Recognition of Cottonscope, an instrument for testing cotton fibre maturity, fineness, ribbon width and micronaire

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1. **Instrument**
   - ***Instrument:*** Cottonscope (see Figure 1)
   - ***Target type of recognition:*** Testing for cotton classing houses, spinning mills and related quality assurance purposes.
   - ***Prototype or full recognition:*** Full recognition

Fig. 1 Cottonscope instrument

2. **General description:** This test method covers the determination of cotton fibre linear density or gravimetric fineness (herein referred to as fineness), ribbon width, maturity and Micronaire using the Cottonscope instrument.

   Samples for Cottonscope are any loose, chemically untreated cotton fibre specimens. Fibre samples can be taken before harvest from the plant, during and after ginning, during mill processing or unravelled from any unscoured and chemically untreated cotton yarn or fabric.

   Cottonscope is a proprietary instrument that measures the average (gravimetric) fineness (herein referred to as fineness) (H), ribbon width (D), maturity (M) and Micronaire (X) of cotton fibre. The instrument also provides distributions of the M and D results.

3. **Target Group:** Low volume classification, quality assurance (in cotton breeding, gins and spinning mills) and industrial research.

4. **Function Principle:** Loose cotton fibres are cut into snippets approximately 0.9 mm long using a purpose built guillotine or mechanical corer. Longer snippets, i.e., >1.5 mm can be measured but are more likely to be entangled after cutting and be less dispersed in solution when added to the instrument's measurement bowl. A large number of

entangled snippets affects the accuracy and precision of measurements. The snippets are weighed, dropped into the instrument's water filled bowl and dispersed by a magnetic stirrer so that they spread randomly across the instrument's camera viewing port, which is submerged in the bowl and illuminated using polarized light. A 50 mg specimen cut from a cotton sample of average fineness, e.g. between 160 and 200 mtex, will produce >200,000 snippets. Colour digital images of the snippets, which are magnified 5X, are captured by the camera and analysed by proprietary software to determine values of H, D, M and X.

Twenty thousand (20,000) snippets are measured per test. This means that no more than 10% of the total population of snippets (200,000) are measured in a 50 mg specimen from a sample of average fineness. The randomness with which snippet (images) are captured and measured is improved by a magnetic stirrer that randomly switches rotation direction in the water bowl, altering the direction of the suspended snippets.

The polarized light source that illuminates the snippets in the water bowl generates contrasting colour images between mature and immature cotton fibre snippets. Mature fibres are red and immature fibres are clear or dark grey (see Figure 2).

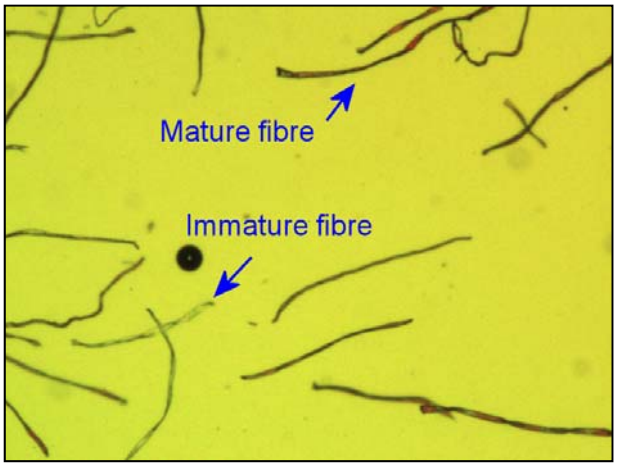

Fig. 2 Mature and immature fibres (as indicated) in the Cottonscope field-of-view

5. **Usefulness/benefits:**
   - ***Able to differentiate fine, mature cotton fibre from coarse, immature fibre.***
     The instrument measures fineness and maturity independently, so that independent results for both are given.

