

# INTERNATIONAL WOOL TEXTILE ORGANISATION

## TECHNOLOGY & STANDARDS COMMITTEE

Raw Wool Group

Chairman: A.C. BOTES (South Africa)

NICE MEETING

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Variable Test Specimen Mass Airflow Round Trial

By

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### **SUMMARY**

Results are reported for an Interlaboratory Round Trial involving measurement of Mean Fibre Diameter (MFD) by Airflow using a test specimen which can vary in mass from 2.400g to 2.600g. The Variable Mass technique was compared with the existing Fixed Mass  $2.500 \pm 0.004$ g technique as per the statistical procedures outlined in IWTO-0. The trial was conducted in AWTA Ltd. Laboratories in Sydney, Melbourne and Fremantle.

For the range of wools from 16.7 to 32.0 microns MFD, results show equivalent performance between MFD measurements using the Standard Fixed Mass (2.500g) and the Variable Mass technique. In accordance with a recommendation made at IWTO Technical Committee Nice 1998, the Variable Mass technique was not used for measurement of wools greater than 32 micron MFD. Further changes are recommended to IWTO-28 such that the Variable Mass technique is not used for wools less than the finest IH Interwoollabs Top, which is currently 16.7 micron MFD.

The Variable Mass technique has recently been trialed by NZWTA Ltd. As a result of these trials, NZWTA Ltd. has recommended a modification to the Variable Mass calibration procedure, resulting in small changes in measured MFD. The NZWTA Ltd. recommendation has been applied successfully to the results in this report.

### **INTRODUCTION**

The Variable Mass technique was introduced at Nice 1997 meeting of IWTO in a paper entitled "The Use of Variable Test Specimen Mass when Measuring Mean Fibre Diameter by Airflow" (1). The technique requires calibrations to be performed for each of 2.400g, 2.500g and 2.600g test specimens and develops an appropriate calibration equation for test specimen masses from 2.400g to 2.600g.

The aforementioned paper recommended that changes be made to IWTO-28 to accommodate the Variable Mass technique. Whilst the recommended changes were approved, AWTA Ltd was instructed to conduct further research in two areas. The first was to clarify the suitability of the Variable Mass technique for ultra fine wools less than 17 microns MFD. The second was to carry out a trial involving more than one Laboratory so that the measurement precision of the Variable Mass technique could be compared with the existing Fixed Mass technique. Results are reported in this paper.

In addition, a modified Variable Mass calibration procedure, recommended by NZWTA Ltd. (2), is examined. A comparison is performed between the Variable and Fixed Mass techniques using the NZWTA Ltd. calibration procedure.

## **METHOD**

### **Calibration Type 1 (approved IWTO Nice Meeting, December 1997)**

A pair of Electronic Airflow Instruments was calibrated for Variable Mass according to the procedure described in IWTO-28-93 in each of the three AWTA Ltd Laboratories in Sydney, Melbourne and Fremantle.

### **Comparison of Variable and Fixed Mass techniques using calibration Type 1**

Figure 1 depicts the trial design. Thirty four greasy wool samples covering the MFD range from 15 $\mu$ m to 32 $\mu$ m were selected. Each sample was divided into three subsamples for measurement in each Laboratory. From each subsample, a total of eight plugs was taken. Four plugs were used for replicate tests using the Fixed Mass technique and the remaining four plugs for replicate tests using the Variable Mass technique. Each replicate test was performed in accordance with IWTO-28 procedures.

Fixed Mass and Variable Mass flow values and variable masses were recorded. For Variable Mass measurements, flow values were substituted into the appropriate quadratic function according to the measured specimen mass. MFD values and the between and within Laboratory components of variance were used to compare the Variable and Fixed Mass techniques.

### **Calibration Type 2 (recommendation by NZWTA Ltd. , IWTO Nice Meeting, December 1998)**

The new procedure recommended by NZWTA Ltd. is similar to the current method except that quadratic functions are used for the relationship of average IH Top flow values versus mass, whereas linear functions are used in the current technique.

### **Comparison of Variable and Fixed Mass techniques using Calibration Type 2**

A comparison was performed as per the method for comparison of techniques described above using a Calibration Type 1 procedure.

All Fixed Mass and Variable Mass flow values and Variable masses used for comparison of the Calibration Type 1 procedure were again used for comparison of Fixed and Variable techniques using a Calibration Type 2 procedure. As such, a direct comparison of the two calibration types was possible.

### **Precision Estimates for the Variable and Fixed Techniques using Type 1 and 2 Calibration methods**

The 95% Confidence Limits for the precision of the Fixed Mass and the Variable Mass techniques using a Type 1 and Type 2 calibration were calculated. An estimate of precision for the Fixed Mass technique published by Marler and Baxter (3) was also included.

## **RESULTS AND DISCUSSION**

### **Calibration (Type 1 and Type 2)**

Each of the three mass calibrations for each instrument in each laboratory had a Mean Square Error (MSE) less than 0.03 $\mu$ m<sup>2</sup> as required by IWTO-28-93.

Figures A1(a) to A3(b) in Appendix A show linear regressions of flow versus mass relationships for each of the six instruments. Similarly for the Type 2 calibration Figures A4(a) to A6(b) in Appendix A show quadratic regressions of the same data. Table A1 in Appendix A gives correlation coefficients for all of the linear regressions, which range in value from 0.9782 to 1.000. The correlation coefficient for each of the quadratic regressions in Calibration Type 2 is always 1.000 since three points are used to fit the flow versus mass relationships.



Figure 1. Schematic diagram of trial to compare MFD measurement by the Variable Mass and Fixed Mass techniques.

**Comparison of Fixed and Variable Mass Techniques using existing calibration (Type 1)**

Figure 2 shows the difference between the Variable and Fixed Mass techniques for replicate 1 measurements (see Figure 1). A summary of statistics is reported in Table 1. Data from all three Laboratories have been combined.

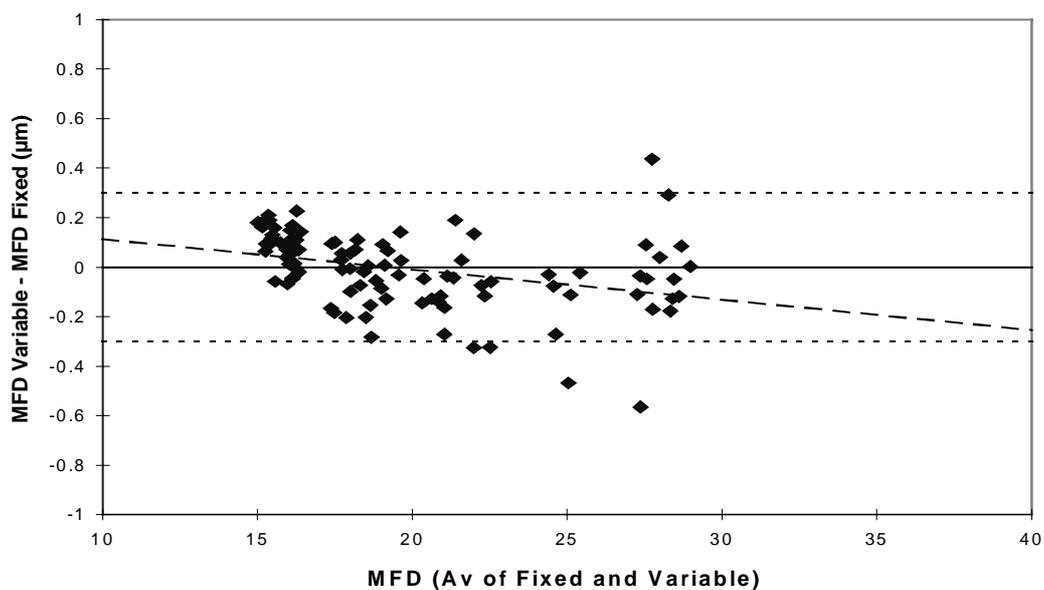


Figure 2. MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using a Type 1 calibration. Data from all three Laboratories is combined.

**(A) Test for Overall Relative Bias & Paired t-test**

	Overall Bias		Paired t-test
	Control	Treatment	
Number	102	102	102
Average	19.8115	19.8044	-0.0071
SD	4.3158	4.2632	0.1529
SE	0.4273	0.4221	0.0151
t value	46.3614	46.9167	-0.4719
p value	0.0000	0.0000	0.6380
<b>Significance</b>			<b>NS</b>

**(B) Test for Correlation**

Number	102
DF	100
R	0.9994
t-value	298.7234
p-value	0.0000
<b>Significance</b>	<b>***</b>

**(C) Test for Level Dependent Bias**

Regression	Slope	Significance	SE of Slope	t-Value	p-value	Rsq
GM	<b>0.9878</b>	<b>***</b>	0.0033	3.6889	0.0004	0.9989
DVA	-0.0123	<b>***</b>	0.0033	3.6665	0.0004	

Table 1. A summary of statistics for the MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using a Type 1 calibration. Data from all three Laboratories have been combined.

Table 1 indicates a significant MFD dependency for the difference between Variable Mass and Fixed Mass techniques. This is clearly illustrated in Figure 2 where there is a distinct positive bias in the order of 0.1µm for ultra fine wools.

The Variable Mass technique relies on individual quadratic calibration curves which are determined by the plug mass. Each of the 201 calibration curves covering the 2.4g to 2.6g plug mass range is based on estimations of flow values for each of the IH Tops whose diameters, in this case, range from 16.7 µm to 37.4 µm (current series 12 Tops). For wools with MFD outside the range of IH Top MFD values, valid comparisons of results for Variable and Fixed Mass techniques requires correct extrapolation of calibration curves. The MFD differences between techniques for ultra fine wools demonstrated in this trial suggests that the quadratic fit may not result in a correct extrapolation.

