, differences in mean values between operators compared with the most experienced operator was <±2%. After correction of operator effects, preparation differences in mean values for the Microdust and Trash Monitor relative to the card were >±2%.

Cotton fineness and maturity are important fiber properties in the textile mill lay down. Some yarn and fabric properties associated with fineness and maturity are dye uptake, nep formation, strength and uniformity of yarn, and resistance to surface abrasion. Fiber fineness and maturity can be defined in various ways (Ramey, 1982; Lord, 1988). In this paper, it is necessary to consider only two definitions of each property. Fineness is expressed as mass per unit length (mtex) and the fundamental measure is cross-sectional perimeter (µm). Maturity is expressed as the degree of wall thickening/0.577 (dimensionless) and the fundamental measure is wall thickness (µm).

The Micromat Tester (Shirley Developments Ltd., Stockport, England) is being used in this laboratory as a reference method to calibrate fast spectroscopy-based instrumentation to measure fineness and maturity (Buco et al., 1998; Montalvo and Faught, 1998). The Micromat is the current model of a series of instruments manufactured by the company to measure fineness and maturity and generally is referred to as the Fineness and Maturity Tester (FMT). This instrument is a double compression airflow device that measures the pressure drop of air drawn through a 4-g sample that is compressed, during the test, to two different densities. The initial and second stage pressure drops are referred to as *PL* and *PH*, respectively, and are converted to fineness and maturity by appropriate empirical equations (SDL 089 Manual, 1994).

A series of improvements to the Micromat has resulted in reduced drift and improved precision (Montalvo and Faught, 1999). To standardize the test method, specifications are being developed for Micromat equipment and to standardize calibration and operation procedures. Standardization of the procedures includes identifying acceptable mechanical cleaners to clean and open the raw cotton mass prior to analysis, and a trained operator who will use a consistent procedure in manually inserting the prepared specimen into the cylindrical sample chamber.

A literature review of sample preparation (Lord and Heap, 1988) indicated that the specimen must be clean, well-opened and randomized. There have been no additional studies published since this review. A poll (Montalvo, unpublished data) revealed five different mechanical cleaners are being used in the United States to prepare FMT specimens. Indeed, some laboratories reported using two or more of the various cleaners.

At cotton testing meetings in this country and abroad, the writer has repeatedly been told of an operator effect on FMT results. A literature review indicates no theoretical or experimental studies have been reported. An operator effect may confound the elucidation of a sample preparation effect, comparability studies within a laboratory, and controlled round-robin evaluations (Montalvo et al., 2000). The objective of this paper is to present research on a new approach to detect and control operator effects using the upgraded Micromat, and the application of the technology to eliminate the problem with sample preparation.

THEORY

Operator Effect on Data

Consider an operator using his fingers to transfer a mechanically cleaned and opened cotton specimen into the Micromat sample chamber.

Case I - No Operator Effect. Assume that a limited number of specimens (n) from the same cotton are inserted by the operator into the sample chamber — with ideal fiber arrangement — and analyzed. By definition, an ideal fiber arrangement does not produce an operator effect on test results. The observed value of the sample mean is:

$$\overline{X} = [X_1 + X_2 + X_i + ...X_n]/n \qquad \text{[eq.1]}$$

where X_i represents the observed *PL* or *PH* values of the ith observation. If the number of samples is sufficiently large then:

$$\overline{X} = \propto \qquad \text{[eq. 2]}$$

where μ is the population or true mean. Since we do not include an allowance for an operator effect, the observed absolute difference between X and μ is:

$$\Delta\overline{X} = \left|\overline{X} - \propto\right| \qquad \text{[eq. 3]}$$

due to variability in fiber fineness and maturity, and in the instrument itself. The usual notations of $\overline{X}$ for sample mean and μ for population mean, respectively, are used herein (Natrella, 1963).