     Micronaire, which has traditionally been used as a measure of fibre fineness, actually measures fibre specific surface area or surface area per unit weight. As a result its values vary concomitantly with both maturity and fineness (see Figure 3). The situation arises therefore where cotton with the same Micronaire value can have very different properties in terms of its textile quality and processing efficiency.

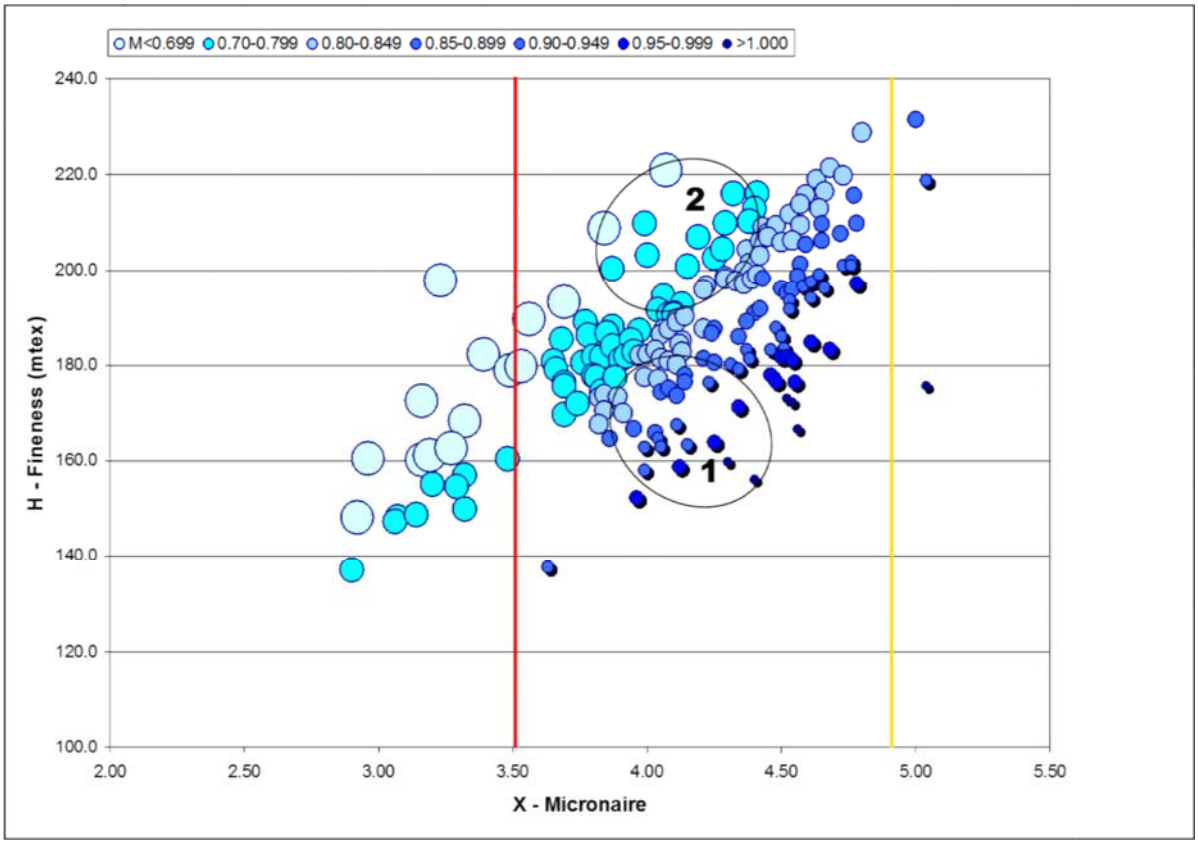

Fig. 3 Relationship between Micronaire (X), fineness (H) and maturity (M). The points indicated in group 1 highlight cotton bales that are both fine and mature. The points indicated in group 2 are coarser and less mature. However, the cotton bales in both groups have the same ranges of Micronaire.

