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Pulps — Estimation of dirt and shives —

Part 4:
Instrumental inspection by reflected light using Equivalent Black Area (EBA) method

Pâtes — Estimation des impuretés et bûchettes —

Partie 4: Examen instrumental par lumière réfléchie utilisant la méthode de la surface noire équivalente (méthode EBA)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 5350-4 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 5, *Test methods and quality specifications for pulps*.

ISO 5350-4 cancels and replaces ISO 15319:1999, *Recycled pulps — Estimation of visible contraries by instrumental means using reflected light*, because ISO 5350-4 is also intended for recycled pulp.

ISO 5350 consists of the following parts, under the general title *Pulps — Estimation of dirt and shives*:

— *Part 1: Inspection of laboratory sheets by transmitted light*

— *Part 2: Inspection of mill sheeted pulp by transmitted light*

— *Part 3: Visual inspection by reflected light using Equivalent Black Area (EBA) method*

— *Part 4: Instrumental inspection by reflected light using Equivalent Black Area (EBA) method*

Introduction

The level of visible dirt present in pulp can impact its usefulness in a specific end-use application. In such cases, the presence of visible dirt specks which are high in number, easily noticed in visual examination, or both, may detract more from the apparent usefulness of the paper material than does a lower number of specks, or specks which are less easily noticed by the eye. Both the number of dirt specks and their visual impact may be important. For someone controlling or monitoring the paper-making process, the absolute physical area of dirt, or the number of dirt specks present in an inspection area, may be of the greatest importance. For the end user of the paper material, the overall visual impression may be the critical parameter.

This part of ISO 5350 is complementary to ISO 5350-3, which concerns visual inspection of mill pulp by reflected light using the Equivalent Black Area (EBA) method.

ISO 5350-1 and ISO 5350-2 are based on visual inspection by transmitted light.

Pulps — Estimation of dirt and shives —

Part 4:
Instrumental inspection by reflected light using Equivalent Black Area (EBA) method

1 Scope

This part of ISO 5350 specifies a method using instrumental inspection by reflected light for the estimation of visible dirt and shives in pulp manufactured in sheets, in terms of Equivalent Black Area (EBA) of dirt specks within the physical area range of 0,02 mm^2 to 3,0 mm^2. Using the algorithm prescribed in this part of ISO 5350, the maximum dirt size is limited to 3,0 mm^2. Extension to other speck sizes (for example, those greater than 3,0 mm^2 in physical area) may require changes in equipment, calculation procedures, or both, and is not covered in this part of ISO 5350. This part of ISO 5350 cannot be used for physical area measurements, since it may not correctly measure the dirt specks for that mode of measurement.

The specimen to be evaluated should have a brightness, as determined by ISO 3688, of 30 % or greater. It may be necessary to reform some pulp sheets into laboratory sheets, if the surface is too rough or textured.

This part of ISO 5350 is also intended for recycled pulp.

2 Normative references

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

ISO 3688, *Pulps — Preparation of laboratory sheets for the measurement of diffuse blue reflectance factor (ISO brightness)*

ISO 5269-1, *Pulps — Preparation of laboratory sheets for physical testing — Part 1: Conventional sheet-former method*

ISO 5269-2, *Pulps — Preparation of laboratory sheets for physical testing — Part 2: Rapid-Köthen method*

ISO 7213, *Pulps — Sampling for testing*

3 Terms and definitions

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

3.1
sheet
sheet of pulp taken from a bale, or a part of a roll of pulp

3.2
test piece
area taken for inspection

3.3
laboratory sheet
sheet formed from disintegrated pulp

3.4
contrary in pulp
any unwanted particle, of specified minimum size and having a contrasting colour with respect to the surrounding area of the sheet, according to the comparison chart given in Annex B

3.5
dirt
any non-fibrous contrary

3.6
shive
sliver of wood, or fibre bundle

3.7
equivalent black area (EBA)
area of one of the round black spots (a $Y_{c/2}$ value of 2,4 %) that has the same apparent area when examined visually upon its white background (a $Y_{c/2}$ value of 81,5 %) as does the dirt speck when examined visually upon the particular sheet in or upon which it is embedded

NOTE 1 A larger "grey" dirt speck has the same visual impact as a smaller "black" one when viewed on the same sheet and under the same conditions.

