

## Australian/New Zealand Standard™

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### **Wool—Calculation of IWTO combined certificates for deliveries of raw wool**

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[IWTO title: Calculation of IWTO combined certificates for deliveries of raw wool]

## AS/NZS 1362:1998

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The following interests are represented on Committee TX/12:

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Australian Wool Research and Promotion Organisation  
CSIRO—Division of Wool Technology  
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## Australian/New Zealand Standard™

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# Wool—Calculation of IWTO combined certificates for deliveries of raw wool

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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee TX/12, Wool to supersede AS/NZS 1362:1996, *Wool—Calculation of IWTO combined certificates for yield and mean fibre diameter of raw wool in deliveries*.

It is technically equivalent to and has been reproduced from IWTO-31-96, *Calculation of IWTO combined certificates for deliveries of raw wool*.

For the purposes of this Standard, the IWTO text should be modified as follows:

- (a) **Page 14, Clause 6.2.3.4** Following ‘and (6.3.7)’ add ‘or (6.3.8)’.
- (b) **Page 28, Clause 7.3.2.4** Following ‘and (7.3.7)’ add ‘or (7.3.8)’.

The objective of this Standard is to provide the wool industry with a method for calculating the yield and mean fibre diameter of raw wool for the issue of a test certificate.

As this Standard is reproduced from an international publication, the following applies:

- (i) Its number appears on the cover and title page while the International Standard number appears only on the cover.
- (ii) Insert the word ‘normative’ beneath the title in Appendix A.

References to IWTO Standards should be replaced by Australian/New Zealand Standards, as follows:

| <i>Reference to IWTO Standard</i> |                                                                                            | <i>Australian/New Zealand Standard</i> |                                                                                                 |
|-----------------------------------|--------------------------------------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------|
| IWTO                              |                                                                                            | AS/NZS                                 |                                                                                                 |
| 19                                | Determination of wool base and vegetable matter base of core samples of raw wool           | 1134                                   | Wool—Determination of wool base and vegetable matter base of core samples of raw wool           |
| 28                                | Determination of the Airflow Method of the mean fibre diameter of core samples of raw wool | 1133                                   | Wool—Determination by the Airflow Method of the mean fibre diameter of core samples of raw wool |
| 38                                | Method for grab sampling greasy wool from bales                                            | 1363<br>1363.1                         | Wool—Grab sampling—Greasy wool<br>Part 1: Method for grab sampling greasy wool from bales       |
| Core Test Regulations             |                                                                                            | 4447                                   | Wool—IWTO Core Test Regulations                                                                 |

The term ‘normative’ has been used in this Standard to define the application of the appendix to which it applies. A ‘normative’ appendix is an integral part of a Standard.

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## AUSTRALIAN/NEW ZEALAND STANDARD

# CALCULATION OF IWTO COMBINED CERTIFICATES FOR DELIVERIES OF RAW WOOL

*(Revised Version)*

## 0. Brief History

Originally prepared by the IWTO Raw Wool Certification Sub-committee, in collaboration with the Standards Association of Australia, and approved by the IWTO Standardisation Sub-committee as an IWTO Test Method Under Examination, IWTO(E)-4, Rome, May 1973. Revised text, prepared by the IWTO Raw Wool Certification Sub-committee, approved by the IWTO Standardisation Sub-committee and adopted by the IWTO Statutes & Agreements Committee as an IWTO Standard Test Method, Paris, January 1979. A further revised text was prepared by the Raw Wool Certification Sub-committee, approved by the Standardisation Sub-committee and adopted by the IWTO Statutes & Agreements Committee, Ostend, June 1986.

The current text was prepared by the Raw Wool (Technical) Group, approved by the Technology & Standards Committee and the Commercial Regulations & Contracts Committee, and adopted by the General Assembly, Cape Town, 1996. This text represents a major revision in that it amalgamates generic combination calculation procedures, previously incorporated in a range of raw wool test methods, into this Specification.

## 1. Foreword

In addition to having specifications for the determination of the Wool Base, Mean Fibre Diameter, Fibre Diameter Distribution, Coefficient of Variation of Fibre Diameter Distribution, Vegetable Matter Base, Staple Length, Staple Strength and Position of Break, and Colour of Raw Wool\*, the wool industry requires a standard

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|              |                                                                                                                                        |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------|
| * IWTO-8:    | Method of Determining Fibre Diameter and Percentage of Medullated Fibres in Wool and Other Animal Fibres by the Projection Microscope. |
| IWTO-12:     | Measurement of the Mean and Distribution of Fibre Diameter Using the Sirolan-Laserscan 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-47:     | Measurement of the Mean and Distribution of Fibre Diameter of Wool Using an OFDA.                                                      |
| DRAFT TM-56: | Method for the Measurement of Colour in Raw Wool.                                                                                      |

procedure for calculating certifiable test and weight data for deliveries, from the actual test data for the component lots of raw wool which have been individually tested. In particular, where presale testing is an established basis for selling, individual sale lots are tested on behalf of the wool grower. After sale, selected lots meeting the trading Contract specifications are allocated by the buyer to appropriate deliveries.

When the separate test results for each component lot in a delivery are combined mathematically, data having a high level of precision are obtainable. This precision increases with increasing numbers of tested lots being combined.

This method also provides for the calculation of an IWTO Combined Certificate (By Subtraction), but only under restricted circumstances where no more than 5% by weight of the certified delivery is to be deleted, with such portion having being separately certified. Such Certificates will have a precision which is slightly less than that achieved by testing the final delivery according to the relevant IWTO Test Method.

## **2. Scope**

This method sets out the calculation procedures for combining the Wool Base, Vegetable Matter, Commercial Yields and/or Mean Fibre Diameter test results of component lots in a delivery of raw wool, for which the issue of one overall Certificate is required. The method also sets out the calculation procedures for combining the Mean Fibre Diameter when Fibre Diameter Distribution data are available, and for combining the individual Fibre Diameter Distributions. In addition the method sets out the calculation procedures for combining Staple Length, Staple Strength, and Position of Break. Calculation procedures for combining Colour Tristimulus Values are also included. The precisions of the test results reported on the Certificate are specified.

