Roughness of paper and paperboard, stylus (Emveco-type) method
(Revision of T 575 om-07)
(underscores and strikeouts indicate changes from Draft 1)

1. **Scope**

1.1 This method measures the surface roughness of paper and paperboard used in contact printing processes. It may not be used for tissue or creped paper and may not be suitable for newsprint that is inspected for visual anomalies which cannot be detected with this equipment. The method is not useful for measuring surface waviness.

1.2 This method uses a stylus to mechanically trace the paper surface which differs from methods that relate the rate of air flow leakage to paper roughness.
2. **Summary**

A skid containing a free-floating stylus rests on the test specimen backed by a smooth anvil. The skid is weighted to keep the specimen flat and also acts as a surface reference plane for the stylus. The test specimen is fed into a drive unit to advance the paper at a controlled traversing speed. As the paper is advanced beneath the skid, the roughness of the specimen causes vertical displacements of the stylus which are recorded at a prescribed interval. The recorded signal is mathematically analysed in such a way that the impact of waviness is minimized and short-span roughness is emphasized.

3. **Significance**

For printing considerations it is important to analyze the number and steepness of surface asperities occurring over short spans since these are more difficult to transfer ink into as opposed to the longer span wavy features of the paper surface. This method characterizes the abruptness of the paper surface or roughness occurring over $25-250 \, \mu m$ (0.001-0.010 in.) spans which can impact print quality.

4. **Definitions**

4.1 *Roughness*. The degree to which the surface texture contains short-span or fine irregularities. Roughness can be superimposed on a wavy surface.

4.2 *Waviness*. The degree to which the surface texture contains long-span irregularities or undulations in surface texture.

4.3 *Skid*. A weighted reference surface that houses the stylus and has a radius much larger than the irregularities being measured. Also referred to as the measuring head.

4.4 *Stylus contact force*. The stylus force, acting perpendicular to the test surface when the skid is loaded on the test piece backed by the anvil.

4.5 *Microdeviation*. The average of the squared difference in point-to-point vertical stylus readings. Sensitive to abrupt changes in the surface topography and less sensitive to gradual changes in surface topography. See Appendix A.1 for a mathematical expression.

4.6 *Microaverage*. The mean difference in point-to-point vertical stylus readings. See Appendix A.1 for a mathematical expression.

4.7 *Sample spacing*. The x-axis (the direction in which the specimen is traversed) distance between successive readings.

4.8 *Traversing speed*. The velocity at which the test specimen is advanced past the stylus tip.
4.9 **Evaluation length.** The x-axis (the direction in which the specimen is traversed) distance over which the specimen is traced by the stylus. Mathematically equal to the product of the sample spacing and the number of samples collected.

5. **Apparatus**

5.1 **Test instrument** having:

5.1.1 **Displacement transducer:** A displacement transducer with a working range of 0.25 mm (0.010 inches) and a linearity of 0.5 % of full range and a resolution of 0.0003 mm (0.00001 inches).

5.1.2 **Stylus Geometry.** Conical stylus with 60° included angle with flat stylus tip with a diameter of 32 ± 5 micrometers (0.00125 ± 0.0002 inches). The tip of the stylus shall be made of a hard and low-friction material (i.e., diamond) and have a smooth surface.

5.1.3 **Stylus contact force.** A stylus force between 5-10 mN (0.001-0.002 lbf) acting against the test surface over the entire displacement working range.

5.1.4 **Skid.** A skid with a contact diameter of 50 ± 2 mm (1.97 ± 0.08 inches) and a contact force of 4 ± 1 N (0.9 ± 0.2 lb) acting uniformly against the test piece and housing the stylus in the center of the skid. The contact surface acting against the test piece shall be made of hard material (i.e., steel or glass). The skid shall have a surface so flat that all points of the skid are within two parallel planes, 0.05 mm (0.002 inches) apart.

5.1.5 **Backing.** An anvil of equal or larger dimension to act as a backing for the skid. The backing is made of a hard material (i.e., steel or glass) having a surface so flat that all points of the skid are within two parallel planes, 0.05 mm (0.002 inches) apart.

