Report to the Interwoollabs Management Committee

The Importance of the Coefficient of Variation (or Standard Deviation) of Fibre Diameter in Selecting Calibration Tops.

by

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Background

Until recently, the only fibre diameter measurement system requiring calibration samples was the Airflow. The Airflow system had become, and still is, the predominant method for trading wool (from raw wool to tops).

The introduction of the newer technologies, Laserscan and OFDA, have brought with them a requirement to have the Projection Microscope measurements (both Mean and Coefficient of Variation or Standard Deviation) made available for calibration. It was proposed that the Projection Microscope Means be used for calibrating the Airflow Instruments. This will only work if the Mean Fibre Diameter measured by the Projection Microscope and Airflow are the same. This report examines the importance of the Coefficient of Variation or Standard Deviation of Fibre Diameter in selecting calibration tops.

Most people have lost sight of the early development of the Airflow system of measurement. In particular, the relationship between the measurements made by the Airflow (AF) method and the Projection Microscope (PM) method. The developers of the AF recognised that they would only be the same if specific conditions were met. The Airflow was known to be influenced by the Coefficient of Variation of Fibre Diameter (CVD) of the sample and the density or medullation content of the sample. The relationship for CVD was proposed to be:

$$D_{AF} = \frac{D_{PM}\left(1+C_S^2\right)}{\left(1+C_C^2\right)} \quad \text{.......... (1)}$$

where:

D_{AF} = Mean Fibre Diameter by AF

D_{PM} = Mean Fibre Diameter by PM

C_S = The Fractional Coefficient of Variation of Fibre Diameter by PM of the sample being measured (i.e. CVD% / 100)

C_C sample = The Fractional Coefficient of Variation of Fibre Diameter by PM of the equivalent top diameter used for calibrating the Airflow used for the measurement.

Equation 1 clearly shows that for the Airflow and Projection Microscope methods to agree, the Fractional Coefficients of Variation of Fibre Diameter must agree (i.e. $C_S = C_C$), all other things being equal.

An examination of the data, where AF and PM Mean and CVD are available, (collected by Interwoollabs from 1977 to 1996), reveals that there is a linear relationship between CVD and Mean Fibre Diameter (MFD) as well as Standard Deviation (SD) and Mean Fibre Diameter (see figures 1 & 2).

Figure 1: The Relationship Between Coefficient of Variation of Fibre Diameter (CVD) and Mean Fibre Diameter (MFD).

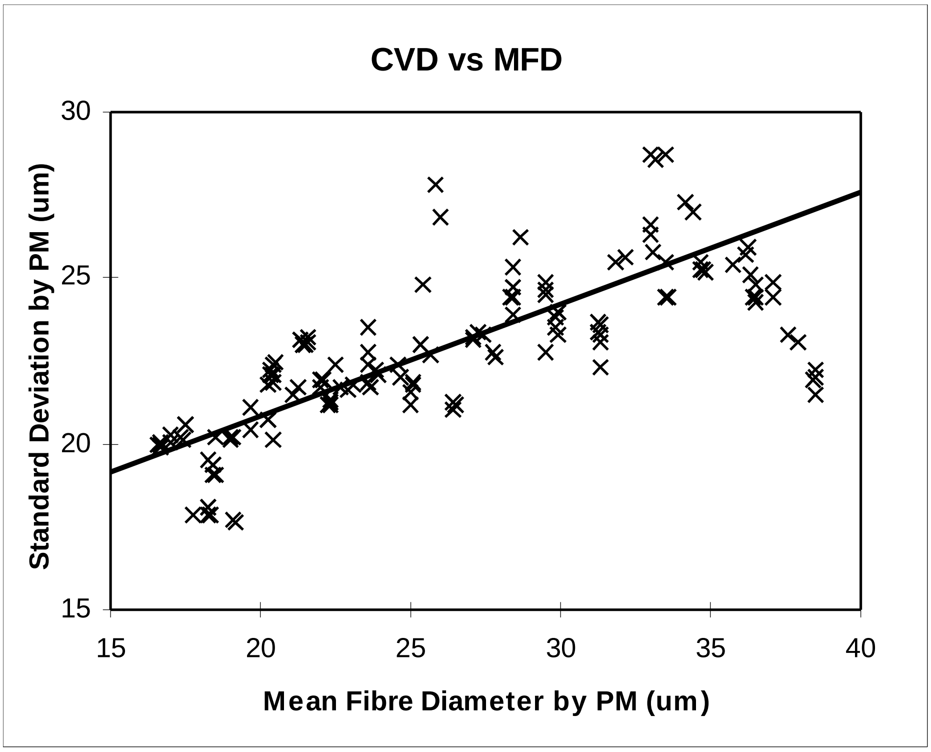
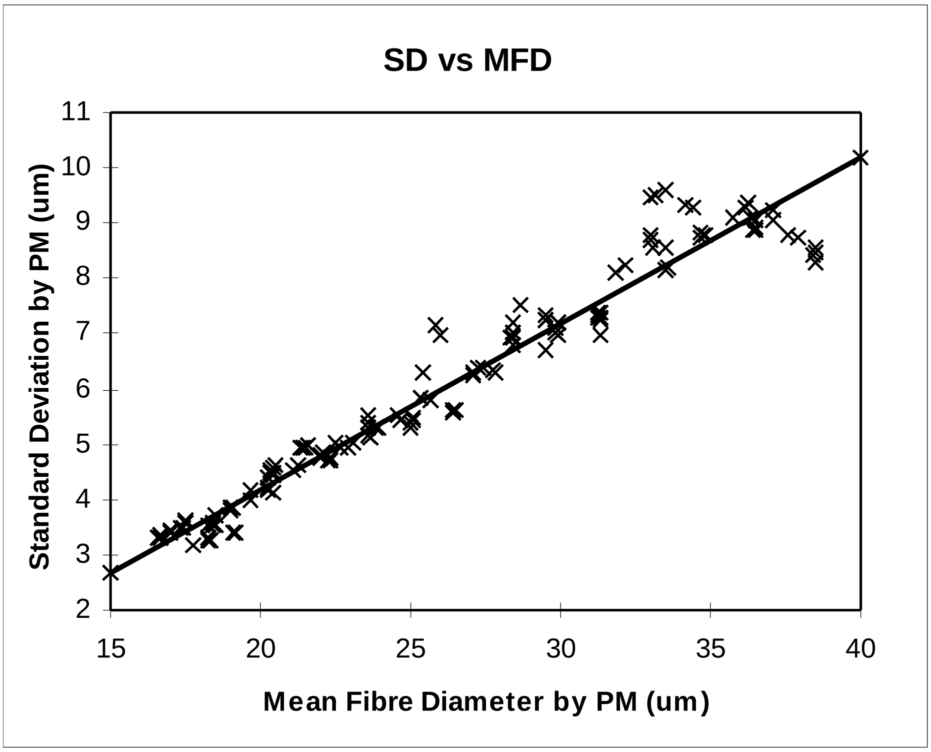