- ***Fineness values are determined by direct principle***, i.e. by the cut and weigh method.
- ***Maturity and ribbon width values are determined by direct principle***, i.e. by interference colour according to ASTM Test Method 1442 and width analysis of polarized light microscope images respectively.
- ***Distribution of maturity and ribbon width vales are given.***
- ***Maturity and ribbon width values can be tested without pre-conditioning test samples.***
- ***Cottonscope test specimens are small (50 mg)*** meaning that very small fibre samples, e.g., fibre from immature bolls or unravelled from raw yarn, can be evaluated.

6. Application Range of Testing:

- ***Range of recognition:*** Cottonscope is calibrated to measure H, D, M and X values on any form of raw cotton, e.g., harvested directly from the plant through to intermediate mill products such as sliver and fibres that have been unravelled from raw yarn or fabric. Note that woven raw fabric should be washed to remove any sizing agent(s), air or oven dried and reconditioned under standard temperatures and humidity before testing.

- ***Additional range:*** Cottonscope can also be used to measure the fineness and ribbon width of other staple fibres and/or filaments that can be cut into snippets and dispersed in the instrument's water bath.

7. Results parameters and definitions:

- ***See also TABLE 1.***
- ***Fibre maturity (M)*** is defined as per the criteria described in ASTM Test Method D1442. The maturity (ratio) scale by this method ranges from 0 to 1.2. The value is low for immature fibres and high for mature fibres. The Cottonscope software calculates maturity ratio values for individual fibres captured by the camera and builds a histogram to represent the distribution of values in the test specimen. The shape of the histogram can also be used as a parameter to identify plant growth and processing consequences on fibre maturity.

  Figures 4(a) and (b) show screen views from the instrument including the distribution diagrams for M and D respectively.

- ***(Gravimetric) fineness (H)*** is measured as a factor of concentration of fibre snippets and their combined length dispersed in the instrument's water bowl. The water bowl has a fixed volume, which allows the concentration of fibre snippets in a given specimen to be determined. Only average values of H are given.
- ***Ribbon width (D)*** is defined as the width of the fibre at any point along its length. The Cottonscope software measures ribbon width for each fibre and builds a histogram to represent the distribution of values in the test specimen. The shape of the histogram can also be used as a parameter to identify plant growth and processing consequences on fibre ribbon width.
- ***Micronaire (X)*** is calculated from average M and H values using Lord's equation[1].

[1] Lord, E., Air Through Plugs of Textile Fibres, Part II. The Micronaire Test for Cotton, *J. Textile Inst.*, **47**, T17-T47, 1956

TABLE 1 – Cottonscope reported parameters and statistics

Parameter	Nominal range[2]	Unit	Reported statistics
Maturity (M) *(direct measure)*	0.60-1.20	NA	Average Standard deviation Frequency distribution
Fineness (H) *(direct measure)*	110-350	Millitex (mg/km)	Average
Ribbon width (D) *(direct measure)*	12-27	Microns (10^{-6} m)	Average Standard deviation Frequency distribution
Calculated Micronaire (X)	2.6-5.6	µg/inch	Average Standard deviation