A single Electronic Airflow instrument used in this trial was selected in order to demonstrate potential problems with obtaining flow values from the extrapolated portions of calibration curves. Using calibration curves based on 2.4g, 2.5g and 2.6g plug masses a range of MFD values less than the finest IH Top were substituted into each calibration equation in order to estimate flow. Results are plotted in Figure 3.

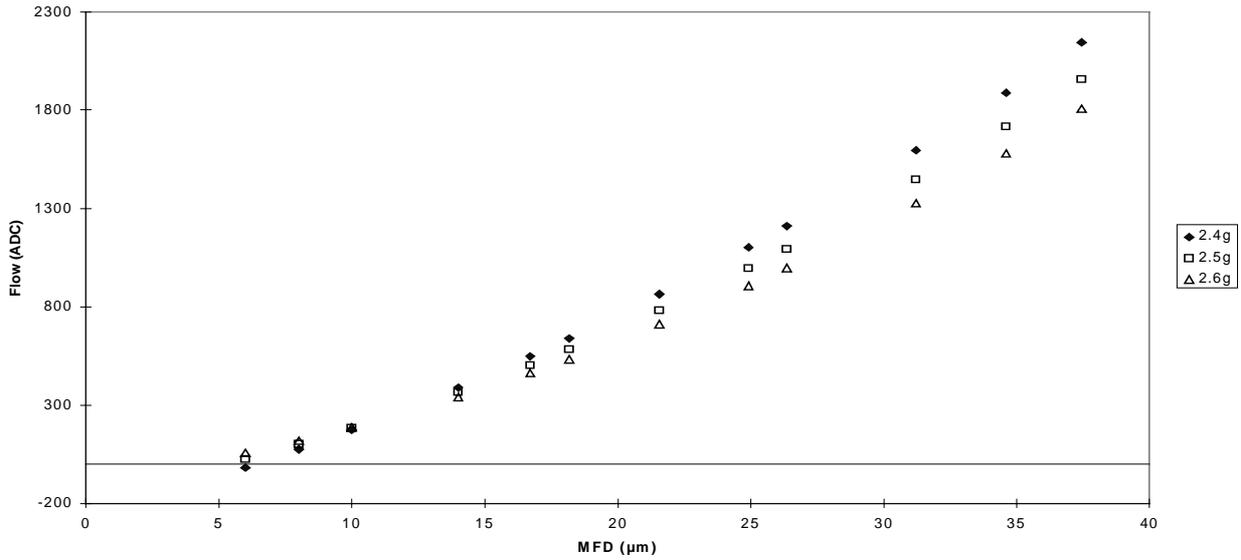


Figure 3. Calibration curves at 2.4g, 2.5g and 2.6g plug masses for Electronic Airflow 5. Measured flow values are plotted in the IH Top range from 16.7 to 37.4 µm. Flow values for MFD below this range were determined by substituting MFD values of 6, 8, 10 and 14 µm into each of the three quadratic equations.

Estimation of flow in the extrapolated portion of calibrations curves may not be highly reliable given the extent to which curves merge for ultrafine wools. Figure 3 shows curves crossing over in the region from 10 to 12 µm MFD indicating that flow values for 2.6g test specimens would be higher than flow values for 2.4 g test specimens at the same MFD diameter.

In order to remove any uncertainty of the effect on MFD of extrapolating calibration relationships for different test specimen masses, it was decided to limit the MFD of samples to within the MFD range of IH Tops for this trial. It follows that wools below 16.7 µm were removed from the Variable versus Fixed Mass comparison in this report. Figure 4 is a reproduction of Figure 2 with the data below 16.7 µm eliminated. A summary of statistics is reported in Table 2.

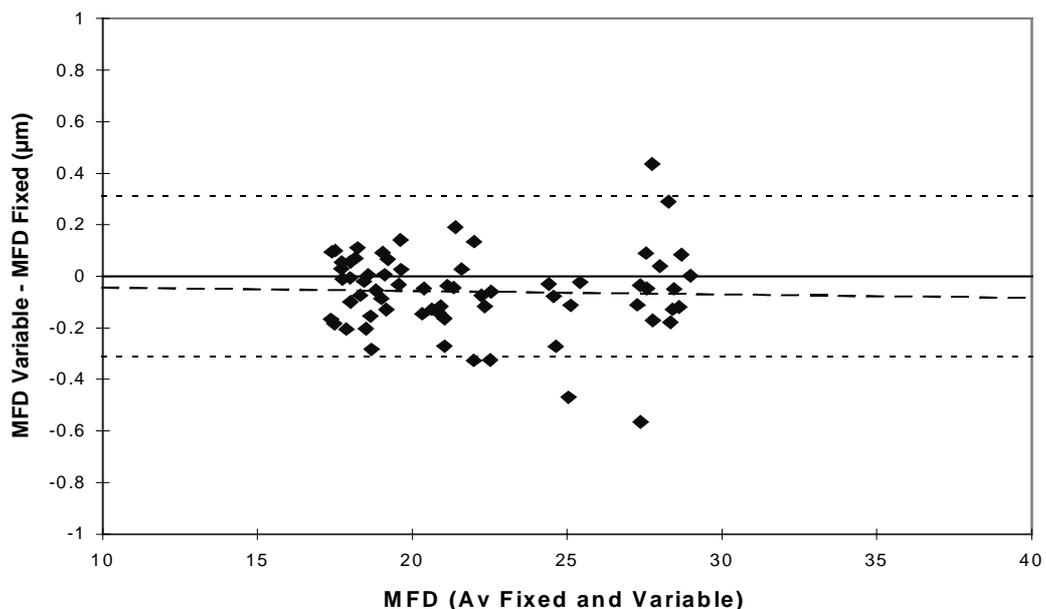


Figure 4. MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using a Type 1 calibration for wools greater than 16.7 µm. Data from all Three Laboratories have been combined.

**(A) Test for Overall Relative Bias & Paired t-test**

	Overall Bias		Paired t-test
	Control	Treatment	
Number	66	66	66
Average	21.9894	21.9299	-0.0595
SD	3.8988	3.8936	0.1585
SE	0.4799	0.4793	0.0195
t value	45.8194	45.7574	-3.0501
p value	0.0000	0.0000	0.0033
<b>Significance</b>			<b>**</b>

**(B) Test for Correlation**

Number	66
DF	64
R	0.9992
t-value	196.6391
p-value	0.0000
<b>Significance</b>	<b>***</b>

**(C) Test for Level Dependent Bias**

Regression	Slope	Significance	SE of Slope	t-Value	p-value	Rsq
GM	<b>0.9986</b>	<b>NS</b>	0.0051	0.2671	0.7902	0.9983
DVA	-0.0014	<b>NS</b>	0.0051	0.2669	0.7904	

Table 2. A summary of statistics for the MFD differences between Variable and Fixed Mass techniques for replicate 1 using a Calibration Type 1 for wools greater than 16.7  $\mu\text{m}$ .

Table 2 shows no level dependent bias for the differences between Variable and Fixed Mass techniques following elimination of data less than 16.7  $\mu\text{m}$  MFD. The Variable Mass technique was, on average, 0.06  $\mu\text{m}$  less than the Fixed Mass technique. The majority of this difference is contributed by Melbourne laboratory only. The difference between the Variable and Fixed Mass techniques in Sydney and Fremantle laboratories was not statistically significant.

**Comparison of Fixed and Variable Mass Techniques using NZWTA Ltd. recommended Calibration Type 2**

Figure 5 gives the difference between the Variable and Fixed Mass techniques for replicate 1 measurements using a Type 2 calibration. A summary of statistics for this comparison is reported in Table 3.

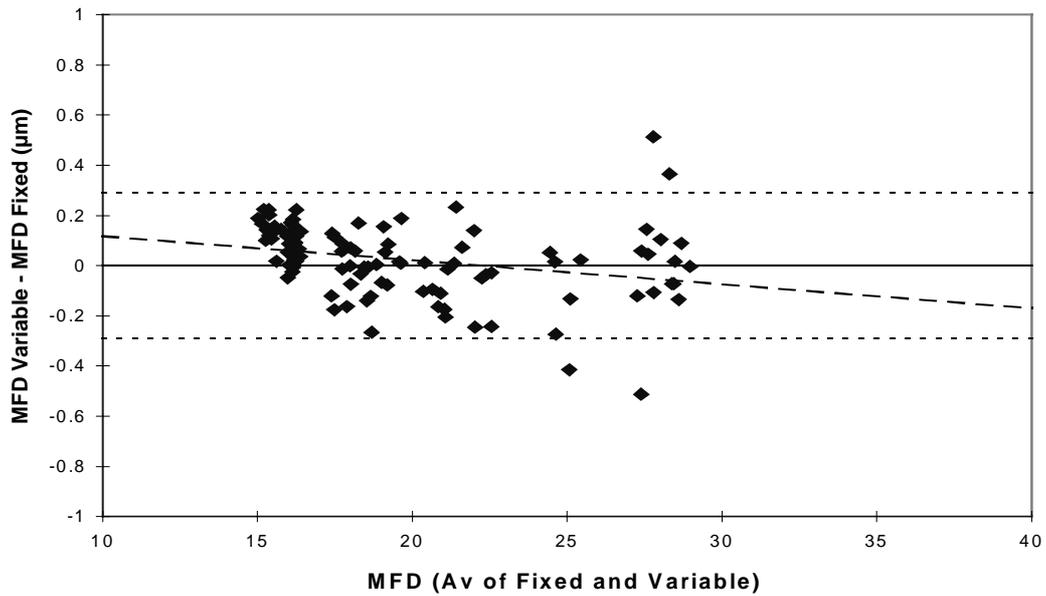


Figure 5. MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using a Type 2 calibration. Data from all three Laboratories have been combined.