Figure 2: The Relationship Between Standard Deviation of Fibre Diameter (SD) and Mean Fibre Diameter (MFD).



In the case of SD there was an apparent breakdown of the relationship beyond about 32µm MFD. The best regression to use for the association was all data with MFD < 32µm. This limit was imposed on both the CVD and SD relationships to yield the following:

CVD = 0.3357 MFD + 14.1399 .... (2)

SD = 0.2992 MFD - 1.7880 .... (3)

The Impact of CVD and SD on Differences Between AF and PM.

Using Equations 1 to 3, it is possible to calculate the estimated AF value for increasing departures of CVD and SD from the derived relationship (equation 2 or 3). The simulations are presented in Tables 1 and 2 for CVD and SD respectively. The method used was to assume 8 different samples had PM values ranging from 15 to 45 µm in steps of 5µm. The CVD or SD for the nominated diameter was calculated using the equation 2 or 3 and these were deemed to be the calibration values CVC and SDC. A departure of a known amount (0.5, 1.0, 1.5, 2.0 and 2.5 for CVD and 0.2, 0.4, 0.6, 0.8 and 1.0 for SD) was added to the CVC or SDC to give the sample values CVS and SDS. This could then be used to calculate an Airflow estimate (AF est.) from equation 1.

Table 1: The Effect of CVD on Differences in Measured MFD by AF and PM.

Table 1a: CVD Difference = 0.5%				
Nominal pm	cvc	cvs	AFest	Difference
15	19.18	19.68	15.03	0.03
20	20.85	21.35	20.04	0.04
25	22.53	23.03	25.05	0.05
30	24.21	24.71	30.07	0.07
35	25.89	26.39	35.09	0.09
40	27.57	28.07	40.10	0.10
45	29.25	29.75	45.12	0.12

Table 1b: CVD Difference = 1.0%				
Nominal pm	cvc	cvs	AFest	Difference
15	19.18	20.18	15.06	0.06
20	20.85	21.85	20.08	0.08
25	22.53	23.53	25.11	0.11
30	24.21	25.21	30.14	0.14
35	25.89	26.89	35.17	0.17
40	27.57	28.57	40.21	0.21
45	29.25	30.25	45.25	0.25

Table 1c: CVD Difference = 1.5%				
Nominal pm	cvc	cvs	AFest	Difference
15	19.18	20.68	15.09	0.09
20	20.85	22.35	20.12	0.12
25	22.53	24.03	25.17	0.17
30	24.21	25.71	30.21	0.21
35	25.89	27.39	35.26	0.26
40	27.57	29.07	40.32	0.32
45	29.25	30.75	45.37	0.37

Table 1d: CVD Difference = 2.0%				
Nominal pm	cvc	cvs	AFest	Difference
15	19.18	21.18	15.12	0.12
20	20.85	22.85	20.17	0.17
25	22.53	24.53	25.22	0.22
30	24.21	26.21	30.29	0.29
35	25.89	27.89	35.35	0.35
40	27.57	29.57	40.42	0.42
45	29.25	31.25	45.50	0.50

Table 1e: CVD Difference = 2.5%				
Nominal pm	cvc	cvs	AFest	Difference
15	19.18	21.68	15.15	0.15
20	20.85	23.35	20.21	0.21
25	22.53	25.03	25.28	0.28
30	24.21	26.71	30.36	0.36
35	25.89	28.39	35.45	0.45
40	27.57	30.07	40.54	0.54
45	29.25	31.75	45.63	0.63

Table 2: The Effect of SD on Differences in Measured MFD by AF and PM.