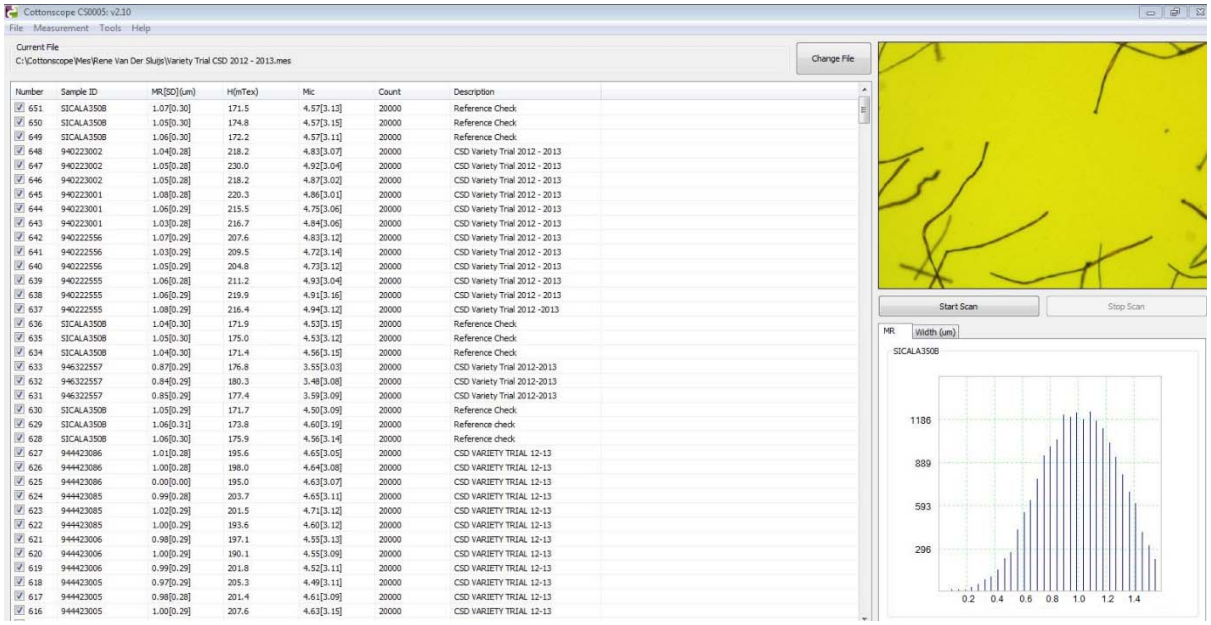

Fig. 4(a) Screen view of the Cottonscope instrument showing maturity distribution

[2] Nominal range of average values found in the majority of commercially harvested cotton across different regions, varieties and species