**(A) Test for Overall Relative Bias & Paired t-test**

	Overall Bias		Paired t-test
	Control	Treatment	
Number	102	102	102
Average	19.8115	19.8345	0.0230
SD	4.3158	4.2746	0.1490
SE	0.4273	0.4232	0.0148
t value	46.3614	46.8625	1.5599
p value	0.0000	0.0000	0.1219
<b>Significance</b>			<b>NS</b>

**(B) Test for Correlation**

Number	102
DF	100
R	0.9994
t-value	299.7539
p-value	0.0000
<b>Significance</b>	<b>***</b>

**(C) Test for Level Dependent Bias**

Regression	Slope	Significance	SE of Slope	t-Value	p-value	Rsq
GM	<b>0.9905</b>	<b>**</b>	0.0033	2.8898	0.0047	0.9989
DVA	-0.0096	<b>**</b>	0.0033	2.8760	0.0049	

Table 3. A summary of statistics for the MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using a Type 2 calibration. Data from all three Laboratories have been combined.

Table 3 indicates significant MFD dependency for the difference between Variable Mass and Fixed Mass techniques. This is clearly illustrated in Figure 4 where there is a distinct positive bias in the order of  $0.1\mu\text{m}$  for ultra fine wools.

Figure 6 is a reproduction of Figure 5 with the data below  $16.7\mu\text{m}$  eliminated. A summary of statistics is reported in Table 4.

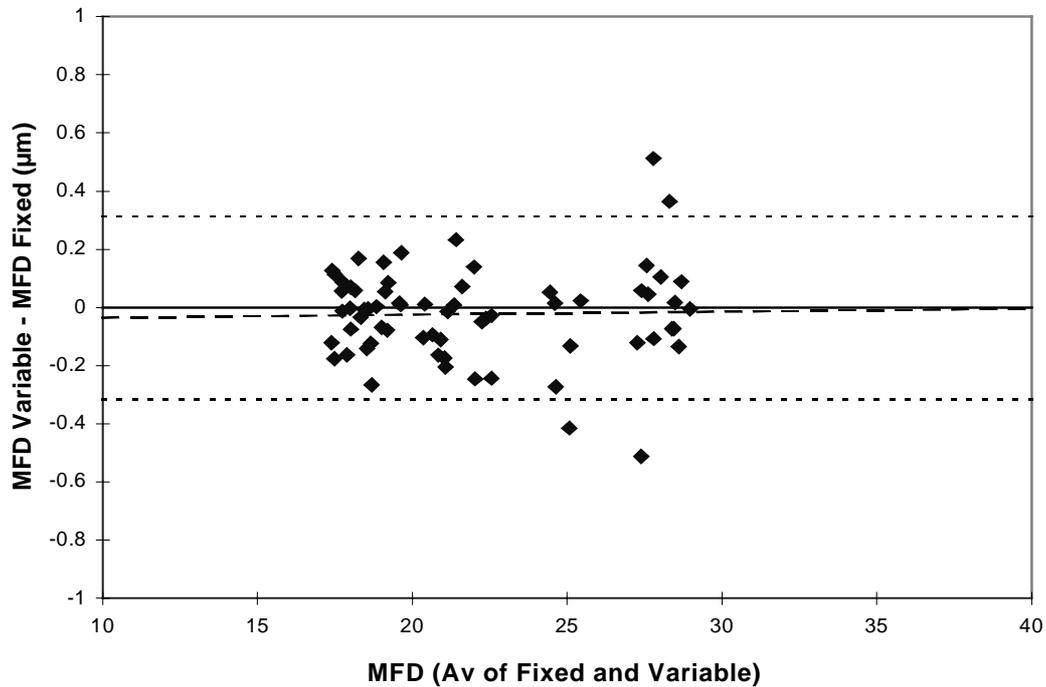


Figure 6. MFD differences between Variable and Fixed Mass techniques for replicate 1 measurements using Calibration Type 2 for wools greater than  $16.7\mu\text{m}$ . Data from all Laboratories have been combined.

**(A) Test for Overall Relative Bias & Paired t-test**

	Overall Bias		Paired t-test
	Control	Treatment	
Number	66	66	66
Average	21.9894	21.9666	-0.0228
SD	3.8988	3.9029	0.1602
SE	0.4799	0.4804	0.0197
t value	45.8194	45.7245	-1.1551
p value	0.0000	0.0000	0.2523
<b>Significance</b>			<b>NS</b>

**(B) Test for Correlation**

Number	66
DF	64
R	0.9992
t-value	194.7167
p-value	0.0000
<b>Significance</b>	<b>***</b>

**(C) Test for Level Dependent Bias**

Regression	Slope	Significance	SE of Slope	t-Value	p-value	Rsqr
GM	<b>1.0010</b>	<b>NS</b>	0.0051	0.2019	0.8406	0.9983
DVA	0.0010	<b>NS</b>	0.0051	0.2020	0.8405	

Table 4. A summary of statistics for the MFD differences between Variable and Fixed Mass techniques for replicate 1 using Calibration Type 2 for wools greater than 16.7  $\mu\text{m}$ . Data from all Laboratories have been combined.

Table 4 gives a value of -0.02 for the overall average difference between the techniques using a Calibration Type 2. This represents a decrease in the differences between the Variable and Fixed techniques of 0.04  $\mu\text{m}$  when compared to data from a Calibration Type 1.

**Precision Estimates for the Variable and Fixed Techniques using Type 1 and 2 Calibration methods**

The 95% Confidence Limits for the precision of the Variable Mass technique using Type 1 and Type 2 calibration methods are given in Figure 7. Also included are the 95% precision estimates for wools measured in this trial using the Fixed Mass technique. The published precision estimates for the Fixed Mass technique calculated by Marler and Baxter (3) are also shown.

Table A2 in Appendix A gives the between and within lab components of variance and the 95% Confidence Limits for each wool for both the Variable (calibration Type 1 procedure) and Fixed Mass techniques. Table A3 provides similar information for the Type 2 calibration procedure.

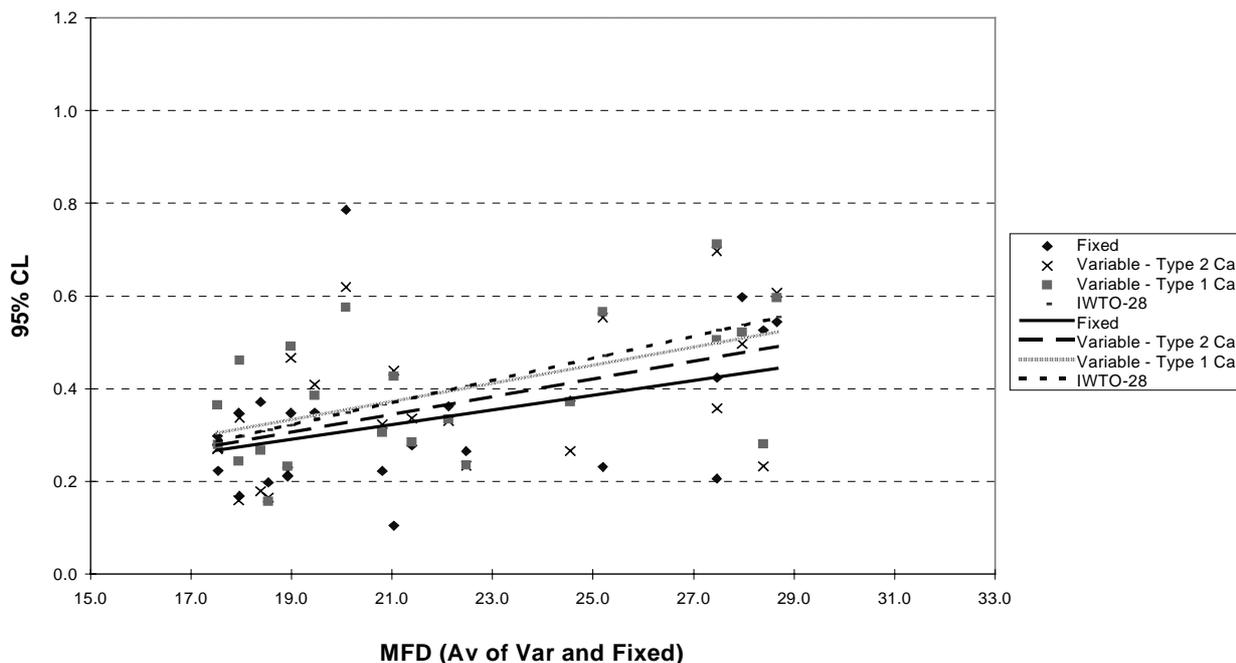


Figure 7. The 95% Confidence Limit for the precision of the Fixed Mass technique and the Variable Mass technique using Type 1 and 2 calibration methods. Also included is precision estimate for IWTO-28 calculated by Marler and Baxter (3).

Figure 7 shows equivalent performance in terms of precision between Variable Mass calibration methods 1 and 2, and the precision estimate in IWTO-28-93.

## CONCLUSION

The Variable Mass technique was assessed in an Interlaboratory Round Trial involving AWTA Ltd Laboratories in Sydney, Melbourne and Fremantle. It was assessed under the existing calibration method for Variable Mass and a modified method recommended by NZWTA Ltd..

There is strong evidence that the Variable Mass technique is not suitable for wools less than 16.7  $\mu\text{m}$  MFD, which is the MFD of the finest IH Top in this trial. Between 16.7 $\mu\text{m}$  and the upper limit of 32 $\mu\text{m}$ , however, the Variable Mass technique has been shown to give equivalent precision to the current IWTO-28-93 Standard Fixed Mass technique. A small negative bias of 0.06 $\mu\text{m}$  was found between the Variable and Fixed Mass techniques but this difference was attributed to one laboratory only.