NOTE 2 The Equivalent Black Area (EBA) of a dirt speck determined visually is generally less than its physical area. The EBA approaches the physical area only as the speck becomes large.

4 Principle

The test pieces to be examined are inspected on both sides with reflected light. The area of all contraries larger than a specified value and showing contrast, with respect to the surrounding area of the sheet are estimated. The total Equivalent Black Areas (EBA) of the contraries are calculated, and the total number and the total Equivalent Black Area (EBA) of dirt and shives are reported as the number of contraries per square metre and as square millimetre per square metre (number of contraries/m^2 and mm^2/m^2), respectively.

5 Apparatus

An automatic device for counting of contraries shall include the following parts.

5.1 Detector, of the densitometric type, with at least 256 grey levels (G.L.) of sensitivity with the physical pixel resolution having an effective area of 0,020 mm^2 or less. The detector shall view the specimen normal to its surface. The light is un-polarized and is concentrated in the visible portion of the spectrum, such that 95 % of the detected light reflected from a white surface will be between 380 nm and 740 nm with the spectral peak between 500 nm and 600 nm. The illumination shall be diffuse, or axially symmetric, with an incident angle of $45^\circ \pm 5^\circ$. The uniformity of the illumination on the specimen stage before any software corrections shall be within $\pm$ 4 %. The specimen stage shall be shielded to prevent influence from ambient conditions.

NOTE Precision improves with resolution. Therefore it is advisable to have as high a pixel resolution as is practical for the smallest dirt specks. However, to prevent false detections arising from sheet micro-structure, the effective minimum physical pixel resolution must not go below 0,002 mm^2.

5.2 Analyser, incorporating "Equivalent Black Area" (EBA) calculations, and using a technique called the "visual impact parameter" (see [1] in the Bibliography, and Annex A). This parameter permits the system to perceive dirt and shives in the same manner, as would a human judge.

5.3 Certified calibration plates, which shall be matte and have at least one solid white area and a solid black area. There are to be two other image areas containing a minimum of 16 dots, each with a $Y_{c/2}$ value difference to their background of 25 % and 55 %. Each set of certified calibration plates is numbered and provided with a calibration certificate containing the correction factors for the $Y_{c/2}$-reflectance of the dots. Additionally, the certified calibration plates shall meet the specifications in Annex B. These plates are available from TAPPI[1)].

NOTE It is known that large amounts of fluorescence in paper can cause possible problems with the calibration or measurement using this method. However, that effect will be normally minimal, since the reflectance values are measured at the $Y_{c/2}$ value, not at 457 nm for brightness.

6 Sampling

6.1 General

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, make sure that the test portions taken are representative of the whole sample.

6.2 Pulp sheets

From each test unit, select ten or more sheets having a total exposed area (both sides) of at least 10 m^2. Keep the specimen sheets clean between two outer extra sheets.

NOTE There may be instances where less than 10 m^2 is examined. This may be acceptable when the quantity of dirt in the pulp exceeds the minimum required to reach a chosen level of counting precision (see 7.2) and the sample is representative of the manufacturing process.

Some pulp sheets contain deep corrugations, which may cast shadows or prevent consistent detection of the dirt specks at some locations in the sheet. Such pulp sheets shall be reformed into laboratory sheets for examination.

6.3 Slush or flash-dried pulp

Take a sample and form into specimen sheets in a carefully cleaned stainless steel sheet-former, in accordance with ISO 5269-1 or ISO 5269-2. Make a sufficient number of sheets so that they have a total exposed area (both sides) of at least 0,4 m^2. Restrain the sheets while drying on drying plates, taking care to avoid contamination and wrinkling.

NOTE In thick pulp sheets, dirt specks may be embedded throughout the thickness of the sheet. When pulp is reformed into a new product, then these embedded dirt specks may have a different impact.

