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Measurement of the Fineness of Superfine Wool: Effect of the revised LASERSCAN Calibration Function on comparisons between Airflow, LASERSCAN and OFDA

By

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SUMMARY

A previous study of the measurements of mean fibre diameter of fleece samples from superfine sheep, using Airflow, LASERSCAN and OFDA, reported significant diameter dependent differences between the instruments[1]. In the fineness range of 14 to 19 microns, LASERSCAN was biased coarse with respect to Airflow, the bias decreasing with decreasing fineness. The OFDA was biased coarse with respect to Airflow by approximately the same amount as LASERSCAN at 19 microns, but below 16 microns the OFDA was biased finer than Airflow. Previously reported differences between the Standard Deviation and Coefficient of Variation measurements produced by LASERSCAN and OFDA were confirmed, with OFDA consistently measuring higher than LASERSCAN. This experiment has been repeated, using the same methodology and fresh samples from the same mob of sheep. However, the LASERSCAN measurements were conducted using the revised calibration function developed by Irvine and Barry[2]. This has shown that the OFDA/Airflow relationship has remained stable, but the LASERSCAN is now coarser than the Airflow in the range 15.5-19 microns and finer than the Airflow below 15.5 microns. The bias is still strongly diameter dependent. Large differences in SD and CVD as measured by both instruments have been significantly reduced.

INTRODUCTION

The previous study of the differences between Airflow, LASERSCAN and OFDA demonstrated commercially significant biases over the range 14 to 19 microns, and associated some of the differences from the Airflow with the effects of Coefficient of Variation in Diameter[1]. There was an error in this analysis and an errata has been appended to this report. The CVD accounts for only a very small proportion of the difference.

Irvine and Barry[2] developed a new calibration function for the LASERSCAN that improved accuracy at the extremes of the diameter range for calibrations made with Interwoollab Tops. They expected this would result in improved accuracy for very fine wools less than 16 microns, by providing a lower estimate of fibre fineness for these wools. Knowles[3] reported a study of New Zealand superfine wools in the range 15.5 to 17.0 microns, using the revised LASERSCAN calibration, and found no difference between the LASERSCAN and the Airflow. Baxter[4] has argued that the differences between LASERSCAN and OFDA in estimating the fineness of ultra-fine wools are due to extrapolation errors in the LASERSCAN calibration.

This report repeats the earlier work by the author[1], using fresh samples from the same flock of sheep, but where the LASERSCAN measurements have all been based on Irvine and Barry's new calibration function.

The report also discusses the on-going problems in reconciling the differences between the instruments and suggests that these differences are to some extent irreconcilable due to the different definitions of fibre fineness employed by the instruments in conducting the measurements. Harig has also made this point[a].

METHOD AND MATERIALS

The fleece samples were obtained from a superfine clip located in the Mudgee district west of Sydney. The owner of this particular clip has extensive experience at sampling, testing and then classing on the basis of the test results, and consistently produces a lot of wool less than 15.0 microns, and other lots in the range 15 to 16 microns.

Approximately 30 grams of sample was obtained from an identical position on each animal by the woolgrower a few weeks before shearing. The samples were identified and despatched to the laboratory in sealed plastic bags. Once received the samples were cut to a shorter length in an industrial paper shredder, and washed with hot water and detergent. Each sample was passed twice through a Shirley analyser to produce a web of randomly oriented fibres. The carded sample was conditioned, mini-cored and a sample of 1000 snippets from the mini-cores was measured in a single LASERCAN instrument. All the individual washed and analysed samples were retained.

Subsequently the samples were sorted into classes of 0.5 microns, based on the mean diameter determined by the LASERSCAN instrument. This was the basis of the earlier experiment and used again in order to maintain consistency.

From each of the class intervals in the range 13.0 to 19.5 microns a set of approximately 40 separate samples was selected at random, sufficient to give a global sample of 80 to 100 grams for each class interval. These samples were hand blended, and then split into 4 sub-samples of approximately 20 grams. Each sub-sample was passed twice through the same Shirley Analyser and conditioned from the dry side for eight hours in a standard atmosphere.

Each sub-sample was then split into two further specimens. Four 2.500-gram plugs from one of these specimens were measured twice on one Airflow and four plugs from the other specimen were measured twice on the other Airflow. The resultant 32 Airflow plugs, representing the global sample from each class interval were retained, and each plug was mini-cored and measured on two LASERSCAN instruments. The plugs were then individually mini-cored again and measured on a single OFDA instrument. Both Airflow and LASERSCAN instruments were calibrated with the Series 12 Interwoollabs tops before measurement. The OFDA instrument was also calibrated with the Series 12 Interwoollabs tops using the cores calibration defined in IWTO-47. The mean diameters of the global samples, and the confidence intervals for each mean, were calculated for each instrument, using the 64 individual measurements in the case of Airflow and LASERSCAN, and 32 individual measurements in the case of OFDA.

RESULTS

Individual Fleece Samples

On this occasion no analysis was conducted on the results from the individual fleece samples because Airflow measurements were not conducted.

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[a] Presentation to the Yarn and Fabric Group, IWTO, Dresden, 1998

Global Samples

The global samples were examined in detail, using Airflow, LASERCAN and OFDA. The results obtained by all instruments on all the global samples in the previous paper[1] are shown in Tables 1 and 2. The results from this experiment are shown in Tables 3 and 4.

TABLE 1: Mean Diameter for Airflow, LASERSCAN and OFDA using original Calibration Function

Class Interval (μm)	Airflow (μm)		LASERSCAN (μm)		OFDA (μm)		LASERSCAN-Airflow	OFDA-Airflow	LASERSCAN-OFDA
(LASERSCAN)	Mean	95% CL	Mean	95% CL	Mean	95% CL			
14.0-14.5	14.30	0.07	14.53	0.08	13.62	0.09	0.23	-0.67	0.90
14.5-15.0	14.94	0.06	15.04	0.09	14.48	0.13	0.09	-0.47	0.56
15.0-15.5	15.19	0.08	15.40	0.09	14.95	0.14	0.21	-0.24	0.45
15.5-16.0	15.43	0.07	15.85	0.09	15.40	0.13	0.42	-0.04	0.46
16.0-16.5	15.95	0.07	16.40	0.07	16.04	0.11	0.45	0.09	0.36
16.5-17.0	16.37	0.10	16.73	0.10	16.48	0.14	0.36	0.11	0.26
17.0-17.5	16.96	0.07	17.32	0.07	17.08	0.09	0.35	0.12	0.23
17.5-18.0	17.34	0.10	17.68	0.11	17.70	0.15	0.34	0.36	-0.02
18.0-18.5	17.71	0.09	18.26	0.10	18.26	0.13	0.55	0.55	0.00
18.5-19.0	18.18	0.07	18.64	0.09	18.75	0.16	0.46	0.58	-0.12

TABLE 2: Coefficient of Variation for LASERSCAN and OFDA using original Calibration Function

Class Interval(μm)	LASERSCAN (%)		OFDA (%)		LASERSCAN-OFDA
(LASERSCAN)	Mean	95% CL	Mean	95% CL	
14.0-14.5	18.93	0.23	22.96	0.26	-4.03
14.5-15.0	18.52	0.24	22.52	0.31	-3.99
15.0-15.5	18.65	0.24	21.99	0.28	-3.34
15.5-16.0	18.92	0.25	21.87	0.23	-2.95
16.0-16.5	18.71	0.23	21.10	0.33	-2.39
16.5-17.0	19.16	0.25	21.41	0.30	-2.25
17.0-17.5	18.30	0.25	19.77	0.31	-1.47
17.5-18.0	18.77	0.25	20.34	0.34	-1.57
18.0-18.5	19.15	0.22	20.59	0.30	-1.44
18.5-19.0	19.18	0.24	20.46	0.37	-1.27