The modified Variable Mass calibration procedure resulted in a small improvement in the average overall difference between the Variable and Fixed Mass techniques.

## RECOMMENDATION

It is recommended that IWTO-28 be modified to ensure that wools less than the MFD of the Finest IH Top in use at any given time, not be measured using the Variable Mass technique. Changes to the Standard are outlined in Appendix B.

## REFERENCES

1. Doak B T and Mahar T J (1997). The Use of Variable Test Specimen Mass when Measuring Mean Fibre Diameter by Airflow. Proc. IWTO Tech. Comm., Nice Meeting, December 1997, Report No. 7.
2. Knowles D G (1998). The Measurement of Mean Fibre Diameter of Coarse Wool by Airflow Using the Variable Mass Technique. IWTO Tech. Comm., Nice Meeting, December 1998, Report No.4.
3. Marler J W and Baxter B P (1995). Addendum to Report 15: Confidence Limits for Measurement made on Raw Wool. Proc. IWTO Tech Comm., Harrogate Meeting, June 1995, Report No.15.

**APPENDIX A**

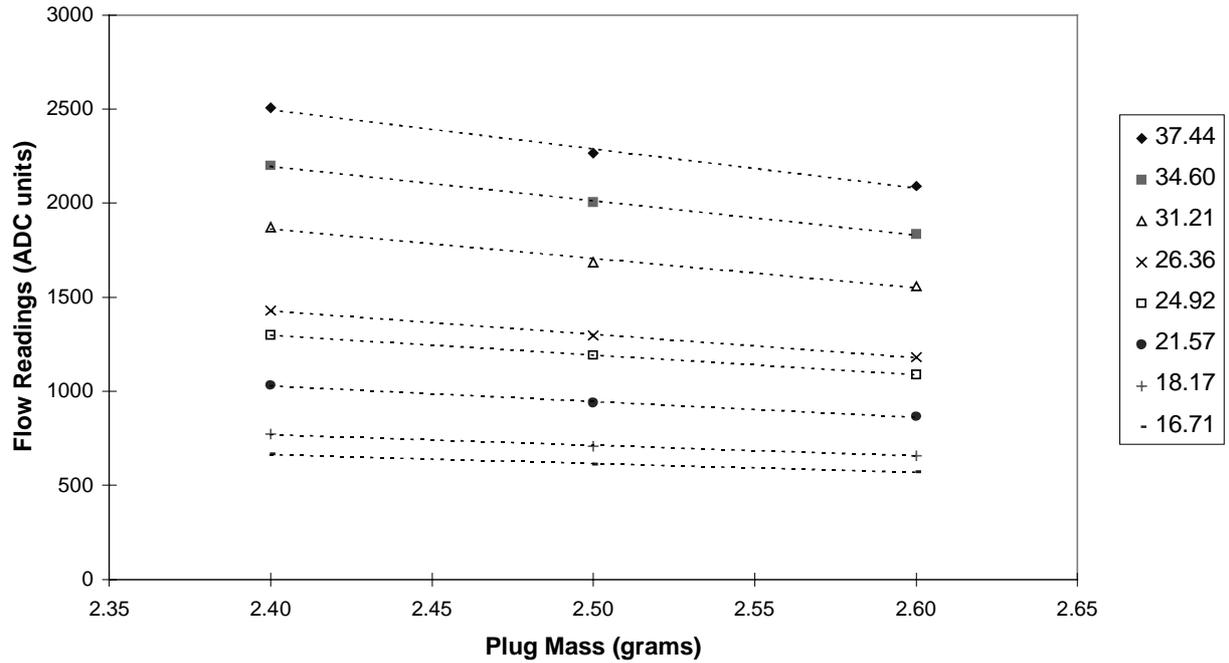


Figure A1(a). Linear regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 1 using 2.400g, 2.500 and 2.600g test specimens.

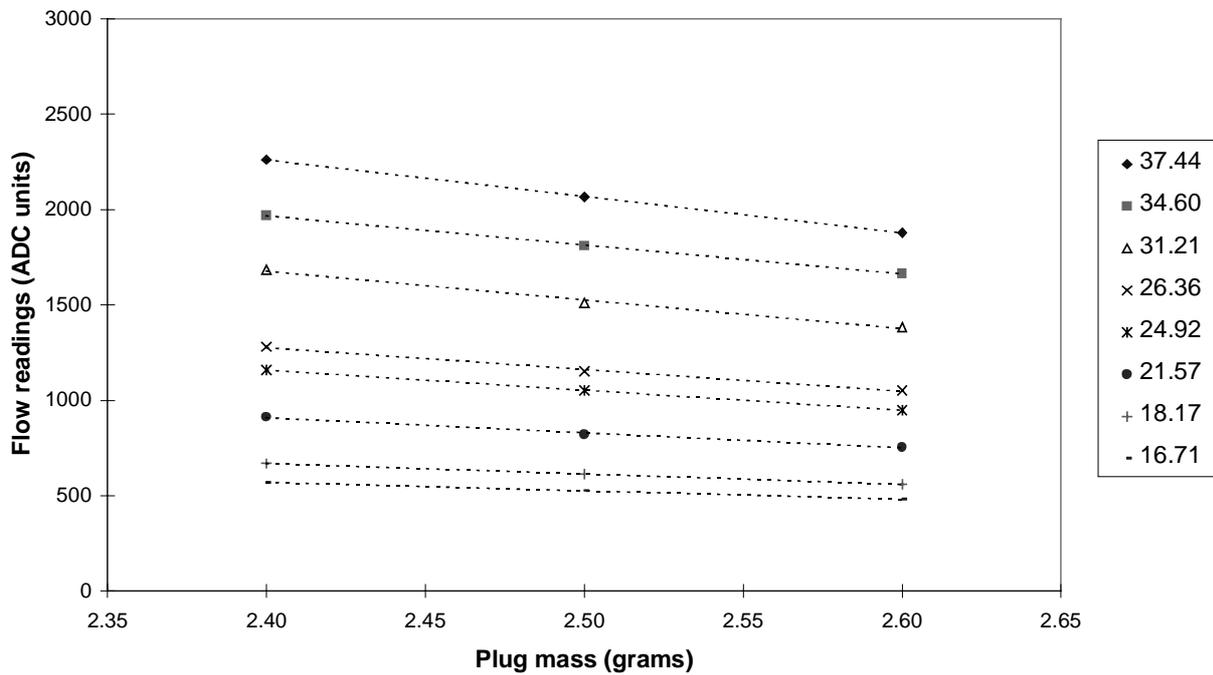


Figure A1(b). Linear Regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 2 using 2.400g, 2.500 and 2.600g test specimens.

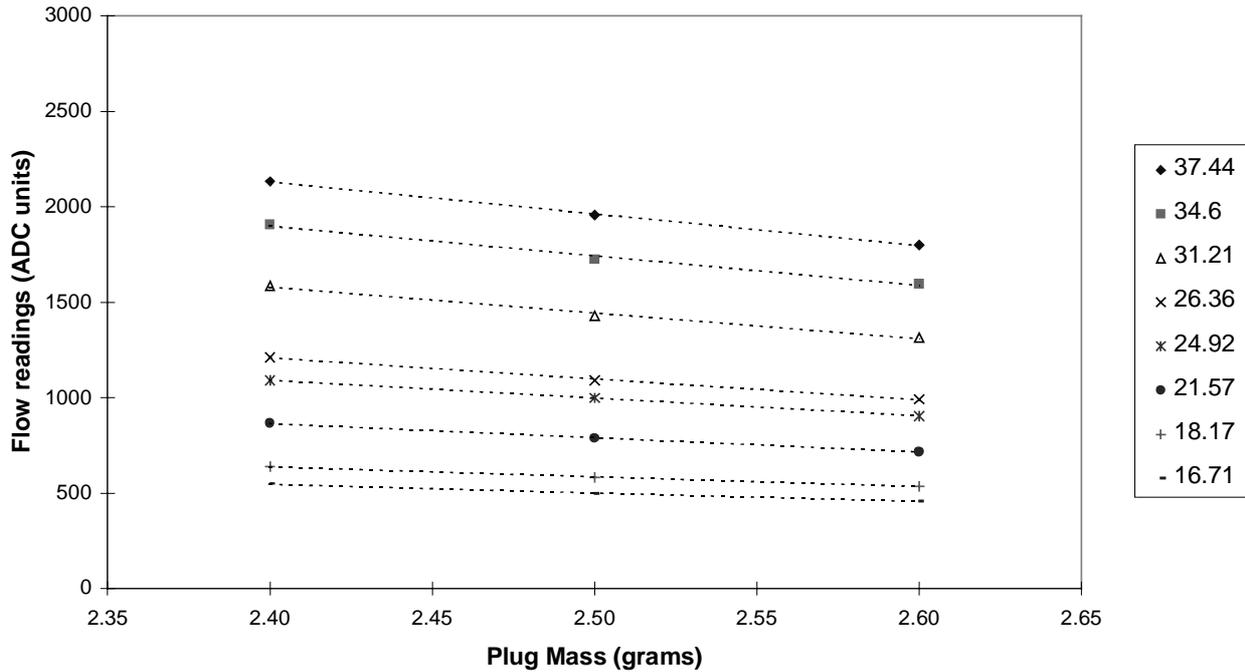


Figure A2(a). Linear Regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 5 using 2.400g, 2.500 and 2.600g test specimens.