7 Procedure

7.1 General

Turn on the light source. Allow the equipment to warm up and adjust the hardware settings according to the instructions or recommendations. The system will have reached a steady-state condition when five consecutive G.L. readings are within 2 % of each other.

7.2 Calibration

7.2.1 General

If there is an adjustable focus on the detector, verify that the calibration-plate image is sharply focused.

1) www.tappi.org

7.2.2 Contrast calibration

7.2.2.1 General

Place the calibration plate with the greatest contrast flat on the stage. If a device is used to hold a sample flat on the stage, then this device shall be used to hold the calibration plate flat.

7.2.2.2 Zero adjust

With the black square in the field of view, scan the black area on the plate, adjust the instrument to report a value of not less than 9 out of 255 grey levels, or 3,5 % of the full grey scale. Successive scans of the black area must give results within $\pm$ 0,4 % G.L. values.

7.2.2.3 Span adjust

With the white square in the field of view, scan the white area on the plate, adjust the instrument to report a value not greater than 220 out of 255 grey levels, or 86,3 % of the full grey-level scale (see Note). Successive scans of the white area must give results within $\pm$ 0,4 % G.L. values. A minimum of 210 G.L. resolutions between the black and white squares is required. The grey-level scale shall be precise enough for each grey level to corresponds to a step of not more than 0,5 % reflectance units.

NOTE The $Y_{c/2}$ percent-reflectance and G.L. are linearly related such that 1 % $Y_{c/2} =$ 2,55 G.L. To determine the G.L value of the Black and White calibration plates, multiply the percentage of $Y_{c/2}$ reported on the certificate by 2,55 provided with the set of calibration plates.

Repeat these two adjustments iteratively until both specifications are achieved.

7.2.3 Equivalent Black Area calibration

Measure each of the calibration plates. Verify that all 16 dots are detected and that the EBA results, measured and reported, agree within 10 % of the average of all 16 dots to those determined from the data supplied with the certified calibration plates. To calculate the EBA of the dots on the plates, multiply the nominal area, as stated in the specifications in Annex B, by the corrected contrast difference reported on the certificates provided with the plates. If they do not match, then check the hardware and/or the condition of the calibration plates. If necessary, verify the correct operation of the equipment with the manufacturer for its adherence to this part of ISO 5350.

Due to digitisation, measurement of the smallest dots on the lowest-contrast plate at the minimum resolution prescribed in this method may give a variation greater than 10 % from the actual EBA, when individual dots are evaluated for verification. Verification should be done by using the average EBA of all 16 dots on a plate.

Follow the manufacturers' instructions regarding the equipment maintenance.

The calibration plates should be stored in the dark, or in a black plastic envelope, to prevent discoloration and loss of contrast. They should be cleaned while dry to remove dust or lint. Avoid scratching the surface, as this may cause the plates to no longer conform to the specification. Periodically measure the $Y_{c/2}$ value of the white square. If the calibration plates fall outside the specifications given in Annex B, then they shall be replaced.

Unless the ambient light changes, or the hardware settings have changed, it is not necessary to recalibrate the hardware for a particular analysis. It should be noted that, with time, light sources age and hence there may be a loss of intensity. Thus, full calibration checks and hardware adjustments shall be made as frequently as specified by the manufacturer.

7.3 Examination

Carefully brush away any loose surface-dirt specks. If the specimen is of low basis weight, like tissue, it may be necessary to back the specimen with a clean white sheet of paper before making the measurements. Avoid measuring samples, which contain smudge marks and/or wrinkles, as these could dramatically affect the results.

Follow the measurement procedure outlined in the instruction manual provided by the instrument manufacturer. Care should be taken to ensure that the specimen is held flat enough so that all dirt specks in the field of view are in focus (see 6.2).