Furthermore the method sets out the procedures for calculating these parameters for the remainder of a delivery or lot of wool, when part of that previously certified delivery or lot is to be removed after being certified separately. These procedures can only be used for the calculation of an “IWTO Combined Test Certificate (By Subtraction)”, under the restricted circumstances described in the IWTO Core Test Regulations, Section 4.2.4.

## **3. Principle**

The Certificate covering a delivery is calculated from the results of the tests on all the individual component lots comprising that delivery or, when subtracting a

component, from the original test results less the separate test results for the component being subtracted.

#### 4. Definitions

For the purposes of this Specification the following definitions shall apply:

**4.1 Individual Test:** A standard certifiable test on a lot of wool, carried out in strict accordance with an approved IWTO Test Method.

**4.2 IWTO Combined Certificate:** A Certificate covering a delivery of wool, in which the results are calculated mathematically from the individual test data for the 2 or more lots being amalgamated to form that delivery, and where the individual certificates have all been produced using the same IWTO Test Method(s).

**4.3 IWTO Combined Certificate (By Subtraction):** A Certificate covering a delivery of wool, in which the results are calculated mathematically by subtracting the data for an individually tested component, from either an IWTO Combined Certificate or from an IWTO Test Certificate covering all bales involved.

**4.4 Delivery:** A bulk of raw wool covered by a Combined Certificate. For the purpose of this method, it comprises 2 or more sale lots, each of which has been tested in accordance with the same IWTO Test Method(s) and for which the test data for each lot has been combined.

**4.5 Lot:** Any number of bales of wool prepared for sale according to accepted trade practices.

**4.6 Raw Wool:** Greasy wool; wool which has been scoured, carbonised, washed or solvent-degreased; scoured skin wools; washed skin wools; and slipe wools. It consists of wool fibre together with variable amounts of vegetable matter and extraneous alkali-insoluble impurities, mineral matter, wool waxes, suint and moisture.

**4.7 Grab Sample:** The raw wool drawn from a lot by the operation of a grab machine in accordance with IWTO-38.

**4.8 Core Sample:** The raw wool drawn by coring methods from a lot, bulk or delivery. For the issue of IWTO Certificates where the core sample is the source of the subsamples for further testing, the sample must be drawn in strict accordance with the IWTO Core Test Regulations to ensure that it is representative.

**4.9 Subsample:** The randomly drawn portion, representative of the grab or core sample, to be used for determination of the parameters defined in the relevant IWTO Test Method(s).

**4.10 Wool Base (B%):** The oven-dry mass of wool fibre free from all impurities, i.e. ash-free, ethyl alcohol extractives-free, and free from all vegetable matter and other alkali-insoluble impurities, expressed as a percentage of the mass of the sample.

**4.11 Vegetable Matter Base (V%):** The oven-dry mass of ash-free, ethyl alcohol extractive-free burrs (including hard heads), twigs, seeds, leaves and grasses present, expressed as a percentage of the mass of the sample.

**4.12 Hard Heads & Twigs Base (H%):** The oven-dry mass of ash-free, ethyl alcohol extractive-free hard heads and twigs, expressed as a percentage of the mass of the sample.

**Note 1:** “Hard Heads” are ring burrs (*Sida platycalyx*), Noogoora burrs (*Xanthium chinese*), Bathurst burrs (*Xanthium spinosum*) and similar burrs of a bean-like or woody character covered in readily removable spines. They do not contribute to a loss of wool during processing.

**Note 2:** “Twigs” are small pieces of stick, woody leaf stalks and similar woody material. They do not contribute to a loss of wool during processing.

**4.13 Commercial Yield:** Any of the Yields, calculated from the Wool Base, Vegetable Matter Base, and Hard Heads & Twigs Base, as specified in Section 3.0 of the IWTO Core Test Regulations. Yields may be expressed either as nett clean mass of a lot or delivery, or as the nett clean mass expressed as a percentage of the nett greasy mass.

**4.14 Mean Fibre Diameter (micrometres):** The length weighted mean thickness of all the fibres in a lot or sample.

**4.15 Fibre Diameter Distribution:** The spread of fibre diameter in a sample or lot of wool, usually represented by 2 parameters, the Mean and the Coefficient of Variation of Fibre Diameter, obtained by measuring the individual diameters of a large number (600-5000) of fibre snippets.

**4.16 Class Intervals:** The classes into which the individual snippet fibre diameter measurements for a sample or lot of wool are grouped, where the micrometre range

of each class is identical, the micrometre value of each interval is an integer, and the micrometre value of the mid point of each class interval is also an integer.

**4.17 Coefficient of Variation (CV%):** A statistical measure of the variability exhibited within a set of values. It expresses the Standard Deviation as a percentage of the Mean; the higher the CV the greater the variability.

**4.18 Staple Length (mm):** The projected length of the outline of an unrestrained staple, as measured along its axis.

**4.19 Staple Strength (Newtons/kilotex):** The maximum force required to rupture a staple per unit of average linear density.

**4.20 Position of Break:** An indication of where a staple breaks during extension, determined by comparing the masses of clean wool in the broken portions of the staple. It does not imply that a break exists in the staple.

**4.21 Clean Colour:** The colour of wool after scouring, usually described by 2 measurements, brightness and yellowness; each of which can affect the dyeing potential of the wool.

**4.22 Tristimulus Value:** One of the 3 reflectance readings obtained when using a colorimeter; specified by the Commission International d'Eclairage (CIE) as X (red), Y (green), and Z (blue). Y and Z are used in specifying the clean colour of wool.

**4.23 Reflectance:** The ratio of radiant flux reflected from a surface to the radiant flux reflected from the surface of an appropriate standard reference material. The reflectance is frequently expressed as a percentage.

**4.24 Radiance Factor:** Estimates of reflectance calculated from the Tristimulus Values.

## **5. Test Method**

### **5.1 Sampling**

Sampling of individual lots shall be conducted in strict accordance with the appropriate procedures set out in the relevant IWTO Regulations.

### **5.2 Testing**

Testing of individual lots shall be conducted in strict accordance with the approved IWTO Test Methods and the relevant IWTO Regulations.

## 6. Calculation of Combined Results

### 6.1 Yield, and Vegetable Matter Base

The combined values for Yield and Vegetable Matter Base of a delivery, shall be calculated as set out in the following.