TABLE 3: Mean Diameter for Airflow, LASERSCAN and OFDA using revised Calibration Function

Class Interval (μm)	Airflow (μm)		LASERSCAN (μm)		OFDA (μm)		LASERSCAN-Airflow	OFDA-Airflow	LASERSCAN-OFDA
(LASERSCAN)	Mean	95% CL	Mean	95% CL	Mean	95% CL			
13.0-13.5	13.53	0.26	13.08	0.23	12.59	0.30	-0.45	-0.94	0.49
13.5-14.0	14.20	0.14	13.85	0.12	13.27	0.15	-0.35	-0.93	0.58
14.0-14.5	14.60	0.08	14.31	0.08	13.80	0.12	-0.29	-0.80	0.51
14.5-15.0	15.00	0.08	14.73	0.08	14.31	0.11	-0.27	-0.69	0.41
15.0-15.5	15.29	0.07	15.21	0.07	14.82	0.09	-0.08	-0.47	0.39
15.5-16.0	15.66	0.08	15.69	0.08	15.29	0.11	0.03	-0.37	0.41
16.0-16.5	16.11	0.09	16.12	0.07	15.79	0.09	0.01	-0.32	0.33
16.5-17.0	16.65	0.10	16.86	0.07	16.69	0.12	0.21	0.04	0.17
17.0-17.5	16.97	0.08	17.26	0.07	17.06	0.12	0.29	0.09	0.20
17.5-18.0	17.43	0.09	17.78	0.08	17.66	0.12	0.35	0.23	0.12
18.0-18.5	17.88	0.10	18.32	0.09	18.21	0.10	0.44	0.33	0.11
18.5-19.0	18.25	0.12	18.66	0.10	18.47	0.15	0.42	0.22	0.20
19.0-19.5	18.63	0.19	19.26	0.16	19.13	0.23	0.64	0.51	0.13

TABLE 4: Coefficient of Variation for LASERSCAN and OFDA using revised Calibration Function

Class Interval(μm)	LASERSCAN (%)		OFDA (%)		LASERSCAN-OFDA
(LASERSCAN)	Mean	95% CL	Mean	95% CL	
13.0-13.5	19.82	0.56	21.89	0.63	-2.07
13.5-14.0	19.01	0.31	20.58	0.38	-1.57
14.0-14.5	19.32	0.22	20.63	0.27	-1.30
14.5-15.0	19.53	0.21	20.98	0.20	-1.45
15.0-15.5	19.46	0.21	20.87	0.23	-1.41
15.5-16.0	19.41	0.22	21.00	0.27	-1.59
16.0-16.5	18.71	0.18	19.93	0.23	-1.22
16.5-17.0	19.05	0.19	20.00	0.22	-0.95
17.0-17.5	19.14	0.19	20.14	0.25	-1.00
17.5-18.0	18.37	0.20	19.04	0.22	-0.66
18.0-18.5	19.04	0.20	19.45	0.25	-0.41
18.5-19.0	18.39	0.27	18.85	0.34	-0.47
19.0-19.5	19.09	0.40	19.33	0.47	0.24

There are a number of obvious differences in these Tables. It is clear from the columns showing the differences between the three instruments, that there are still diameter dependent trends in the differences for the diameter range studied. For similar ranges the differences between Airflow and OFDA have not changed very much between the two experiments. However, there has been quite a change in the differences between LASERSCAN and OFDA and this is clearly illustrated in Figures 1 and 2. These show the mean diameters measured by LASERSCAN and by OFDA plotted as a function of the mean diameter measured by Airflow. In Figure 1, drawn from the earlier paper[1], the old calibration function was used for the measurements, and in Figure 2 the new calibration function was used.

The other striking change that has been introduced by the new LASERSCAN calibration is in the difference in Standard Deviation (SD) and Coefficient of Variation in Diameter (CVD). In the previous paper[1] the CVD was shown to be quite large, and becoming increasingly larger as the diameter decreased. The differences are now markedly reduced. This is illustrated by Figure 5, which compares the differences observed previously with those that occurred with the new information reported in this paper. Figure 3 and 4 show similar plots for the Mean Fibre Diameter differences and for the SD differences respectively. Figures 3, 4 and 5 all use LASERSCAN Mean Fibre Diameter as the reference on the x-axis.

Figures 6 and 7 compare the histograms produced by LASERSCAN using the new calibration with those produced by OFDA. In these examples individual fleece samples have been used. One of these is extremely fine (about 13 microns) and the other slightly coarser (about 15 microns). The instruments still measure different means on these samples, confirming the information in Figures 2 and 3, but the distributions are more closely aligned than reported in the previous study.

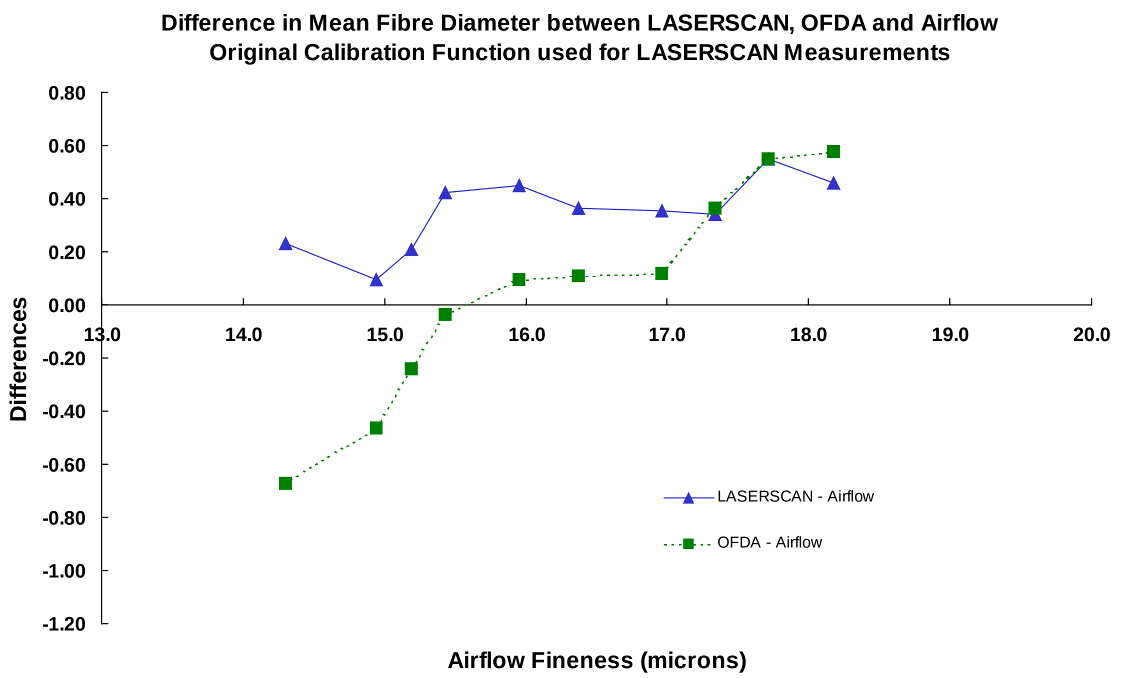

Figure 1: Differences in Mean Fibre Diameter between LASERSCAN, OFDA and Airflow using the original LASERSCAN calibration function