Case II - Operator Effect. For each specimen, there is the potential for an operator effect to be introduced in the chamber and thus, variability in instrument readings. Consider [eq. 1] rewritten to show for the limited number of n specimens from the same cotton, an operator effect for the ith observation with expected value θ_i. The observed value of the sample mean is now

$$X' = [X_1 + X_2 + \theta_i + ... + X_n]/n \qquad \text{[eq. 4]}$$

and the absolute difference between *X*' and μ is

$$\Delta X' = \left|X' - \mu\ \right|. \qquad \text{[eq. 5]}$$

Due to the operator effect, $\Delta\overline{X}' > \Delta\overline{X}$ and

$$\left|X' - \mu\right| > \left|\overline{X} - \mu\right|. \qquad \text{[eq. 6]}$$

Stripping the Operator Effect from the Mean Data

By stripping the operator effect from $\overline{X}$', the inequality given by [eq. 6] becomes

$$\left|X' - \mu\right| = \left|X - \mu\right|. \qquad \text{[eq. 7]}$$

To make $\overline{X}' = \overline{X}$, operator effects must be removed from a data set prior to calculation of mean values.

The two most important types of operator effects introduced into the sample chamber are assumed to be an air channel in the chamber or a tightly packed cluster of fibers. An air channel in the sample chamber would result in little or no resistance to air flow and produce a θ_i value less than $\overline{X}$. A tightly packed cluster of fibers would be more air impermeable compared with the surrounding fibers in the chamber and result in θ_i greater than $\overline{X}$.

The range of the expected value of θ_i across both types of operator induced changes may vary from essentially 0 mm water (a significant air channel exists) to >1000 mm water (a significant fiber clustering effect). Thus, a continuum of θ_i values is possible.

An operator effect is a random event and will appear as a positive or negative "spike" of varying magnitude in a data set. The standard threshold to identify outliers is ±3 standard deviations from the mean for normally distributed data (Natrella, 1963). After insuring that Micromat data is normally distributed, this threshold can be applied by a computer program that uses an iterative procedure to remove one outlier at a time.

Sample Preparation Effect on Corrected Data

Case I - No Preparation Effect. The original calibration equations for the FMT were based on specimens prepared on a card. The card settings had been carefully adjusted prior to sample preparation to give specimens that are clean, opened, and contain an insignificant fiber fraction that is mechanically abraded or broken. Carding introduces fiber orientation instead of randomizing it.

Therefore, by definition there is no preparation effect on *PL* and/or *PH* readings for specimens cleaned in a card. In this paper, the card is the reference mechanical cleaner used in the test for a bias caused by cleaning the fibers in a different type of cleaner. *PL* and *PH* readings derived from the card and other types of mechanical cleaners are stripped of the operator effect prior to examination for a preparation effect.

Case II - Preparation Effect. Suppose that a mechanical cleaner other than the card is used to clean the Micromat specimens. Assume that a significant fraction of the cleaned fibers are physically damaged or are condensed into a fiber arrangement that results in a bias in the *PL* or *PH* values. The net effect is a preparation effect.

The appearance of a preparation effect in a data set reveals itself as a persistent shift in instrument readings relative to the readings obtained from samples cleaned on a card. A preparation effect may be an intrinsic characteristic of a mechanical cleaner or it may result from improper settings.

MATERIALS AND METHODS

Cottons

The Agricultural Marketing Service in Memphis provided three raw cottons with micronaire values of 5.72, 4.24, and 2.67. All three cottons were used in the operator and preparation effect studies.

SRRC Upgraded Micromat

All cotton samples were analyzed on the 089 Micromat Tester (Shirley Developments Ltd, Stockport, England) which had been upgraded at the Southern Regional Research Center (SRRC) (Montalvo and Faught, 1999). The most important features of our revisions to the Micromat are the sealing of the air flow system, the installation of a leak detector module (LDM), and the use of physical standards dubbed headspace resistance standards (HRS; Figure 1) (Montalvo et al., 2001; Von Hoven et al., 2001). Calibration is a three step process. The calibration order is detector, air flow system, and sample chamber volume (the detector is used to calibrate the other instrumental settings and the air flow system is needed to calibrate the chamber volume). Calibration details have been presented elsewhere (Von Hoven et al., 2001). Results on the upgraded Micromat are more accurate and precise compared with results before upgrading.