#### 6.1.1 Notation

- (a) For the  $i$ th lot, where  $i = 1, 2, 3, \dots, q$  and  $q$  is the total number of lots in the delivery

$B_i$  = Wool Base (%)

$M_i$  = nett greasy mass (kg)

$V_i$  = Vegetable Matter Base (%)

$H_i$  = Hard Heads & Twigs Base (%)

$Y_i$  = Commercial Yield of nett clean mass (kg)

- (b) For the delivery

$M$  = nett greasy mass (kg)

$B$  = Wool Base (%)

$V$  = Vegetable Matter Base (%)

$H$  = Hard Heads & Twigs Base (%)

$Y$  = Commercial Yield (%)

#### 6.1.2 Combined Calculations

The following formulae are used for calculating the overall data covering the delivery:

$$\text{Total nett greasy mass (kg),} \quad M = \sum_{i=1}^q M_i \quad (6.1.1)$$

$$\text{Wool Base (\%),} \quad B = \frac{\sum_{i=1}^q M_i B_i}{M} \quad (6.1.2)$$

$$\text{Vegetable Matter Base(\%),} \quad V = \frac{\sum_{i=1}^q M_i V_i}{M} \quad (6.1.3)$$

$$\text{Hard Heads \& Twigs Base (\%),} \quad H = \frac{\sum_{i=1}^q M_i H_i}{M} \quad (6.1.4)$$

$$\text{Commercial Yield (\%),} \quad Y = \frac{\sum_{i=1}^q Y_i}{M} * 100 \quad (6.1.5)$$

**Note:** For IWTO Combined Certificates (and IWTO Combined Certificates (By Subtraction)), all Commercial Yields reported shall be calculated from the sum (or difference) of the relevant Commercial Yield clean masses of the component parts, expressed as a percentage of the sum (or difference) of the nett greasy masses of those component parts. The Commercial Yield (%) so calculated shall be reported as “ROUNDED” to 1 decimal place.

It is important to understand that the total clean mass on the IWTO Certificate is unlikely to be reproduced exactly by direct calculations from the Wool Base (%), Vegetable Matter Base (%), and Hard Heads & Twigs Base (%) data reported. This is particularly the case for Top and Noil Yields, Card Sliver Yields and Australian Carbonising Yields (all of which involve a deduction for processing loss related to the level of vegetable matter), but can also arise due to the rounding resulting from this clean mass addition (subtraction) procedure.

### 6.1.3 Precision

The gain in precision generated by combining a large number of individual lot tests covering the components of a delivery is evident from Table 6.1.1. This gain is due to the reduction in the between-tests component of variance, which results from such a combination. The methods used to calculate the precision of Wool Base results are set out in Appendix A.

**TABLE 6.1.1**  
**Example of Precision of**  
**Combined Yield Tests for a 500 Bale Delivery**  
 (Australian Merino Wool, Wool Base 50%)

| Bales per Test Lot | Test Lots in Delivery | 95% Confidence Limits ( $\pm$ )<br>of Mean Wool Base for<br>Total Delivery (%) |
|--------------------|-----------------------|--------------------------------------------------------------------------------|
| 500                | 1                     | 1.50                                                                           |
| 100                | 5                     | 0.68                                                                           |
| 50                 | 10                    | 0.49                                                                           |
| 25                 | 20                    | 0.36                                                                           |

**Note:** The precision data in the Table 6.1.1 is taken from the relevant Specification (IWTO-19, Table G1), and calculated for the example deliveries using equation A2.1.3 described in Appendix A of this Specification. This example uses the confidence intervals for 50% Wool Base, with sampling conducted by machine coring at 20 cores per lot, and assumes that the Mean Wool Base of the individual lots in the delivery are similar.

## 6.2 Fibre Diameter

### 6.2.1 Notation

- (a) For the  $i$ th lot, where  $i = 1, 2, 3, \dots, q$  and  $q$  is the total number of lots in the delivery

$B_i$  = Wool Base (%)

$M_i$  = nett greasy mass (kg)

$D_i$  = Mean Fibre Diameter ( $\mu\text{m}$ )

$C_i$  = Fractional Coefficient of Variation of Diameter

$S_i$  = estimated Standard Deviation of Diameter ( $\mu\text{m}$ )

**Note 1:**  $C_i = S_i/D_i$

$n_{i,k}$  = the number of fibre snippets measured for the  $k$ th class interval

$d_k$  = the nominal diameter of the  $k$ th class interval of the measured diameter distribution where  $k = 0, 1, 2, \dots, m$

**Note 2:** The value of  $m$  is determined from the number of class intervals, the micrometre value of each class interval, and the range of micrometre values incorporated in the diameter distribution. For IWTO-12 and IWTO-47,  $m = 80$  and for IWTO-8,  $m = 40$ . This assumes 1 micrometre class intervals for the former and 2 micrometre class intervals for the latter, and a range of 80 micrometres in both instances. However these restrictions do not affect the generality of equation 6.2.5. They are imposed by the measuring instrument design.

(b) For the delivery

$M$  = nett greasy mass (kg)

$B$  = Wool Base (%)

$D$  = Mean Fibre Diameter ( $\mu\text{m}$ )

$C$  = Fractional Coefficient of Variation of Diameter

$S$  = estimated Standard Deviation of Diameter ( $\mu\text{m}$ )

and  $n_k$  = the calculated number of snippets in the  $k$ th class interval where  $k = 0, 1, 2, \dots, m$

## 6.2.2 Combination Calculations

### 6.2.2.1 Mean Fibre Diameter

The Mean Fibre Diameter of a delivery of wool, determined by a method such as the Airflow Method, where distribution data are not available, shall be calculated from equation (6.2.1)\*.

$$D = \frac{MB}{\sum_{i=1}^q \frac{M_i B_i}{D_i}} \quad (6.2.1)$$

The Mean Fibre Diameter of a delivery of wool, determined by an IWTO test method which provides the distribution data, shall be calculated from equation (6.2.2).