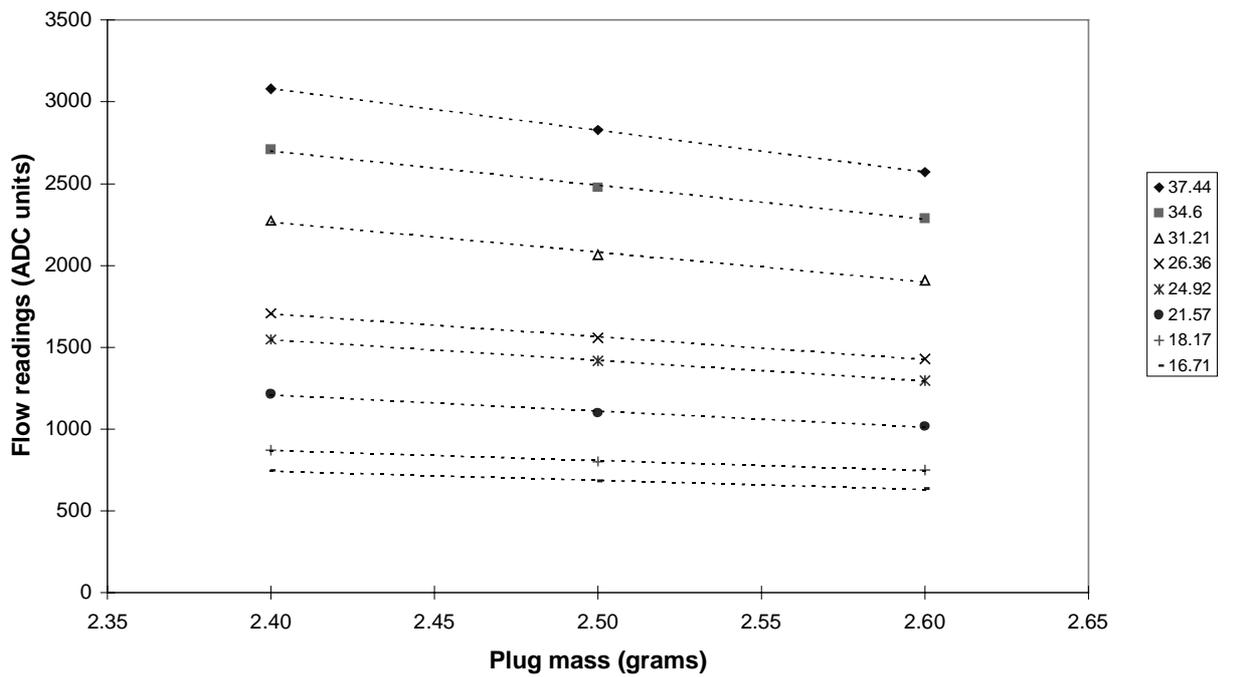


Figure A2(b). Linear Regressions of flow versus mass for each of the 8 IH Tops on Electronic Airflow Meter 6 using 2.400g, 2.500 and 2.600g test specimens.

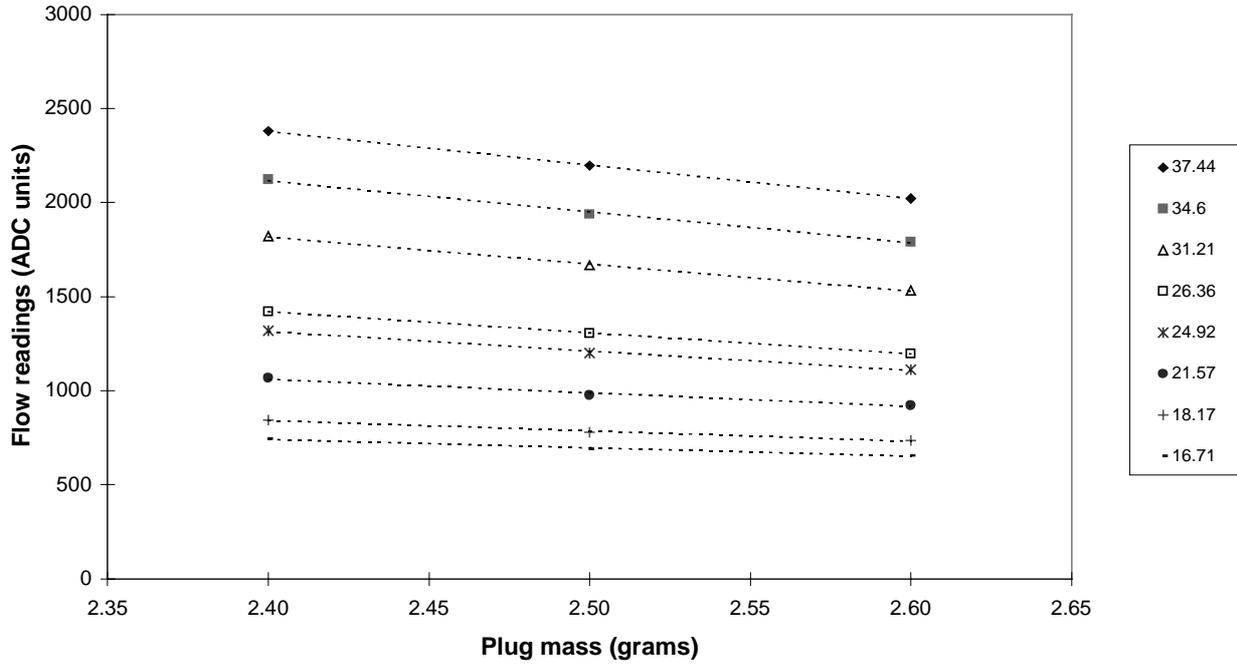


Figure A3(a). Linear Regressions of flow versus mass for each of the 8 IH Tops on Electronic Airflow Meter 7 using 2.400g, 2.500 and 2.600g test specimens.'

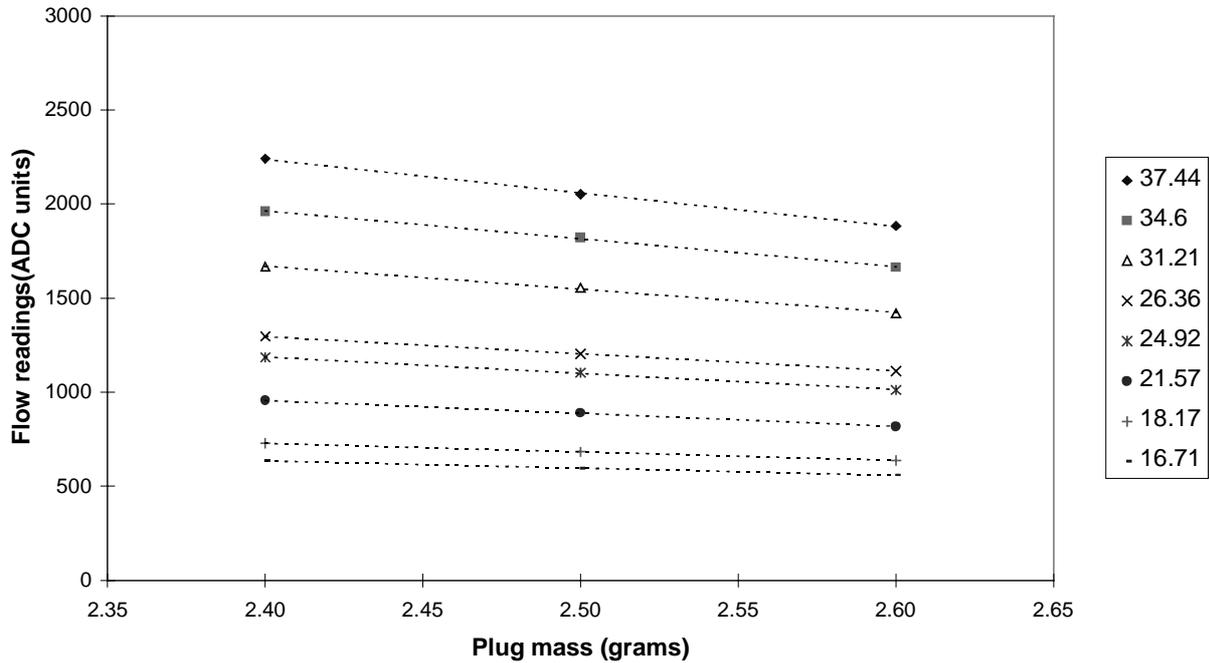


Figure A3(b). Linear Regressions of flow versus mass for each of the 8 IH Tops on Electronic Airflow Meter 8 using 2.400g, 2.500 and 2.600g test specimens.

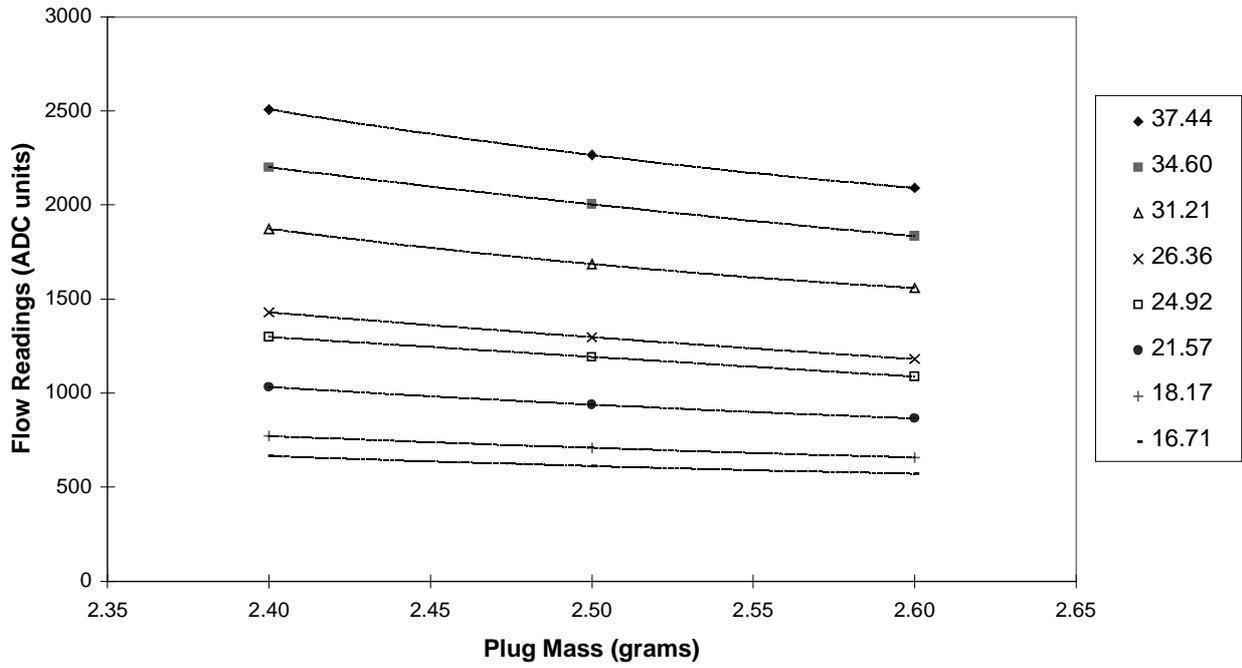


Figure A4(a). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 1 using 2.400g, 2.500 and 2.600g test specimens.