Comparative Micromat Analysis of Operator Effects

For each of the three cottons, bulk samples were mechanically cleaned on the card, 4-g specimens weighed, and grouped into sets. A set is six 4-g specimens for each of the three cottons. The specimens were allowed to condition at least one night prior to analysis. Specimens and the Micromat were in a conditioned laboratory with the target values of 21.11 ± 0.56 ^{o}C (70 ± 1^{o}F) and 65 ± 2% relative humidity. After the final weighing of a specimen to exactly 4.000 g, the Micromat operator used his fingers to manipulate the specimen into the shape of a cylinder approximately 5 cm (2 in) in diameter and 25.4 cm (10 in) in length. Beginning at one end of the cylindrical-shaped fiber matrix, the specimen was manually inserted into the sample chamber. The chamber lid was closed and the analysis procedure initiated. There were three operators. SF was a full-time employee and DF and DR were part-time employees who attended a local university.

The procedure for the comparative analysis of operator effects was as follows. One of the three cottons was picked at random for Micromat analysis. At least two of the three operators were present during any comparative run. They each operated the machine in succession. The first operator analyzed the first set of six specimens from the cotton picked at random. Next, the second operator analyzed the first set of six specimens from the same cotton run by the first operator. At this point, the third operator may have replaced one of the other two operators and analyzed the first set of six specimens from the same cotton run by the other operators. All three operators used this procedure to analyze the second, third, and fourth sets of six specimens from the same bale. The two remaining cottons were picked at random and analyzed in a similar manner by all three operators.

This procedure resulted in nine groups of 24 specimens per cotton run on the FMT. The total number of specimens analyzed in the operator effects study was 216 specimens; 3 cottons x 3 operators x 24 specimens/cotton/operator.

To confirm that Micromat data sets are normally distributed, normal probability plots were constructed (Fearn, 2000; Filliben, 1977; Natrella, 1963). The plots were strongly linear. For example, r = 0.988 even with one or two easily discernible operator outliers. A computer software program written at SRRC was used to strip the outliers from each data set and to compute corrected means.

Comparative Micromat Analyzes of Preparation Effects

For each of the three cottons, samples were mechanically cleaned at different locations on different cleaners. These cleaners used were the Shirley Analyzer (SDL America, Inc., Charlotte, NC), the Microdust and Trash Monitor (MTM) (Schaffner Technologies, Knoxville, TN); and the Fineness and Maturity Tester Model 3 opener (SDL America, Inc., Charlotte, NC), respectively at the Cotton Quality Research Station in Clemson, SC, Cotton Incorporated in Cary, NC, and the International Textile Center in Lubbock, TX. At our laboratory in New Orleans the card, Shirley Analyzer and the MTM were each used. The samples cleaned at the other locations were then sent to the lab in New Orleans for running on the Micromat.

Four-gram specimens of the cleaned cottons were weighed and grouped into sets of six specimens. After conditioning, the three operators described above analyzed the cotton on the Micromat for the preparation effects study. This resulted in groups of 24 specimens from each of the three cottons run on the instrument after mechanical cleaning. The total number of cleaned specimens analyzed in the preparation effects study was 432; 3 cottons x 6 cleaners x 24 specimens/cotton/cleaner. Mean values were corrected for operator error.

Finally, 4-g specimens of the three raw cottons were weighed without prior cleaning and grouped into a set of six specimens per cotton. The total number of specimens was 18; 3 cottons x 6 specimens/cotton. The operator SF analyzed these samples on the FMT.

RESULTS AND DISCUSSION

Operator Effects on Micromat and Assignable Causes

The operator outlier summary is presented in Table 1. Eleven *PL* and *PH* outliers were found in eight of the 18 groups of data. Aside from gross blunder by the experimenter, the distribution of the outliers in this table correlates with the assignable causes. All of the observations (n = 24), which contained a single outlier (i.e. outside the 3-sigma limit), for one of the three cottons analyzed by the three operators, SF, DF, and DR is shown in Figure 2. Figure 2 is an example of the data before outlier removal.