Table 2a: SD Difference = 0.2um						
Nominal pm	sdc	cvc	sds	cvs	afest	difference
15	2.70	0.18	2.90	0.19	15.07	0.07
20	4.20	0.21	4.40	0.22	20.08	0.08
25	5.69	0.23	5.89	0.24	25.09	0.09
30	7.19	0.24	7.39	0.25	30.09	0.09
35	8.68	0.25	8.88	0.25	35.09	0.09
40	10.18	0.25	10.38	0.26	40.10	0.10
45	11.68	0.26	11.88	0.26	45.10	0.10

Table 2b: SD Difference = 0.4um						
Nominal pm	sdc	cvc	sds	cvs	afest	difference
15	2.70	0.18	3.10	0.21	15.15	0.15
20	4.20	0.21	4.60	0.23	20.17	0.17
25	5.69	0.23	6.09	0.24	25.18	0.18
30	7.19	0.24	7.59	0.25	30.19	0.19
35	8.68	0.25	9.08	0.26	35.19	0.19
40	10.18	0.25	10.58	0.26	40.19	0.19
45	11.68	0.26	12.08	0.27	45.20	0.20

Table 2c: SD Difference = 0.6µm						
Nominal pm	sdc	cvc	sds	cvs	afest	difference
15	2.70	0.18	3.30	0.22	15.23	0.23
20	4.20	0.21	4.80	0.24	20.26	0.26
25	5.69	0.23	6.29	0.25	25.27	0.27
30	7.19	0.24	7.79	0.26	30.28	0.28
35	8.68	0.25	9.28	0.27	35.29	0.29
40	10.18	0.25	10.78	0.27	40.30	0.30
45	11.68	0.26	12.28	0.27	45.30	0.30

Table 2d: SD Difference = 0.8µm						
Nominal pm	sdc	cvc	sds	cvs	afest	difference
15	2.70	0.18	3.50	0.23	15.32	0.32
20	4.20	0.21	5.00	0.25	20.35	0.35
25	5.69	0.23	6.49	0.26	25.37	0.37
30	7.19	0.24	7.99	0.27	30.38	0.38
35	8.68	0.25	9.48	0.27	35.39	0.39
40	10.18	0.25	10.98	0.27	40.40	0.40
45	11.68	0.26	12.48	0.28	45.40	0.40

Table 2e: SD Difference = 1.0µm						
Nominal pm	sdc	cvc	sds	cvs	afest	difference
15	2.70	0.18	3.70	0.25	15.41	0.41
20	4.20	0.21	5.20	0.26	20.45	0.45
25	5.69	0.23	6.69	0.27	25.47	0.47
30	7.19	0.24	8.19	0.27	30.48	0.48
35	8.68	0.25	9.68	0.28	35.49	0.49
40	10.18	0.25	11.18	0.28	40.50	0.50
45	11.68	0.26	12.68	0.28	45.51	0.51

From Table 1 it can be seen that for any given departure in CVD the calculated difference is strongly diameter dependent. Thus if one were trying to establish limits to restrict the potential difference between AF and PM to say ± 0.2* µm, then the departures in CVD from the base relationship would need to vary with MFD.

In the case of SD (see Table 2) the diameter dependence is reduced substantially[#] and a ± 0.2* µm difference could be achieved by limiting the departures in SD to ± 0.4 µm from the value calculated from equation 3.

The Benefits of Limiting the Departures in SD

Using the data collected between 1977 to 1996, one can compare the effect of limiting the SD of the sample tops on the measured differences between AF and PM. As the Airflow is also influenced by other factors such as medullation, the difference between the measured AF and an Estimated Airflow (AF est.) calculated

