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**Pulps — Determination of fibre length  
by automated optical analysis —**

**Part 2:  
Unpolarized light method**

*Pâtes — Détermination de la longueur de fibre par analyse optique automatisée —*

*Partie 2: Méthode de la lumière non polarisée*





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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 6, *Paper, board and pulps*.

ISO 16065 consists of the following parts, under the general title *Pulps — Determination of fibre length by automated optical analysis*:

- *Part 1: Polarized light method*
- *Part 2: Unpolarized light method*

This second edition cancels and replaces the first edition (ISO 16065-2:2007), of which it constitutes a minor revision with the following changes:

- a new precision statement that complies with the requirements of ISO/TR 24498 has been added.

# Pulps — Determination of fibre length by automated optical analysis —

## Part 2: Unpolarized light method

### 1 Scope

This part of ISO 16065 specifies a method for determining fibre length by automated optical analysis using unpolarized light.

The method is applicable to all kinds of pulp. However, fibrous particles shorter than 0,2 mm are not regarded as fibres for the purposes of this part of ISO 16065 and, therefore, are not included in the results.

NOTE ISO 16065-1 deals with the determination of fibre length using polarized light.

### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 638, *Paper, board and pulps — Determination of dry matter content — Oven-drying method*

ISO 4119, *Pulps — Determination of stock concentration*

ISO 5263-1, *Pulps — Laboratory wet disintegration — Part 1: Disintegration of chemical pulps*

ISO 5263-2, *Pulps — Laboratory wet disintegration — Part 2: Disintegration of mechanical pulps at 20 °C*

ISO 5263-3, *Pulps — Laboratory wet disintegration — Part 3: Disintegration of mechanical pulps at > 85 °C*

ISO 7213, *Pulps — Sampling for testing*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

#### 3.1

##### **unpolarized light**

light composed of light waves whose planes of vibration are randomly oriented

#### 3.2

##### **mean length**

*L*

total length of all fibres counted divided by the number of fibres

Note 1 to entry: See Formula (3).

**3.3**  
**length-weighted mean length**

$L_l$   
average of the length-weighted fibre-length distribution

Note 1 to entry: See Formula (4).

**3.4**  
**mass-weighted fibre length**

$L_w$   
average of the mass-weighted fibre-length distribution

Note 1 to entry: See Formula (5).

## 4 Principle

The fibres suspended in the water are routed through a measuring cell, where the lengths of the individual fibres are measured. A suitable unpolarized light source is used to create the high-contrast image between the fibres and the background. The numerical and weighted average fibre lengths and fibre-length distributions of the pulp are calculated.

## 5 Apparatus and auxiliary materials

Ordinary laboratory equipment and the following are required.

**5.1 Fibre-length analyser**, consisting of a measurement section and a sample transport system.

The measurement section consists of a measuring cell, through which the fibres in the water are drawn. There is a uniform unpolarized light source on one side of the cell and a sensitive detector [for example, a charge coupled device (CCD) camera] on the same or on the opposite side of the measuring cell. The flow orientates the fibres into a focal depth no thicker than 0,5 mm normal to the sample flow. The sample flow can be stopped when the CCD camera takes a picture. The detector indicates the fibre length from the image of the fibre. The analyser shall have a resolution that is equal to or better than 100 µm over the range 0 mm to 7 mm, and an accuracy of at least 0,01 mm.

**5.1.1 Measuring system**, constructed so that air bubbles and non-fibrous particles greater than 0,2 mm do not have any effect on the results.

**5.2 Disintegrator**, as described in ISO 5263-1, ISO 5263-2, or ISO 5263-3.

**5.3 Verification fibres**, made of rayon with suggested lengths of about 0,5 mm, 3,0 mm, and 7,0 mm, with an accuracy of 0,01 mm.

The fibres shall be provided by the producer of the analyser, together with statistical data showing the mean length and the length distribution of each type of verification fibre.

**5.4 Reference pulp**<sup>1)</sup>, a commercial reference pulp is available. A quantity of pulp for which the length-weighted fibre length has previously been determined, using this part of ISO 16065.

NOTE In-house reference pulp can also be used.