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\* The procedure has been discussed by Fell, Andrews and James, J. Text. Inst., 1972, 63, 125.

$$D = \frac{\sum_{i=1}^q \left( \frac{M_i B_i}{D_i (1 + C_i^2)} \right)}{\sum_{i=1}^q \left( \frac{M_i B_i}{D_i^2 (1 + C_i^2)} \right)} \quad (6.2.2)$$

#### 6.2.2.2 Fractional Coefficient of Variation

The Fractional Coefficient of Variation of Fibre Diameter of a delivery of wool, where the Mean Fibre Diameter has been obtained using an IWTO test method which provides the distribution data, shall be calculated from equation (6.2.3).

$$C = \left[ \frac{\sum_{i=1}^q M_i B_i}{D^2 \sum_{i=1}^q \left( \frac{M_i B_i}{D_i^2 (1 + C_i^2)} \right)} - 1 \right]^{\frac{1}{2}} \quad (6.2.3)$$

The unrounded Mean Fibre Diameter and the unrounded Fractional Coefficient of Variation shall be used in the determination of equation (6.2.3).

#### 6.2.2.3 Standard Deviation

The Standard Deviation of the Fibre Diameter Distribution of a delivery of wool shall be calculated from equation (6.2.4).

$$S = CD \quad (6.2.4)$$

#### 6.2.2.4 Fibre Diameter Distribution

The Fibre Diameter Distribution for a delivery of wool shall be calculated from equation (6.2.5):\*

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\* P J Semmel and P J Sommerville, "Mathematical Combination of Measured Fibre Diameter Histograms for Greasy and Scoured Wool", IWTO Raw Wool (Technical) Group, Nice, Dec. 1995.

$$n_k = \left[ \sum_{i=1}^q \left( \frac{M_i B_i n_{i,k}}{\sum_{k=0}^m d_k^2 n_{i,k}} \right) \right] * \left[ \frac{\sum_{k=0}^m \sum_{i=1}^q n_{i,k}}{\sum_{k=0}^m \sum_{i=1}^q \left( \frac{M_i B_i n_{i,k}}{\sum_{k=0}^m d_k^2 n_{i,k}} \right)} \right] \quad (6.2.5)$$

### 6.2.3 Precision

Tables 6.2.1 and 6.2.2 show how the 95% Confidence Limits for the Mean Fibre Diameter and for the Standard Deviation in Fibre Diameter of a delivery vary, respectively, according to the number of component tests conducted. Details of precision are given in Appendix A.

**TABLE 6.2.1**  
**Example of Precision of Combined Mean Fibre Diameter Tests**  
**for a 500 Bale Delivery**  
 (Australian Wool, 25µm)

| Bales<br>per<br>Test Lot | Test Lots<br>in<br>Delivery | 95% Confidence Limits (±) of Mean Fibre Diameter<br>for Total Delivery |            |            |            |
|--------------------------|-----------------------------|------------------------------------------------------------------------|------------|------------|------------|
|                          |                             | IWTO-8-89                                                              | IWTO-12-95 | IWTO-28-93 | IWTO-47-95 |
| 500                      | 1                           | 0.95                                                                   | 0.48       | 0.57       | 0.48       |
| 100                      | 5                           | 0.42                                                                   | 0.21       | 0.25       | 0.21       |
| 50                       | 10                          | 0.30                                                                   | 0.15       | 0.18       | 0.15       |
| 25                       | 20                          | 0.21                                                                   | 0.11       | 0.13       | 0.11       |

**Note 1:** The precision data in Table 6.2.1 are taken from the relevant Specifications and calculated for the example deliveries using equation A2.1.3 in Appendix A of this Specification. This example uses the confidence intervals for Australian Wool, 25µm, and assumes that the Mean Fibre Diameter of the individual lots in the delivery are similar.

**TABLE 6.2.2**  
**Example of Precision of Combined Standard Deviation**  
**for a 500 Bale Delivery**

(For wool with a standard deviation in diameter of 5µm)

| Bales per Test Lot | Test Lots in Delivery | 95% Confidence Limits (±) of Standard Deviation in Diameter for Total Delivery (µm) |            |            |            |
|--------------------|-----------------------|-------------------------------------------------------------------------------------|------------|------------|------------|
|                    |                       | IWTO-8-89                                                                           | IWTO-12-95 | IWTO-28-93 | IWTO-47-95 |
| 500                | 1                     | NA                                                                                  | 0.23       | NR         | 0.31       |
| 100                | 5                     | NA                                                                                  | 0.10       | NR         | 0.14       |
| 50                 | 10                    | NA                                                                                  | 0.07       | NR         | 0.10       |
| 25                 | 20                    | NA                                                                                  | 0.05       | NR         | 0.07       |

**Note 1:** The precision data in Table 6.2.2 is taken from the relevant Specifications and calculated for the example deliveries using equation A2.1.3 in Appendix A of this Specification. This example uses the limits for 5µm, and assumes that the Mean Fibre Diameter of the individual lots in the delivery are similar.

**Note 2:** Not all test methods report the confidence level for the Standard Deviation. This is indicated by NA (not available). IWTO-28-93 cannot provide an estimate of Standard Deviation and this is indicated by NR (not relevant).

### 6.3 Staple Length, Staple Strength and Position of Break

The combined values of a delivery, shall be calculated as set out in the following.

#### 6.3.1 Notation

- (a) For the  $i$ th lot, where  $i = 1, 2, 3, \dots, q$  and  $q$  is the total number of lots in the delivery:

$B_i$  = Wool Base (%)  
 $M_i$  = nett greasy mass (kg)  
 $L_i$  = Mean Staple Length (mm)  
 $S_i$  = Mean Staple Strength (Newtons/kilotex)  
 $C_i$  = Fractional Coefficient of Variation of Staple Length  
 $X_i$  = Fractional Coefficient of Variation of Staple Strength  
 $Tip_i$  = percentage of staples that broke in the Tip region

$Mid_i$  = percentage of staples that broke in the Middle region

$Bas_i$  = percentage of staples that broke in the Base region

(b) For the delivery:

$L$  = Mean Staple Length (mm)

$S$  = Mean Staple Strength (Newtons/kilotex)

$C$  = Fractional Coefficient of Variation of Staple Length

$X$  = Fractional Coefficient of Variation of Staple Strength

$Tip$  = percentage of staples that broke in the Tip region

$Mid$  = percentage of staples that broke in the Middle region

$Bas$  = percentage of staples that broke in the Base region

### 6.3.2 Combination Calculations

#### 6.3.2.1 Mean Staple Length

The combined Mean Staple Length shall be calculated from equation (6.3.1)\*.

$$L = \frac{\sum_{i=1}^q M_i B_i}{\sum_{i=1}^q M_i B_i / L_i} \quad (6.3.1)$$

#### 6.3.2.2 Mean Staple Strength

The combined Mean Staple Strength shall be calculated from equation (6.3.2).

$$S = \frac{\sum_{i=1}^q M_i B_i S_i / L_i}{\sum_{i=1}^q M_i B_i / L_i} \quad (6.3.2)$$

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\* Formulas in equations (6.3.1), (6.3.2), (6.3.3), and (6.3.4) rest on the hypothesis that staple length and staple linear density are independent within each separate consignment and, moreover, that the average value of the linear density does not change between consignments.