5.1.6 **Drive unit,** for advancing the test piece beneath the stylus with constant traversing speed of 10 ± 1 mm/s (0.4 ± 0.04 inches/s). The advance of the test piece must be recorded every 0.25 mm (0.010 inches) with an accuracy of at least 0.025 mm (0.001 inches).

5.1.7 **Display** for calibration purposes showing zero and span and a means of adjusting both.

5.1.8 **Computer Interface and Software** to specify control parameters for sample spacing, number of samples, and traversing speed and to output test metrics.

6. **Calibration**

6.1 **Calibration** is accomplished with certified shims or step height block within the range of 0.025 - 0.250 mm (0.001 – 0.010 inches) accurate to the nearest 0.0025 mm (0.0001 inches).

6.2 **Zero adjustment.** Place a level shim beneath the skid and lower the skid onto the shim and zero the stylus position to read 0 within 0.001 mm (0.00004 inches). The bottom of the skid is the reference plane (datum).

---

1Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.
for the stylus. Recheck the zero if a span adjustment is made. The anvil should not be used as the surface to zero the stylus since it can wear over time.

6.3 Span adjustment. Insert a shim or step height block beneath the skid. Adjust span to read the shim or step height to the certified thickness within 0.0025 mm (0.0001 inches). Recheck the zero, and then recheck span again if the zero setting is adjusted.

7. Sampling

Samples shall be selected in accordance with TAPPI T 400 “Sampling and Accepting a Single Lot of Paper, Paperboard, fiberboard or Related Products.”

8. Conditioning

Condition the sample in accordance with TAPPI T 402 “Standard Conditioning and testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products.”

9. Test specimens

9.1 The test area shall be free of folds, wrinkles, welts, or holes.

9.2 The length in the x-axis (the direction in which the specimen is traversed) is not limited, but shall be loosely rolled and pulled by the drive unit without slippage. The length of the test piece shall be at least 175 mm (6.9 inches) to accommodate a sufficient number of readings. Sample width, orthogonal to the traversing direction (y-axis), shall be a minimum of 50 mm (1.97 inches) and should not exceed 305 mm (12 inches) to avoid levering lifting the skid because of the lever effect.

9.3 The standard orientation is for the stylus to traverse cross-grain (cross-direction). In general, roughness measurements will be lower in the grain (machine) direction.

10. Procedure

10.1 Verify that the instrument is stationed on a level and rigid surface free from vibration. A vibration dampening pad can be placed under the instrument provided the device remains level and sturdy.

10.2 Set the sample spacing to 0.25 mm (0.010 inches), number of samples to 500, and traversing speed to 10 mm/s (0.4 inches/s).

10.3 Place the test specimen under the skid with the test surface facing upward and feed into the drive unit. Loosely roll long strips to allow the strip to feed into the machine without slippage.
11. Report

11.1 Report the average of ten readings to the nearest whole number in units of microdeviations, for each side tested. Note whether the unit of measure is imperial or SI.

11.2 Indicate the sample spacing and the evaluation length.

NOTE 1: Recalculation to other sampling spacing is not according to this standard.

11.3 Indicate the number of specimens tested, the standard deviation for each side tested, and the grain orientation of the trace if it is not in the cross-direction.

11.4 If microaverage is included in the report, express the result in micrometers or mils (thousandths of an inch) to three significant digits.

12. Precision

12.1 The following estimates of repeatability and reproducibility as defined in TAPPI T 1200 “Interlaboratory Evaluation of Standards to Determine TAPPI Repeatability and Reproducibility.” Estimates are based on an interlaboratory study conducted in 2002 involving 10 laboratories. This data is based on four materials including, two grades of linerboard, one grade of uncoated offset and one grade of bleached paperboard. The precision estimates are based on the average of 10 readings per test and three tests per laboratory, on each material. A more detailed chart of example results is included below:

\[
\text{Repeatability (within a laboratory)} = 13\%
\]
\[
\text{Reproducibility (between laboratories)} = 23\%
\]

12.2 Repeatability and reproducibility are estimates of the maximum difference (at 95% C.I.) which should be expected when comparing test results for materials similar to those described above under similar test conditions. These estimates may not be valid for different materials or testing conditions.

