5. Background to Wool Metrology

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Learning objectives

By the end of this topic, you should have:

- some knowledge of the history of wool metrology
- an understanding of the essential technical requirements of wool measurement systems
- an understanding of the sources of variation within wool metrology systems
- knowledge of the procedures by which metrology standards are developed, including the role of IWTO, and
- knowledge of the procedures whereby the technical limitations of metrology systems is managed

Key terms and concepts

Mean Fibre Diameter, Wool Base, Vegetable Matter Base, Staple Length and Strength, Precision, Accuracy, Bias, Errors, Sensitivity, Selectivity, Equivalence, Retests, Maximum Retest Ranges, Confidence Intervals, Variance, Standard Deviation, Mean, IWTO, IWTO Specifications, IWTO Regulations.

5.1 About wool metrology

What is wool metrology?

Put quite simply, metrology is the science of measurement. In broad terms metrologists are generally focussed upon developing (evaluating) technologies and systems for objectively measuring the quality attributes of raw materials and manufactured products. This general definition applies as much to wool as to any other material.

Why measure wool?

It is essential that raw materials and products meet the requirements of those who use them (Sommerville 1998). This **fitness for use** defines their quality. There are two general aspects of quality: **quality of design** and **quality of conformance**.
Raw materials and products are generally available in various grades or levels of quality. These variations are often intentional, and consequently the appropriate technical term in such instances is quality of design. For example, all wool suits serve the same basic function, but they are available in a range of designs, fabrics and prices, aimed at specific market segments.

On the other hand, quality of conformance is how well the product conforms to the specifications and tolerances required by the design. Quality of conformance is influenced by a number of factors. In the case of wool suits these may include the following:

- Variability of the greasy wool
- Choice of the manufacturing processes
- Operation of these processes
- Training and supervision of the work force
- Type of quality-assurance system (process controls, tests, inspection activities etc.)
- Extent to which these quality assurance systems are followed, and
- Motivation of the workforce to achieve quality.

Every product, including wool, possesses a number of elements that jointly describe its fitness for use. These elements are often called **quality characteristics**. Quality characteristics may be of several types, for example:

1. **Physical:** length, weight, fineness, yarn evenness
2. **Sensory:** handle, feel, appearance, colour
3. **Time Orientation:** reliability, durability, serviceability.

Subjective judgements are prone to error. In Figure 5.1, one table seems more elongated than the other - but their dimensions are in fact identical. The study of perception is a whole area of science by itself, and there is more than ample evidence of how easily human senses are fooled.

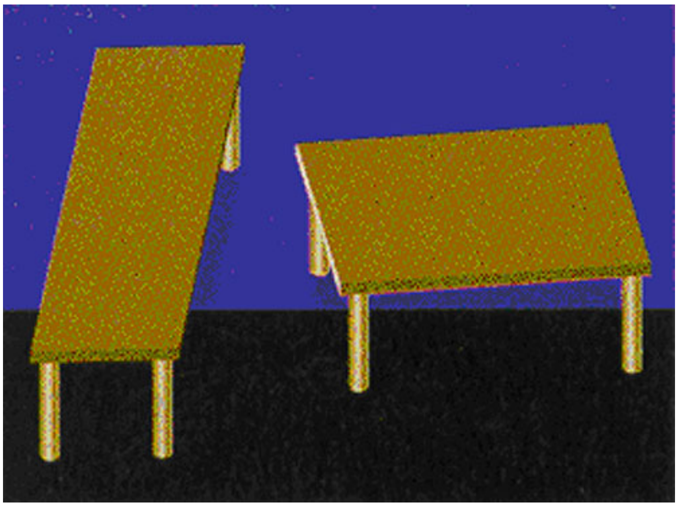

Figure 5.1 Fooling the eye. Source: Holmes (1998).

Quality characteristics can be estimated subjectively, or they can be assigned a numerical value using objective measurements. Traditionally, the hand and the eye were the major tools used to determine the value and processing attributes of wool, but the hand and the eye alone are prone to error (see Figure 5.1). Today, at all levels of the industry, technology providing objective measurements is increasingly replacing the senses of vision and touch.

Generally it is difficult (and expensive) to provide customers with raw materials and products that have flawless quality characteristics. A major reason for this difficulty is **variability**. There is a certain amount of variability inherent in any raw material or product and consequently any two products can never be identical. Wool is an extremely variable material. It varies along the fibre, between fibres, between staples, between animals, between mobs, between bloodlines and between regions. If the wool industry wishes to improve quality and reduce overall cost it must find ways of restricting or controlling the impact of this inherent variability of the fibre on the quality of finished textile products. Wool metrologists have provided us with some of the means to do this.

A brief history of raw wool metrology

The use of objective measurements in wool processing goes back more than a century. The first recorded attempt to objectively measure wool's most important characteristic, fibre fineness, was in 1777, when Daubenton measured the width of some wool fibres under a microscope by comparison with lines drawn on a piece of quartz (Sommerville 1999). During the 19th century and the first half of the 20th century, the microscope became the favoured instrument for directly determining the fineness of wool tops. However, it was the development of coretesting in the USA after 1937, by the USDA, US Customs and the Boston Wool Trade Association that made the representative sampling of bales of greasy or scoured wool possible, and led to the development of test methods, which were able to provide more accurate and precise estimates of the important value-determining characteristics of greasy wool in mill consignments.

A major breakthrough in wool metrology occurred in the period 1945 to 1955 with the development of the Airflow instrument, thereby providing a relatively inexpensive but indirect method for measuring the fineness of tops. In the UK, WIRA and the British Wool Federation developed yield and fineness test methods, and both the USA and Europe established different processing and moisture tolerances to estimate commercial yields of fibre obtained from greasy wool. CSIRO in Australia developed manual pressure core equipment and with the AWTA Ltd in Australia and NZWTA Ltd in New Zealand designed coretesting equipment suitable for large volume testing.

By the late 1960's methods for preparing and measuring the fineness of greasy wool by Airflow had also been developed, and this instrument, despite its known limitations, became the primary technology for measuring the fineness of wool (Sommerville 1998).

The international adoption of common sampling and testing procedures became possible through the International Wool Textile Organisation (IWTO). Although the organisation was established in 1928, it was not until 1965 that technical and commercial delegates at IWTO were able to agree on coretesting processes, which are the basis of the methods used universally today. With the development of grab sampling and staple measurement tests in Australia during the 1970's and early 1980's, it was IWTO that enabled a common sampling and measurement process to be adopted for all wool growing countries.

Once wool metrologists had developed the sampling and testing technologies and Standard Test Methods became available, the impetus for the growth in objective measurement of mill consignments and then presale farm lots was driven by the users of wool, to assist them in ensuring the quality of conformance of the yarns, fabrics and garments they produced. Wool producers were initially reluctant to adopt objective measurement and sale by sample of auction lots, but adoption accelerated throughout the 1970's as price differentials between untested and tested lots became evident.