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1) Reference pulp is available, for example, from the device supplier or the National Institute of Science & Technology, Gaithersburg, MD, USA (NIST). The reference pulp is provided in sheet form. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

**5.5 Dilution water**, free of non-fibrous material and air bubbles greater than 5 µm, and having an evaporation residue less than 50 mg/l.

Non-fibrous particles can be removed from the water by filtering (pore size of 5 µm) and the air bubbles can be removed by the application of heat, vacuum, and/or a settling time.

## 6 Sampling

If the test is being made to evaluate a pulp lot, the sample shall be selected in accordance with ISO 7213. If the test is made on another type of sample, report the source of the sample and, if possible, the sampling procedure used.

From the sample received, select the specimens so that they are representative of the whole sample.

## 7 Preparation of sample

### 7.1 Disintegration

If the sample is in dried form, determine the dry matter content, in accordance with ISO 638. If the sample is in slush form, determine the stock concentration, in accordance with ISO 4119.

**NOTE** It is preferable to measure the never-dried pulps without disintegration, because excessive disintegration can generate fines and reduce the fibre length in some pulps.

#### 7.1.1 Dry pulp samples

If the sample is in dried form, tear the specimens into pieces before soaking. Tear the pieces evenly throughout the thickness of the pulp sheet. By visual assessment, ensure that the fibres are properly separated. Do not cut the sample, as this will cause fibre shortening. Soak the specimen, according to the relevant part of ISO 5263.

Disintegrate the specimens, if required (see the note in [7.1](#)), using the apparatus described in the relevant part of ISO 5263. If the disintegrator described in ISO 5263 is used, the soaking time, the oven-dry mass of the pulp, the amount of water to be used in the disintegration, and the number of revolutions are specified in the relevant part of ISO 5263. Use the dilution water ([5.5](#)). For the removal of latency from the mechanical pulps, follow the recommendations given in ISO 5263-3.

For the pulps containing the fibre bundles [e.g. Canadian high-freeness thermo-mechanical pulp (TMP) and chemithermo-mechanical pulp (CTMP)], it can be difficult to measure the fibre length, since the fibre bundles can plug the flow cell. If plugging occurs, then screening is recommended to remove the fibre bundles. Screening can bias the results since it removes the fibre bundles, which preferentially contain the longer fibres. After screening, ensure that the fibres are completely separated and fully dispersed.

**WARNING — Very long fibres (e.g. hemp, cotton, and flax) can require some special sample preparation techniques if they are so long that part of the fibres are outside the measuring window, or if they cause blocking of the fibre-orientating cell.**

#### 7.1.2 Wet pulp samples

Dilute to the consistency required for accurate measurements, following the instructions in [7.2](#).

The wet pulp samples can contain the fibre bundles, and if plugging occurs, follow the instructions given in [7.1.1](#).

### 7.2 Stock dilution

Stir and take an aliquot from the uniformly dispersed specimen from [7.1](#). Dilute by serial dilution, to the concentration recommended by the instrument's manufacturer, or to that determined by the tests over

the concentration range. When taking the sample, the diluted suspension shall be agitated continuously. Do not stir with a rotary movement because the sample dilution will not be homogenous.

NOTE Pouring the test sample back and forth will achieve the desired agitation.

The recommended mass fraction to be used in this method is 0,010 % to 0,025 % for softwood pulp and 0,004 % to 0,010 % for hardwood pulp. Mixed stocks should be treated as hardwood pulps. In order to get accurate measurements, the suspension shall be diluted using the dilution water ([5.5](#)).

## **8 Procedure**

### **8.1 Measurement procedure**

The suspension shall be agitated continuously to ensure complete mixing. Take at least a 50-ml test portion from the continuously agitated dilute sample. Carry out the test according to the instructions of the instrument manufacturer. The minimum number of fibres to measure shall be that at which the mean length reaches a steady-state variance of 0,01 mm (i.e. measuring more fibres does not change the mean-length value by more than 0,01 mm). If the apparatus does not continuously provide fibre-length values during a test, a minimum of 5 000 fibres shall be measured.