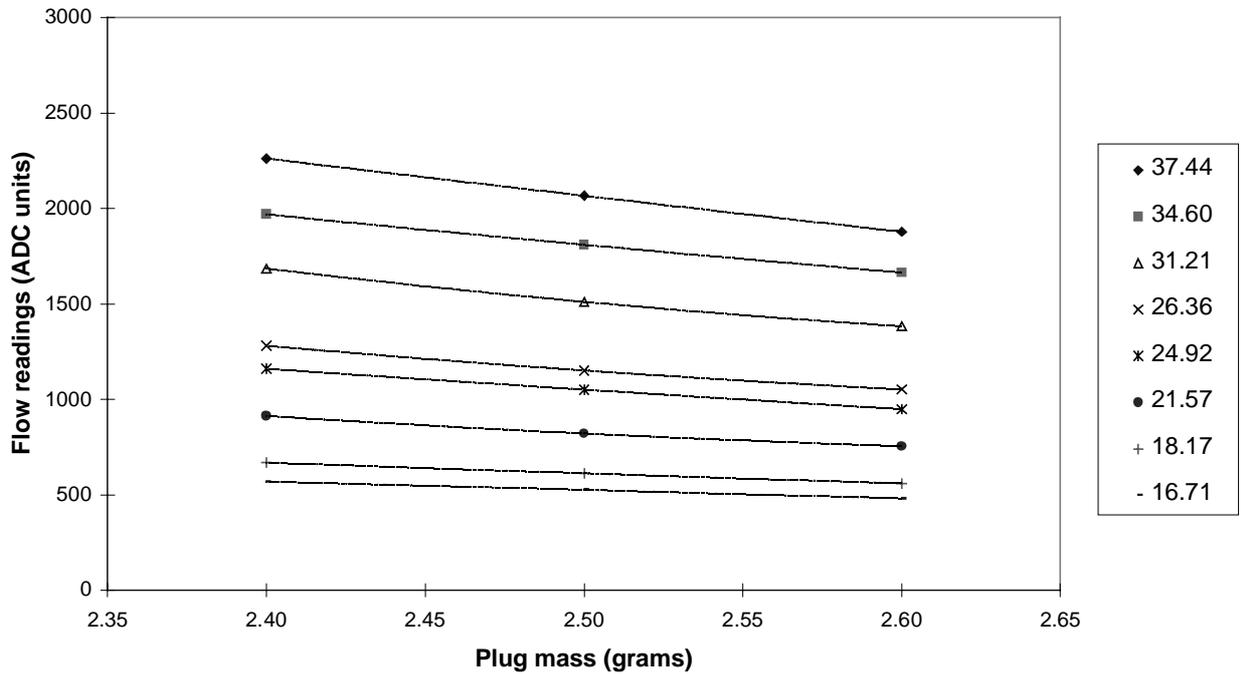


Figure A4(b). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 2 using 2.400g, 2.500 and 2.600g test specimens.

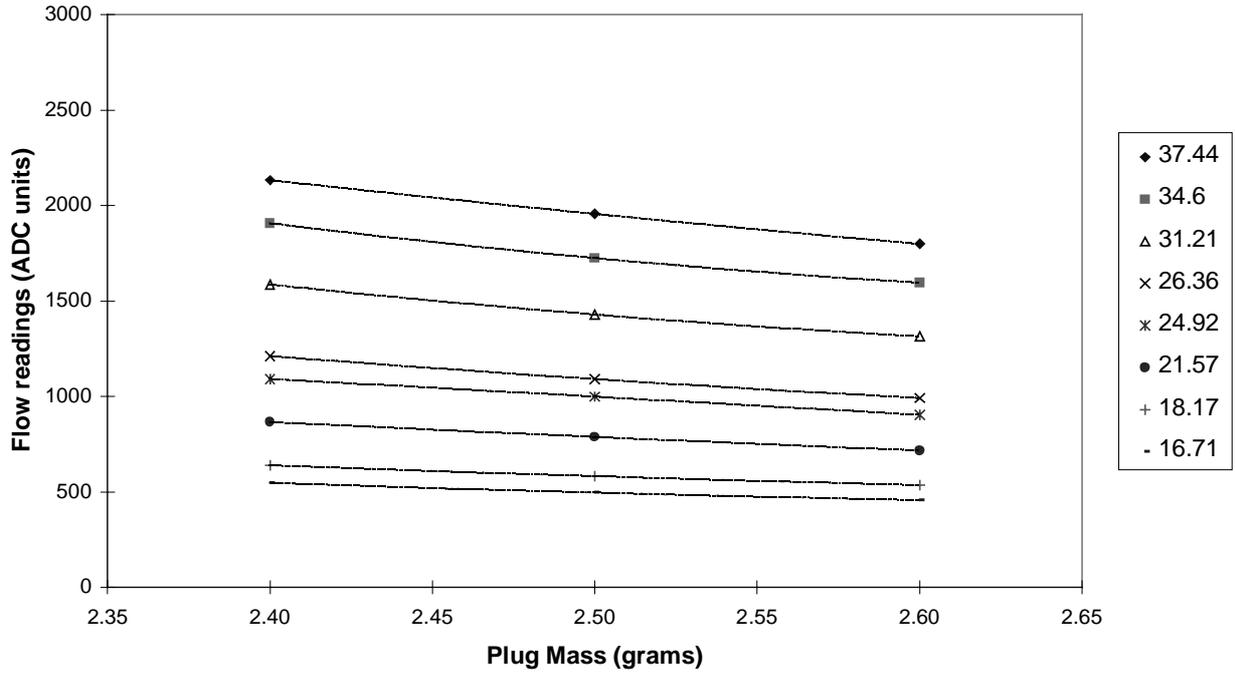


Figure A5(a). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 5 using 2.400g, 2.500 and 2.600g test specimens.

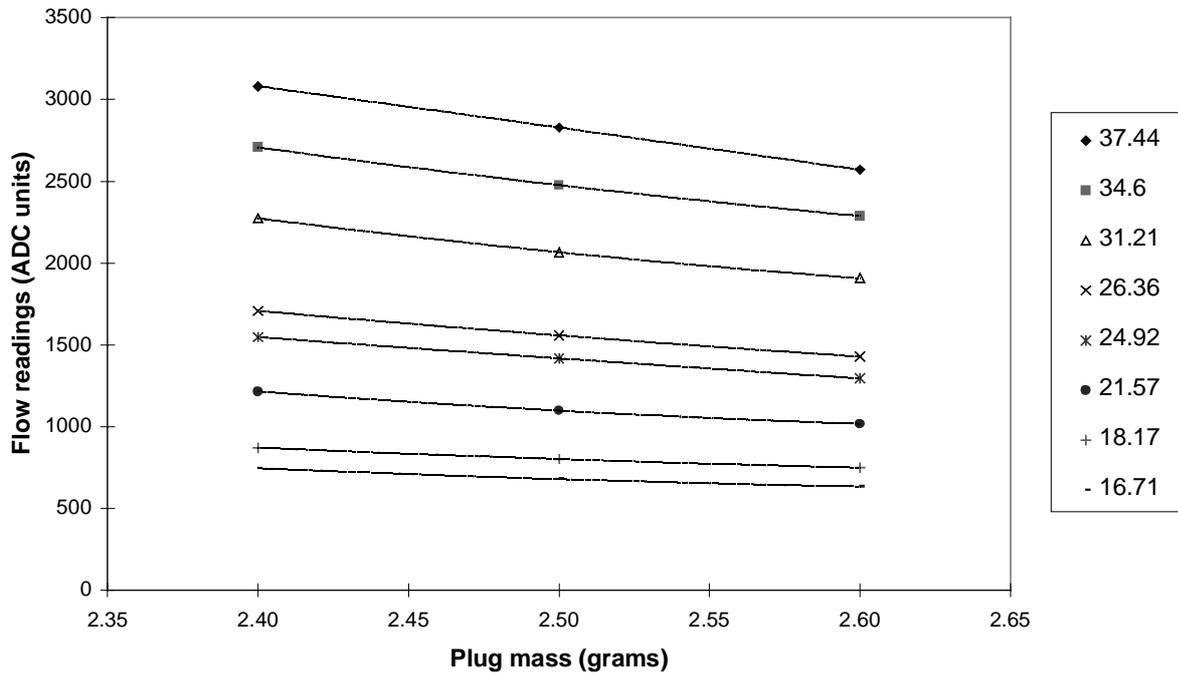


Figure A5(b). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 6 using 2.400g, 2.500 and 2.600g test specimens.