The development of the Airflow also provided sheep breeders with a rapid and relatively inexpensive means to obtain objective information about the fineness of the wool produced by individual sheep. The value of this information, when used in conjunction with the traditional techniques associated with the senses of vision and touch, had already been demonstrated (Newton-Turner et al. 1953).

Since 1999, new technologies for determining fineness of greasy wool (Sirolan-Fleecescan, OFDA2000) have become available. The advantage of these technologies over the Airflow primarily lies in their facility to be used for on-farm testing services, rather than laboratory based testing services. While much remains to be done to improve these technologies they offer a means to conveniently and efficiently integrate objective measurement of wool fibre fineness into wool harvesting and classing systems, as well as simultaneously providing information for breeding decisions.

What are the measurable quality characteristics of wool?

Describing wool

As wool progresses from the sheep's back to a product in a retailer's store it undergoes a number of transformations. These include scouring, carding, combing, spinning, weaving, dying and making up.

Greasy and Scoured Wool is described generically as "Raw Wool". Carded wool is described as "Wool Sliver" and when combed, as "Wool Top". Both carded and combed wool are commonly generically described as "Wool Sliver". Once the sliver is spun the generic description becomes "Wool Yarn" and once the yarn is woven it becomes "Wool Fabric".

Raw Wool, Wool Sliver, Wool Yarn, and Wool Fabric have different "quality characteristics" and specific test methods have been and are being developed to objectively measure these characteristics. While the focus of this topic is on metrology directed at quantifying the quality characteristics of raw wool and sliver, many of the concepts are equally applicable to yarns and fabrics.

What can be measured?

Greasy wool

The important parameters that can now be measured for greasy wool are:

- Wool Base
- Vegetable Matter Base and Hardheads and Twigs
- Mean Fibre Diameter, Standard Deviation and Coefficient of Variation of Diameter
- Staple Length, Strength and Position of Break
- Colour (Brightness and Yellowness), and
- Bulk.

A small proportion of the Australian clip is also certified for colour. Contrast this with the New Zealand clip where almost 100% is measured for colour. Similarly 70% of Australian Wool is measured for Staple Length and Strength whereas only a minor proportion is measured in New Zealand. Some of these parameters assume different importance depending upon the breed of sheep from which the wool is harvested and the commercial requirements in the country of origin.

Other, non-certified information, such as Mean Fibre Curvature and Vegetable Matter broken down into Burrs and Seed and Shive (as well as Hard Heads and Twigs, and Along Fibre Profile, and Dark and Medullated Fibre is also available.
Scoured Wool.

Essentially the same parameters can be measured for scoured wool as can be measured for greasy wool. The major exception is Staple Length and Strength as once greasy wool is scoured the conformation of the merino wool staple is destroyed. Instead fibre length of scoured wool can be measured as "Length after Carding".

Commonly, measurements are also made on the moisture content (expressed as regain), grease content and ash content. Occasionally the pH of the scoured wool is also measured.

Wool sliver

The key parameters that can be measured on wool sliver are:

- Hauteur
- Barbe
- Colour
- Contamination by dark fibres and/or neps
- Moisture Content expressed as regain
- Grease content.

5.2 Technical requirements of wool metrology systems

Basic concepts

The primary requirement of any measurement system is that the parameter to be measured is clearly defined. The converse of this is that frequently the measurement system itself defines the parameter being measured. This is not a contradiction. We do not live in a perfect world and frequently compromise is necessary. Unfortunately, the latter instance lends itself to circumstances where different measurement systems can be developed (and frequently are) which purport to measure the same quality characteristic, but provide quite different numbers. Usually this is not a problem of measurement per se – it is a problem of definition of the property being measured.

Table 5.1 Objective criteria for evaluating testing systems. Source: Sommerville (2001).

Criterion	Numerical Measure
1. Precision	Absolute Standard Deviation Relative Standard Deviation Coefficient of Variation Variance
2. Bias	Absolute Systematic Error Relative Systematic Error
3. Sensitivity	Calibration Sensitivity Analytical Sensitivity
4. Detection Limit	Blank plus 3 times the standard deviation of the blank
5. Range	Limit of quantitation (LOQ) to limit of linearity (LOL)
6. Selectivity	Coefficient of Selectivity

Science defines systems that measure a particular characteristic by direct reference to primary reference standards such as length or weight, as **primary systems**. Systems that measure the same characteristic, but require calibration by reference to a primary system are **secondary systems**. These distinctions are important because different instruments or methods based on primary systems should be expected to give the same answers, whereas those based on secondary systems may not, particularly if they define the quality characteristic in a different way.

For the Wool Industry objective measurements now provide the primary information used to determine the market value of raw wool and wool sliver. They ensure that wool producers get paid a fair price and that processors are able to purchase greasy wool and then manufacture tops, yarns and fabrics of a specified quality.
As new technology emerges new systems will be developed for measuring parameters for which standard test methods already exist (e.g. Projection Microscope, Airflow, Laserscan, OFDA100). Given the commercial importance of objective measurement to the modern industry it is critical that the measurement systems provide equivalent results, or at the very least that differences between them can be quantitatively defined.

Two or more wool testing systems can be said to be technically equivalent provided they have the same overall precision (encompassing sampling and measurement), the same bias, the same sensitivity, the same detection limit, the same selectivity and operate over the same range. From a commercial perspective the same criteria will apply.

This does beg the question of how “sameness” is to be determined. However, as indicated in Table 5.1, each of these characteristics can be quantified.

The capability of any new and as yet undiscovered technological systems for measuring the commercially important characteristics of greasy wool must also be judged against these criteria.

Sampling - the number one issue

Objective determination of defined characteristics of materials usually involves measurements based on a small proportion of the total material of interest. In materials that are **homogeneous**, obtaining a representative sub-sample of the whole is a relatively simple problem. Where there is **heterogeneity**, obtaining a sub-sample that is representative of the whole is a much more difficult task.

Wool is clearly a **heterogeneous** material, both in the bulk or when still on the sheep’s back. The sampling procedures for sale lots or consignments of wool have been carefully developed to ensure that the sample represents the bulk with a predictable degree of error. The requirements for sampling the bulk also extend to further sub-sampling of the sample itself, in order to measure a specific characteristic. The theory and practice of these sampling regimes will not be considered in detail here. Suffice to say the same theory and practice must also be applied when sampling individual animals.

Generally, modern analytical instruments provide increased speed, more ease and convenience of use, and often less skill is required of the operator. However, particularly in the case of analysis of greasy wool, results provided by such instrumentation are diminished in value unless an appropriate sampling regime is defined and strictly followed. Sampling is the first and most important step in any wool testing system.

Accuracy and precision

Precision describes the reproducibility of results - that is, the agreement between numerical values of two or more replicate measurements, or measurements that have been made in exactly the same way. Generally, the precision of a testing system can be obtained simply by repeating the measurement, using the same technique, a number of times.