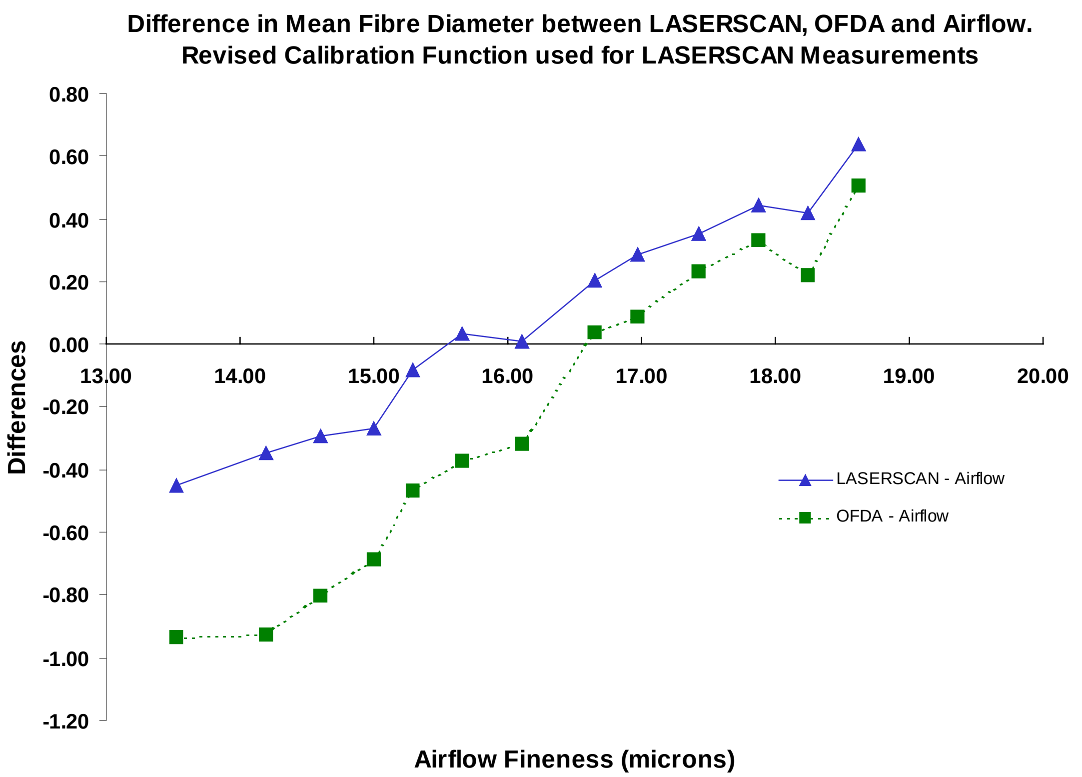

Figure 2: Differences in Mean Fibre Diameter between LASERSCAN, OFDA and Airflow using the revised LASERSCAN calibration function.

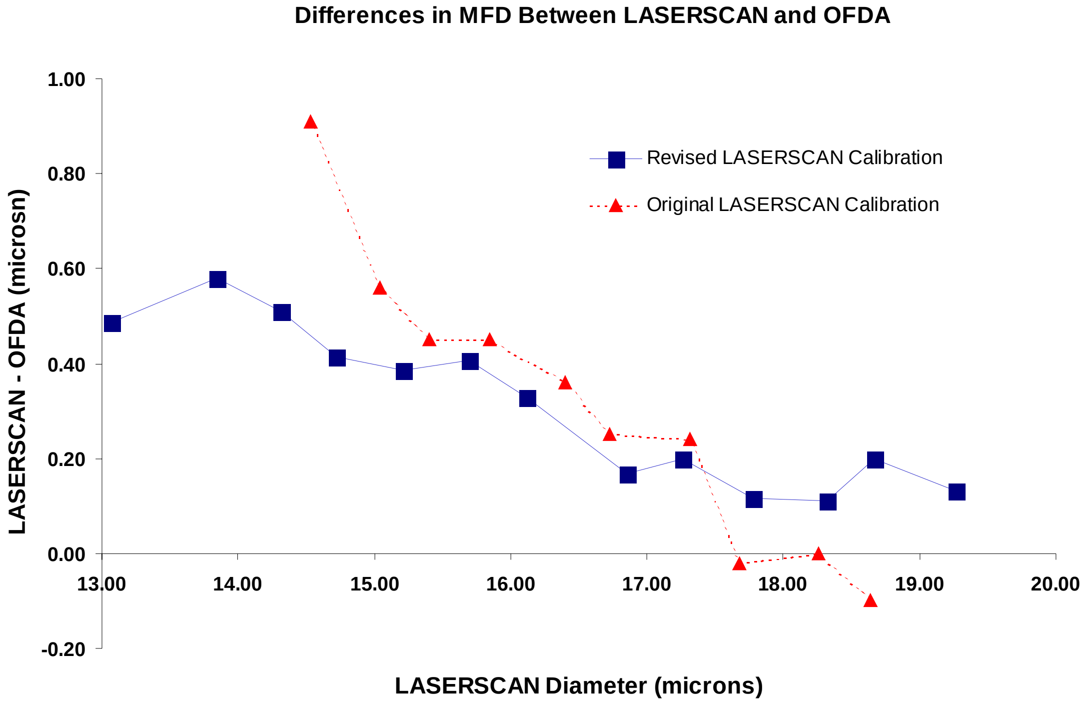

Figure 3: The differences in Mean Diameter between LASERSCAN and OFDA observed in the previous study and in this study are summarised in this chart. The revised calibration function for the LASERSCAN has reduced the differences in the very fine samples but diameter dependent trends remain.

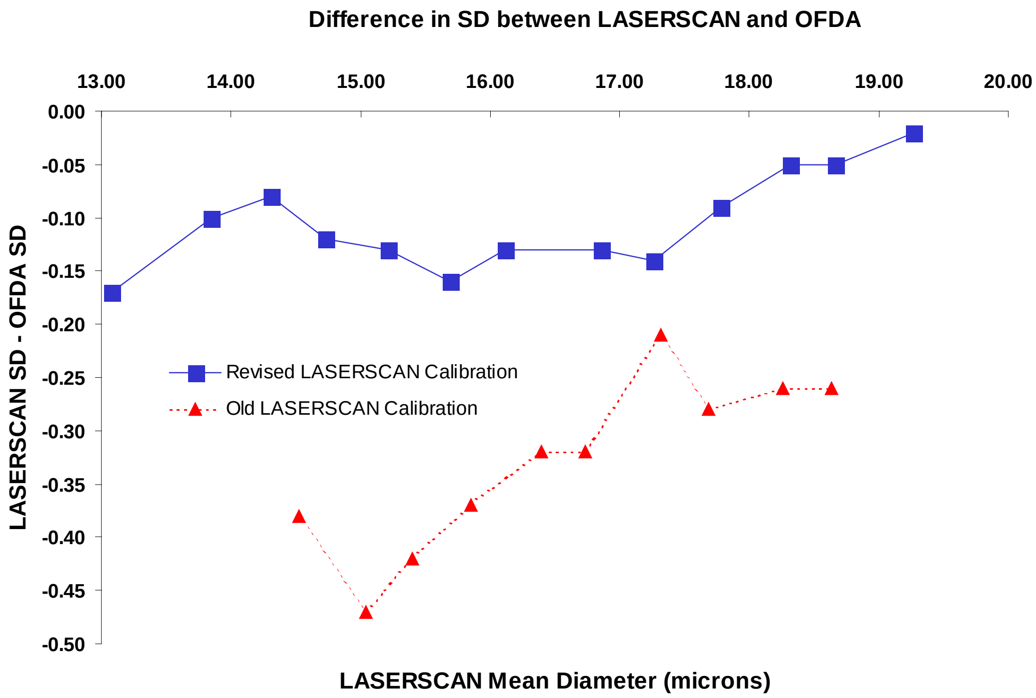

Figure 4: The differences in Standard Deviation (SD) between LASERSCAN and OFDA observed in the previous study and in this study are summarised in this chart. The revised calibration function for the LASERSCAN has significantly reduced the differences, but a diameter dependent trend appears to remain.