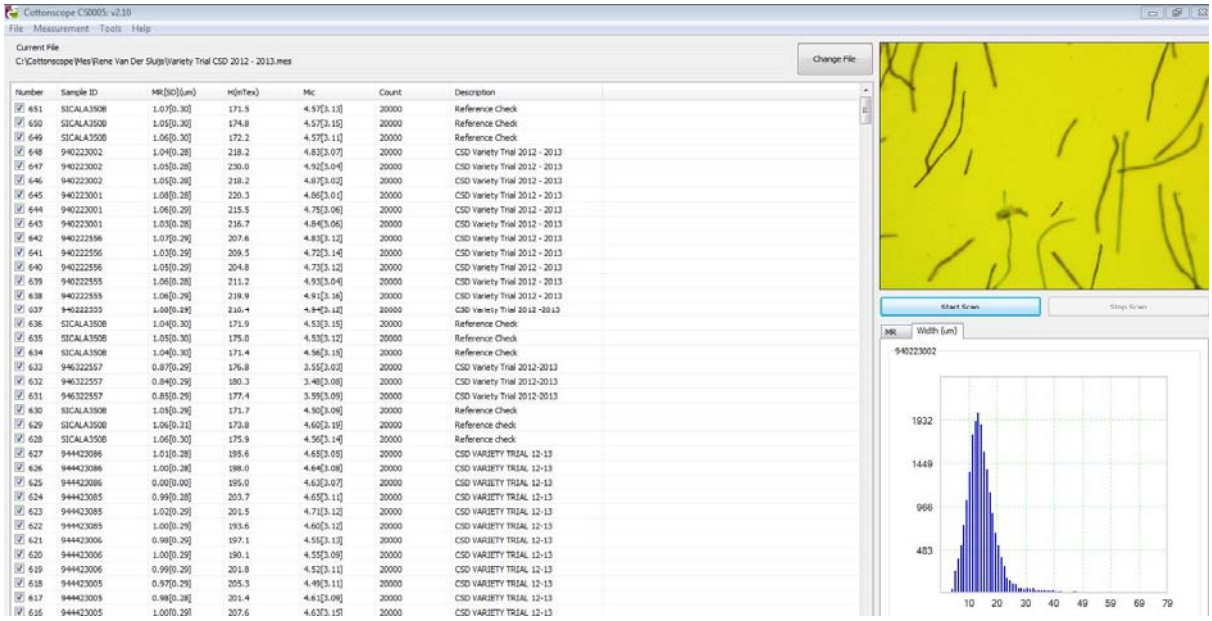

Fig. 4(b) Screen view of the Cottonscope instrument showing ribbon width distribution

8. **Testing procedure:**
   - ***Recommended number of tests:*** Regimes for sampling test specimens from fibre samples or lots need to be determined using competent statistical analyses. Between 3 and 5 specimens (of 50 mg) are typically measured per sample.
   - ***Description:*** Sampled fibres are guillotined (see Figure 5) or cored to produce snippets for testing. Each test specimen shall weigh 50.0 ±0.5 mg. Use a brush to thoroughly clean the preparation area, weighing tray and cutting device or guillotine of snippets before preparing the next sample. Weighed snippets are tipped into the instrument's water bowl and allowed to submerge and then disperse. Once the snippets are dispersed, start the test.

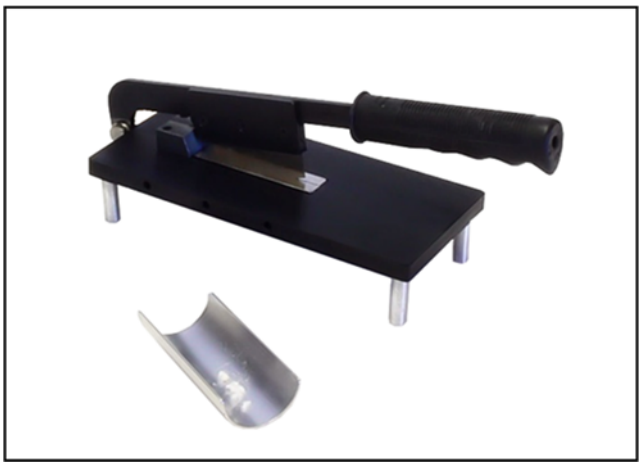

Fig. 5 Picture of benchtop guillotine used to prepare fibre snippets for evaluation

   - ***Necessary surrounding:*** The Cottonscope instrument should be located on a vibration free table or bench top in a dry, low draft location away from direct sunlight.

9. **Testing preparation time, sample preparation time and test time:**

- ***Testing preparation time:*** Preparation of instrument for measurement without water change (once per week or as required) is less than five minutes. This period allows for the instrument's LED lights to warm-up and for the pump to reprime and check flow.
- ***Sample preparation time:*** Depends on sample. Samples for H analysis and for X calculation are required to be conditioned as per ASTM Test Method D1776, i.e. 24 hours passive conditioning under standard conditions. Maturity and ribbon width values do not require samples to be conditioned. An experienced operator who is also preparing, i.e. guillotining and weighing, specimens can complete 180 tests per eight hour day.
- ***Test time:*** One test specimen (20,000 snippets) takes less than 30 seconds to be measured and discharged from the instruments water bowl. Including snippet preparation one test can be completed by an experienced operator in 2 minutes and 40 seconds.