Precision is often confused with **accuracy**. Accuracy simply describes the correctness of a result and **must always be determined by reference to a primary system**. Strictly speaking, the only type of measurement that can be described as completely accurate is one that involves counting objects. **All other measurements contain errors and are really only approximations or estimates**.

Ideally, the accuracy and the precision of any measurement system will be identical, but frequently they are not. It is quite possible to have a very precise secondary measurement system (the answers are highly reproducible), which differs consistently from the "true" value. This does not limit its usefulness, **provided it is used in all instances where comparisons must be made**. However, without a primary system against which a secondary system can be calibrated, there is always a risk that the values provided by a secondary system will not be consistent when determined by different facilities or over a period of time.

Three terms are widely used to describe the precision of a set of replicate data:

- standard deviation
- variance, and
- coefficient of variation.

These terms have statistical significance and are defined, together with some related terms, in Table 5.2.

The main objective in standardising any testing system is to ensure a predictable and commercially acceptable precision of the measurements.

Table 5.2 Defining the precision of analytical methods. Source: Sommerville (2001).

Terms	Definition
Absolute Standard Deviation	$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$
Relative Standard Deviation	$RSD = \frac{s}{\bar{x}}$
Standard Deviation of the Mean,	$s_m = \frac{s}{\sqrt{N}}$
Coefficient of Variation	$CV = \frac{s}{\bar{x}} \cdot 100$
Variance of the mean	s_m^2
Confidence Level (95%)	$CL = \pm 1.96\sqrt{s_m^2}$
x_i = numerical value of the i[th] measurement $\bar{x}$ = the mean of N measurements = $\frac{\sum_{i=1}^{N} x_i}{N}$	

Bias

Analysts are concerned with two types of errors:

- random or indeterminate errors, and
- systematic or determinate errors.

The error in the mean of a number of replicate measurements is equal to the sum of these two errors.

Random or indeterminate errors impact upon precision. Bias may have little or no effect on precision, but it has a significant effect upon accuracy.

Bias is a result of systematic or determinate errors. Systematic errors always act in one direction, resulting in a consistently larger or a consistently smaller result than that provided by the reference measurement. In general, bias can only be determined by reference to measurements provided by primary measurement systems (i.e. systems based on direct reference to primary metric standards such as length and weight). Bias can exist between measurements provided by secondary measurement systems (systems calibrated against primary systems), but unless the bias can be confirmed by reference to a primary measurement system, the analyst may never be sure whether one or both of the secondary measurement systems are responsible for the bias. Bias can result from several causes, and generally, these can be classified into one of six groups.

- **Sampling**: Inadequate design of sampling systems can result in a sample that is biased. A biased sample may still be useful depending on the intended use of the measurements made on the sample. Samples taken from a defined location on sheep will almost certainly be a biased representation of their fleeces. If the purpose of these samples is to obtain information to assist in ranking sheep for breeding purposes, the bias can be acceptable, provided it is similar across all sheep to be ranked. However, if the purpose of the samples is to obtain information to predict characteristics in classed lines of wool produced from the sheep, then the bias may be unacceptable

- **Differences in fundamental assumptions**: In the case of wool fibre fineness, different assumptions about the geometry of the fibre by different instrumental methods, may lead to bias

• **Personal errors**: Bias can also be the result of blind prejudice. Most of us, however honest, have a natural tendency to estimate scale readings in a direction that improves the precision of a set of results, or causes the results to fall closer to a preconceived notion of the true value. When sampling wool this source of bias is particularly important. Measurement of staple length and strength requires the selection of a representative set of wool staples. In the early stages of the development of the IWTO Test Method, it was observed that staff with wool knowledge generally selected a set of staples that were longer than those selected by staff with little or no wool knowledge

• **Instrumental errors**: Bias can be caused by instrument drift, or by assumptions made by the technology used in the instrument. The OFDA 100 instrument, used for determining the mean fibre diameter distribution characteristics of wool has been shown to exhibit biases in either Mean Fibre Diameter or Standard Deviation of Diameter, depending upon how the calibration samples are prepared. The instrument must use separate calibration systems for unbiased estimates of either parameter

• **Method errors**: An example of this type of bias is the failure to maintain rigid control over the environmental conditions that impact upon the measurement (for example temperature and humidity, or measuring fibre diameter without removing attached grease, wax and suint)

• **Interferences**: Bias can also be caused by interferences that arise from the constituents of the sample. In fibre measurements, where most methods use physical measurement techniques, bias from this source is unlikely, provided the sample is prepared appropriately. In the case of fibre diameter, the presence of extraneous material such as a synthetic fibre, or very fine vegetable matter, is an example of this effect.

Bias may be constant over the range of variation of the characteristic being measured, or it may vary over this range. One of the objectives of standardising wool testing systems is the elimination or at least the minimisation of bias. Where bias cannot be eliminated, provided it is not level dependent, the measurement technology may still be useful.

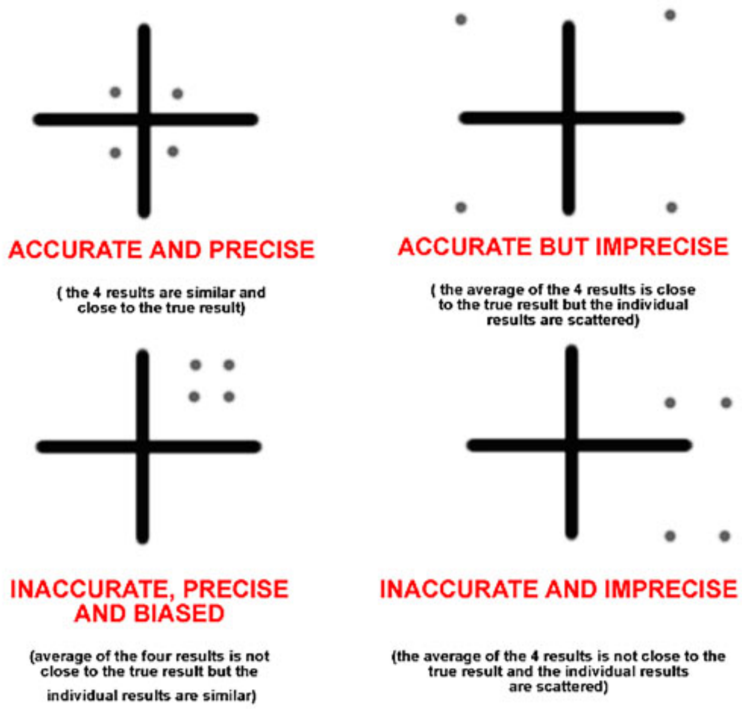

Figure 5.2 This illustration demonstrates the difference between ACCURACY, PRECISION and BIAS. The "true" result is defined as the point where the two lines intersect and the 4 dots represent the results of 4 separate measurements. Source: Douglas (2000).