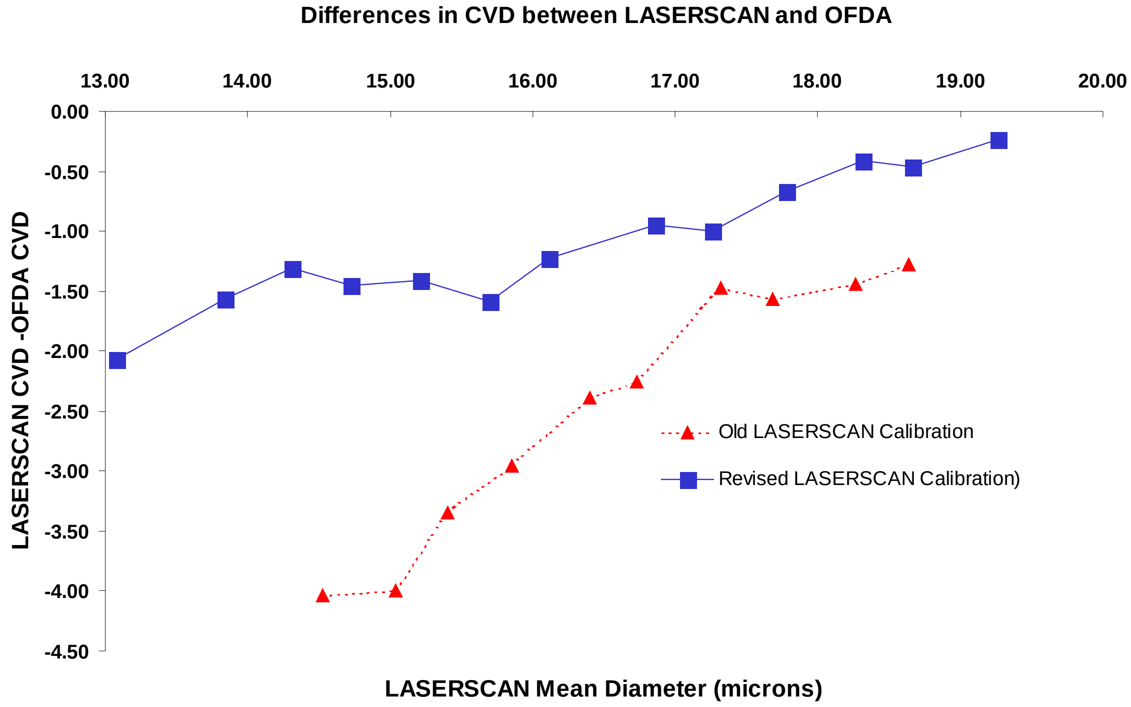

Figure 5: The differences in Coefficient of Variation in Diameter (CVD) between LASERSCAN and OFDA observed in the previous study and in this study are summarised in this chart. The revised calibration function for the LASERSCAN has significantly reduced the differences.

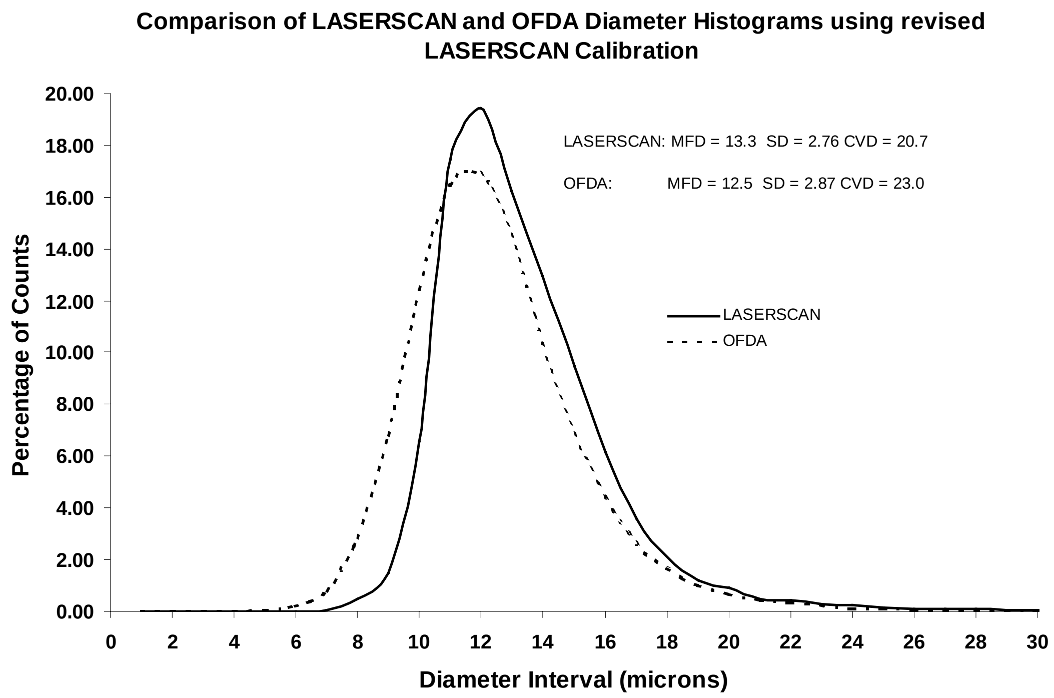

Figure 6: Comparison of LASERSCAN and OFDA histograms for 13-micron wool. The LASERSCAN histogram is based on 20,000 snippets and the OFDA histogram on 43500 counts.

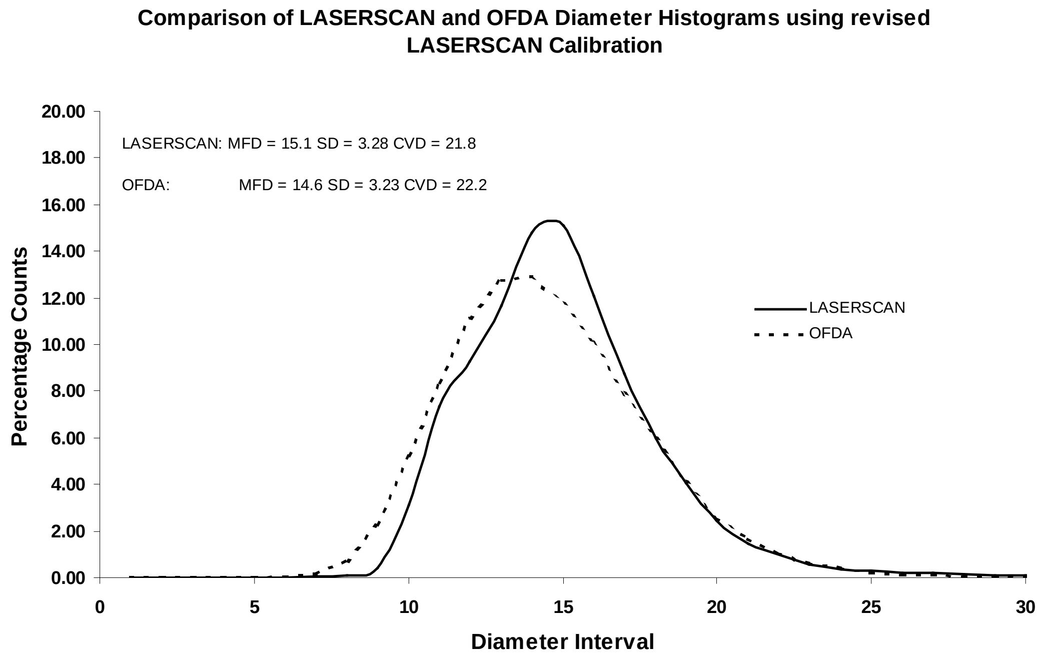

Figure 7: Comparison of LASERSCAN and OFDA histograms for 15-micron wool. The LASERSCAN histogram is based on 20,000 snippets and the OFDA histogram on 48500 counts.