10. Reference method, reference materials:

- ***Reference material:*** Cottonscope values have been judged against H, M and D values produced by tedious examination of individual, magnified fibre cross-sections. Relationships with equivalent values by these and other test methods are highly significant[3, 4, 5, 6] particularly if the number of cross-sections analysed is high (>3000) and the cross-sections are carefully prepared and measured[7, 8].
- ***Calibration material:*** Cottonscope algorithms were calibrated using known cotton standards from a dedicated reference set of cottons produced by Hequet *et al*[9]. Samples from this reference set were measured on the manufacturer's standard instrument
- ***How to calibrate:*** The instrument calibration is stable, however it is recommended instruments should be recalibrated on a monthly basis using the same or similar calibration routine within the Cottonscope software. The calibration is used to check the instrument's light levels, which determine the clarity and colour of the camera images, which are analysed to produce the reported results. The instrument calibration uses cotton and polyester fibre reference samples, which cover ~~the entire~~ a range of measurements for H, M and D. A minimum of five reference or calibration samples is preferred for each variable. Examples of current calibration sample reference values are shown in Table 2. The calibration procedure is progressed using

[3] Gordon, SG and Phair, NL, An investigation of the interference colours transmitted by mature and immature cotton fiber under polarized light microscopy, *Proceed. Beltwide Cotton Conferences, 2005 New Orleans, 2284-2290*

[4] Abbott, AM, Higgerson JG, Long, RL, Lucas, SR, Naylor, GRS, Tischler, C and Purmalis, MM, An instrument for determining the average fiber linear density (fineness) of cotton lint samples, *Textile Research Journal Vol 80(9): 822–83*

[5] Rodgers J, Delhom C and Fortier C, Rapid measurement of cotton fiber maturity and fineness by image analysis microscopy using the Cottonscope. *Text. Res. Journal 2012 Vol 82(2): 259–271*

[6] Paudel D, Hequet E and Abidi N, Evaluation of cotton fiber maturity measurements. *Industrial Crops and Products* 45 2012, pp 435-44

[7] Higgerson, GJ, Pate, M and Naylor, GRS, Determination of cotton fiber maturity and linear density (fineness) by examination of fiber cross-sections. Part 1: Comparison of two image analysis systems used in conjunction with optical microscopy *Textile Research Journal 2013 Vol. 83(13): 1398-1413*

[8] Naylor, GRS, Pate, M and Higgerson, Determination of cotton fiber maturity and linear density (fineness) by examination of fiber cross-sections. Part 2: A comparison optical and scanning electron microscopy *Textile Research Journal 2014 84(18): 1939-1947*

[9] Hequet, E. F., B. Wyatt, N. Abidi and D. P. Thibodeaux. 2006. Creation of a set of reference material for cotton fiber maturity measurements. Textile Res J. 76(7): 576-586

the instrument's software. Follow software prompts to initiate, store and select calibrations.

TABLE 2 – Example of Cottonscope calibration fibre values

Cottonscope Reference Results				
Sample ID	**H (mtex)**	**M**	**D (um)**	**X**
31105	268.4	0.890	16.52	5.48
gm-39	136.1	0.598	16.27	1.92
5740	160.7	0.785	15.42	3.36
5741	193.8	0.888	15.35	4.45
5742	248.5	0.895	15.96	5.06
PL7*	-	-	27.54	-
PL12*	-	-	17.99	-
PL14*	-	-	13.05	-

*Polyester staple fibre. Other listed fibre is cotton.

11. Applicable Standard Test Methods:

- *ASTM Test Methods:* D123 Terminology Relating to Textiles;
- D1441 Sampling of Cotton Fibers for Testing;
- D1442 Maturity of Cotton Fibers (Sodium Hydroxide Swelling and Polarized Light Procedures);
- D1448 Micronaire Reading of Cotton Fibers;
- D1776 Conditioning and Testing Textiles and
- D7139 Terminology for Cotton Fibers

12. Test Result Repeatability/Reproducibility

The precision of this test method is based on an inter-laboratory study of the test method for H, M, D and X values conducted in 2012/13. Three laboratories tested 104 different samples[9] a total of nine times for each property. Every "test result" represents represented an individual determination of at least 20,000 fiber snippets.

Repeatability (r) - The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

Repeatability can be interpreted as maximum difference between two results, obtained under repeatability conditions, that which is accepted as plausible due to random causes under normal and correct operation of the test method. Repeatability limits are listed in Tables 3 - 6 below.