There is a negative correlation between operator experience with the Micromat and the number of outliers. SF is the most experienced operator, while DF is less experienced and DR is the least experienced. There is a strong negative correlation (r = -0.93) between the micronaire value of the cottons and the number of outliers. The number of *PL* and *PH* outliers is about equal and therefore independent of the compression stage — initial or second — of the test. There are almost twice as many

Table 1. Summary of operator outliers for instrument pressure drop readings of the Micromat Fineness and Maturity Tester

Micronaire	***PL*[a]**			***PH*[a]**		
	Operators[b]					
	SF	**DF**	**DR**	**SF**	**DF**	**DR**
5.72						**1**
4.24			**1**			**1**
2.67		**1**	**3**	**1**	**1**	**2**

Totals:	**by operator**		**by micronaire**		**by reading**	
	SF	**1**	**5.72**	**1**	***PL***	**5**
	DF	**2**	**4.24**	**2**	***PH***	**6**
	DR	**8**	**2.67**	**8**		

by sign compared to mean values	
negative	**7**
positive	**4**

[a] **Initial (*PL*) and secondary (*PH*) pressure drops.**

[b] **SF, DF, and DR are operators in order of decreasing experience in Micromat operation.**

negative as positive outliers. These observations are consistent with the negative outliers assigned to an air channel in the chamber and the positive outliers assigned to a tightly packed cluster of fibers.

Maintaining the fixed fiber mass of 4 g in the specimen chamber requires that the total length of fiber — assuming that the fibers lie end-to-end — increases as the micronaire value decreases with concomitant increase in packing inconsistencies. The first compression (*PL*) initializes the compression process by establishing the relative positions between adjacent fibers; this suggests that the frequency of *PL* and *PH* operator outliers should be about equal to each other. In regards to the relative number of negative and positive outliers, it should be more difficult for the operator to spread the fibers evenly across the entire cross-sectional area of the chamber so that more negative outliers should be expected.

Operator Effects on Relative Standard Deviations

An operator outlier does not indicate a trend or run in the data, but there is an increase in variability and therefore, more uncertainty in the mean values. The relative standard deviation of the mean *PL* and *PH* values for all eight groups of data with outliers is illustrated in Figures 3 and 4. In this context, the relative standard deviation is the ratio of the standard deviation before outlier removal to that after outlier removal.

The procedure to compute the *PL* relative standard deviation follows. First, examination of Table 1 reveals three groups of data, 4.24 micronaire cotton (DR the operator), 2.67 micronaire cotton (DF the operator), and 2.67 micronaire cotton (DR the operator), with *PL* outliers. Second step, the standard deviation (mm water) before and after outlier removal are tabulated and then used to compute the relative standard deviation. The computed ratios for micronaire 4.24 are 4.95/1.73 = 2.86 (DR); micronaire 2.67 are 29.7/5.65 = 5.26 (DR); and micronaire 2.67 are 8.30/5.16 = 1.61 (DF). The final step involved inserting the three bars, whose length equals to the ratio of standard deviations, into the bar graph (Figure 3). The ratios of *PL* variability ranged from 1.61 (DF) to 5.26 (DR).

Similarly, five groups of data produced *PH* outliers (Table 1). As a result, there are five error bars in Figure 4. The ratio of *PH* variability ranged from 1.32 (DF) to 16.66 (DR). These results

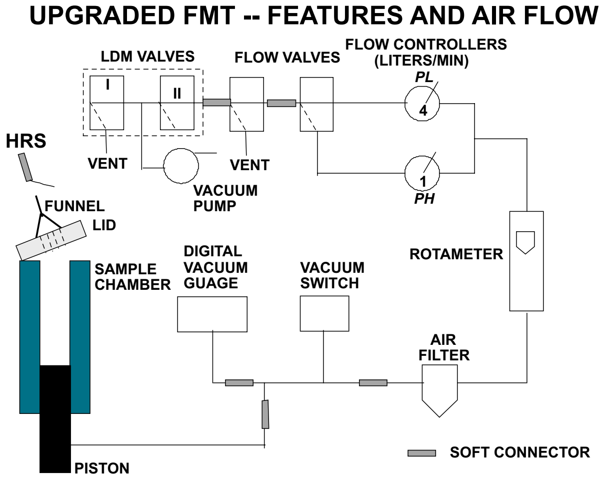

Figure 1. Upgraded Micromat at the Southern Regional Research Center includes headspace resistance standards (HRS) and leak detector module (LDM) and air flow. *PL* and *PH* are the initial and second stage pressure drops, respectively.