Sensitivity

Sensitivity of an instrument or a testing system refers to its ability to discriminate between small differences in the material being analysed. In wool testing three factors limit sensitivity:

- the slope of an instrument's calibration curve
- the precision of the instrument, and
- the error in the sampling system.

If two instruments have equal precision the one having the steeper calibration curve will have the greater sensitivity. Conversely if two instruments have calibration curves with identical slope, the one having the greater precision will have the greater sensitivity. In testing wool, the errors arising from sample variation are generally so large that they mask any differences in sensitivity between measurement instruments.

Detection limit

The detection limit is a minimum value of the characteristic being measured that can be detected at a known confidence level. This is not an important issue, for example, when measuring mean fibre diameter, because wool fibres never approach zero fineness, and most measurements are conducted within ranges that exceed the probable detection limit by factors greater than three. However, if attempts currently underway to produce ultra fine flocks succeed (see AWTA May 2001 Newsletter, downloadable from http://www.awta.com.au) then this may become an increasingly important factor. It is already a very important factor to be considered in developing instruments to measure dark fibre contamination in wool, because the minimum quantity of such fibres generally considered to be important is extremely low.

Range

The useful range of an analytical method can be defined as the lowest point at which a measurement can be made (the detection limit or the LOQ), to the point at which the calibration departs from linearity (LOC). However, some measurement systems have non-linear calibration functions. The useful range in these instances is more difficult to define.

Selectivity

Selectivity refers to the degree to which the analytical method is free from interferences by other species in the sample matrix. This is generally not a major issue when testing wool. However, as indicated previously, it may be an issue for measurement of fibre diameter if extraneous synthetic fibres or very fine vegetable matter is present in the sample.

5.3. Development of standard test methods

The most important issue with any measurement, or measurement technology, is to achieve a predictable consistency of the results. Consistency can only be obtained after standardisation of sampling and testing processes, and to do this, data must be collected on:

- sampling and sample preparation variation
- calibration techniques for test instruments
- between-instrument comparisons
- repeatability of measurements on the same wools, and
- between-laboratory effects.

With this data, a Test Method can be established, the precision of the test calculated and, if required by industry, a Standard Test Method issued.

This does not imply that every measurement technology needs to be progressed to Test Method status before it can be used. There are numerous measurement systems used by scientists and engineers that never develop into Standard Test Methods. Waiting for every measurement system to be developed into a standard will inhibit the very research required to develop the method, and stunt any exploration of its potential. However, in commercial situations, where the measurement adds value to the raw material or product, predictable consistency of results is critical in developing commercial confidence. This can only be provided by Standard Test Methods.

The role of IWTO

Background

The International Wool Textile Organisation or IWTO (also known as the Federation Laniere Internationale) was established in 1928 as an arbitration body for the international trade of wool and wool products, and was born out of an arbitration agreement signed between the representative bodies of the British and French wool-textile industries in 1927.

IWTO soon realised that in order for contracts to be fully specified objective techniques for measuring wool characteristics and invoice weights were required, thereby minimising the likelihood of a dispute but also providing an objective basis for arbitration should a dispute arise. Consequently IWTO now plays a central role in fostering the development of internationally accepted Test Specifications for raw wool, wool sliver, yarns and fabrics.

Its primary objectives are:

- to maintain a permanent connection between the Wool Textile Organisations of member- countries
- to represent the Wool Textile Trade and Industry in all branches of economic activity
- to promote, support or oppose measures or activities affecting the trade and industry
- to promote the study and solution of economic and commercial questions affecting the trade and industry
- to ensure the functioning of the International Arbitration Agreement in the Wool Textile Trade and Industry
- to collect and disseminate statistical and other information of interest to the Trade and Industry
- to develop and maintain International Standards and Regulations for objectively measuring the characteristics of raw wool, wool sliver, yarns and fabrics.

Membership of IWTO is based on National Committees from member countries, each of which appoints delegates to attend each meeting. The membership of each National Committee is decided by the industry in the particular country it represents but it is normally based on representative organisations from different sectors of the industry within that country. However, in some cases private companies, as distinct from sectional industry organisations, are also members of National Committees. And IWTO also offers Associate Membership to organisations or companies.

IWTO meets once each year. The meeting is in April/May/June, and occurs in a different country, at the invitation of that country's National Committee.
Such events, attended by some 300 delegates, provide the forum for the various committees established by IWTO to conduct their business, and for discussion and exchange between members on issues of interest to the industry, thereby making it possible to adopt convergent positions to overcome specific problems.

Structure

Supply and demand chain groups

The various Committees that form the IWTO structure are divided into a **Supply Chain** group and a **Demand Chain** group, which together cover the complete pipeline of the wool textile industry (see Figure 5.3).

Supply meets demand zone committee

In the Supply Meets Demand Zone Committee both groups come together via the committee/forum chairpersons (and other invited personnel) to share and discuss their work, thereby providing direct feedback between the two groups. This Committee also develops overall strategies for various activities of IWTO for consideration by the Assembly.

Market intelligence forum
This Forum supports the Supply and the Demand groups with regular updates and analysis concerning world wide markets relevant to the wool industry.