<table>
<thead>
<tr>
<th>Material</th>
<th>Grand Mean</th>
<th>Stnd Dev Between Labs</th>
<th>Repeatability R and % r</th>
<th>Reproducibility R and % R</th>
<th>Labs Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleached Board</td>
<td>43.5</td>
<td>2.9</td>
<td>8.5</td>
<td>10.6</td>
<td>9/10</td>
</tr>
<tr>
<td>42 lb. Linerboard</td>
<td>298.9</td>
<td>21.7</td>
<td>22.1</td>
<td>68.8</td>
<td>10</td>
</tr>
<tr>
<td>69 lb. Linerboard</td>
<td>147.4</td>
<td>10.2</td>
<td>25.1</td>
<td>35.0</td>
<td>10</td>
</tr>
</tbody>
</table>

*0.25 mm sample spacing and 125 mm evaluation length per specimen. Results are based on measurements in mils.
13. Additional information

13.1 Effective date of issue: to be assigned.

13.2 Changes in the 2013 edition were minor editorial; however, a separate method will be created for the new stylus.

14. Keywords

Paper, Paperboard, Roughness, Smoothness, Printability, Linerboards

References


Appendix A.1. Calculation of roughness expressed as microdeviation and microaverage

The unit analysis in calculating microdeviation is non-standard and therefore it is termed microdeviation to simplify the roughness terminology. The calculation is designed to weight abrupt changes in successive readings.

\[
\text{Microdeviation} = \frac{1000}{n-1} \sum_{i=2}^{n} (x_i - x_{i-1})^2
\]  

(A1)

where

Microdeviation = paper roughness, microdeviations (md)

\(x = \) vertical displacement of the stylus, micrometers or thousandths of an inch

\(n = \) number of samples in the evaluation length, dimensionless

Since the calculation involves squaring the difference in successive readings it is important to state the basic unit of measure used for the vertical displacement of the stylus, micrometers or thousandths of an inch.

Microaverage examines the average deviation from point-to-point readings. The unit of measure shall be reported with the result.

\[
\text{Microaverage} = \frac{1}{n-1} \sum_{i=2}^{n} |x_i - x_{i-1}|
\]  

(A2)
where

Microaverage = average point-to-point difference, micrometers (thousandths of an inch)

\[ x = \text{vertical displacement of the stylus, micrometers or thousandths of an inch} \]

\[ n = \text{number of samples in the evaluation length, dimensionless} \]

The vertical displacement of the stylus is relative to the bottom of skid which is set during zero calibration (see Section 6).

*Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department.*
1. Scope

1.1 This method measures the surface roughness of paper and paperboard used in contact printing processes. It may not be used for tissue or creped paper and may not be suitable for newsprint that is inspected for visual anomalies which cannot be detected with this equipment. The method is not useful for measuring surface waviness.

1.2 This method uses a stylus to mechanically trace the paper surface which differs from methods that relate the rate of air flow leakage to paper roughness.
2. Summary

A skid containing a free-floating stylus rests on the test specimen backed by a smooth anvil. The skid is weighted to keep the specimen flat and also acts as a surface reference plane for the stylus. The test specimen is fed into a drive unit to advance the paper at a controlled traversing speed. As the paper is advanced beneath the skid, the roughness of the specimen causes vertical displacements of the stylus which are recorded on a prescribed interval. The recorded signal is mathematically analysed in such a way that the impact of waviness is minimized and short-span roughness is emphasized.

3. Significance

For printing considerations it is important to analyze the number and steepness of surface asperities occurring over short spans since these are more difficult to transfer ink into as opposed to the longer span wavy features of the paper surface. This method characterizes the abruptness of the paper surface or roughness occurring over 25-250 micrometers (0.001-0.010 inch) spans which can impact print quality.

4. Definitions

4.1 Roughness. The degree to which the surface texture contains short-span or fine irregularities. Roughness can be superimposed on a wavy surface.

4.2 Waviness. The degree to which the surface texture contains long-span irregularities or undulations in surface texture.

4.3 Skid. A weighted reference surface that houses the stylus and has a radius much larger than the irregularities being measured. Also referred to as the measuring head.

4.4 Stylus contact force. The stylus force, acting perpendicular to the test surface when the skid is loaded on the test piece backed by the anvil.

4.5 Microdeviation. The average of the squared difference in point-to-point vertical stylus readings. Sensitive to abrupt changes in the surface topography and less sensitive to gradual changes in surface topography. See Appendix A.1 for a mathematical expression.