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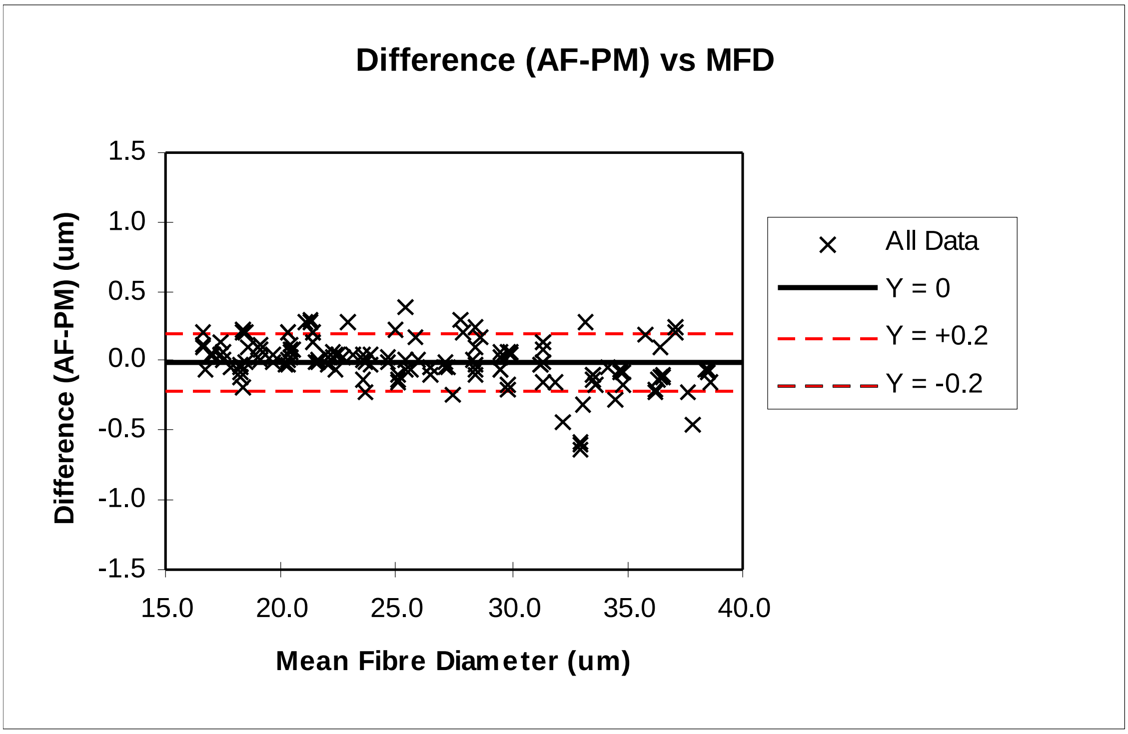
* The choice of ± 0.2µm as a difference between AF and PM is a practical way to place some limits on the purchase of Round Trial tops and is not to be confused with the final limits to be set for acceptable calibration tops.

[#] This is not surprising as CVD = SD / MFD so if SD is linearly related to MFD, then CVD would be inversely proportional to MFD.

from the PM data was also examined. Figures 3 to 5 show the relationships progressively eliminating samples that have the greatest departures in SD.

Figure 3: Relationships for the Differences Between the Airflow MFD (AF) and the PM MFD and the Estimated Airflow (AF est.) - All data from 1977 to 1996 (i.e. 143 data points).