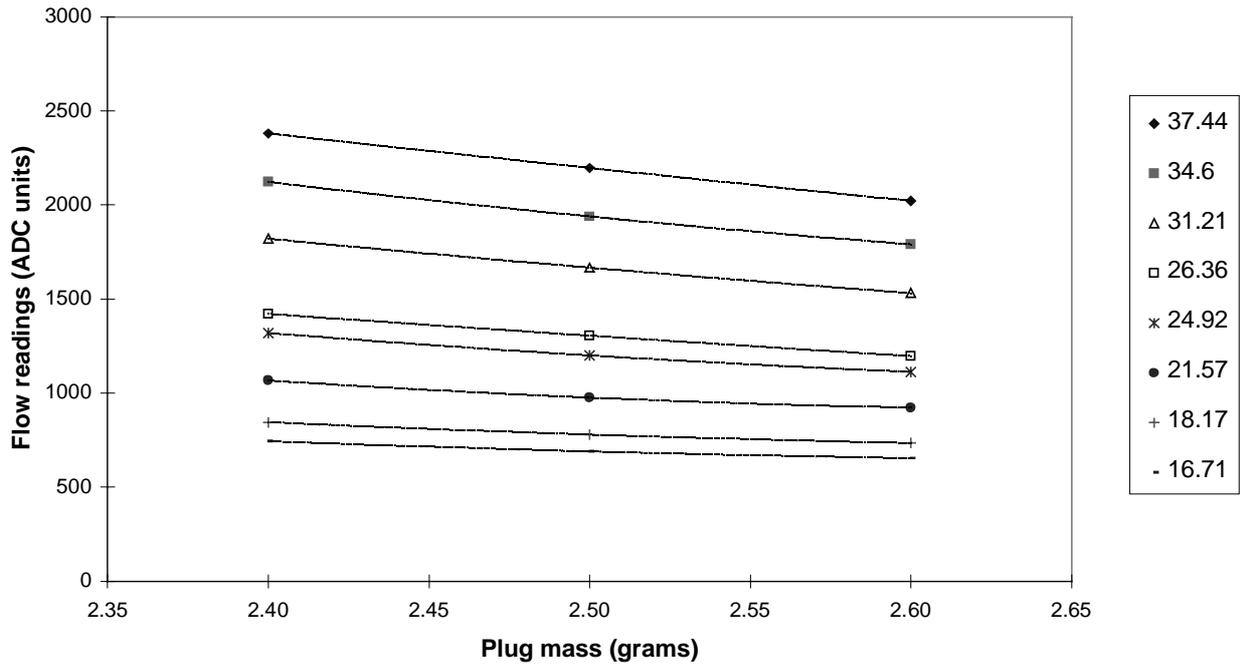


Figure A6(a). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 7 using 2.400g, 2.500 and 2.600g test specimens.

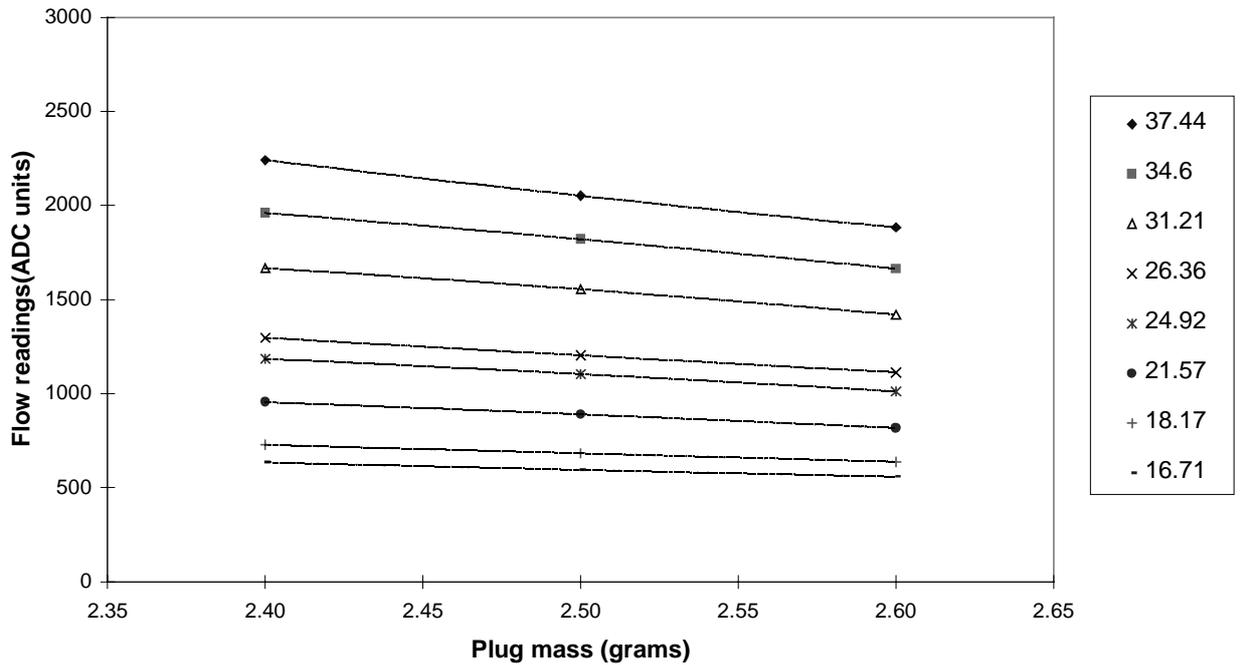


Figure A6(b). Quadratic regressions of flow versus mass data for each of the 8 IH Tops on Electronic Airflow Meter 8 using 2.400g, 2.500 and 2.600g test specimens.

<b>MFD</b>	<b>Auto 1</b>	<b>Auto 2</b>	<b>Auto 5</b>	<b>Auto 6</b>	<b>Auto 7</b>	<b>Auto 8</b>
16.71	0.9947	0.9998	0.9939	0.9873	0.9870	0.9994
18.17	0.9970	0.9997	0.9971	0.9944	0.9891	1.0000
21.57	0.9950	0.9914	0.9992	0.9888	0.9782	0.9988
24.92	1.0000	0.9997	0.9999	0.9997	0.9924	0.9987
26.36	0.9916	0.9941	0.9962	0.9982	0.9997	0.9999
31.21	0.9883	0.9924	0.9913	0.9943	0.9987	0.9972
34.6	0.9981	0.9994	0.9904	0.9967	0.9963	0.9989
37.44	0.9913	0.9999	0.9989	1.0000	0.9998	0.9989

Table A1: Summary of R<sup>2</sup> values for linear regressions of flow versus mass

Wool	Average $\mu\text{m}$	Fixed Technique						Variable Mass Technique - Type 1 calibration					
		MSB	MSW	Var B	Var W	Tot Var	95% CL	MSB	MSW	Var B	Var W	Tot Var	95% CL
		labs	labs					labs	labs				
1	17.5	0.066	0.001	0.022	0.001	0.023	0.298	0.097	0.003	0.031	0.003	0.035	0.364
2	17.5	0.020	0.009	0.004	0.009	0.013	0.223	0.058	0.001	0.019	0.001	0.020	0.279
3	17.9	0.065	0.014	0.017	0.014	0.031	0.348	0.045	0.001	0.015	0.001	0.015	0.244
4	18.0	0.018	0.002	0.005	0.002	0.007	0.169	0.135	0.016	0.040	0.016	0.055	0.462
5	18.4	0.097	0.005	0.031	0.005	0.036	0.371	0.035	0.010	0.008	0.010	0.018	0.267
6	18.5	0.027	0.002	0.008	0.002	0.010	0.198	0.016	0.001	0.005	0.001	0.006	0.156
7	18.9	0.033	0.001	0.011	0.001	0.012	0.211	0.023	0.009	0.005	0.009	0.014	0.233
8	19.0	0.090	0.002	0.029	0.002	0.031	0.348	0.187	0.001	0.062	0.001	0.063	0.491
9	19.5	0.081	0.007	0.025	0.007	0.032	0.348	0.114	0.001	0.037	0.001	0.039	0.386
10	20.1	0.469	0.007	0.154	0.007	0.161	0.786	0.250	0.004	0.082	0.004	0.086	0.576
11	20.8	0.033	0.003	0.010	0.003	0.013	0.222	0.069	0.002	0.022	0.002	0.024	0.306
12	21.0	0.001	0.004	-0.001	0.004	0.003	0.105	0.099	0.021	0.026	0.021	0.047	0.426
13	21.4	0.058	0.001	0.019	0.001	0.020	0.278	0.028	0.017	0.004	0.017	0.021	0.284
14	22.1	0.101	0.001	0.034	0.001	0.034	0.362	0.032	0.028	0.001	0.028	0.029	0.334
15	22.5	0.029	0.013	0.005	0.013	0.018	0.266	0.025	0.009	0.005	0.009	0.014	0.236
16	24.5	0.073	0.018	0.018	0.018	0.036	0.374	0.066	0.021	0.015	0.021	0.036	0.371
17	25.2	0.036	0.003	0.011	0.003	0.014	0.231	0.236	0.007	0.077	0.007	0.083	0.566
18	27.5	0.119	0.011	0.036	0.011	0.047	0.424	0.104	0.047	0.019	0.047	0.066	0.504
19	27.5	0.017	0.008	0.003	0.008	0.011	0.206	0.330	0.033	0.099	0.033	0.132	0.712
20	28.0	0.260	0.010	0.083	0.010	0.093	0.598	0.184	0.014	0.057	0.014	0.071	0.522
21	28.4	0.202	0.007	0.065	0.007	0.072	0.526	0.012	0.025	-0.004	0.025	0.020	0.280
22	28.7	0.213	0.009	0.068	0.009	0.077	0.544	0.251	0.013	0.079	0.013	0.093	0.596

Table 2: Between and Within Lab components of variance and 95% Confidence Limit for the Variable and Fixed techniques - Variable Mass calibration Type 1.