4.6 Microaverage. The mean difference in point-to-point vertical stylus readings. See Appendix A.1 for a mathematical expression.

4.7 Sample spacing. The x-axis (the direction in which the specimen is traversed) distance between successive readings.

4.8 Traversing speed. The velocity at which the test specimen is advanced past the stylus tip.
4.9 **Evaluation length.** The x-axis (the direction in which the specimen is traversed) distance over which the specimen is traced by the stylus. Mathematically equal to the product of the sample spacing and the number of samples collected.

5. **Apparatus**

5.1 **Test instrument** having:

5.1.1 **Displacement transducer:** A displacement transducer with a working range of 0.25 mm (0.010 inches) and a linearity of 0.5 % of full range and a resolution of 0.0003 mm (0.00001 inches).

5.1.2 **Stylus Geometry.** Conical stylus with 60° included angle with flat stylus tip with a diameter of 32 ± 5 micrometers (0.00125 ± 0.0002 inches). The tip of the stylus shall be made of a hard and low friction material (i.e., diamond) and have a smooth surface.

5.1.3 **Stylus contact force.** A stylus force between 5-10 mN (0.001-0.002 lbf) acting against the test surface over the entire displacement working range.

5.1.4 **Skid.** A skid with a contact diameter of 50 ± 2 mm (1.97 ± 0.08 inches) and a contact force of 4 ± 1 N (0.9 ± 0.2 lbf) acting uniformly against the test piece and housing the stylus in the center of the skid. The contact surface acting against the test piece shall be made of hard material (i.e., steel or glass). The skid shall have a surface so flat that all points of the skid are within two parallel planes, 0.05 mm (0.002 inches) apart.

5.1.5 **Backing.** An anvil of equal or larger dimension to act as a backing for the skid. The backing is made of a hard material (i.e., steel or glass) having a surface so flat that all points of the skid are within two parallel planes, 0.05 mm (0.002 inches) apart.

5.1.6 **Drive unit,** for advancing the test piece beneath the stylus with constant traversing speed of 10 ± 1 mm/s (0.4 ± 0.04 inches/s). The advance of test piece must be recorded every 0.25 mm (0.010 inches) with an accuracy of at least 0.025 mm (0.001 inches).

5.1.7 **Display** for calibration purposes showing zero and span and a means of adjusting both.

5.1.8 **Computer Interface and Software** to specify control parameters for sample spacing, number of samples, and traversing speed and to output test metrics.

6. **Calibration**

6.1 **Calibration** is accomplished with certified shims or step height block within the range of 0.025 - 0.250 mm (0.001 – 0.010 inches) accurate to the nearest 0.0025 mm (0.0001 inches).

6.2 **Zero adjustment.** Place a level shim beneath the skid and lower the skid onto the shim and zero the stylus position to read 0 within 0.001 mm (0.00004 inches). The bottom of the skid is the reference plane (datum).

---

1Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.
for the stylus. Recheck the zero if a span adjustment is made. The anvil should not be used as the surface to zero the stylus since it can wear over time.

6.3 Span adjustment. Insert a shim or step height block beneath the skid. Adjust span to read the shim or step height to the certified thickness within 0.0025 mm (0.0001 inches). Recheck the zero, and then recheck span again if the zero setting is adjusted.

7. Sampling

Samples shall be selected in accordance with TAPPI T 400 “Sampling and Accepting a Single Lot of Paper, Paperboard, fiberboard or Related Products.”

8. Conditioning

Condition the sample in accordance with TAPPI T 402 “Standard Conditioning and testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products.”

9. Test specimens

9.1 The test area shall be free of folds, wrinkles, welts, or holes.

9.2 The length in the x-axis (the direction in which the specimen is traversed) is not limited, but shall be loosely rolled and pulled by the drive unit without slippage. The length of the test piece shall be at least 175 mm (6.9 inches) to accommodate a sufficient number of readings. Sample width, orthogonal to the traversing direction (y-axis), shall be a minimum of 50 mm (1.97 inches) and should not exceed 305 mm (12 inches) to avoid leveraging the skid.

9.3 The standard orientation is for the stylus to traverse cross-grain (cross-direction). In general, roughness measurements will be lower in the grain (machine) direction.