Choose a consistent target of counting precision (percentage uncertainty) and measure enough pulp surfaces to reach that precision. By the nature of the sampling of randomly distributed dirt, if one sheet of pulp is found to contain N dirt specks, then replicate sheets of pulp from the same lot should be found to contain $N \pm \sqrt{N}$ dirt specks two times out of three. For example, if a certain area of pulp is found to contain 100 dirt specks, another region with the same area should have (100 $\pm$ 10) dirt specks, or a counting precision of 10 %. If another specimen only contains 25 dirt specks, then replicate areas should contain (25 $\pm$ 5) dirt specks for a counting precision of 20 %. Therefore, to reach a consistent target of 10 % uncertainty in the dirt count, one measures as much pulp surface as needed to reach a minimum count of 100 dirt specks.

The precision of EBA is more complicated to estimate than the counting precision of the dirt count, because the total count is inflated by many small dirt specks that contribute relatively little to the total EBA. To reach a target precision on EBA, one should count at least twice as many dirt specks as would be needed to reach the same precision in the particle count. For example, one would count 200 dirt specks to reach a 10 % precision on EBA.

8 Expression of results

For all contraries, calculate the total equivalent black area, expressed in square millimetres per square metre (mm^2/m^2), and the total number of contraries, expressed in number per square metre ($number/m^2$).

Calculate the uncertainty of counting according to Equation (1)

$$P = \frac{\sqrt{n}}{n} \times 100 \qquad (1)$$

where

P is the uncertainty of counting, expressed in percent (%);

n is the total number of contraries detected.

9 Precision

9.1 General

The precision statement for this part of ISO 5350 is based on data from an interlaboratory trial conducted in 2002. Trial sample materials consisted of newsprint and paperboard. The nominal ISO brightness was about 57 % for the newsprint and about 16 % for the paperboard.

NOTE The scope specifies that this method is applicable to materials that have a brightness of at least 30 %. However, the paperboard used in the precision study was outside the scope of the method but was included because materials with lower brightness are frequently tested using this method. Consequently, the precision statement with the newsprint is most representative of this method.

Repeatability and reproducibility are estimates of the maximum difference (at 95 % confidence) which should be expected when comparing two test results for materials similar to those used in the trial under similar test conditions. These estimates may not be valid for different materials or testing conditions.

9.2 Repeatability

The repeatability estimates were derived from four laboratories for each sample and each test result was the mean of five determinations. In all cases, a sufficient number of particles were counted to keep the percentage uncertainty of counting, P, to under 7 %. The results are shown in Table 1.

Table 1 — Repeatability for determination of total equivalent black area

Sample	Total EBA mm^2/m^2		Number of contraries/m^2	
	Mean value, mm^2/m^2	**Repeatability,** r and (% r)	**Mean value,** Number/m^2	**Repeatability,** r and (% r)
Newsprint	31,9	5,8 (18)	873	148 (17)
Paperboard	107	16,0 (15)	2 567	489 (19)

9.3 Reproducibility

The reproducibility estimates were derived from four laboratories for each sample and each test result was the mean of five determinations. In all cases, a sufficient number of particles were counted to keep the percentage uncertainty of counting, P, to under 7 %. The results are shown in Table 2.

Table 2 — Reproducibility for determination of total equivalent black area

Sample	Total EBA mm^2/m^2		Number of contraries/m^2	
	Mean value, mm^2/m^2	**Reproducibility,** r and (% r)	**Mean value,** Number/m^2	**Reproducibility,** r and (% r)
Newsprint	31,9	15,6 (49)	873	479 (55)
Paperboard	107	114 (107)	2 567	2 565 (100)

10 Test report

The test report shall include the following information:

a) a reference to this part of ISO 5350;

b) the date and place of testing;

c) all information for the complete identification of the samples;

d) the total equivalent black area, in square millimetres per square metre (mm^2/m^2), and the total number of contraries, as the number of contraries per square metre, and the uncertainty as a percent;

e) report whether the test was made on pulp sheets or laboratory sheets;

f) report any deviations from this part of ISO 5350;

g) if a minimum size other than 0,02 mm^2 has been used.