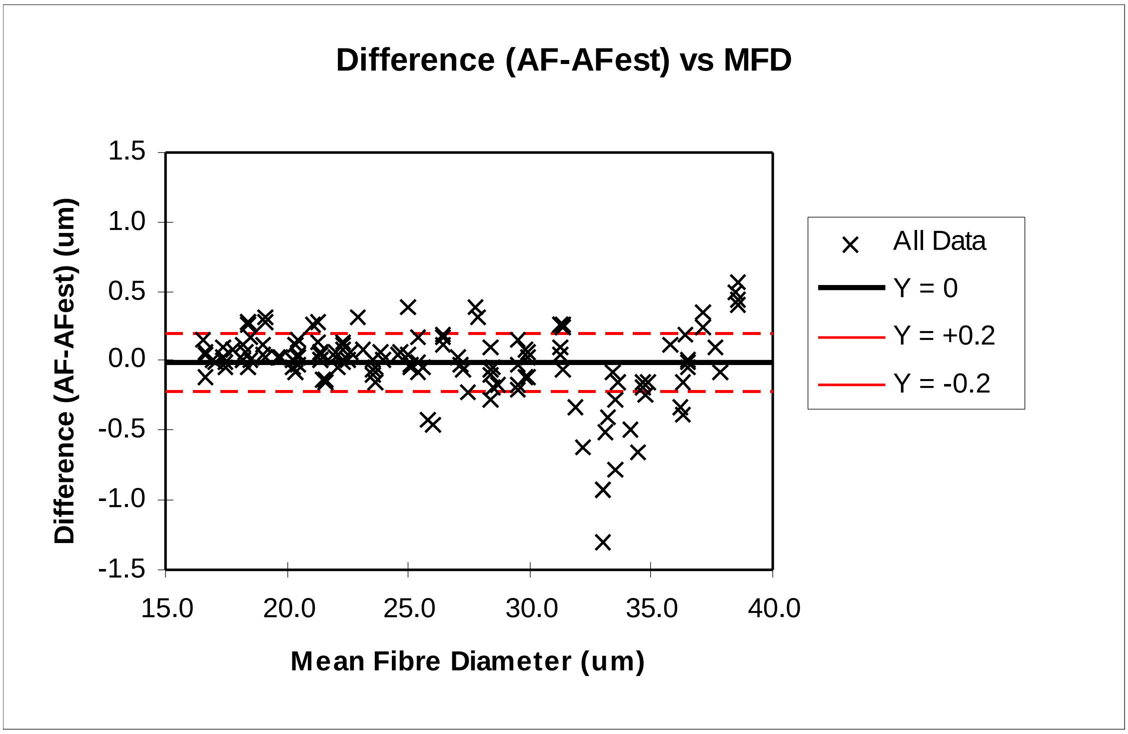
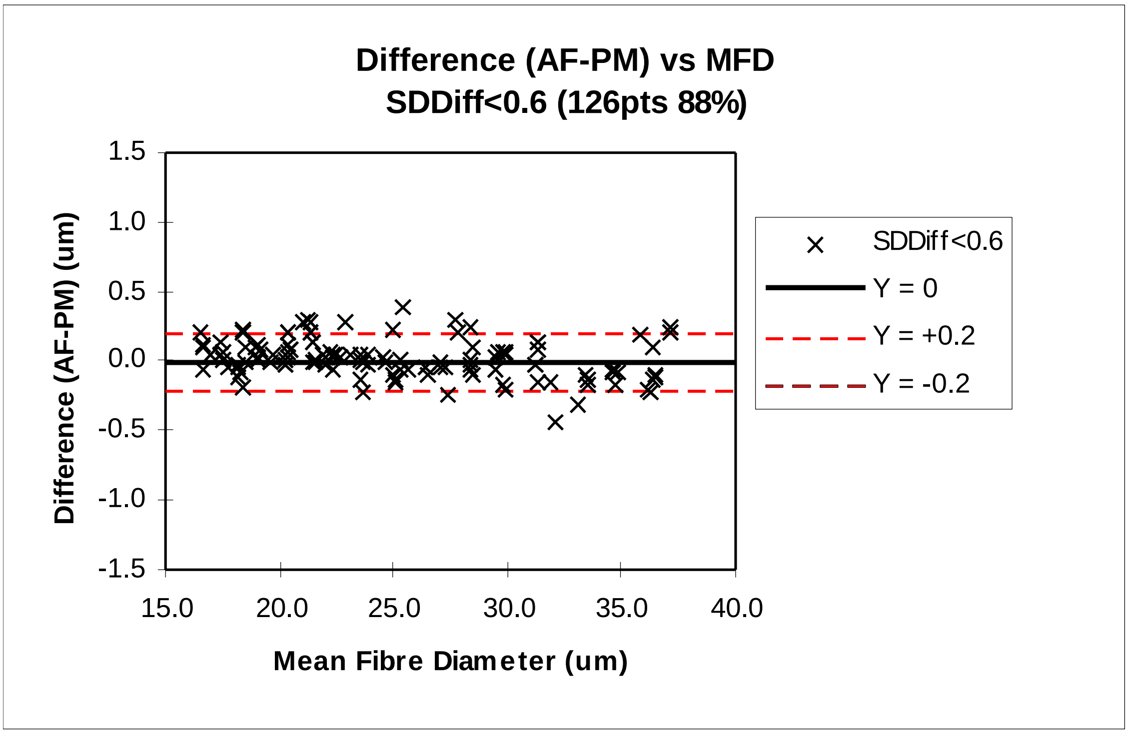


Figure 4: Relationships for the Differences Between the Airflow MFD (AF) and the PM MFD and the Estimated Airflow (AF est.) - Only data that is within ± 0.6 of the calculated SD.