### 6.3.2.3 Coefficient of Variation of Staple Length or Staple Strength

The combined mean Fractional Coefficient of Variation of Staple Length shall be calculated from equation (6.3.3).

$$C = \left[ \frac{\sum_{i=1}^q M_i B_i L_i (C_i^2 + 1)}{L \sum_{i=1}^q M_i B_i} - 1 \right]^{\frac{1}{2}} \quad (6.3.3)$$

The combined mean Fractional Coefficient of Variation of Staple Strength shall be calculated from equation (6.3.4).

$$X = \left[ \frac{\sum_{i=1}^q M_i B_i S_i^2 (X_i^2 + 1)/L_i}{S \sum_{i=1}^q M_i B_i S_i/L_i} - 1 \right]^{\frac{1}{2}} \quad (6.3.4)$$

The unrounded Mean Staple Length and Mean Staple Strength are used in the calculation of the Fractional Coefficients of Variation for Staple Length and Staple Strength respectively.

### 6.3.2.4 Position of Break

The position of break of a delivery indicates the percentage of staples that are expected to break in each of 3 regions (Tip region, Middle region, and Base region) of the consignment. The combined result is calculated using equations (6.3.5), (6.3.6) and (6.3.7):

$$Tip = \frac{\sum_{i=1}^q Tip_i M_i B_i / L_i}{\sum_{i=1}^q M_i B_i / L_i} \quad (6.3.5)$$

$$Mid = \frac{\sum_{i=1}^q Mid_i M_i B_i / L_i}{\sum_{i=1}^q M_i B_i / L_i} \quad (6.3.6)$$

$$Bas = \frac{\sum_{i=1}^q Bas_i M_i B_i / L_i}{\sum_{i=1}^q M_i B_i / L_i} \quad (6.3.7)$$

or

$$Bas = 100 - Tip - Mid \quad (6.3.8)$$

### 6.3.3 Precision

Table 6.3.1 shows how the 95% Confidence Limits for the Staple Length and Staple Strength of a delivery vary according to the component tests conducted.

**TABLE 6.3.1**  
**Example of Precision of Combined Staple Length and Staple Strength**  
**Tests for a 500 Bale Delivery Tested According to IWTO-30-93**

| Bales per Test Lot | Test Lots in Delivery | 95% Confidence Limits (±) of Staple Length for Total Delivery (mm) | 95% Confidence Limits (±) of Staple Strength for Total Delivery (N/kt) |
|--------------------|-----------------------|--------------------------------------------------------------------|------------------------------------------------------------------------|
| 500                | 1                     | 5.3                                                                | 5.9                                                                    |
| 100                | 5                     | 2.4                                                                | 2.6                                                                    |
| 50                 | 10                    | 1.7                                                                | 1.9                                                                    |
| 25                 | 20                    | 1.2                                                                | 1.3                                                                    |

**Note:** The precision data in Table 6.3.1 is taken from IWTO-30-93 and calculated for the example deliveries using equation A2.1.3 in Appendix A of this Specification. The data for 2 operators preparing staples has been used. The example assumes that the Mean Staple

Length and Staple Strength of the individual lots in the delivery are similar.

#### 6.4 Tristimulus Values

The procedure for combining clean colour tristimulus measurements on individual lots is based on the observation of Friele\* that a function  $f(R)$  of the reflectance  $R$  can be defined such that the functions may be combined by a simple weighted averaging. That is, for the additive combination of 2 wools the following equation may be used.

$$(P_1 + P_2) \cdot f(R) = P_1 \cdot f(R_1) + P_2 \cdot f(R_2)$$

where  $P_1$  and  $P_2$  are the clean masses of each portion and Friele's function has the form

$$f(R) = \exp \frac{-0.3(1-R)^2}{2R}$$

The constant, 0.3 is the scattering coefficient, as given by Friele, for loose wool or wool felt.

##### 6.4.1 Notation

- (a) For the  $i$ th lot, where  $i = 1, 2, 3, \dots, q$  and  $q$  is the total number of lots in the delivery:

|                              |                                                                              |
|------------------------------|------------------------------------------------------------------------------|
| $B_i$                        | = Wool Base (%)                                                              |
| $M_i$                        | = nett greasy mass (kg)                                                      |
| $X_i, Y_i, \text{ and } Z_i$ | = the measured Tristimulus Values                                            |
| $R_i$                        | = the equivalent Radiance Factor for $X_i, Y_i, Z_i$ , as appropriate, where |

$$\text{for } X_i: \quad R_i(X) = \frac{1}{78.2} \left( X_i - \frac{19.8}{118.1} Z_i \right) \quad (6.4.1)$$

$$\text{for } Y_i: \quad R_i(Y) = \frac{Y_i}{100} \quad (6.4.2)$$

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\* L F C Friele, J.Text.Inst., 1952, 43, pp 604-611.

and for  $Z_i$ :  $R_i(Z) = \frac{Z_i}{118.1}$  (6.4.3)

$Rp_i(R_i)$  = the value of the Radiance Factor for each Tristimulus Value, corrected for cell losses, where, as a general expression:

$$Rp_i(R_i) = 1.27 R_i - 0.17 R_i^2 - 0.0078 \quad (6.4.4)$$

**Note:** Equation (6.4.4)\* has been derived empirically from measurements of Tristimulus Values behind glass and directly against the port of an ICI colorimeter.

$F_i$  = the value of the Friele function for each corrected radiance value where

$$F_i(Rp_i) = \exp \left[ -0.15 \frac{(1 - Rp_i)^2}{Rp_i} \right] \quad (6.4.5)$$

(b) For the delivery

$X, Y, \text{ and } Z$  = the combined Tristimulus Values  
 $R$  = the equivalent combined Radiance Factor for  $X, Y, Z$  as appropriate, where

for  $X$ :  $R(X) = \frac{1}{78.2} \left( X - \frac{19.8}{118.1} Z \right)$  (6.4.6)

for  $Y$ :  $R(Y) = \frac{Y}{100}$  (6.4.7)

for  $Z$ :  $R(Z) = \frac{Z}{118.1}$  (6.4.8)

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\* B Thompson and M J Hammersley, J.Text.Inst., 1978, 1, pp 1-7.