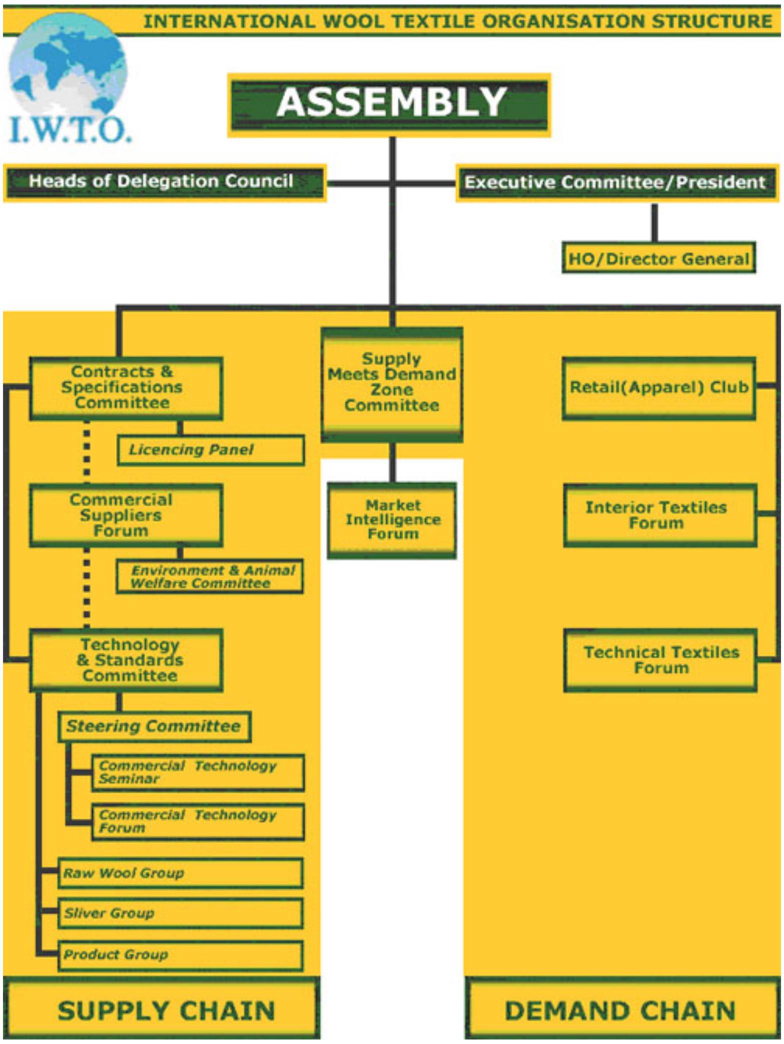

Figure 5.3 Structure of IWTO conferences. Source: AWTA (2005).

Supply chain committees/forums

These Committees/Forums develop and maintain the technical and commercial documentation utilised by the various parties along the supply chain. These include:

Blue Book Developed over the years by the IWTO, the Blue book represents the basis for the conditions under which most of the world wool trade conducts its business. The rules contained in it are agreed between the various players in the wool-textile trade and industry. They are therefore fair and objective since they are not imposed upon by any one group upon another. The Blue Book is regularly reviewed to reflect the current commercial practice and requirements.

Arbitration The International Wool Textile Arbitration Agreement, set out in the Blue Book provides for the resolution of disputes arising between partners from different countries. Such a procedure ensures a fair and efficient settlement by the involvement of committed and experienced arbitrators from the industry.

Red Book IWTO develops and regularly updates a large number of Test-Methods to ensure standardisation and reliability of tests carried out on the fibre and to maximise and enhance its unique intrinsic characteristics.

Regulations Associated with each test method are regulations which govern their application, interpretation and other procedures associated with their use. The regulations include formal procedures and technically determined criteria for assessing the validity of test results subject to dispute or suspected to be in error.

Committees/Forums in this area include:
- Contracts and Specifications Committee
- Commercial Suppliers Forum
- Technology and Standards Committee.

Contracts and specifications committee
This Committee deals with the adoption of Test-Methods and Regulations and with the wording of the IWTO Arbitration and other international Agreements set out in the Blue Book. It also maintains IWTO regulations associated with wool measurement and trading. It examines the impact of any changes arising from technical meetings on commercial regulations and advises the IWTO Assembly.

Licensing panel
IWTO Laboratory Licensing determines the circumstances under which IWTO Test Certificates may be issued. The Panel maintains a register of laboratories holding IWTO accreditation. The Licensing Panel provides the criteria required to issue IWTO Test Certificates for specific Test-Methods and Regulations to laboratories requesting licencing, and ensures that these criteria are met. This initiative gives enhanced credibility to wool testing.

Commercial suppliers forum
This is a traditionally active meeting, covering issues relating to the wool supply chain post farm gate to topmaking, spinning and weaving.
It does this by:
- providing a forum for growers to discuss wool production issues and for them to interact with traders and processors
- discussing matters of direct concern to scourers, combers, topmakers, and woollen and worsted spinners and weavers
- maintaining a dialogue with other IWTO Committees on yarn and cloth production, quality and demand, and
- examining the impact of any changes to technical standards on yarn and cloth manufacture and trade.

The Forum can provide advice to the Contracts and Specifications Committee on items placed before this Committee for decision and recommendation to the Assembly

Environment and welfare committee
Directly linked to the Commercial Suppliers Committee and rapidly growing in significance, this Committee monitors national and international environmental regulations set by Government and determines the impact on the wool industry. It advises the IWTO Assembly on appropriate actions to promote the wool industry in relation to environmental issues.

Technology and standards committee
This committee co-ordinates the submission and circulation of technical reports and maintains the IWTO technical standardisation process.
Its objectives are:

- to provide a forum for exchanges between scientists, research workers and industrialists twice per year, so as to review existing wool knowledge and the progress made in different fields and to promote the practical application of this knowledge to the wool trade and industry
- to develop efficient IWTO Test Methods having application within the wool textile industry, for approval by the Assembly

- to develop Sampling and Certification Procedures and Regulations, governing the uniform application of Test Specifications in industry, for approval by the Assembly, subject to their recommendation by the Commercial Regulations Committee
- to encourage interaction between the commercial and technical sectors of IWTO
- to ensure that its structure and that of its Technical Groups facilitate the optimal use of available time during IWTO Conference/Meetings weeks.

The Technology and Standards Committee is the approving body for Draft Test Methods and for amendments to enhance existing IWTO Test Methods, which are deemed to be editorial clarifications only.

It is also the body, which recommends completed Specifications for formal adoption as full IWTO Test Methods, or for their relegation to a lesser status, to the Contracts and Specifications Committee.

The **Terms of Reference** governing the activities of the Committee can be viewed on the **IWTO Website** (www.iwto.org).

Steering committee
The day-to-day operations of the Technology and Standards Committee are managed by a Steering Committee comprised of the Chairman, Deputy Chairman, Secretary-General, Technical Coordinator and the 4 Chairmen of the Technical Groups. The Immediate Past Chairman is an ex-officio non-voting Member for a maximum period of 2 years. This Steering Committee meets immediately prior to the first Technology and Standards Committee Meeting and it also conducts a Review Meeting prior to the final Meeting of the Technology and Standards Committee i.e. the Standardisation Session.

Commercial technology forum
Organised by the Steering Committee this forum provides for presentation of Technical Reports on general issues of metrology, and on physical and chemical topics relating to research and development of industrial processes and/or applications of technology.

Commercial technology seminar
Also organised by the T and S Steering Committee this seminar provides for presentations from technology suppliers or associates covering new equipment or processes with application in the wool industry.

Raw wool group
Responsible for IWTO technical standards associated with greasy and commercially scoured wool.

Sliver group
Responsible for IWTO technical standards associated with partially processed wool in the form of slivers.

Product group
This group specialises in product specification. The group is positioned to deal with technical issues surrounding products and the consumer at end of the demand pipeline that arise from the commercial committees.

Demand chain forums

Retail (apparel) club
The IWTO — Retail Club focuses on all activities at the level of marketing and retailing of wool products. The Club is responsible for the input and exchange of know-how on marketing and retailing with the other levels of the wool pipeline.

Interior textiles forum
The IWTO — Home Interiors Forum focuses on all activities at the level of marketing and retailing of all wool and wool-blend products related to the Home Interiors industry sector, such

as carpets and home textiles. It represents the full supply chain of the sector in those specific matters to wool. The Committee's brief also includes the Craft and Handknitting Sectors.