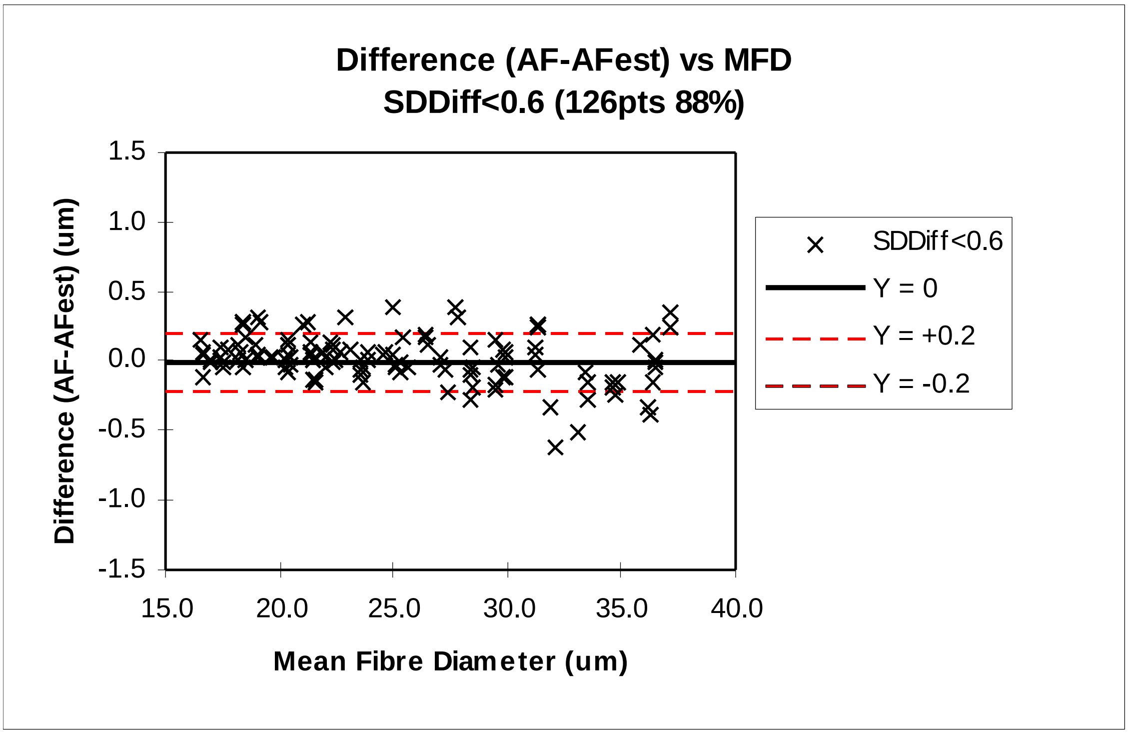
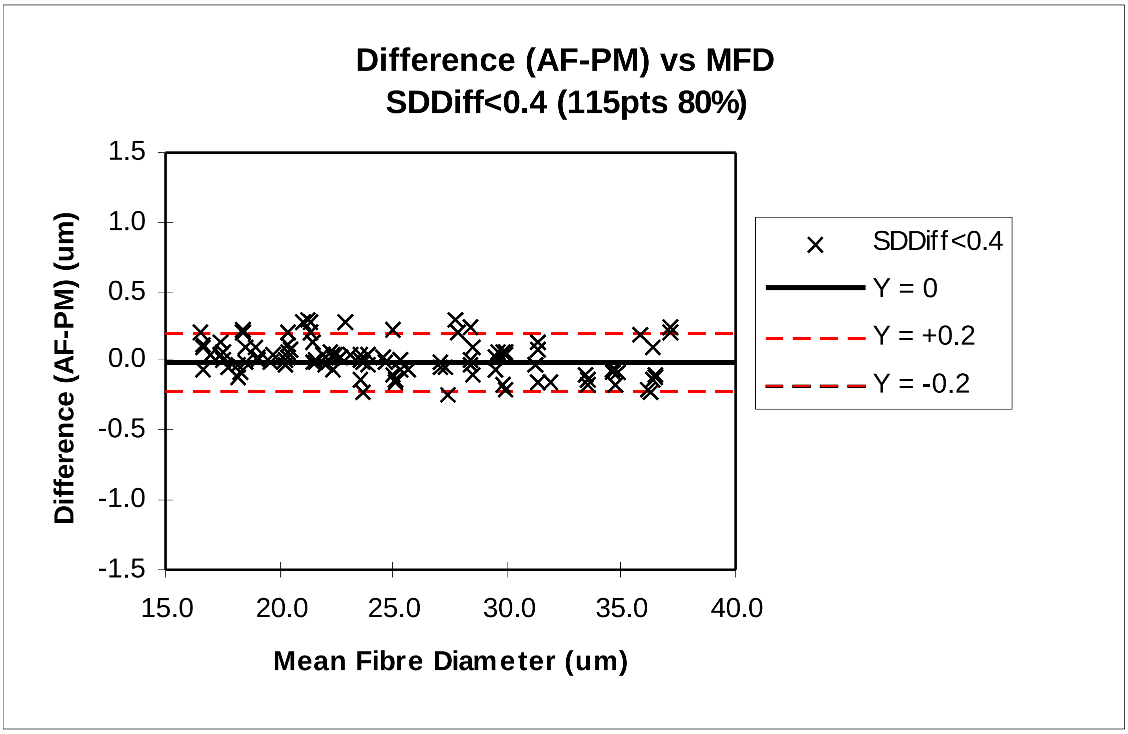
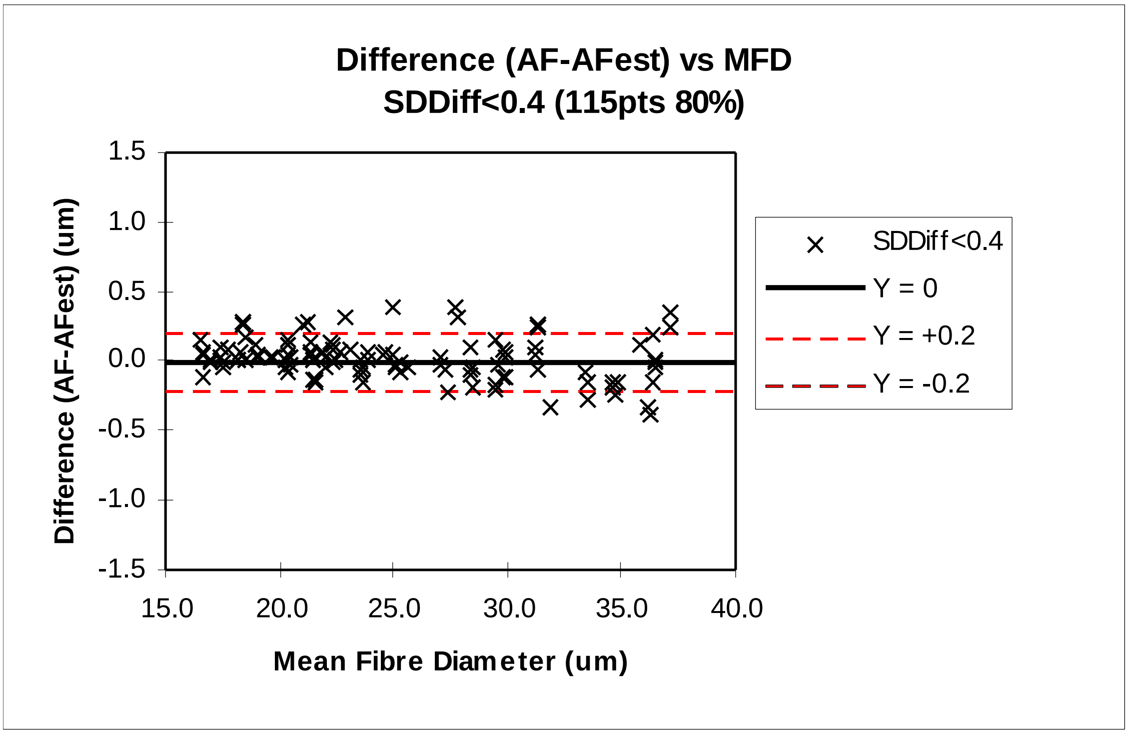