DISCUSSION

The author has recently reported an investigation of the behaviour of the Airflow instrument and concluded that for ultra-fine wools (<16 microns) extrapolation of the calibration based on Interwoollabs tops may not be appropriate[5]. The instrument exhibits an increasingly coarse bias, as the diameter becomes increasingly finer than the finest calibration top. This effect is the most probable explanation for the differences between Airflow and LASERSCAN and OFDA on ultra-fine wools, not the coefficient of variation in diameter, as previously reported. The revised calibration function for the LASERSCAN has resulted in a situation where this instrument, in relation to Airflow, behaves similarly to OFDA.

Since the first draft Test Methods for LASERSCAN and OFDA were introduced in 1991 at the IWTO conference in Nice, considerable time and effort has been devoted to elucidating the differences between Projection Microscope, Airflow, LASERSCAN and OFDA, and considerably less time and effort on highlighting their similarities. The debate about these differences has largely overshadowed the fact that IWTO Test Methods now exist for all these instruments and the process of developing these test methods has always ensured that the formal technical requirements of IWTO for the establishment of IWTO Specifications have more than adequately been met. In reality, IWTO now has a number of Test Specifications for specifying fibre fineness, all of which are fit for purpose, provided the basis for their use in commercial trading of wool is adequately specified.

The data reported in this paper shows that recent improvements in the LASERSCAN calibration system have more closely aligned this instrument with OFDA for wools less than about 16 microns. It must be stressed that the amount of wool produced around the world within this range is extremely small – no more than a few hundred bales. So differences in this area are not of critical importance to the Wool Industry. However, the data has also confirmed that for some of the more common superfine wools, in the range 17.0 to 19.5 microns, significant unexplained differences between Airflow and LASERSCAN and OFDA remain.

The fineness[b] of wool fibres is of fundamental importance to spinners and weavers. The finer the fibres, and the fewer the number of fibres present in a cross section of yarn produced from the fibres, the more flexible the yarn. These factors are the major determinants of the quality of wool fabrics. It is desirable therefore, that the different instruments now available to measure wool fibre fineness provide equivalent answers. It is understandably concerning to Wool Producers, Wool Traders and Wool Processors that differences appear to exist between these instruments. However, there are fundamental reasons why these differences exist and why it is most unlikely that in every instance they will ever be totally resolved. An understanding of this rests on an understanding of the definition of fibre fineness that has been developed by the Wool Industry.

Essential Elements of Measurement Systems

Systems that measure a particular characteristic by direct reference to primary reference standards such as length or weight are frequently referred to as **primary systems**. Systems that measure the same characteristic, but require calibration by reference to a primary system are referred to as **secondary systems**.

An essential requirement for any measurement system is that its **accuracy** and **precision** can be defined. These terms can easily be confused. Accuracy refers to the closeness of the measurements to the "true" value. Accuracy must always be determined by reference to a primary system. Precision refers to the reproducibility of the measurements. However, precision does not need to be determined by reference to a primary system.

Ideally, the accuracy and the precision of a measurement system will be identical, but frequently they are not. It is quite possible to have a very precise secondary measurement system that differs consistently from the "true" value. This does not limit its usefulness, **provided it is used in all instances where comparisons must be made**.

IWTO has long recognised that when measurement systems are developed, two competing factors must be reconciled. The measurement system must have an acceptable accuracy and precision, but also deliver measurements at an acceptable cost. For a specific test method increasing accuracy and precision invariably implies increasing the cost.

Defining Wool Fibre Fineness

When referring to the "true" value of a particular characteristic, it is essential to carefully define exactly what is meant. This is particularly the case for a characteristic such as wool fibre fineness. Fineness is a relative term, and therefore somewhat subjective. Numerically quantifying fibre fineness requires the measurement of a particular geometrical dimension of the fibre. In the case of wool fibres this is not as simple as it may at first seem.

Most of us have an intuitive understanding of the meaning of "mean diameter" in referring to a length of pipe, because we imagine that a pipe is circular. Indeed if each fibre of wool had an exactly circular transverse cross section, and the diameter of this circular cross section was exactly the same along the length of the fibre, then this uniform geometry would make the definition of the fineness of wool exceedingly simple. But wool fibres are neither circular in cross section, nor of uniform thickness along their length.

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[b] The term "Mean Fibre Diameter" in the context of wool fibres is a little misleading, since it implies that wool fibres have a circular cross section. In describing the thickness or thinness of wool fibres it is more accurate to use the term "fibre fineness" rather than "fibre diameter". The word "fineness" does not imply any particular geometry for the shape of the cross section.

Figure 8 clearly illustrates this point. It shows the magnified transverse cross sections of a number of wool fibres from a 19-micron wool top. While some fibre cross sections are approximately circular, most of them are not.

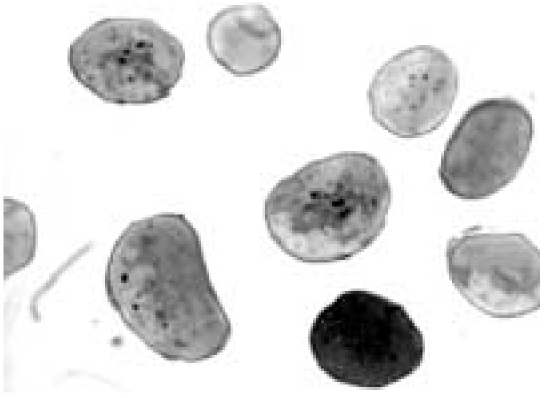

Figure 8: Magnified images of the cross sections of a number of wool fibres from a 19 micron top [c].

Consider these fibre cross sections, and the range of shapes exhibited. How then do we determine the Mean Fibre Diameter? Clearly, if we use a ruler to measure the "diameter" of these images, the "diameter" we obtain for each image will depend where we place the ruler. We could of course use our ruler to measure a very large number of transects across each fibre cross section, and then calculate the average of all these transects, but that would be unbelievably tiresome. And in doing so, we would not have taken account of any variation in the dimensions of the cross section along the length of each fibre. We could only do this by taking a very large number of cross sections and making a large number of measurements – an even more tedious exercise.

Alternatively, we could define the fibre fineness in terms of the area of the cross section. This could be measured using a primary system such as planimetry or a related technique. Once again, the measurement would be slow and tedious because many cross sections would have to be measured to obtain a reasonable estimate of the "area" or fineness of each fibre, and thus the average fineness of the sample.

If fibre fineness is to be objectively measured any definition of fibre fineness must ultimately be related to some geometrical dimension of the fibre. There are effectively only four geometrical dimensions that are suitable. These are:

- the area of the cross section;
- the width of a 2-dimensional projected image;
- the area of the surface; or
- the area of a 2-dimensional projected image.

Due to the non-uniform geometry of wool fibres a meaningful estimate of fibre fineness requires a large number of measurements of any one of these geometrical features.

Measuring Wool Fibre Fineness

Over the past 175 years a number of different techniques have been explored, with varying degrees of success, in order to provide an objective numerical description of the fineness of wool fibres. The International Wool Textile Organisation (IWTO) has developed Specifications for 4 of these techniques.