### **8.2 Verification procedure using verification fibres**

#### **8.2.1 General**

Check the performance of the analyser regularly and always after cleaning. A verification procedure shall include a calibration check every week and a performance check every month. If the analyser is used infrequently, check the calibration prior to each use.

#### **8.2.2 Calibration check with verification fibres**

Run a calibration check using the verification fibres ([5.3](#)).

In the check, record the data for at least 5 000 fibres or until a 1 % coefficient of variation (CV) level on the mean-length value is achieved. Prepare a new portion of calibration fibres for each check.

Use only the verification fibres that have been dispersed on the same day as the calibration check is made, since rayon fibres tend to flocculate.

Stir the fibre suspension, when taking an aliquot from the suspension. Ensure that the fibres do not form flocks. If they do, the calibration check cannot be carried out.

It is very important that the pulp suspension is continuously agitated, to prevent the fibres from settling.

Compare the fibre-length data obtained with the data provided for the verification fibres by the manufacturer. If the results of the calibration check lie outside the tolerance limits given, clean the system and run a new calibration check. If the new data still lie outside the tolerance limits, follow the recommendations given by the manufacturer of the analyser.

#### **8.2.3 Performance check using reference pulp**

The calibration check is not sufficient to give a true picture of the functioning of the analyser. Check the performance of the analyser every month using fibres from a reference pulp ([5.4](#)).

Prepare and analyse the reference-pulp sample, following the procedure described in this part of ISO 16065. Compare the data achieved with the specifications of the supplier of the reference pulp, or with the previous performance checks if an in-house reference pulp is used. The tolerance limit for a length-weighted fibre length of chemical pulps is  $\pm 1,5$  %.



If the check data lie outside the tolerances given, clean the analyser and run a new check. If the data are still outside the tolerances given, contact the manufacturer of the analyser for service.

Ensure that the reference material is available for future performance checks. If not, select a suitable material for use as a reference pulp and determine its length-weighted fibre length, using this part of ISO 16065 to provide a basis for future comparisons.

## 9 Calculation and expression of results

### 9.1 Method of calculation

The number of fibres ( $n_i$ ) in each class of length ( $l_i$ ) is counted.

For each class, the percentage frequency by number,  $f_i$ , is calculated using Formula (1)

$$f_i = \frac{n_i}{\sum n_i} \times 100 \quad (1)$$

and the percentage length-weighted frequency,  $f'_i$ , is calculated using Formula (2)

$$f'_i = \frac{n_i l_i}{\sum n_i l_i} \times 100 \quad (2)$$

where

$n_i$  is the number of fibres in the  $i$ th class;

$l_i$  is the central length of the  $i$ th class, in millimetres;

$\sum n_i$  is the total number of fibres in all classes;

$\sum n_i l_i$  is the sum of the products,  $n_i \times l_i$ , for all classes.

### 9.2 Characteristic distribution values

#### 9.2.1 Lengths

Formulae (3), (4), and (5) are used for calculating the required quantities and the mean fibre length (other quantities can also be calculated for particular purposes).

a) The mean length of the fibres:

$$L = \frac{\sum n_i l_i}{\sum n_i} \quad (3)$$

NOTE 1 The numerical mean fibre length is not always the most meaningful indicator of the fibre length, because the effect of short fibres is emphasized. A better formula is often the length-weighted mean fibre length.

b) The length-weighted mean length of the fibres ( $L_l$ ):

$$L_l = \frac{\sum n_i l_i^2}{\sum n_i l_i} \quad (4)$$

c) The mass-weighted fibre length of the fibres ( $L_w$ ):

$$L_w = \frac{\sum n_i l_i^3}{\sum n_i l_i^2} \quad (5)$$

NOTE 2 In the interpretation of the length-weighted mean length, it is assumed that all fibres have identical coarseness. In the interpretation of the mass-weighted fibre length, it is assumed that the fibre coarseness is proportional to the length. This proportionality does not hold for mechanical pulps and pulp mixtures.