Figure 5: Relationships for the Differences Between the Airflow MFD (AF) and the PM MFD and the Estimated Airflow (AF est.) - Only data that is within ± 0.4 of the calculated SD.





From the point of view of gaining some insight as to the likely number of tops that would meet a tighter specification in the difference between AF and PM (e.g. ± 0.2µm and ± 0.1 µm) an examination of the data points in figures 3 to 5 is presented in the following two tables.

Table 3: Percentage of Lots within ± 0.2µm

	No SD Limit	SD Difference < 0.6	SD Difference < 0.4
Total Number	143	126	115
AF-PM	77	79	80
AF-AF est.	72	79	82

Table 4: Percentage of Lots within ± 0.1µm

	No SD Limit	SD Difference < 0.6	SD Difference < 0.4
Total Number	143	126	115
AF-PM	56	58	59
AF-AF est.	48	48	57

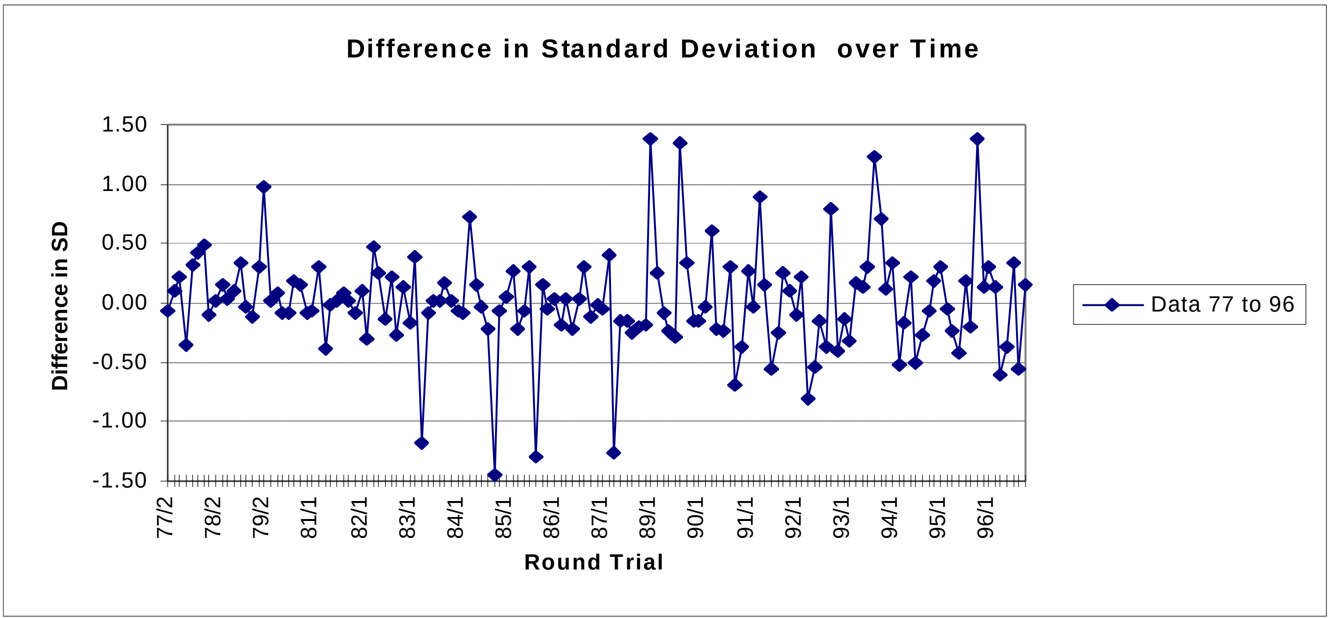
The limits of ± 0.4µm on SD should have produced 100% of the samples with the differences between AF and PM within ± 0.2µm. This was clearly not the case indicating that there are factors other than the CVD operating. These are likely to include the uncertainty in the measured result, medullation and density of the fibre. For any one wool, these can either compensate for the effect of SD departures or make the comparison worse

The key issue from the Management Committee's point of view should be to keep the differences between AF and PM to within ± 0.1µm of each other. Hence by limiting the SD departure from a known relationship to ± 0.4 µm for round trial tops and then selecting on the basis of measurement only those tops that meet a requirement of the difference between AF and PM to be within ± 0.1µm would mean that about 60% of the round trial tops would be likely contenders to become potential calibration standards. If this is too low, the SD departure may need to be restricted further.