- Projection Microscope
- Airflow
- Sirolan LASERSCAN
- OFDA (Optical Fibre Diameter Analyser)

Only the Projection Microscope is traceable to primary reference standards. In simple terms this means that the Projection Microscope is calibrated by reference to units of length, not by reference to "standard

[c] Photograph provided by Peter Turner, CSIRO Division of Wool Technology, Belmont, Victoria, Australia

wools". On the other hand, Airflow, LASERSCAN and OFDA **must** be calibrated using "standard wools", where the "standard values" for these "standard wools" have initially been determined by Projection Microscope. In this sense the Projection Microscope is the primary system, and the others are secondary systems.

All these instruments provide a measurement of Mean Fibre Diameter (MFD) or "fineness". With the exception of the Airflow, they also provide information about the distribution of fibre fineness, from which we can derive the Standard Deviation (SD) and the Coefficient of Variation in Diameter (CVD).

The advantage of the calibrated systems is that the variability between instruments is considerably less than the variability between operators of the Projection Microscope. Therefore they can provide more precise measurements at a lower cost.

Comparison of the Instruments

Most us are aware that duplicate measurements of fibre fineness on the same sample will probably be different, irrespective of the instrument used. The difference arises predominantly from the variability of the fibre, but is confounded by other sources of variation in the measurement system. The objective of IWTO Specifications is to contain these sources of variation within an acceptable and predictable range, while at the same time providing the measurement at an acceptable cost.

The precision limits of the IWTO Specifications for determination of MFD of raw wool by Projection Microscope[d], Airflow[e], OFDA[f] and LASERSCAN[g] are summarised in Table 5. The Projection Microscope is the least precise, while the OFDA and the LASERSCAN are the most precise. These precision limits can be substantially reduced, at a cost, by measuring more than one sample. For example, testing duplicate samples will improve the precision by 29%, and testing triplicate samples will improve the precision by 42%. The question of how much precision is enough is fundamentally an economic rather than a technical decision. The development of the IWTO Specifications has primarily been aimed at improving prediction of processing performance, and thereby facilitating the purchasing and trading of wool. Given that most processing consignments consist of a number of individual farm lots, the precision of the average MFD for such consignments is substantially better than indicated by the limits in Table 5.

Table 5: Precision of the Instruments used for determining the Fineness of Wool Fibres.

Instrument	Precision (95% Confidence Level)	
	20 µm	35 µm
Projection Microscope	± 0.87 µm	± 1.07 µm
Airflow	± 0.45 µm	± 0.80 µm
OFDA	± 0.36 µm	± 0.67 µm
LASERSCAN	± 0.32 µm	± 0.70 µm

The major issue that has developed over the past 7 years concerns the fact that there are systematic differences or biases between the instruments. These exist to a lesser extent for wool tops than for raw wool.

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[d] IWTO-8-89, *Method for Determining Fibre Diameter and Percentage of Medullated Fibres in Wool and other Animal Fibres by the Projection Microscope*

[e] IWTO-28-93, *Determination by the Airflow Method of the Mean Fibre Diameter of Core Samples of Raw Wool*

[f] IWTO-47-95, *Measurement of the Mean and Distribution of Fibre Diameter of Wool using an Optical Fibre Diameter Analyser*

[g] IWTO-12-95, *Measurement of the Mean and Distribution of Fibre Diameter using the Sirolan-LASERSCAN Fibre Diameter Analyser*

Reconciling the Differences

Each of these instruments uses different geometric definitions of fibre fineness. This is a fundamental difference, which must result in differences being observed for certain wools, particularly where the characteristics of the wools differ in some way from the calibration wools[h] and/or the fibre fineness is outside the range of the calibration wools.

The Projection Microscope measures the average width of the 2-dimensional projected image. The OFDA attempts to emulate this by using a television camera to replace the human eye, and a computer program to replace the human hand and the human brain. Nevertheless, the **OFDA is not an exact replica of the projection Microscope**. There are fundamental differences in the measurement techniques employed, and the assumptions made. On the other hand the Airflow responds to the surface area of a bulk sample of fibres, while the LASERSCAN responds to the projected area of a segment of each fibre.

One may well ask which instrument provides the "true" result? Given that the Projection Microscope is the industry accepted primary measurement system for determining the fineness of wool fibres, the extent to which a particular instrument emulates the Projection Microscope must be the criterion that is used to determine whether or not a particular instrument provides the "true" answer. To do otherwise would require the wool industry to change the definition of fibre fineness that has been in place for over 50 years. The reality is that none of the calibrated instruments exactly emulate the Projection Microscope in all instances, but for a wide range of wool types the correspondence is very close.

For more than 25 years the Airflow, rather than the Projection Microscope, has been the industry's accepted baseline for commercial and technical evaluation of wool fibre fineness. This has been in the full knowledge that the Airflow does not always closely emulate the Projection Microscope[17]. This clearly demonstrates that for the wool industry the "true" answer is not the primary criterion for establishing the usefulness of a specification for fibre fineness. The cost, the precision and the predictability of processing performance, coupled with an understanding of the discrepancies that may occur in particular circumstances, are far more important.

If this is the case, then with respect to precision, there is no particular technical reason to favour Airflow, LASERSCAN or OFDA for the specification of MFD for most commercial consignments of wool. What is more important is that the same specification is used to determine fibre fineness for any individual consignment at all points in the production, marketing and processing pipeline. If this is not done then the industry must be prepared to make judgements about any differences that are observed in the light of knowledge about the differences that may occur.

This approach is also entirely appropriate for Wool Producers who choose to use objective information to assist them in improving the productivity of their flocks. For this particular application, all the calibrated instruments are sufficiently precise to provide the necessary information about the fibre fineness. It is also an appropriate approach for those producers who choose to use objective measurements of fleece samples to assist them to class their wool. However, in the latter case, the producer should not expect to accurately predict the sale lot MFD if the fleece measurements are based on a technology other than the technology used to determine the MFD of the sale lot.

IWTO has decided that for the moment, Airflow will remain the basis for determining MFD for the purpose of trading consignments of wool fibre. LASERSCAN and OFDA results can be provided as

[h] In the case of the Airflow instrument it is well known that changes in the effective density of the fibre, which occurs in medullated wools, can cause significant errors. It is also known that differences in CVD of the sample from the CVD of the calibration top will also cause small errors in measurement of MFD by this instrument.

well, to enable the users of the information to establish new core/comb comparisons based on the new instrumentation. This decision is reviewed annually. This is a sensible and practical approach.

However, in the longer term it is over simplistic to assume that precision is the only significant issue to be considered. All the formulae used to predict processing performance are based on assumptions about accuracy. The major attraction of the new technologies of LASERSCAN and OFDA is the potential to improve the prediction of processing performance, through the provision of information about fineness distribution as well as mean fineness, and they do offer some potential for further improvement in precision at an acceptable cost. If there are inherent inaccuracies in the measurement of MFD by these instruments, these inaccuracies are likely to affect the predictive capability of the measurements. This is why it is important to minimise any differences, or at least to identify the reasons why they occur or the particular wools for which they occur. However, these circumstances are no different from those that have applied to the Airflow for the past 25 years. The IWTO Specification for the Airflow carries quite explicit notes warning that for wool types such as lambs wool and medullated wool inaccuracies may occur. It is entirely feasible that future versions of the specifications for OFDA and LASERSCAN will carry similar notes for appropriate situations as and when they are identified. Indeed, the specification for OFDA already includes a note concerning the difference in SD that has been observed.

