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Paper and board — Determination of internal bond strength

Papier et carton — Détermination de la force de cohésion interne

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Foreword

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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*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

This corrected version of ISO 16260:2016 replaces the entire text of the erroneously published version dated 2015-06-01.

Introduction

Paper and board sheets may, during printing, conversion or specific product applications, be subjected to impulses, impacts or shock loads of sufficient magnitude to cause structural failure. Commonly observed in-plane structural failures include surface picking, blistering and interior delimitation.

This International Standard describes one method for determining the internal bond strength of a product of pulp, paper or board. There are other published methods[4][8] for determining “Z” or thickness direction tensile strength, but in this method, the delaminating force is applied at a rate very much higher than in other methods. This method may, therefore, be preferred for predicting sheet performance under printing or converting conditions.

Paper and board — Determination of internal bond strength

1 Scope

This International Standard describes a method to measure the energy required to rapidly delaminate a test piece of paper or board. Rupture of the test piece in the "Z" or thickness direction is initiated by a pendulum having a defined mass, moving at a defined velocity.

The procedure is suitable for both single- and multi-ply papers and boards, including coated sheets and those that are laminated with synthetic polymer films. It is particularly suitable for papers and boards that may be subjected to z-direction[4][8] rapid impacts, impulses or shock loads during printing or conversion.

The test procedure entails the adherence of double-sided adhesive tape to both sides of the test piece under pressure. For this reason, the method may be unsuitable for materials that might be structurally damaged by compression or are porous enough to permit migration of the tape adhesive into or through the test piece.

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 186, *Paper and board — Sampling to determine average quality*

ISO 187, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

EN 755-2:2013, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 2: Mechanical properties*

3 Terms and definitions

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

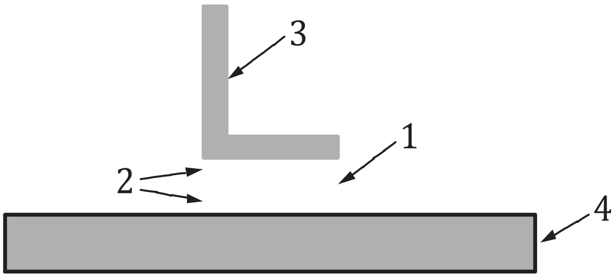
3.1
internal bond strength
average potential energy, expressed as J/m^2 of surface, required to delaminate a test piece under the conditions of the test

Note 1 to entry: The result is the difference of the potential energy before and the remaining energy after delaminating the test piece.

3.2
test assembly
test piece, laminated between two pieces of double-sided adhesive tape, with the bottom side of the lower tape adhered to a rigid metal anvil and the upper side of the upper tape adhered to an "L"-shaped aluminium platen

4 Principle

A square test piece is adhered to a flat metal anvil by means of double-sided adhesive tape. An "L"-shaped aluminium platen with the same surface area as the test piece is then adhered to the upper surface of the test piece, again, using double-sided adhesive tape. The assembly is shown in Figure 1. The assembly is secured in position and a pendulum allowed to impact the upper inside surface of the platen, causing it to rotate about its outside corner, splitting the test piece in the "Z" or thickness direction (see Figure 2). The energy absorbed in rupturing the test piece is calculated from the measurement of the subsequent over-swing of the pendulum and the known masses and dimensions of the system components.



Key

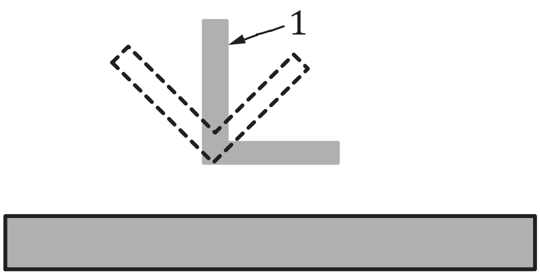
1 test piece

2 double-sided adhesive tape

3 aluminium platen

4 metal anvil

Figure 1 — Components of a test assembly



Key

1 pendulum strike point and direction

Figure 2 — Pendulum to anvil strike point

Precision data are provided in Annex B.

Verification of the measuring instrument compliance using an impact device is described in Annex C.

5 Apparatus and technical data

5.1 Apparatus

5.1.1 Device for the preparation of the test assembly, with the dimensions 25,4 mm ± 0,2 mm × 25,4 mm ± 0,2 mm for testing by pressing the components of the test assembly together at a controlled pressure for a controlled time. During the pressure cycle, the aluminium platen (5.1.4) should be securely clamped in position to prevent flexing.

NOTE Most commercially available preparation stations are capable of simultaneously preparing five test assemblies.

Ensure that the test instrument is levelled in the front–back and left–right directions and the pendulum is horizontal when in the latched position.

5.1.2 Pendulum, mounted on a pedestal by means of a horizontal spindle supported on low-friction bearings. The pendulum shall be free to rotate from a horizontal position through at least 180°. At its free end, the pendulum carries a metal striker ball which contacts the inside face of the aluminium platen on the test assembly when the pendulum reaches the vertical position. To minimize energy losses due to vibration, the centre of gravity of the pendulum should be at the point of impact of the striker ball with the aluminium platen. There should be no looseness in the construction of pendulums that have augmented weight assemblies.

5.1.3 A means for securing the pendulum in a horizontal position, with provision for a rapid, vibration-free release.

5.1.4 Test assembly, is formed from a stationary anvil (base) and a separable aluminium platen that is a right angle in cross section together with the test piece and adhesive tape (see Figure 1).