Annex A
(normative)

Equivalent Black Area (EBA) calculations

A.1 Centre-surround filter

First, the digitised image is filtered with a “centre-surround” filter. If the intensity of the pixel at each location (i, j) is called $X(i, j)$, and if the average background in a 1,0 mm^2 area centred on the pixel (i, j) is called $Y(i, j)$ then the filtered intensity $I(i, j) = X(i, j) - Y(i, j)$. There are various ways to estimate the background intensity $Y(i, j)$ but any pixels inside a dirt speck should be excluded from the estimate of $Y(i, j)$. If all the potential filter pixels fall within a dirt speck, then other means may be explored to sense the background immediately around the dirt speck (within 0,5 mm of the speck perimeter). For example, it may be necessary to expand the width of the background filter only at these locations where the usual filter is entirely within a very large speck.

A.2 Contrast threshold

The threshold T is the grey-level increment corresponding to a difference of 10 % reflectance. Each pixel (i, j) is considered “detected” as a part of a speck if $I(i, j) \geqslant T$.

A.3 EBA

The EBA of a speck is proportional to the sum of the $I(i, j)$ values for all “detected” pixels:

$$\text{EBA} = k \sum_{(i,j) \supset [I(i,j) \geqslant T]} I(i, j) \qquad \text{(A.1)}$$

The constant of proportionality is determined by the calibration procedure described in A.5. The total EBA is the sum of all the EBA values from the individual specks.

A.4 Calibration plates

The original EBA scale was established by the TAPPI Dirt Estimation Chart used in TAPPI Test Method T 437 (see [2] in the Bibliography). A 1,0 mm^2 dot on that card has an EBA of 1,0 mm^2 by definition. The Ricco's law (see [1] in the Bibliography) parameter I of such a dot equals the nominal area multiplied by the difference in reflectance of the white card and the black ink. This reflectance difference is 83 %. The calibration plates used for the present method each have their own assigned value of reflectance difference between background and dot. For example, one of the plates may have an assigned reflectance difference of 20 %, which is only one-quarter of the contrast of the dots on the original dirt estimation chart, and a dot on that plate with a physical area of 1,0 mm^2 would have a nominal EBA of 0,25 mm^2.

Each calibration plate contains 16 dots with physical areas ranging from 0,04 mm^2 to 1,5 mm^2. The nominal EBA of each dot will be given by:

$$\text{EBA(nominal)} = \text{(stated physical area)} \times \frac{\text{(Background reflectance} - \text{dot reflectance)}}{83\ \%} \qquad \text{(A.2)}$$

A.5 Calibration process

Calibration involves determining the calibration constant k in the calculation of EBA. Use the instrument to measure the EBA of the 16 dots on the calibration plate with the calibration constant k temporarily reset to 1,0. Determine the proper calibration constant k as the ratio of the nominal EBA to the measured EBA of the 16 dots on the plate.

$$k = \frac{\text{Nominal EBA}}{\text{Measured EBA}} \tag{A.3}$$

Equivalently, k is the slope of a plot of nominal EBA versus measured EBA for the 16 dots.

Annex B
(normative)

Calibration-plate information

The calibration plates used in this method are the same as those described in Tappi Test Method T 563 (see [3] in the Bibliography) and are available from that organization (www.tappi.org).

The plates were designed assuming that the reflectance contrast of each of the 16 dots in a set would equal that of the reference grey square to the side of the dots in a set. Consequently, each set of calibration plates is tested and certified by an independent accredited laboratory. The plates in a set are assigned a serial number and provided with a certificate that reports the $Y_{c/2}$ reflectances for the black and white plates, as well as the $Y_{c/2}$ correction factors for the dots on the plate with the highest contrast. Only the $Y_{c/2}$ values reported on the certificate shall be used when calibrating the apparatus.

Bibliography

[1] JORDAN, B.D. and NGUYEN, N.G. Emulating the TAPPI Dirt Count with a Microcomputer, *JPPS*, **14**(1), J16-19 (1988)

[2] TAPPI Test Method T 437 om-03, *Dirt in paper and paperboard*

[3] TAPPI Test Method T 563 om-03, *Equivalent Black Area (EBA) and count of visible dirt in pulp, paper and paperboard by image analysis*

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