The significance of the differences between OFDA and LASERSCAN in determining SD also needs to be put in context. The most immediate observation is that OFDA is likely to produce different estimates of comfort factor than LASERSCAN, for the coarse wools, and for some this might seem to be a significant issue. For medium wools there will be little difference. However, when making such comparisons some attention should also be paid to the precision of this particular measurement. Estimates of comfort factor are not very precise.

In terms of processing predictions, the effect of the differences in SD, and hence CVD, on prediction of top fineness is very small, and generally too small to be of any real technical importance.

It may be considered desirable that only one instrument is used throughout the wool industry. However, this is a totally unrealistic expectation. In any event it is a situation that has never existed. There are still some combing mills that measure MFD in the top using Projection Microscope rather than Airflow. The industry participants will decide on commercial and technical grounds which if any measurement system predominates in the future. The availability of the new technology provides an opportunity for choice that has not existed previously. It is a situation that other industries have long since learned to handle.

The truth is that a sample of wool remains the same, irrespective of the exact value of fineness assigned to it by any one of these instruments. The sooner the industry accepts the fact that these technologies measure different definitions of fibre fineness, the sooner it can begin to work out procedures and mechanisms to enable production, purchasing and processing to proceed on an equitable commercial and technical basis.

CONCLUSIONS

Examination of the results obtained for Mean Fibre Diameter and Coefficient of Variation in Diameter by LASERSCAN, after the introduction of the revised calibration function developed by Irvine and Barry[2], has shown that for ultra-fine wools (<16 microns) the LASERSCAN and OFDA are now more closely aligned. However, significant diameter differences remain between these instruments themselves, and between these instruments and the Airflow.

The differences that do exist are to some extent due to the different definitions of fibre fineness employed by these instruments. However, these differences are not intrinsically limiting to the usefulness of these instruments. What is required is an understanding that commercial trading can proceed on the basis of any one of the available test methods, provided the parties to the contract agree on the method to be employed in the contract specifications.

ACKNOWLEDGEMENTS

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ERRATA

Summary

Report No. 15, presented to the Boston meeting of the Technical Committee in May 1997, discussed the results of measurements of Mean Fibre Diameter of superfine wool using Airflow, LASERSCAN and OFDA. Significant differences between the three instruments were observed. Among other matters the contribution of Coefficient of Variation in Mean Fibre Diameter (CVD) to these differences was discussed. In presenting the data relevant to this particular discussion an error was made in Figures 10 and 11 in the report. Amended versions of these figures have been produced and are presented here. The comments in the original report suggesting that the CVD may account for a significant proportion of the difference between LASERSCAN and Airflow are incorrect. The effect of CVD is relatively small, and other more fundamental factors must be contributing.

The correction for effects of Coefficient of Variation in Diameter can be derived from the expression developed by Anderson and Warburton[6].

$$d_a = d_p\left(1 + C_p^2\right) \qquad (1)$$

where
d_p = length proportioned mean diameter
C_p = Coefficient of Variation in d_p
d_a = observed Airflow diameter

In comparing two samples, correction for the effect of CVD can be derived from the ratio

$$\frac{d_{a1}}{d_{a2}} = \frac{d_{p1}}{d_{p2}} \cdot \frac{1 + C_{P1}^2}{1 + C_{P2}^2} \qquad (2)$$

Consider the case where the samples have the same length proportioned mean diameter, $d_{p1} = d_{p2}$, but different CVD's ($C_{p1} \neq C_{p2}$). Equation 2 assumes the form:

$$\frac{d_{a1}}{d_{a2}} = \frac{1 + C_{P1}^2}{1 + C_{P2}^2} \qquad (3)$$

Equation 3 forms the basis of any corrections, but more usefully expressed as follows:

$$d_{a1} = d_{a2} \cdot \frac{1 + C_{P1}^2}{1 + C_{P2}^2} \quad (4)$$

If it is assumed that d_{a1} is the actual observed Airflow Diameter, d_{obs}, of the sample, and d_{a2} is the assigned Airflow diameter, d_{ass} of a calibration top with the same length proportioned mean diameter as the sample then:

$$d_{obs} = d_{ass} \cdot \frac{1 + C_{obs}^2}{1 + C_{ass}^2} \quad (5)$$

For a calibration top the assigned Airflow value is equivalent to the assigned length proportioned mean diameter as determined by the Projection Microscope.

In preparing the original versions of Figures 10 and 11, the value of the LASERSCAN Mean and the OFDA Mean respectively was erroneously inserted as the observed Airflow value into equation 5. The original figures and the amended versions of the same figures are included in this report. The references to the Baird Correction and the Marler Correction in the legends on these figures are to regression equation development by Baird[7] and Marler[4] to describe the relationship between Standard Deviation and Mean Fibre Diameter for the Interwoollabs Calibration Tops.

It is quite clear that the CVD has only a small effect, if any, on the difference between LASERSCAN and Airflow that was reported. The same comment applies to the difference between OFDA and Airflow.

The error was identified when an attempt was made to apply the same analysis to another set of samples, where some aspects of the experiment described in report 15 had been repeated.

This error did not occur in other papers by Sommerville[8] and by Lindsay and Marler[9], where similar calculations were involved, and which were also presented to the Boston meeting of the Technical Committee.