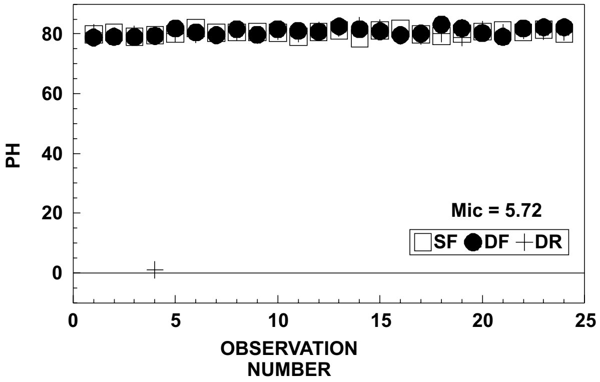

Figure 2. Determination of second stage pressure drop (*PH*) for cotton with micronaire (Mic) of 5.72. SF, DF, and DR are operators. There is one outlier by DR (observation # 4).

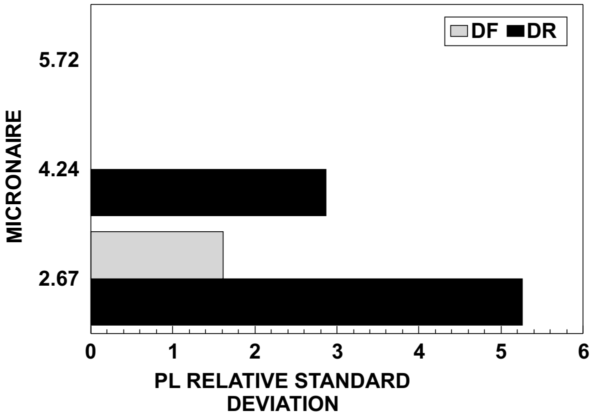

Figure 3. Ratio of standard deviation (uncorrected relative to operator-corrected, dimensionless) for the initial stage pressure drop (*PL)* data sets with outliers.

demonstrate the need to remove operator outliers from a data set before computation of mean values.

Test for Operator Effects on Corrected Results

The results of testing for operator effects on corrected mean fineness, maturity, perimeter, and thickness data after stripping operator outliers from the repeat specimens are shown in Table 2. The results are presented as the percentage difference for operators DF and DR relative to SF.

The ranges in percentage difference in the data are -1.67 to 1.43 for fineness, -1.52 to 1.59 for maturity, -1.61 to 1.53 for cross-sectional perimeter, and -0.50 to 0.22 for wall thickness. In analyzing the data, we arbitrarily considered differences >±2% as indicative of an "operator effect". This is not a standard value and is not referenced. All of the differences are <±2.0% and, therefore, of no practical importance.

Preparation Effects on Operator Corrected Mean Micromat Data

The summary of preparation bias is listed in Table 3 for mean fineness, maturity, perimeter, and thickness values corrected for operator error. All nine instances of bias in the fiber properties originated from the MTM. Tables 4 to 6 document the results for each cotton analyzed. Means were computed after removing operator outliers from the 24 replicates generated for each cotton treatment (i.e., cleaning by a specific mechanical cleaner). Percentage differences in mean values are relative to the card.

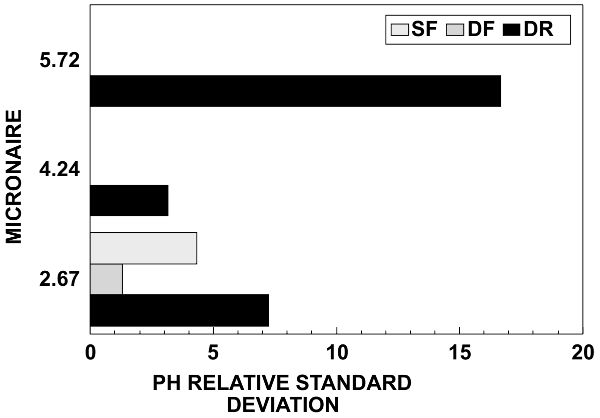

Figure 4. Ratio of standard deviation (uncorrected relative to operator corrected, dimensionless) for the second stage pressure drop (*PH)* data sets with outliers.