$R_p(R)$  = the Radiance Factor  $R$ , corrected for cell losses,

where 
$$R_p(R) = 1.27R - 0.17R^2 - 0.0078 \quad (6.4.9)$$

$F$  = the value of the Friele function for each corrected radiance value

where

$$F(R_p) = \exp \left[ -0.15 \frac{(1 - R_p)^2}{R_p} \right] \quad (6.4.10)$$

#### 6.4.2 Combination Calculations

The **Radiance Factors** for **each Tristimulus Value** for each component lot shall be calculated from the measured values of the Tristimulus Values using equations (6.4.1), (6.4.2), and (6.4.3).

The Radiance Factor corresponding to each Tristimulus Value for each component lot shall be corrected for cell losses using equation (6.4.4).

The Friele function for each corrected Radiance Factor for each component lot shall be calculated from equation (6.4.5). This will result in 3 values per lot.

The equivalent Friele functions for the component lots, derived from equivalent Tristimulus Values shall be combined using equation (6.4.11):

$$F = \frac{\sum_{i=1}^q M_i B_i F_i}{\sum_{i=1}^q M_i B_i} \quad (6.4.11)$$

The **corrected** value of **each combined Radiance Factor** for  $X$ ,  $Y$ , and  $Z$  shall then be calculated from equation (6.4.12):

$$R_p = \frac{1}{0.3} \left[ 0.3 - \ln F - \sqrt{(\ln F - 0.3)^2 - 0.09} \right] \quad (6.4.12)$$

The **uncorrected** value of **each combined Radiance Factor** for X, Y, and Z shall then be calculated from equation (6.4.13):

$$R = \frac{I}{0.34} \left[ 1.27 - \sqrt{(1.27)^2 - 0.68 (Rp + 0.0078)} \right] \quad (6.4.13)$$

The combined Tristimulus Values shall be calculated from each combined uncorrected Radiance Factor using transformations of equations (6.4.6), (6.4.7), and (6.4.9) as follows:

$$X = 78.2R(X) + 19.8R(Z) \quad (6.4.14)$$

$$Y = 100R(Y) \quad (6.4.15)$$

$$Z = 118.1R(Z) \quad (6.4.16)$$

### 6.4.3 Precision

Table 6.4.1 shows how the 95% Confidence Limits for the values of X, Y, Z and Y-Z for a delivery vary respectively according to the number of component tests conducted. Details of precision are given in Appendix A.

**TABLE 6.4.1**  
**Example of Precision of Combined Tristimulus**  
**Values for a 500 Bale Delivery**

| Bales per<br>Test Lot | Test Lots in<br>Delivery | 95% Confidence Limits (±) of Tristimulus<br>Values for Total Delivery |                  |                  |                  |                   |
|-----------------------|--------------------------|-----------------------------------------------------------------------|------------------|------------------|------------------|-------------------|
|                       |                          | Blender Method                                                        |                  |                  |                  | Carding<br>Method |
|                       |                          | X                                                                     | Y                | Z                | Y-Z              | Y-Z               |
| 500                   | 1                        | 2.2                                                                   | 2.3              | 3.0              | 1.0              | 1.5               |
| 100                   | 5                        | 1.0                                                                   | 1.0              | 1.3              | 0.4 <sub>5</sub> | 0.6 <sub>7</sub>  |
| 50                    | 10                       | 0.7 <sub>0</sub>                                                      | 0.7 <sub>3</sub> | 0.9 <sub>5</sub> | 0.3 <sub>2</sub> | 0.4 <sub>7</sub>  |
| 25                    | 20                       | 0.4 <sub>9</sub>                                                      | 0.5 <sub>1</sub> | 0.6 <sub>7</sub> | 0.2 <sub>2</sub> | 0.3 <sub>4</sub>  |

- Note 1:** The precision in Table 6.4.1 is taken from the relevant Draft Test Method (DRAFT TM-56) and is calculated for the example deliveries using equation A2.1.3 in Appendix A of this Specification. The calculation assumes that the values for the individual lot are similar.
- Note 2:** The precision data is provided for 2 preparation systems. These are described in Appendix A of DRAFT TM-56.
- Note 3:** This is a Draft Test Method and has not yet been approved as a full test method.

## 7. Calculation of Combined Results by Subtraction

The combined values of the remainder of a delivery, shall be calculated as set out in the following.

### 7.1 Yield and Vegetable Matter Base

#### 7.1.1 Notation

- (a) For the original delivery consisting of  $q$  lots where  $i = 1, 2, 3, \dots, q$

$M_i$  = nett greasy mass (kg) of the  $i$ th lot  
 $B_i$  = Wool Base (%) of the  $i$ th lot  
 $V_i$  = Vegetable Matter Base (%) of the  $i$ th lot  
 $H_i$  = Hard Heads & Twigs Base (%) of the  $i$ th lot  
 $Y$  = calculated Commercial Yield nett clean mass (kg)

- (b) For the remainder of the delivery

$M_r$  = calculated nett greasy mass (kg)  
 $B_r$  = calculated Wool Base (%)  
 $V_r$  = calculated Vegetable Matter Base (%)  
 $H_r$  = calculated Hard Heads & Twigs Base (%)  
 $Y_r$  = calculated Commercial Yield (%)

- (c) For the component subtracted from the original delivery

$M_s$  = nett greasy mass (kg)  
 $B_s$  = Wool Base (%)  
 $V_s$  = Vegetable Matter Base (%)  
 $H_s$  = Hard Heads & Twigs Base (%)  
 $Y_s$  = Commercial Yield nett clean mass (kg)

### 7.1.2 Combination by Subtraction Calculations

For the remainder of the delivery;

the nett greasy mass shall be calculated from equation (7.1.1):

$$M_r = \sum_{i=1}^q M_i - M_s \quad (7.1.1)$$

the Wool Base (%) shall be calculated from equation (7.1.2):

$$B_r = \frac{\sum_{i=1}^q M_i B_i - M_s B_s}{M_r} \quad (7.1.2)$$

the Vegetable Matter Base (%) shall be calculated from equation (7.1.3):

$$V_r = \frac{\sum_{i=1}^q M_i V_i - M_s V_s}{M_r} \quad (7.1.3)$$

the Hard Heads & Twigs Base (%) shall be calculated from equation (7.1.4):

$$H_r = \frac{\sum_{i=1}^q M_i H_i - M_s H_s}{M_r} \quad (7.1.4)$$

and the Commercial Yield (%) shall be calculated from equation (7.1.5):

$$Y_r = \frac{(Y - Y_s) 100}{M_r} \quad (7.1.5)$$

### 7.1.3 Precision After Subtraction

Subtracting a tested component from a delivery results in some loss of precision for the remainder of the delivery. Table 7.1.1 illustrates likely decreases in precision in such cases.