Variation of departures in SD over time.

If one were to proceed with a strategy to impose a limit of ± 0.4 µm on any departures in SD from a given base then it is important that such departures are stable over time. Figure 6 presents the data from 1977 to 1996 on a time basis.

Figure 6: The Departures in SD from a Given Base for the Round Trials Conducted from 1977 to 1996.



Overall the trend is not too bad but there seems to have been a change in procedures implemented which had an effect on Round Trial samples from about 1988 to the present. There is much more variation from 1988 to 1996 compared to 1977 to 1988 (the four results that show large negative departures from 1983 to 1987 were the special coarse tops prepared in New Zealand with better uniformity than would be expected for normal wools of such diameters).

A brief discussion with David Ward on this issue has suggested that about that time there was a move away from very tight constraints over the types of tops (100% Fleece Wool, Good Style, No Bellies Wool, No Mazamet Wool etc.) to commercial tops. This move is probably partly responsible for the differences that we are now seeing between AF and PM. Clearly from the data 1977 to 1988 a tolerance of 0.4 µm on SD seems to be workable in practice.

<u>RECOMMENDATIONS:</u>

The procedures for selecting, preparing and trialing tops for Interwoollabs Round Trials published in July 1987 be amended as follows (revision marks on the right hand side show the areas of change):

<u>Procedures for Selecting, Preparing and Trialing Interwoollabs Tops</u>

(1) All wool tops purchased for Interwoollabs' use must be of good style, having normal levels of medullation (i.e. in the coarser qualities) and preferably being comprised entirely of fleece wool.

(2) The Between-Fibre Standard Deviation of the top shall be within 0.4µm of the expected value for it's diameter based on the equation:

$$SD = 0.2992\ MFD - 1.7880$$

The SD and MFD being measured by a member of the Management Committee who has access to a Laserscan Instrument.

(3) All wool tops will be gilled a total of 6 times (including the normal combing gillings) to ensure homogeneity both within and between bobbins. Tops having an estimated fineness of less than 23 µm will be double combed before the gillings.

(4) Whenever the results of round trials on newly purchased top show poor agreement between the average Airflow and Microprojection results (i.e. differences greater than ± 0.1 µm), the top will not be used again, remaining stock will be sold and a replacement top will be purchased. The aim is to have as many suitable tops as possible from which to select the future series of standards.

(5) The increase the available number of potential standard calibration tops (given that repeat round tests must have been conducted to establish accurate nominal values and to obtain both Airflow and Microprojection values for each such top), the number of top lots per round test will be increased. In the case of Airflow tests, a total of 8 lots (previously 6) will be tested, with at least 6 results having to be within the limits of acceptance. In the case of Microprojection, a total of 4 lots (previously 3) will be tested, with at least 3 results having to be within the limits of acceptance.

Except where it is considered necessary, there will be no special lots in future trials.

(6) To ensure that data for Airflow and Microprojection values are collected independently of each other, the top lots in each Microprojection round trial will be different from those used in the same Airflow round trial.

(7) Before any new series of IH calibration standards is issued, the standards provisionally selected by the management committee will be subjected to a final calibration check among the committee members' laboratories to ensure that they produce an acceptable calibration curve, as defined in IWTO-6-86.

(8) In determining the normal value for each IH standard to be used for the calibration of Airflow instruments, the average Airflow results obtained from the repeat round tests will be used (excluding statistically selected outliers).

(9) In determining the nominal value for each IH standard to be used for the calibration of Laserscan and OFDA instruments, the average Projection Microscope results obtained from the repeat round tests will be used (excluding statistically selected outliers).

(10) Prior to the release of any new standards, the president shall report to the IWTO General Assembly to nominal values for the next series of tops using the following format:

11th Series of IH Standards

valid: 01.01.1996 - 31.12.1997

Standard Values to be used for
the calibration of the Instruments
for the fibre diameter measurements.

Standard Values			
	Airflow	Projection Microscope	
Standard No.	Mean Fibre Diameter (µm)	Mean Fibre Diameter (µm)	Distribution of Fibre Diameter (CV%)
1	17.05	17.01	20.16
2	19.23	19.13	17.70
3	20.61	20.49	22.50
4	24.92	25.05	21.71
5	27.09	27.09	23.18
6	31.21	31.28	23.54
7	34.14	34.31	27.17
8	37.31	37.11	24.68