In analyzing the data, we again arbitrarily considered differences >±2% as indicative of a "preparation effect". Generally, the percentage differences in preparation increased with decrease in micronaire. At 5.72 micronaire, there were no mechanical cleaners that demonstrated a preparation difference (>±2%) relative to the card. At 4.24 micronaire, differences >±2% for fineness, maturity, and perimeter values were observed with the MTM operating at Cotton Incorporated. At 2.67 micronaire, differences >±2% for fineness, maturity, and perimeter values were observed with the MTM operating at both the SRRC and at Cotton Incorporated.

For the 4.24 micronaire, differences >±2% on only one of the two MTMs utilized in the study are

Table 2. Results of operator effects on corrected mean fineness and maturity data for cotton with micronaire values of 5.72, 4.24, and 2.67

		Difference from Operator SF (%)			
Micronaire	**Operator[a]**	**Fineness**	**Maturity**	**Perimeter**	**Thickness**
5.72	**SF**	**216.0 mtex**	**1.115**	**52.68 µm**	**3.378 µm**
	DF	**1.43**	**- 1.52**	**1.53**	**- 0.50**
	DR	**0.46**	**- 0.89**	**0.57**	**- 0.30**
4.24	**SF**	**156.1 mtex**	**1.011**	**47.04 µm**	**2.654 µm**
	DF	**1.10**	**- 0.89**	**1.00**	**- 0.14**
	DR	**- 0.50**	**- 0.035**	**- 0.24**	**- 0.28**
2.67	**SF**	**121.4 mtex**	**0.6608**	**51.32 µm**	**1.743 µm**
	DF	**- 0.45**	**0.70**	**- 0.57**	**0.22**
	DR	**- 1.67**	**1.59**	**- 1.61**	**0.17**

[a] **SF, DF, and DR are operators in order of decreasing experience in Micromat operation.**

indicative of different instrument settings. With the 2.67 micronaire cotton, differences >±2% on both MTMs may indicate that a preparation effect is an intrinsic characteristic of this machine on low micronaire cottons. These results indicate that the settings (including air flow rate) on both cleaners should be checked and matched against the manufacturer's recommendations.

Under no circumstances should raw cotton be tested with the FMT (Tables 4 to 6). Fineness and maturity data will be biased due to testing raw fibers. To aid in understanding on a fundamental level the nature of the bias, the data includes the corresponding perimeter and wall thickness values. The error in perimeter ranged from 3.5 to 43%. The error in thickness was always less than the 2%

Table 3. Summary of the effect of different mechanical cleaners (preparation bias) at four locations[a] on mean fineness, maturity, and perimeter corrected for operator error for cotton with micronaire values of 5.72, 4.24 and 2.67

Micronaire	Fineness, Maturity, & Perimeter[b]		
	Mechanical Cleaner[c]		
	Shirley	MTM	FMTO
5.72			
4.24		CI	
2.67		SRRC; CI	
Totals:	by cleaner	by micronaire	by property
	Shirley 0	5.72 0	Fineness 3
	MTM 9	4.24 3	Maturity 3
	FMTO 0	2.67 6	Perimeter 3
		by sign compared with mean values	
		negative	3 fineness; 3 perimeter
		positive	3 maturity

[a] SRRC (Southern Regional Research Center), CI (Cotton Incorporated), Clemson (Cotton Quality Research Station, Clemson, SC), and ITC (International Textile Center, Lubbock, TX).

[b] There was no effect of cleaner on thickness.

[c] Shirley (Shirley Analyzer), MTM (Microdust and Trash Monitor), FMTO (FMT 3 opener).