**TABLE 7.1.1**  
**Example of the Reduction in Precision of Wool Base**  
**when 5 % by Mass of the Original Lot is Subtracted**  
 (Australian Merino Fleece Wool, Wool Base 50%)

| Bales per Test Lot | Test Lots in Delivery | 95% Confidence Limits ( $\pm$ ) of Wool Base |                            |                        |
|--------------------|-----------------------|----------------------------------------------|----------------------------|------------------------|
|                    |                       | Original Delivery of 500 Bales               | Subtracted Lot of 25 Bales | Remainder of 475 Bales |
| 500                | 1                     | 1.50                                         | 1.63                       | 1.58                   |
| 100                | 5                     | 0.68                                         | 1.63                       | 0.72                   |
| 50                 | 10                    | 0.49                                         | 1.63                       | 0.53                   |
| 25                 | 20                    | 0.36                                         | 1.63                       | 0.39                   |

**Note 1:** Example used is the same as in Table 6.1.1.

**Note 2:** Variance of the remainder is calculated using equation A3.1.3, Appendix A.

## 7.2 Fibre Diameter

The combined values of the remainder of a delivery, shall be calculated as set out in the following:

### 7.2.1 Notation

(a) For the original delivery consisting of  $q$  lots where  $i = 1, 2, 3, \dots, q$

$M_i$  = nett greasy mass (kg) of the  $i$ th lot

$B_i$  = Wool Base (%) of the  $i$ th lot

$D_i$  = Mean Fibre Diameter ( $\mu\text{m}$ ) of the  $i$ th lot

$C_i$  = Fractional Coefficient of Variation of the  $i$ th lot

$S_i$  = Standard Deviation of Diameter ( $\mu\text{m}$ ) of the  $i$ th lot

$n_{i,k}$  = the number of fibre snippets measured for the  $k$ th class interval

$d_k$  = the nominal diameter of the  $k$ th class interval of the measured diameter distribution where  $k = 0, 1, 2, \dots, m$

**Note:** The comments in **Note 2** of Section 6.2.1 apply in this instance also.

(b) For the remainder of the delivery

$M_r$  = calculated nett greasy mass (kg)  
 $B_r$  = calculated Wool Base (%)  
 $D_r$  = calculated Mean Fibre Diameter  
 $C_r$  = calculated Fractional Coefficient of Variation  
 $S_r$  = calculated Standard Deviation of Diameter ( $\mu\text{m}$ )  
 $n_{r,k}$  = the number of fibre snippets measured for the  $k$ th class interval

(c) For the component subtracted from the original delivery

$M_s$  = nett greasy mass (kg)  
 $B_s$  = Wool Base (%)  
 $D_s$  = Mean Fibre Diameter ( $\mu\text{m}$ )  
 $C_s$  = calculated Fractional Coefficient of Variation  
 $S_s$  = calculated Standard Deviation of Diameter ( $\mu\text{m}$ )  
 and  $n_{s,k}$  = the calculated number of fibre snippets in the  $k$ th class interval for the delivery where  $k = 0, 1, 2, \dots, m$

## 7.2.2 Combination by Subtraction Calculations

**Note:** Combination by Subtraction for all Fibre Diameter Measurements must be on the basis that the subtracted part is tested using the same test method as the component lots in the original delivery.

### 7.2.2.1 Mean Fibre Diameter

The Mean Fibre Diameter of the remainder of the delivery, when the Mean Fibre Diameter has been determined by a method such as IWTO-28, **where the diameter distribution data are not available**, shall be calculated from equation (7.2.1) as follows:

$$D_r = \frac{M_r B_r}{\sum_{i=1}^q \frac{M_i B_i}{D_i} - \frac{M_s B_s}{D_s}} \quad (7.2.1)$$

The Mean Fibre Diameter of the remainder of the delivery, when the Mean Fibre Diameter has been determined by a method such as IWTO-8, IWTO-12 or

IWTO-47, where the diameter distribution data are available, shall be calculated from equation (7.2.2) as follows:

$$D_r = \frac{\sum_{i=1}^q \left[ \frac{M_i B_i}{D_i (1 + C_i^2)} \right] - \frac{M_s B_s}{D_s (1 + C_s^2)}}{\sum_{i=1}^q \left[ \frac{M_i B_i}{D_i^2 (1 + C_i^2)} \right] - \frac{M_s B_s}{D_s^2 (1 + C_s^2)}} \quad (7.2.2)$$

#### 7.2.2.2 Fractional Coefficient of Variation

The Fractional Coefficient of Variation of the remainder of a delivery shall be calculated from equation (7.2.3) as follows:

$$C_r = \left[ \frac{\sum_{i=1}^q M_i B_i - M_s B_s}{D_r^2 \left[ \sum_{i=1}^q \left( \frac{M_i B_i}{D_i^2 (1 + C_i^2)} \right) - \left( \frac{M_s B_s}{D_s^2 (1 + C_s^2)} \right) \right]} - 1 \right]^{\frac{1}{2}} \quad (7.2.3)$$

The unrounded Mean Fibre Diameter and the unrounded Fractional Coefficient of Variation shall be used in the determination of equation (7.2.3).