### 9.2.2 Coefficient of variation

Calculate the coefficient of variation (%) from the frequency distribution using Formula (6)

$$CV = \frac{s}{L} \times 100 \quad (6)$$

where the standard deviation  $s$ , in millimetres, is given by Formula (7)

$$s = \left( \frac{\sum (l_i - L)^2 n_i}{\sum n_i} \right)^{1/2} \quad (7)$$

However, if the values  $L$  and  $L_l$  are calculated, the coefficient of variation (%) can be calculated using Formula (8)

$$CV = 100 \left( \frac{L_l}{L} - 1 \right)^{1/2} \quad (8)$$

### 9.2.3 Expression of the frequency distribution

If a length-distribution graph is required, express it

- by a frequency diagram representing the number and/or the percentage of the fibres in each length interval employed, expressed as a function of the length and/or
- by a cumulative frequency diagram indicating the percentage as a function of fibres greater than a given length, expressed as a function of the length.

## 10 Test report

The test report shall give the following information:

- a) a reference to this part of ISO 16065 (i.e. ISO 16065-2);
- b) the date and place of testing;
- c) all information for complete identification of the sample;
- d) the type of instrument used;
- e) whether the sample, or specimen, was screened to remove the fibre bundles;
- f) the total number of fibres tested;
- g) the length-weighted mean length and mass-weighted fibre length of the fibres, and, if required, the numerical mean length;
- h) the frequency diagram and the cumulative frequency diagram, if a distribution graph is required;
- i) the class intervals used, if required;
- j) the number of fibres in each class, if required;
- k) any operations not specified in this part of ISO 16065, or in the International Standards to which reference is made, or regarded as optional, which might have affected the results.

## Annex A (informative)

### Precision

#### A.1 General

The precision data are based on five pulp samples [two softwoods, one hardwood, one TMP, and one pressurized groundwood (PGW)] tested by four different laboratories, according to this part of ISO 16065. Four types of commercial apparatus were used, namely, Pulp Expert<sup>2)</sup>, Morfi<sup>2)</sup>, FibreLab<sup>2)</sup>, and Fibre Master<sup>2)</sup>. Each laboratory used a different type of apparatus.

The calculations have been made according to ISO/TR 24498.

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates could not be valid for different materials or different test conditions.

NOTE Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77, where  $2,77 = 1,96 \sqrt{2}$ .

The pooled repeatability and reproducibility data are presented in [Tables A.1](#) and [A.2](#), respectively.

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2) Pulp Expert, Morfi, FibreLab, and Fibre Master are examples of suitable products that may still be available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

## A.2 Repeatability

**Table A.1 — Estimation of the repeatability of the test method**

Sample	Number of laboratories	Length-weighted mean fibre length mm	Standard deviation $s_r$ mm	Coefficient of variation $C_{V,r}$ %	Repeatability limit $r$ mm
Softwood, unrefined	4	2,07	0,027	1,3	0,08
Softwood, refined	4	2,10	0,090	4,3	0,25
Hardwood, unrefined	4	0,75	0,053	7,1	0,15
Thermo-mechanical pulp (TMP) (CSF = 134)	4	1,60	0,037	2,3	0,11
Pressurized ground-wood (PGW) pulp (CSF = 65)	4	0,88	0,040	4,6	0,11

NOTE Canadian Standard Freeness.

## A.3 Reproducibility

**Table A.2 — Estimation of the reproducibility of the test method**

Sample	Number of laboratories	Length-weighted mean fibre length mm	Standard deviation $s_R$ mm	Coefficient of variation $C_{V,R}$ %	Reproducibility limit $R$ mm
Softwood, unrefined	4	2,07	0,11	5,2	0,30
Softwood, refined	4	2,10	0,11	5,3	0,30
Hardwood, unrefined	4	0,75	0,061	8,2	0,17
Thermo-mechanical pulp (TMP) (CSF = 134)	4	1,60	0,27	16,7	0,75
Pressurized ground-wood (PGW) pulp (CSF = 65)	4	0,88	0,17	19,7	0,47

NOTE Canadian Standard Freeness.

## A.4 Comparison of results between instruments using unpolarized and polarized light and by microscopy

The same samples as mentioned above were also analysed with instruments using polarized light and by microscopy. The correlation with the polarized light and microscopy results were 97,9 % and 96,9 %, respectively.

## Bibliography

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- [4] ISO/TR 24498, *Paper, board and pulps — Estimation of uncertainty for test methods*