Table 4. Results of preparation effect on corrected mean fineness, maturity, perimeter, and thickness data for 5.76 micronaire cotton

Mechanical Cleaner[a]	Lab[b]	Difference Relative to the SRRC Card (%)			
		Fineness	Maturity	Perimeter	Thickness
Card	SRRC	218 mtex	1.095	53.4 µm	3.24 µm
Shirley Analyzer	SRRC	- 1.49	0.73	- 1.12	- 0.12
	Clemson	0.96	- 0.73	0.86	- 0.15
MTM	SRRC	- 0.55	0.73	0.64	0.33
	CI	- 1.80	1.74	1.74	0.54
FMTO	ITC	- 1.30	0	- 0.66	- 0.66
Raw Cotton	SRRC	2.87	- 3.93	3.48	- 1.82

[a] MTM (Microdust and Trash Monitor), FMTO (FMT 3 opener), raw cotton is not cleaned.

[b] SRRC (Southern Regional Research Center, New Orleans , LA), Clemson (Cotton Quality Research Station, Clemson, SC), CI (Cotton Incorporated, Cary, NC), and ITC (International Textile Center, Lubbock, TX).

threshold and, therefore, independent of preparation treatment.

CONCLUSIONS

For the Micromat Tester, *PL* and *PH* repeat readings are normally distributed and the one or two questionable points outside the "3-sigma limit" in the various data sets are, in fact, operator outliers. The experimental circumstances that led to the outliers are an air channel or a tightly packed cluster of fibers in the sample chamber. After stripping the outliers from the sets of measurements on the same cottons by three operators, mean differences in the calculated fineness and maturity values are too small to be of practical significance.

Preparation effects of the MTM on operator corrected mean Micromat data may be due to improper settings of this mechanical cleaner at mid micronaire values and perhaps an intrinsic characteristic at low micronaire values. This work has shown that the examination of operator outliers leads to improved fiber quality measurements and ultimately to an improved understanding of the experimental factors, which prevent a measurement process from being "in-control".

ACKNOWLEDGMENTS

We gratefully acknowledge analysis of the cottons on the Micromat by Danielle Francois and

Table 5. Results of preparation effect on corrected mean fineness, maturity, perimeter, and thickness data for 4.24 micronaire cotton

Mechanical Cleaner [a]		Difference Relative to SRRC Card (%)			
	Lab[b]	Fineness	Maturity	Perimeter	Thickness
Card	SRRC	159 mtex	0.9913	47.9 µm	2.64 µm
Shirley Analyzer	SRRC	- 1.51	1.68	- 1.61	0.57
	Clemson	- 0.42	0.48	- 0.44	0.15
MTM	SRRC	- 0.99	0.51	- 0.74	- 0.11
	CI	- 2.98	2.57	- 2.73	0.45
FMTO	ITC	- 0.84	0.71	- 0.77	0.11
Raw Cotton	SRRC	6.53	- 5.67	6.27	- 1.21

[a] MTM (Microdust and Trash Monitor), FMTO (FMT 3 opener), raw cotton is not cleaned.

[b] SRRC (Southern Regional Research Center, New Orleans , LA), Clemson (Cotton Quality Research Station, Clemson, SC), CI (Cotton Incorporated, Cary, NC), and ITC (International Textile Center, Lubbock, TX).

Table 6. Results of preparation effect on corrected mean fineness, maturity, perimeter, and thickness data for 2.67 micronaire cotton

Mechanical Cleaner[a]		Difference Relative to SRRC Card (%)			
	Lab[b]	Fineness	Maturity	Perimeter	Thickness
Card	SRRC	126 mtex	0.654	52.5 µm	1.76 µm
Shirley	SRRC	- 1.99	0.43	- 1.16	- 0.74
	Clemson	- 1.35	- 0.81	- 0.27	- 1.19
MTM	SRRC	- 3.34	3.26	- 3.22	0.34
	CI	- 6.36	3.38	- 4.80	- 0.97
FMTO	ITC	-1.51	- 0.64	- 0.42	- 1.19
Raw Cotton	SRRC	47.4	- 28.0	43.1	- 0.57

[a] MTM (Microdust and Trash Monitor), FMTO (FMT 3 opener), raw cotton is not cleaned.