Reproducibility (R) - The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

Reproducibility can be interpreted as maximum difference between two results, obtained under reproducibility conditions, that which is accepted as plausible due to random causes under normal and correct operation of the test method. Reproducibility limits are listed in Tables 3 - 6 below.

Any judgment in accordance with the above statements would have an approximate 95% probability of being correct.

Table 3. Fineness H (units) millitex (mg/km)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Mean	**197.9**	**8.5**	**9.7**	**23.9**	**27.0**
Maximum	264.4	21.8	21.8	61.1	61.1
Minimum	142.4	4.5	4.5	12.7	12.7

Table 4. M (units) no units – a ratio of fibre (cell) wall thickening

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Mean	**0.825**	**0.007**	**0.011**	**0.020**	**0.030**
Maximum	0.926	0.037	0.044	0.105	0.123
Minimum	0.625	0.004	0.005	0.011	0.015

Table 5. Ribbon width D (units) microns µm (10^{-6} m)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Mean	**15.080**	**0.121**	**0.320**	**0.338**	**0.895**
Maximum	17.277	0.275	0.684	0.769	1.915
Minimum	13.566	0.068	0.193	0.190	0.541

Table 6. Calculated Micronaire (units) no units (nominally µg/inch but no longer directly calibrated with these values)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Mean	**4.266**	**0.073**	**0.108**	**0.204**	**0.301**
Maximum	5.474	0.454	0.549	1.271	1.538
Minimum	1.877	0.038	0.051	0.105	0.143

- ***Precision:*** The difference between specimens from the same sample of irrigated, machine picked and saw-ginned cotton measured repeatibly in standard conditioned laboratory using well trained operators will acheive CVs for the following properties: M < 1.7%, H < 5.0% and D < 1.0%***.***

  The measurement of a consistent quality, machine picked cotton using a test regime of one in three bales (with two specimens tested per bale sample), provided a precision of between 4 and 5% for X, between 1.2 and 1.5% for M, less than 1% for D and between 6.8 and 7.5% for H[10]. These values incorporate between bale and instrument variance but not inter-laboratory variance. It is noted these values (for X and M) were similar or better than high volume instrument values.

  Precision is improved by increasing the number of sub-samples measured per bale.

- ***Bias:*** For reliable measurement of fineness, care is required to precisely measure the weight of the sample. The average sample size is 50 mg and a 1 mg error translates to a 2% error in the fineness result.

- ***Differences:*** It is advised if there are differences of practical significance between reported tests for two or more instruments or laboratories, comparative tests should be performed to determine any statistical or operational bias between them, using competent statistical analysis. Ideally, these tests are performed using the same homogenous material.

13. Comparison to reference method: Cottonscope values have been judged against maturity, fineness and ribbon width values produced by tedious examination of individual, magnified fibre cross-sections. Relationships with equivalent values by these and other older test methods are highly significant.

14. Comparison to other test methods in Round Trials: No formal comparisons in Round Trials, e.g. the Bremen Round Trials, have been completed, although comparisons of Cottonscope results with other test methods have been published in peer review literature – see list of published references appended to this case.

[10] Gordon, S., Precision of Cottonscope data, Presentation to ICCTM Meeting, Bremen 2014.