Technical textiles forum
This Forum bundles all know-how, information and activities of technical textiles related to wool. This concerns especially the sectors of automotive, healthcare, apparel, aerospace, furnishings, toys and consumer products.

Other committees

General assembly
The General Assembly is IWTO's sovereign body and meets at the end of every conference to present and formally endorse the decisions made by the various Committees meeting during the conference. As it is the closing forum it provides a summary and overview of the Congress, including industry announcements.

Heads of delegation council
This makes recommendations to the Assembly concerning full membership status of National Committees, recommends to the Assembly the dates and locations of future Meetings and International Wool Congresses, and sets the annual budget. The Council's responsibilities include operational aspects, financial control of IWTO and examination of the function of IWTO and the future directions of the organisation.

The Heads of Delegation Council is composed of the Vice-President, the Past Presidents and the Members of the Executive Committee and chaired by the President of IWTO.

Executive committee
Composed of the President, Vice-President, Treasurer and three additional elected Members the Executive Committee administers the affairs and operations of the International Wool Textile Organisation and oversees its daily management in accordance with the Directives of the Assembly and the policy guidelines established by the Heads of Delegation Council.

An introduction to IWTO specifications

IWTO has developed procedures (IWTO-0-1) for the development, review, progression or regulation of IWTO Test Methods and Draft Test Methods.

Prior to 1971, all approved Specifications were known as IWTO Test Methods. In November, 1971, regulations were laid down to establish a new category of Test Method called a Test Method Under Examination, to facilitate control over the commercial application of developing Specifications.

In December, 1991 detailed consideration was given to the procedures for the review and withdrawal of Standards, together with the need for guidance on the format for presenting supporting technical information. A document was prepared and it was agreed to replace the Test Method Under Examination title with that of Draft Test Method.

The main difference between an IWTO Test Method and a Draft Test Method is that the latter has not yet demonstrated sufficient reproducibility to meet the technical standards for acceptable inter-laboratory variation. Whilst Draft Test Methods define the standard methodology being developed, they have no official status for commercial usage, unless agreed between the contracting parties.

Draft Test Methods represent the first formal approval stage in the development of IWTO Test Methods. The responsible Technical Group normally continues the work to upgrade them to full IWTO Test Method status as quickly as possible. Draft Test Methods provide an opportunity for both technical and commercial evaluation of the developing methodology, during its logical progression to full standardisation. They are normally held at this status for a minimum of two years.

Normally Draft Test Methods precede the full Test Method status. However, in exceptional circumstances, such as when important weaknesses are identified, full Test Methods can be downgraded to Draft Test Method status.

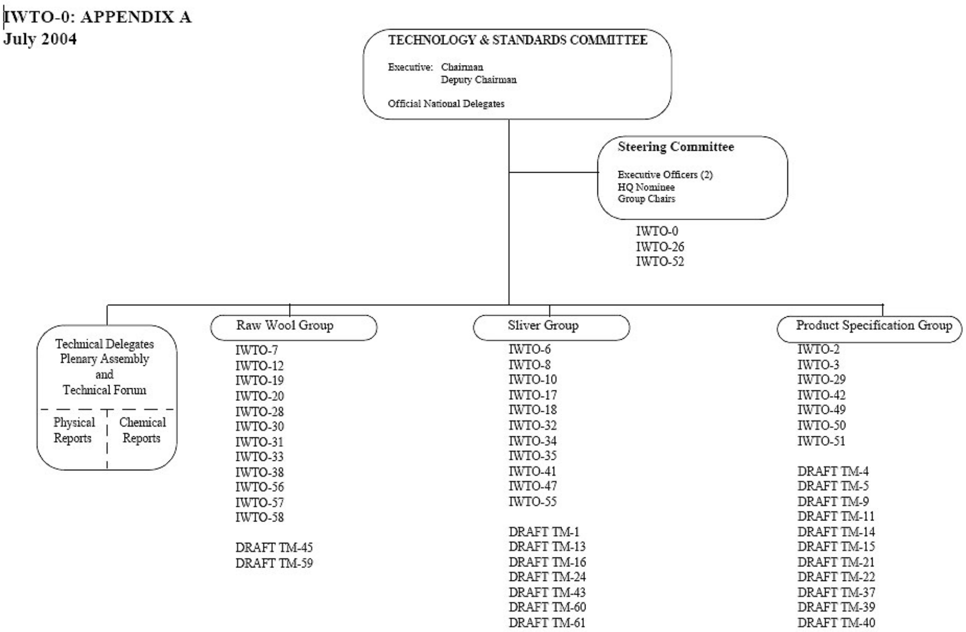

Figure 5.4 Assigned responsibilities for maintaining IWTO Test Methods. Source: IWTO-0-1.

IWTO-0-1, while defining the process to be followed in developing Standard Test Methods, includes 4 key appendices.

- **Appendix A** documents which Draft Test Methods and full Test Methods are the responsibility of each of the technical groups operating under the umbrella of the Technology and Standards Committee

- **Appendix B** describes how to present supporting data for a new method, and includes a comprehensive description of the statistical analysis required, particularly when another method already exists. The analysis considers the equivalence of the new method to the existing method

- **Appendix C** provides guidelines on drafting and presenting a Test Method

- **Appendix D** describes a number of statistical techniques that can be applied to estimate precision limits for IWTO Test Methods. However, these procedures assume that the variances for the particular parameter determined by the method are independent of the level of the parameter. In situations where this is demonstrated not to be the case, Appendix B describes the appropriate analysis to be applied.

Application of IWTO test specifications

Figure 5.3 shows the assigned responsibilities for managing IWTO Specifications by the technical groups operating under the auspices of the Technology and Standards Committee.

The key methods that are used to specify greasy wool are listed in Table 5.3.

Table 5.3 IWTO test specifications for greasy wool.

IWTO-0	Introduction to IWTO Specifications: Procedures for the Development, Review, Progression or Relegation of IWTO Test Methods and Draft Tests Methods
IWTO-12	Measurement of the Mean and Distribution of Fibre Diameter Using the SIROLANLASERSCAN Fibre Diameter Analyser
IWTO-19	Determination of Wool Base and Vegetable Matter Base of Core Samples of Raw Wool
IWTO-28	Determination by the Airflow Method of the Mean Fibre Diameter of Core Samples of Raw Wool
IWTO-30	Determination of Staple Length and Staple Strength
IWTO-31	Calculation of IWTO Combined Certificates for Deliveries of Raw Wool
IWTO-38	Method for Grab Sampling Greasy Wool from Bales
IWTO-47	Measurement of the Mean and Distribution of Fibre Diameter of Wool Using and Optical Fibre Diameter Analyser (OFDA).
IWTO-56	Method for the Measurement of Colour of Raw Wool

The information provided by these test specifications is applied in two ways:

- To predict the performance of the wool during processing so that it meets the specifications provided by the processor
- To establish market value of the wool and thereby determine the price to be paid to the producer.