FIGURE 10: ORIGINAL VERSION

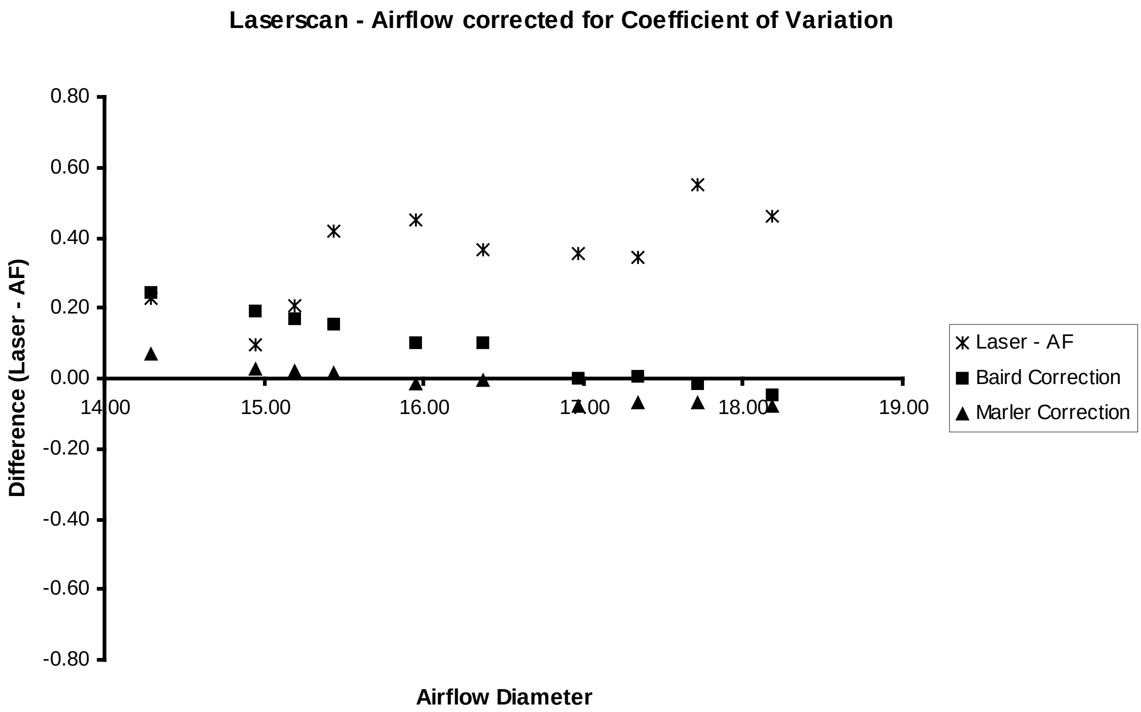


FIGURE 10: AMENDED VERSION

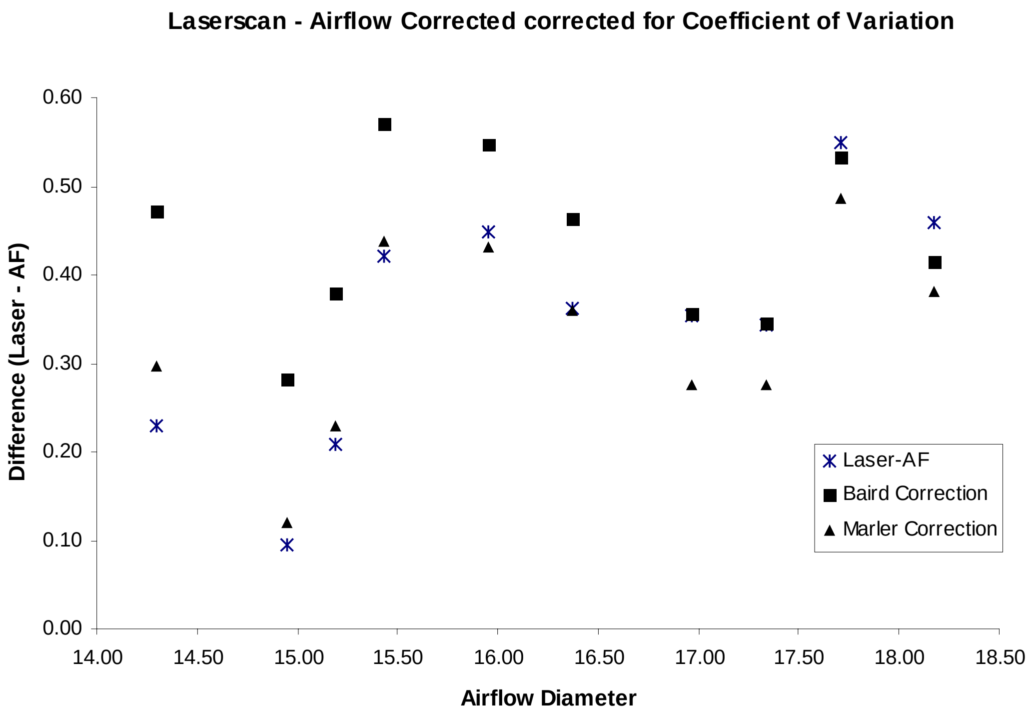


FIGURE 11: ORIGINAL VERSION

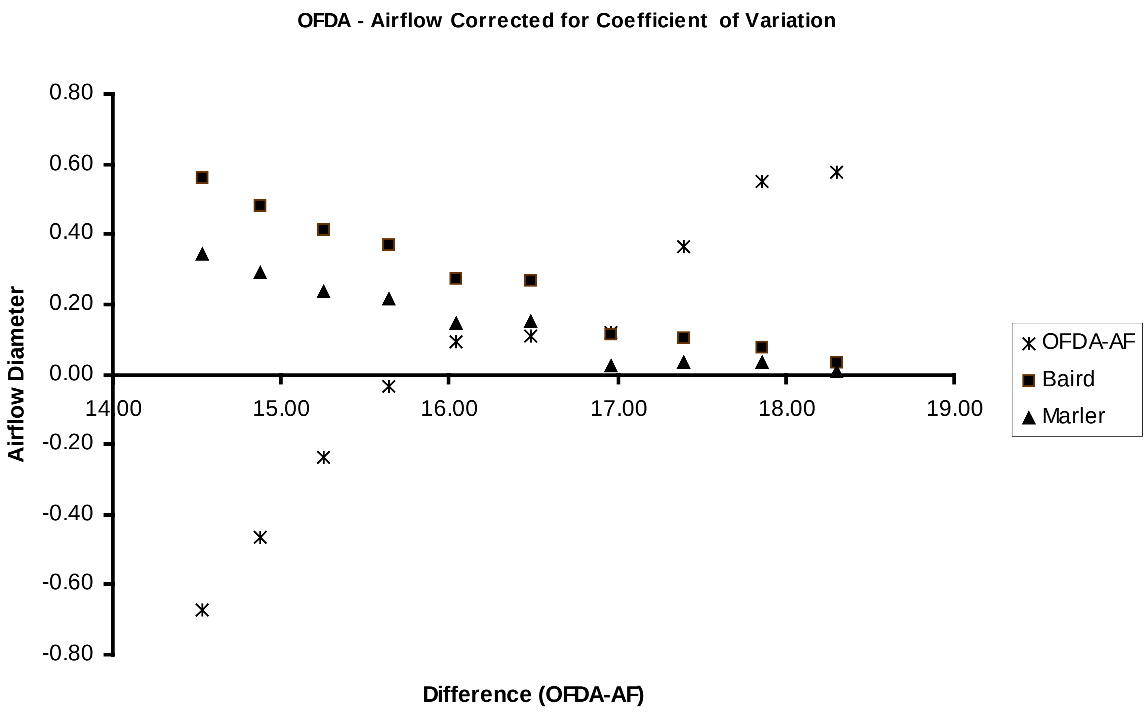
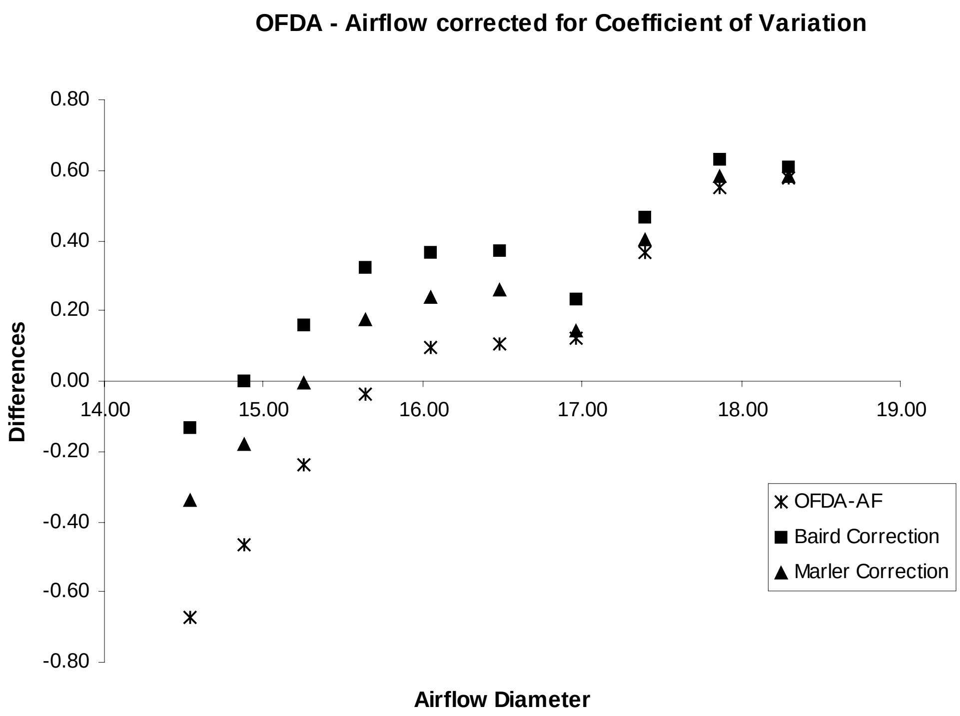


FIGURE 11: AMENDED VERSION



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