15. Manufacturer-independent check: NA

16. External influences/measurement uncertainty:

- If sample preparation and calibration proceed according to established procedures then random variation between test results of the same sample are minimized. A balance with an accuracy to four significant places (0.0000 grams) is required to obtain accurate and precise snippet weights (50.0 milligrams).
- Variation due to specimen preparation arises when loose fibre samples are unduly compressed during cutting with the guillotine resulting in clumped fibre snippets that then do not disperse properly in the instrument's water bowl. To ensure this does not happen, or to limit this occurrence, the fibre bundle should not exceed a linear density of four grams per meter (4 ktex).
- Variation in specimen preparation between the guillotine and pneumatic corer can be countered by developing instrument calibrations specific to the preparation method.
- Specimen preparation areas (guillotine and balance) need to be kept clean of excess fibre snippets to avoid cross-contamination.
- The daily measurement of a control cotton fibre is recommended to ensure instrument stability is checked routinely. There is no method prescribed in this standard for preparing a control cotton. However, it is noted that a daily control cotton can be prepared by obtaining a large enough amount of the same cotton and ensuring that it is uniformly blended. Sliver from the drawing process in a mill represents an excellent control cotton for the Cottonscope, or cotton from a single bale that has been mechanically opened and then thoroughly blended.
- Accurate test specimen weight is important for precise fineness values. For the average specimen size of 50 milligrams, a one milligram error translates to a 2% error in the fineness value.
- The specimen should be free of plant trash (leaf, stem and seed pieces), dust and other contaminants. Very small fragments of trash and dust do not immediately effect the instrument's results, however it is understood that these may affect the clarity of the bath over time and thus the clarity of the image required for measurement. When the water bath clarity is affected, the instrument's software provides a warning that either the light level is too low or that the measurements are affected by blockages (fibre clumps, bubbles and/or trash). If this occurs then (i) the camera viewing area should be cleaned with a small brush, (ii) the water in the bath should be changed and/or (iii) samples should be cleaned ahead of specimen preparation.

17. Maintenance and Service:

- Instrument area should be kept clean.
- Water should be replaced weekly or more frequently depending on sample and throughput. Water changes are required more often if trashy and/or dusty cotton is being measured.

18. Additional information: See Operation Manual

19. Technical Data/Instrument Settings: See Operation Manual

20. Manufacturer contact: Instrument and guillotine are available from Cottonscope Pty. Ltd., 13 Willcock Street, Ardross 6153, Western Australia, Phone: +61 8 9316 9499 or Fax: +61 8 9316 9199.

Proponents of this recognition application are Dr Stuart Gordon (CSIRO) stuart.gordon@csiro.au and Mr Hy Hwang (Cottonscope) hyhwang@gmail.com .

21. Responsible ITMF ICCTM Coordinator: Dr Jean-Paul Gourlot (CIRAD)

22. Additional information for reviewers:

- Brims M and Hwang H. Introducing Cottonscope: A rapid and precise measurement of cotton fibre maturity based on Siromat, In: Proceedings of the 2010 Beltwide Cotton Conference, (Bill Robertson ed.), January 4–7, New Orleans, LA, 2010, pp. 1417–1423, National Cotton Council, Memphis, TN, USA.
- Long R, Bange M, Gordon S and Constable, G, Measuring the maturity of developing cotton fibers using an automated polarized light microscopy technique, Text Res J, 2010; **80**: 463–471.
- Naylor G, Gordon S, Hwang H and Brims M, Cottonscope—Rapid, independent and simultaneous measurement of both cotton fiber linear density (fineness) and maturity, In: Proceedings of the 2011 Beltwide Cotton Conference, (Bill Robertson ed.), January 4–7, Atlanta, GA, 2011, pp. 1278–1281, National Cotton Council, Memphis, TN, USA.
- Gordon S and Naylor G, Cottonscope: A new instrument for maturity and fineness measurements. (A) Instrument design, In: Proceedings of the 31st International Cotton Conference, (Friedrich Marquardt ed.). March 21–24, Bremen, Germany, 2012, pp. 133–142. Faserinstuit Bremen e.V., Bremen, Germany.
- Rodgers J and Thibodeaux D, Cottonscope: A new instrument for maturity and fineness measurements. (B) Experimental results and experiences. In: Proceedings of the 31st International Cotton Conference, (Friedrich Marquardt ed.), March 21–24, 2012, Bremen, Germany, 2012, pp. 143–153, Faserinstuit Bremen e.V., Bremen, Germany.