The key parameters that can be certified are shown in the context of their predictive applications in wool processing in Table 5.4.

Table 5.4 Information provided by greasy wool measurements.

Certified Parameters	**Predictive Application**	**Test Method(s)**
Mean Fibre Diameter	Top Diameter	IWTO-28 IWTO-12 IWTO-47
Wool Base Vegetable Matter Base	Schlumberger Dry Top and Noil Yield IWTO Clean Scoured Yield Japanese Clean Scoured Yield Australian Carbonising Yield	IWTO-19
Staple Length Staple Strength Position of Break	TEAM Formulae for: Hauteur Coefficient of Variation of Hauteur Romaine	IWTO-30
Colour	Whiteness of Top Brightness of Top	IWTO-56

Note 1: The TEAM formulae also include terms for Mean Fibre Diameter and Vegetable Matter base. A new TEAM formula arising out of the TEAM-3 Trial adds terms including Coefficient of Variation of Diameter and Coefficient of variation of Staple Length.

Note 2: Measurement of Colour in Greasy Wool has not achieved a significant level of adoption in Australia, in part due to the fact that Australian Merino Wool is renowned for its whiteness and brightness. However, some lines of wool, such as crutchings, skirtings and bellies are often significantly more coloured than fleece wools. There have also been seasons, when conditions have been wet and humid where significant discoloration of fleece wools has occurred. In New Zealand, where cross bred wool predominates, sale lots are routinely measured for Colour. Research has shown that there is a strong relationship between the clean colour of greasy wool and the clean colour of the resultant top.

On farm fibre measurement

While some of the technology used for IWTO Certification has also found application in providing information for selecting animals, the testing systems or protocols used have not been standardised. However, in 2005 Australian Wool Innovation (AWI, http://www.wool.com.au) introduced a system of accreditation and quality control round trials specifically for providers of on-farm fibre measurement (OFFM) services.

The OFFM Quality Assurance Scheme covers:

- OFFM operator accreditation
- proficiency testing
- a QA procedures manual
- new equipment validation
- training and communication.

It aims to provide users with confidence in OFFM technologies, systems and measurements and sets minimum standards for OFFM sampling and measuring.

Future developments

Increasingly, alternative technologies for measuring some parameters are becoming available, and expenditure for research into and development of as yet unknown but hopefully less expensive new technologies is also being considered. Before the commercial implications of using these new technologies can be understood it is necessary to understand the criteria (Table 5.1) for establishing their equivalence to those they are designed to complement or supplant. Topic 17 – Future Developments in Wool Metrology covers this area in more detail.

However, through IWTO-0-1 the wool industry already has a tool that can readily be applied to establish the numerical values of the required criteria and thereby ensure that the integrity of the measurement of raw wool is maintained.

5.4. Technical limitations of wool metrology systems

With the universal use of Test Certificates to define the specification of a wool trading contract, the accuracy and precision of the test results are sometimes questioned. This is particularly so as new measurements are introduced and there is no relaxation of commercial specifications in contracts

Questions that are frequently asked include:

- Why aren't repeat results identical?
- Why do repeat results differ most of the time?

Genetics, environment and nutrition, management and disease influence the properties of wool as a natural fibre. Wool is a variable commodity and wool testing is used to provide an estimate of these properties based on a sample taken from the bulk. When this variable commodity is sampled and tested this, the components of that variation, and variation introduced by the adoption of the official IWTO Methods and Regulations, contribute to each result. For example, the Confidence Limits are calculated from components of variance, which include:

- between-core or between-grab variation;
- within-laboratory variation; and
- between-laboratory variation.

Between-core/between-grab variation

This source of variation is beyond the control of the Test House, and is largely beyond the control of the wool classer, since much of the variation occurs within individual fleeces. This variation differs for wools of different origins and extreme wool types. For example, core sampling schedules are based on taking sufficient number of cores to achieve a sampling precision of ± 0.7% Wool Base. More cores/bale must be taken from bales of South American wools than for Australian wools in order to obtain a similar precision, because the bales of South American wools are usually more variable for yield than Australian wools.

Within-laboratory variation

Within a laboratory, minor equipment and operator differences can exist. Stringent quality control, equipment maintenance and supervision minimises this source of operator variation. The procedure of measuring subsamples/specimens on different instruments reduces the effects of variation between machines and operators.

For example, the IWTO Airflow Test Method, OFDA Test Method and Laserscan Test Method requires 2 instruments to be used and the results averaged for certification. Similarly, staples sampled for ATLAS Staple Length and Strength certification must be prepared by at least 4 operators to minimise bias of any individual operator who might consistently draw longer or shorter staples.

Between-laboratory variation

The subject of bias has already been discussed. Even with bias eliminated, a component of variation between laboratories exists. Each instrument will give some small difference in performance, and laboratory procedures may differ in their interpretation.

In addition, the amount of testing conducted has a direct relationship with the precision of the answer - the greater the amount of testing the more repeatable is the test result. Testing multiple samples randomises some of the within laboratory effects and increases the chance of identifying an error before the result is issued.

When developing test methods, the sources of variation are determined from international inter-laboratory trials. These data form the basis for the calculation of the precision limits of the new method. Precision of a test result is also dependent upon the amount of sampling and testing conducted. The greater the amount of sampling and testing, the better the precision of the test result.

The precision of an individual test result is usually expressed as 95% Confidence Limits, i.e. the limits on either side of the “true” result within which you can expect 95 of 100 repeat measurements to lie. The 95% Confidence Limits for Wool Base, Vegetable Matter Base, Mean Fibre Diameter, Colour, Staple Length and Strength measurements as defined in the IWTO Test Methods and Regulations are shown in Column A of Table 5.5.

Table 5.5 Precision limits and maximum retest ranges.

TEST TYPE	A 95% CONFIDENCE LIMIT (+/-)			B 95% CONFIDENCE LIMIT (+/-)		
WOOL BASE(%)						
Up to 40		2.2			3.1	
40.1 to 45.0		1.9			2.8	
45.1 to 50.0		1.7			2.5	
50.1 to 55.0		1.5			2.1	
55.1 to 60.0		1.3			1.9	
60.1 to 65.0		1.2			1.8	
Above 65.0		1.1			1.6	
VM BASE(%)						
Up to 0.5		0.1			0.3	
0.6 to 1.0		0.3			0.5	
1.1 to 1.5		0.4			0.6	
1.6 to 2.0		0.5			0.8	
2.1 to 3.0		0.6			1.0	
3.1 to 5.0		0.9			2.0	
above 5.0		1.0 to 2.0			3.2	
MEAN FIBRE DIAMETER (μm)						
	Airflow	OFDA	LSN	Airflow	OFDA	LSN
15.0	0.3	0.3	0.2	0.5	0.4	0.3
20.0	0.5	0.4	0.4	0.6	0.4	0.4
25.0	0.6	0.5	0.5	0.8	0.6	0.5
30.0	0.7	0.6	0.6	1.0	0.7	0.7
35.0	0.8	0.7	0.7	1.1	0.9	0.9
40.0	0.9	0.8	0.9	1.3	1.0	1.1
AVERAGE YELOWNESS (units)		1.5			2.1	
STAPLE LENGTH (mm)	Fleece		Non-Fleece	Fleece		Non-Fleece
	4.8		5.4	7		8
STAPLE Strength (N/kt)	Fleece		Non-Fleece	Fleece		Non-Fleece
	5.9		5.9	8		8

Check tests and retests

When test results are questioned by the trade, the Test House usually has a policy to conduct check tests and retests. The procedures are well defined in the IWTO Regulations.