#### 7.2.2.3 Standard Deviation

The Standard Deviation of the remainder of a delivery shall be calculated from equation (7.2.4) as follows:

$$S_r = C_r D_r \quad (7.2.4)$$

#### 7.2.2.4 Fibre Diameter Distribution

The Fibre Diameter Distribution of the remainder of a delivery shall be calculated from equation (7.2.5)\* as follows:

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\* P J Sommerville, "Mathematical Combination by Subtraction of Measured Fibre Diameter Distributions of Greasy and Scoured Wool", Report to IWTO Raw Wool (Technical) Group, Cape Town, April 1996.

$$n_{r,k} = \left[ \sum_{i=1}^q \left( \frac{M_i B_i n_{i,k}}{\sum_{k=0}^m d_k^2 n_{i,k}} \right) - \frac{M_s B_s n_{s,k}}{\sum_{k=0}^m d_k^2 n_{s,k}} \right] * \left[ \frac{\sum_{k=0}^m \sum_{i=1}^q n_{i,k} - \sum_{k=0}^m n_{s,k}}{\sum_{k=0}^m \left[ \sum_{i=1}^q \left( \frac{M_i B_i n_{i,k}}{\sum_{k=0}^m d_k^2 n_{i,k}} \right) - \frac{M_s B_s n_{s,k}}{\sum_{k=0}^m d_k^2 n_{s,k}} \right]} \right] \quad (7.2.5)$$

### 7.2.3 Precision after Subtraction

Table 7.2.1 illustrates likely decreases in precision of Mean Fibre Diameter for the remainder of the delivery, when a component is subtracted.

**TABLE 7.2.1**  
**Example of the Reduction of Precision of Mean Fibre Diameter**  
**when 5% by Mass of Original Lot is Subtracted**  
(Australian Wool, 25µm)

| Bales per Test Lot | Test Lots in Delivery | 95% Confidence Limits (±) of Mean Fibre Diameter for Total Delivery (µm) |                            |                        |
|--------------------|-----------------------|--------------------------------------------------------------------------|----------------------------|------------------------|
|                    |                       | Original Delivery of 500 Bales                                           | Subtracted Lot of 25 Bales | Remainder of 475 Bales |
| 500                | 1                     | 0.57                                                                     | 0.57                       | 0.60                   |
| 100                | 5                     | 0.25                                                                     | 0.57                       | 0.27                   |
| 50                 | 10                    | 0.18                                                                     | 0.57                       | 0.19                   |
| 25                 | 20                    | 0.13                                                                     | 0.57                       | 0.14                   |

**Note 1:** Example used is the same as in Table 6.2.1, using Confidence Limits for IWTO-28.

**Note 2:** Variance of the remainder is calculated using equation A3.1.3.

**Note 3:** Other test methods will give slightly different results, depending upon the overall precision of the method. However provided the precisions are similar, a similar trend is to be expected.

### 7.3 Staple Length, Staple Strength and Position of Break

The combined values of the remainder of a delivery, shall be calculated as set out in the following.

#### 7.3.1 Notation

(a) For the original delivery consisting of  $q$  lots, where  $i = 1, 2, 3, \dots, q$

$B_i$  = Wool Base (%)  
 $M_i$  = nett greasy mass (kg)  
 $L_i$  = Mean Staple Length (mm)  
 $S_i$  = Mean Staple Strength (Newtons/kilotex)  
 $C_i$  = Fractional Coefficient of Variation of Staple Length  
 $X_i$  = Fractional Coefficient of Variation of Staple Strength  
 $Tip_i$  = percentage of staples that broke in the Tip region  
 $Mid_i$  = percentage of staples that broke in the Middle region  
 $Bas_i$  = percentage of staples that broke in the Base region

(b) For the remainder of the delivery

$L_r$  = calculated Mean Staple Length (mm)  
 $S_r$  = calculated Mean Staple Strength (Newtons/kilotex)  
 $C_r$  = calculated Fractional Coefficient of Variation of Staple Length  
 $X_r$  = calculated Fractional Coefficient of Variation of Staple Strength  
 $Tip_r$  = calculated percentage of staples that broke in the Tip region  
 $Mid_r$  = calculated percentage of staples that broke in the Middle region  
 $Bas_r$  = calculated percentage of staples that broke in the Base region

(c) For the component subtracted from the original delivery

$M_s$  = nett greasy mass (kg)  
 $B_s$  = Wool Base (%)  
 $L_s$  = Mean Staple Length (mm)  
 $S_s$  = Mean Staple Strength (Newtons/kilotex)  
 $C_s$  = Fractional Coefficient of Variation of Staple Length  
 $X_s$  = Fractional Coefficient of Variation of Staple Strength  
 $Tip_s$  = percentage of staples that broke in the Tip region  
 $Mid_s$  = percentage of staples that broke in the Middle region  
 $Bas_s$  = percentage of staples that broke in the Base region

### 7.3.2 Combination by Subtraction Calculations

#### 7.3.2.1 Mean Staple Length

The Mean Staple Length for the remainder of a delivery shall be calculated from equation (7.3.1)\*.

$$L_r = \frac{(M_r B_r)}{\sum_{i=1}^q \frac{M_i B_i}{L_i} - \frac{M_s B_s}{L_s}} \quad (7.3.1)$$

#### 7.3.2.2 Mean Staple Strength

The Mean Staple Strength for the remainder of a delivery shall be calculated from equation (7.3.2).

$$S_r = \frac{\sum_{i=1}^q \frac{M_i B_i S_i}{L_i} - \frac{M_s B_s S_s}{L_s}}{\sum_{i=1}^q \frac{M_i B_i}{L_i} - \frac{M_s B_s}{L_s}} \quad (7.3.2)$$

#### 7.3.2.3 Coefficient of Variation of Staple Length or Staple Strength

The mean Fractional Coefficient of Variation of Staple Length for the remainder of a delivery shall be calculated from equation (7.3.3).

$$C_r = \left[ \frac{\sum_{i=1}^q M_i B_i L_i (C_i^2 + 1) - M_s B_s L_s (C_s^2 + 1)}{L_r \left( \sum_{i=1}^q M_i B_i - M_s B_s \right)} - 1 \right]^{\frac{1}{2}} \quad (7.3.3)$$

The mean Fractional Coefficient of Variation of Staple Strength for the remainder of a delivery shall be calculated from equation (7.3.4).

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\* Formulas in equations (7.3.1), (7.3.2), (7.3.3), and (7.3.4) rest on the hypothesis that staple length and staple linear density are independent within each separate consignment and moreover, that the average value of the linear density does not change between consignments.