10. Procedure

10.1 Verify that the instrument is stationed on a level and rigid surface free from vibration. A vibration dampening pad can be placed under the instrument provided the device remains level and sturdy.

10.2 Set the sample spacing to 0.25 mm (0.010 inches), number of samples to 500, and traversing speed to 10 mm/s (0.4 inches/s).

10.3 Place the test specimen under the skid with the test surface facing upward and feed into the drive unit. Loosely roll long strips to allow the strip to feed into the machine without slippage.
11. Report

11.1 Report the average of ten readings to the nearest whole number in units of microdeviations, for each side tested. Note whether the unit of measure is imperial or SI.

11.2 Indicate the sample spacing and the evaluation length.

NOTE 1: Recalculation to other sampling spacing is not according to this standard.

11.3 Indicate the number of specimens tested, the standard deviation for each side tested, and the grain orientation of the trace if it is not in the cross-direction.

11.4 If microaverage is included in the report, express the result in micrometers (thousandths of an inch) to three significant digits.

12. Precision

12.1 The following estimates of repeatability and reproducibility as defined in TAPPI T 1200 “Interlaboratory Evaluation of Standards to Determine TAPPI Repeatability and Reproducibility.” Estimates are based on an interlaboratory study conducted in 2002 involving 10 laboratories. This data is based on four materials including, two grades of linerboard, one grade of uncoated offset and one grade of bleached paperboard. The precision estimates are based on the average of 10 readings per test and three tests per laboratory, on each material. A more detailed chart of example results is included below:

Repeatability (within a laboratory) = 13%
Reproducibility (between laboratories) = 23%

12.2 Repeatability and reproducibility are estimates of the maximum difference (at 95% C.I.) which should be expected when comparing test results for materials similar to those described above under similar test conditions. These estimates may not be valid for different materials or testing conditions.

<table>
<thead>
<tr>
<th>Material</th>
<th>Grand Mean</th>
<th>Stnd Dev Between Labs</th>
<th>Repeatability r and % r</th>
<th>Reproducibility R and % R</th>
<th>Labs Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleached Board</td>
<td>43.5</td>
<td>2.9</td>
<td>8.5</td>
<td>20%</td>
<td>9/10</td>
</tr>
<tr>
<td>42 lb. Linerboard</td>
<td>298.9</td>
<td>21.7</td>
<td>22.1</td>
<td>7%</td>
<td>10</td>
</tr>
<tr>
<td>69 lb. Linerboard</td>
<td>147.4</td>
<td>10.2</td>
<td>25.1</td>
<td>17%</td>
<td>10</td>
</tr>
</tbody>
</table>

*0.25 mm sample spacing and 125 mm evaluation length per specimen
13. **Additional information**

Effective date of issue: to be assigned.

14. **Keywords**

Paper, Paperboard, Roughness, Smoothness, Printability, Linerboards

**References**


**Appendix A.1. Calculation of roughness expressed as microdeviation and microaverage**

The unit analysis in calculating microdeviation is non-standard and therefore it is termed microdeviation to simplify the roughness terminology. The calculation is designed to weight abrupt changes in successive readings.

\[
Microdeviation = \frac{1000}{n-1} \sum_{i=2}^{n} (x_i - x_{i-1})^2 \quad (A1)
\]

where

Microdeviation = paper roughness, microdeviations (md)

\( x = \) vertical displacement of the stylus, micrometers or thousandths of an inch

\( n = \) number of samples in the evaluation length, dimensionless

Since the calculation involves squaring the difference in successive readings it is important to state the basic unit of measure used for the vertical displacement of the stylus, micrometers or thousandths of an inch.

Microaverage examines the average deviation from point-to-point readings. The unit of measure shall be reported with the result.

\[
Microaverage = \frac{1}{n-1} \sum_{i=2}^{n} |x_i - x_{i-1}| \quad (A2)
\]

where
Microaverage = average point-to-point difference, micrometers (thousandths of an inch)

\[ x = \text{vertical displacement of the stylus, micrometers or thousandths of an inch} \]

\[ n = \text{number of samples in the evaluation length, dimensionless} \]

The vertical displacement of the stylus is relative to the bottom of skid which is set during zero calibration (see Section 6).

*Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department.*