Because of the inherent variation, a check test will normally give a slightly different answer to the original test even if no "error" exists. Provided it falls within a statistically based Maximum Retest Range, defined by IWTO, the original and check test data are combined and reissued. No error has occurred in this situation. When a check test or retest exceeds the Maximum Retest Range, an error is acknowledged. This may be obvious, or resolved with additional sampling and/or testing. A new result without the original data is issued.

For information, the IWTO Maximum Retest Ranges for Wool Base, VM Base, Mean Fibre Diameter, Colour, Staple Length and Staple Strength are shown in Column B of Table 5.5.

The key rule for retests, check tests or record check tests is that if the extra data is compatible, i.e. the difference falls within the Maximum Retest Range, then the additional data are combined with the original data and becomes the new result. If the data exceeds the Maximum Retest Range, i.e. an error has deemed to have occurred, then the original result is withdrawn and the new data issued as the result.

While attention often focuses on individual errors, only 0.2% of AWTA Ltd Certificate results are requested to be checked by the trade. Only 0.02% of all Certificate results are found to be in error.

Readings [3]

The following readings are available on web learning management systems

1. Australian Wool Testing Authority Ltd. (AWTA), 2002a, Testing the Wool Clip.
2. Australian Wool Testing Authority Ltd. (AWTA), 2002b, Testing the Wool Clip, Glossary of Terms.
3. Australian Wool Testing Authority Ltd. (AWTA), 2005, Newsletter, April 2005.
4. Douglas, S.A.S., 2000, Wool Trading Requirements and Technical Limitations of IWTO Test Methods, AWTA Ltd, Melbourne.
5. Sommerville, P.J., 2001, Fundamental Principles of Fibre Fineness Measurement Part 1: The Technical and Commercial Requirements of Wool Testing Systems, AWTA Ltd.
6. Sommerville, P.J., 2002, Fundamental Principles of Fibre Fineness Measurement Part 2: Understanding Fibre Diameter Measurement, AWTA Ltd.
7. Whan, R.B. 1973, Potential saving from the sale of wool by measurement, in: 1973, *Objective Measurement of Wool in Australia*, Australian Wool Corporation.

Movies [3]

The following movies are available on web learning management systems

1. Australian Wool Testing Authority Ltd. (AWTA), AWTA Corporate Video.
2. Australian Wool Testing Authority Ltd. (AWTA), Laserscan.

Summary

Summary Slides are available on web learning management systems

This lecture is intended to provide a background to introduce students to the concepts of wool metrology and the standardisation processes that the wool industry has developed since the formation of the International Wool Textiles Organisation in 1928.

The lecture covers 4 areas.

1. Defining wool metrology, why it is used, a brief history of its development and a description of the characteristics of wool that can be measured.
2. A detailed discussion on the technical requirements of wool testing systems.
3. An outline of the procedures and processes whereby the industry manages the development and commercialisation of testing systems.
4. An outline of the procedures and processes used to manage the commercial issues arising from the technical limitations of the testing systems

The lecture assumes an understanding of statistical terms and statistical techniques.

References

Australian Wool Testing Authority Ltd. (AWTA), 2005, Newsletter, April 2005.

Holmes, B. 1998, 'Irresistible Illusions,' *New Scientist,* No. 2150, pp. 37.

International Wool Textile Organisation (IWTO), various Test Method Specifications, www.iwto.org.

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IWTO-0-1 Appendix A, International Wool Textile Organisation Test Method, The Woolmark Company, Valley Drive, Ilkley, West Yorkshire, LS29 8PB United Kingdom

Douglas S.A.S. 2000, Wool Trading Requirements and Technical Limitations of IWTO Test Methods, AWTA Ltd, Melbourne

Newton-Turner H, Hayman R.H., Riches J.H., Roberts N.F. and Wilson L.T. 1953, Divisional Report No. 4 (Series S.W.-2), Division of Animal Health and Production, CSIRO, Melbourne

Sommerville, P.J. 1998, Objective Measurements – More than Pretty Numbers, AWTA Ltd., Melbourne.

Sommerville, P.J. 1999, Technology and Standards Committee, Raw Wool Group, Report RWG03S, IWTO, Florence.

Sommerville, P.J. 2001 Technical and Commercial Requirements of Wool Testing Systems, AWTA Ltd Newsletter, September 2001.

Glossary of terms

Check Test	A Check Test is verification of documentation and calculations forming the basis of the Certificate on which a doubt has been raised and, if possible, a set of additional measurements made, in accordance with the same standard IWTO Test Method as was adopted for the original test, on that portion of the sample material remaining after that original test. Where no sample material remains, a Recore Check Test may be carried out as part of the check testing procedures. Check testing is restricted to tests carried out by the Test House, which conducted the original test.
Recore Check Test	This is a set of measurements made, in accordance with the relevant IWTO Test Methods and Regulations, on a further sample of raw wool drawn from the delivery as part of the check testing procedures. A Recore check test may only be conducted where a Certificate has not been delivered in relation to a contract. Where staple measurements are involved this definition applies to a fresh grab sample taken from the lot rather than a core sample.
Retest	This is a set of measurements made, in accordance with the relevant IWTO Test Methods, on a further sample of raw wool drawn from a delivery for which the original Certificate is in doubt. This differs from a Recore Check Test in that duplicate core (grab) samples are drawn for possible testing by two separate Test Houses to resolve a disputed result. Such sample material must be obtained by recoring (regrabbing) and reweighing all bales, in accordance with the current IWTO Core (Staple) Test Regulations.
Testing Error	A Testing Error is deemed to have occurred if the Maximum Retest Range is exceeded.
Maximum Retest Range	The Maximum Retest Range (i.e. the difference between the values of a retest and the original Test Certificate or an earlier retest) is a statistically (and scientifically) determined upper and lower limit which, provided the test procedure has been rigorously adhered to, will very rarely be exceeded purely by chance. The Maximum Retest Range defines the maximum allowable difference between two test results.

In addition to the above glossary, a comprehensive Glossary of Terms can be found as a reading for this topic (AWTA 2002b.pdf).

Notes – Topic 5 – Background to Wool Metrology