Wool	Average $\mu\text{m}$	Fixed Technique						Variable Mass Technique - Type 2 calibration					
		MSB	MSW	Var B	Var W	Tot Var	95% CL	MSB	MSW	Var B	Var W	Tot Var	95% CL
		labs	labs					labs	labs				
1	17.5	0.066	0.001	0.022	0.001	0.023	0.298	0.049	0.004	0.015	0.004	0.019	0.270
2	17.5	0.020	0.009	0.004	0.009	0.013	0.223	0.056	0.001	0.019	0.001	0.019	0.272
3	17.9	0.065	0.014	0.017	0.014	0.031	0.348	0.016	0.002	0.005	0.002	0.007	0.159
4	18.0	0.018	0.002	0.005	0.002	0.007	0.169	0.076	0.006	0.023	0.006	0.030	0.337
5	18.4	0.097	0.005	0.031	0.005	0.036	0.371	0.018	0.003	0.005	0.003	0.008	0.179
6	18.5	0.027	0.002	0.008	0.002	0.010	0.198	0.020	0.001	0.006	0.001	0.007	0.166
7	18.9	0.033	0.001	0.011	0.001	0.012	0.211	0.018	0.010	0.003	0.010	0.013	0.222
8	19.0	0.090	0.002	0.029	0.002	0.031	0.348	0.158	0.006	0.051	0.006	0.057	0.466
9	19.5	0.081	0.007	0.025	0.007	0.032	0.348	0.128	0.001	0.042	0.001	0.044	0.409
10	20.1	0.469	0.007	0.154	0.007	0.161	0.786	0.284	0.008	0.092	0.008	0.100	0.619
11	20.8	0.033	0.003	0.010	0.003	0.013	0.222	0.071	0.005	0.022	0.005	0.027	0.323
12	21.0	0.001	0.004	-0.001	0.004	0.003	0.105	0.093	0.029	0.021	0.029	0.050	0.439
13	21.4	0.058	0.001	0.019	0.001	0.020	0.278	0.034	0.027	0.002	0.027	0.029	0.336
14	22.1	0.101	0.001	0.034	0.001	0.034	0.362	0.066	0.009	0.019	0.009	0.028	0.331
15	22.5	0.029	0.013	0.005	0.013	0.018	0.266	0.021	0.011	0.003	0.011	0.014	0.235
16	24.5	0.073	0.018	0.018	0.018	0.036	0.374	0.041	0.007	0.011	0.007	0.018	0.266
17	25.2	0.036	0.003	0.011	0.003	0.014	0.231	0.219	0.010	0.070	0.010	0.080	0.554
18	27.5	0.017	0.008	0.003	0.008	0.011	0.206	0.309	0.035	0.091	0.035	0.126	0.697
19	27.5	0.119	0.011	0.036	0.011	0.047	0.424	0.053	0.023	0.010	0.023	0.033	0.358
20	28.0	0.260	0.010	0.083	0.010	0.093	0.598	0.148	0.022	0.042	0.022	0.064	0.497
21	28.4	0.202	0.007	0.065	0.007	0.072	0.526	0.001	0.020	-0.006	0.020	0.014	0.233
22	28.7	0.213	0.009	0.068	0.009	0.077	0.544	0.250	0.019	0.077	0.019	0.096	0.607

Table 3: Between and Within Lab components of variance and 95% Confidence Limit for the Variable and Fixed Mass techniques - Variable Mass calibration Type 2.

## Appendix B

~~Changes were made to IWTO 28-93 following the Nice 1997 Meeting of IWTO to Changes were made to IWTO-28-93 following IWTO Nice Meeting 1997 Changes needed to IWTO-28-93 to enable measurements to be made with a variable test specimen mass between 2.400g to 2.600g. A further change is outlined arising from a Technical Report to this meeting. A further change is\_ aroutlined arising from a Technical Ret 27 to this meeting, '????????????????????????????????The Use of Variable Test Specimen Mass when Measuring Mean Fibre Diameter by Airflow', provides technical support to these changes.~~

*Recommended changes to Clause 4. Essential Requirements*

### **4. Essential Requirements**

(h) Each~~The~~ test specimen must either:

weigh  $2.500 \pm 0.004$ g for a fixed mass test; or,

weigh between 2.400g and 2.600g for a variable mass test. A variable mass test is only applicable for wools with measured diameter greater than or equal to the finest IH Top and greater than the finest IH Top and less than or equal to 32µm.

(i) ~~The~~ Airflow reading must be carried out in the IWTO Standard Atmosphere.

(j) ~~At least two 2.500g test specimens must be measured, with two readings on each of two Airflow Fineness Meters.~~

*Recommended changes to Clause 5.5 Test Specimen*

### **5.5 Test Specimen**

Wool randomly drawn from and representative of the laboratory sample and either:

—— weighing  $2.5 \pm 0.004$  g for a fixed mass test; or,

—— weighing between 2.400g and 2.600g for a variable mass test. Test specimen mass is determined after conditioning to equilibrium with the IWTO Standard Atmosphere ( $20 \pm 2$  ° C,  $65 \pm 3\%$  r.h.).

*Recommended changes to Clause 6.2.6 Preparation of Test Specimens*

### **6.2.6 Preparation of Test Specimens**

~~Passage through a Shirley Analyser blends most wools satisfactorily. If difficulties are experienced in obtaining good agreement between test specimens the following procedure is recommended.~~

~~Spread out the randomised laboratory sample and divide it into eight equal parts. Remove pinches from each of the eight parts until just over 5g of wool fibres have been accumulated.~~

~~Weigh two test specimens (either  $2.5 \pm 0.004$  g each for a fixed mass test, or between 2.400g and 2.600g for a variable mass test) from the randomised laboratory sample.~~

*Recommended changes to Clause 6.3.1. Testing of Specimens*

### 6.3.1 Testing of Specimens

(x) If it is determined by the variable mass procedure that the Mean Fibre Diameter of a test specimen is less than the finest IH Top or less than or equal to the finest IH Top or greater than or equal to  $32.0\mu\text{m}$ , results must be discarded and all subsequent measurements performed using the fixed mass (2.500g) procedure.

*Recommended changes to Appendix 2, Clause 4. Determining the Calibration Equation*

#### 4. Determining the Calibration Equation

(a) Make a horizontal mark 180 mm below the zero mark Z (Figure 1) of the manometer. Fix a scale graduated in mm behind the flowmeter F so that the zero of this scale coincides with a file mark (zero) made near the bottom of the flowmeter. Condition the cut reference slivers in exactly the same way as for new wool samples, as described in Section 6.2.5. It is essential that the cut reference slivers be dried to a regain of less than 10% in exactly the same way (i.e. same drying temperature and time) as is used for raw wool samples, before they are conditioned. Then prepare and weigh five test specimens ( $2.5\text{g} \pm 4\text{ mg}$ ) from each reference sliver as described in Section 5.2.6. Test each according to the method described in Section 6.3.1. Adjust the air valve until the meniscus level of the manometer coincides with the 180 mm reference mark H and note the distance h in mm of the float of the flowmeter from zero. Similarly, obtain a total of ten readings on each reference sliver and calculate the mean reading.

(b) For a Fixed Mass Test

The mean readings of "h" in mm may be plotted against the known values of Mean Fibre Diameter "d" in micrometers, and inspected to ensure that the points lie on a nearly linear curve.

The results obtained must be fitted to a curve using the Least Square Method given below. The regression equation is the Calibration Equation and must be used to determine the relationship between Airflow reading and Mean Fibre Diameter. This is preferably done by direct calculation, but a table relating Airflow reading to Mean Fibre Diameter can also be used.

(c) For a Variable Mass test only

Repeat the procedure outlined in (a) for a test specimen mass of  $2.4\text{g} \pm 0.004\text{g}$ , and repeat again for a test specimen mass of  $2.6\text{g} \pm 0.004\text{g}$ .

The mean readings of "h" in mm may be plotted against the known values of Mean Fibre Diameter "d" in micrometers separately for each of the three values of specimen mass in the case of a variable mass calibration. For each test specimen mass, these points should be inspected to ensure that the points lie on a nearly linear curve.

All calculations must be carried out using a calculator or computer capable of storing at least eight significant figures.

For any given calibration top the flow height (“h”) has been shown<sup>8</sup> to be linearly related to the mass of the test specimen as follows:

$$h = m a + b \dots\dots\dots(1)$$

where “a” and “b” are constants.

For a variable mass test only, calculate the slope, “a”, and intercept, “b”, for the 8 linear relationships between test specimen mass, “m”, and height, “h”, for each of the 8 calibration tops as follows:

$$a = \frac{3 \sum (m.h) - \sum (m) \sum (h)}{3 \sum m^2 - (\sum m)^2}$$

and,  $b = h - m a$

For each of the eight calibration tops, calculate the flow height, “ $\bar{h}$ ”, using (1) for each test specimen mass from 2.400g to 2.600g in increments of 0.001g.

A second order regression of d on  $\bar{h}$  is then performed in the same manner as for a fixed mass calibration which is outlined in the next Clause of this Appendix, 4.1 “Fitting a Curve by the Least Squares Method”, for each test specimen mass. The resulting relationships provide a calibration of the meter for any test specimen mass from 2.400g to 2.600g.

The diameter of a test specimen with a mass between 2.400g and 2.600g can then be calculated in the same manner as for a fixed mass test by selecting the calibration relationship appropriate to the mass of the test specimen.

**Bibliography**

9. Doak, B.T. and Mahar, T.J., IWTO Technical Committee, Dec. 1998, Rep No.5