[b] SRRC (Southern Regional Research Center, New Orleans , LA), Clemson (Cotton Quality Research Station, Clemson, SC), CI (Cotton Incorporated, Cary, NC), and ITC (International Textile Center, Lubbock, TX).

Donald Reed. We also acknowledge mechanical cleaning of the samples by Eric Hequet at the International Textile Center in Lubbock, TX; Brenda Patterson at Cotton Incorporated in Cary, NC; and Carolyn Simpson at the Cotton Quality Research Station in Clemson, NC.

DISCLAIMER

Mention of any proprietary products does not constitute a guarantee or warranty by the USDA and does not imply approval of the product to the exclusion of alternatives that may be available.

REFERENCES

Buco, S.M., J.G. Montalvo, Jr., and S.E. Faught. 1998. Analysis of cotton maturity and fineness by multiple NIR HVIs. Part I. Data analysis. p. 1623-1625. *In* Proc. Beltwide Cotton Conf., San Diego, CA. 5-9 Jan. 1998. Natl. Cotton Counc. Am., Memphis, TN.

Fearn, T. 2000. Plotting to assess normality. NIR News. June. p. 14-15.

Filliben, J.J. 1977. Testing basic assumptions in the measurement process. p. 30-113. *In* J.R. DeVoe (ed.) Validation of the measurement process: ACS Symposium Series 63. American Chemical Society, Washington, DC.

Lord, E., and S.A. Heap. 1988. The origin and assessment of cotton fibre maturity. Int. Institute for Cotton, Technical Research Division, Manchester, England.

Montalvo, J.G., Jr., and S.E. Faught. 1998. Analysis of cotton maturity and fineness by multiple NIR HVIs. Part I. Reference method. p. 1625-1628. *In* Proc. Beltwide Cotton Conf., San Diego, CA. 5-9 Jan. 1998. Natl. Cotton Counc. Am., Memphis, TN.

Montalvo, J.G., Jr., and S.E. Faught. 1999. Headspace resistance standards for the Shirley Developments Ltd. Micromat Tester. Textile Res. J. 4:269-277.

Montalvo, J.G., Jr., T.M. Von Hoven, S. Faught, M. Watson, E. Hequet, J. Knowlton, and S. Buco. 2000. Proposal for an interlaboratory test of fineness and maturity measurements by four upgraded FMTs. Appendix M2:27-35. *In* Proc. 11th ITMF Int. Comm. on Cotton Testing Methods, Bremen, Germany. 29 Feb-1 Mar. 2000. Faserinstitut Bremen e.V., Bremen, Germany.

Montalvo, J.G., T.M. Von Hoven, S. S. Reed, D.L. Francois, and S. Faught. 2001. Organizational and instructional manual for the Micromat Tester. USDA, ARS, Southern Regional Research Center, New Orleans, LA.

Natrella, M.G. (ed.). 1963. Experimental statistics: National Bureau of Standards Handb. 91. U.S. Gov. Print. Office, Washington, DC.

Ramey, H.H., Jr. 1982. The meaning and assessment of cotton fibre fineness. Int. Institute for Cotton, Technical Research Division, Manchester, England.

SDL 089 Micromat Tester Instruction Manual. 1994. Shirley Developments Limited, Stockport, England.

Thibodeaux, P.D., R. Rajasekram, J.G. Montalvo, Jr., and T.M. Von Hoven. 2000. The status of cotton maturity measurements in the new millennium. p. 115-128. *In* Proc. of the Int. Cotton Conf. Bremen, Bremen, Germany, 1-4 Mar. 2000. Faserinstitut Bremen e.V., Bremen, Germany.

Von Hoven, T.M., S. Buco, S. Faught, J. Montalvo, D. Francois, and S. Reed. 2001. Calibration of upgraded FMTs. p. 1307-1309. *In* Proc. Beltwide Cotton Conf., Anaheim, CA. 9-13 Jan. 2001. Natl. Cotton Counc. Am., Memphis, TN.