Anvils intended for use in multiple test piece preparation stations should be indelibly marked to ensure that they are always placed in the same position in the preparation station. The test assembly is securely held in position so that the pendulum strikes the centre of percussion of the aluminium platen when the axis of rotation is at the outside corner of the right angle of the platen (see Figure 2).

5.1.5 A means of registering the peak angular swing of the pendulum after impact with the test assembly.

5.1.6 A means to convert the peak angular swing of the pendulum to an internal bond strength value. Commonly employed methods include optical encoder computer and mechanical scale/friction pointer.

5.1.7 An optional means to extend the range of the instrument. This may be achieved by fitting pendulums of different masses, or by adding augmenting weights to the pendulum, or reducing the surface area of the test piece by an amount not exceeding 50 %. The user of this International Standard should consult the manufacturer of the test instrument regarding the installation and verification of such options. Any such modifications to the instrument shall be included in the test report.

5.1.8 Device suitable for cutting strips of the test material 25,4 mm ± 0,2 mm (5.2.5) wide and of sufficient length to mount in the test assembly preparation device.

5.1.9 Knife or multi-blade cutting device, for separating test assemblies prepared in a multi-station test assembly preparation device.

5.1.10 Double-sided adhesive paper tape, with a creped release liner (see 5.2.4).

5.1.11 Solvent, suitable for removing adhesive residue from the anvils and aluminium platens.

5.2 Technical data

5.2.1 Instrument/pendulum ranges

Table 1 — Instrument and pendulum ranges

	Range 0	Range 1 SB low	Range 2 SB high	Range 3
Measuring range (J/m^2) (recommendation, otherwise, manufacturers' instructions)	50 to 400	100 to 600	200 to 1 200	300 to 2 400
Corresponds to Scott-Bond (SB) scale.		Low-range 0 to 525	High-range 210 to 1 050	
Pendulum length, *L*, (mm), to ±0,2 mm	228,6	228,6	228,6	228,6
Reduced pendulum length[a], *Lred*, (mm)	130 to 140	145 to 170	170 to 190	180 to 200
Mass of pendulum ±4 g	133	190	380	760
Tolerance range potential energy[a] Potential Energy (Nm) calculated from m × g × h	0,29 to 0,31	0,41 to 0,44	0,84 to 0,88	1,60 to 1,72

[a] The decisive factor is the potential energy that is stored in the pendulum at the start of the test. Once the pendulum is released, the potential energy is converted into kinetic energy as the pendulum impacts the aluminium platen. The determination of the reduced pendulum length serves as a fast check-up of the device's condition. A more accurate examination is possible by applying the method described in 5.2.3 (reduced pendulum length, *Lred*).

5.2.2 Aluminium platen/anvil

Aluminium platen:

Alloy EN AW 6060 T66 (AlMgSi0,5 F 22) according to EN 755-2:2013, Table 38.

Devices where the alloy, used for the platen, cannot be identified, only original aluminium platen shall be used.

NOTE "Newer" devices have a marking on the platen that identifies the alloy used. This is not the case for "old" devices.

Compensation: The scales of the Scott-Bond devices contain a compensation that takes account of the original alloy of the platen. If the alloy is changed, the compensation used may not be appropriate and this would lead to erroneous values being obtained. This correction factor is not applicable for digital devices.

Surface: Surface roughness: $Rz \leq 3{,}8$ µm[1][2]

Mass of an aluminium platen: (11,3 ± 0,2) g

Wear and tear: Replacement after 10 000 measurements or when there are significant traces of deformation or pendulum markings.

Anvil:

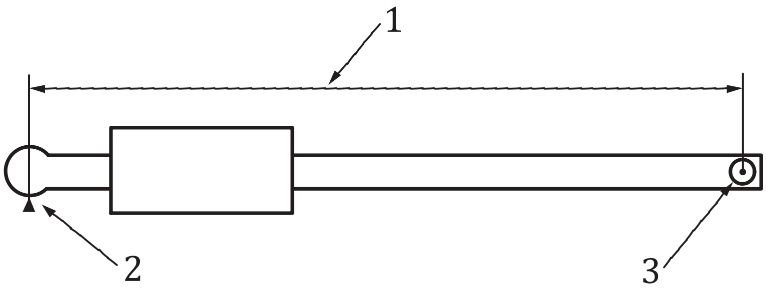
Surface roughness: Rz ≤ 3,8 µm[1][2]

5.2.3 Pendulum

Pendulum point of impact onto the aluminium platen: Centred on the anvil and (21 ± 0,2) mm from the aluminium platen's lower edge without a sample and without adhesive tape.

Quality of the pendulum bearing: Energy loss when freely oscillating <1 %.

Pendulum length: (228,6 ± 0,2) mm, measured as indicated in Figure 3.



Key

1 distance between contact point and centre of pendulum rotation, 228,6 mm ± 0,2 mm

2 contact point for m(90°) total mass at 90° deflection

3 centre of rotation

Figure 3 — Reduced pendulum length, *Lred*

This calculation determines the position of the centre mass on the centreline of the pendulum shaft. It is determined by measuring the average period, t_s, of one oscillation. Deflect the pendulum ≤3 and measure the time for at least 10 oscillations to get a reliable average. Calculate *Lred* according to Formula (1):

$$Lred = \left(\frac{t_s}{2\pi}\right)^2 \times g \qquad (1)$$

where

t_s is the average period of one oscillation (s);

g is the acceleration due to gravity (m/s^2).

5.2.4 Adhesive tape

The adhesive tape shall be according to:

Finat FTM1 = 15 N/(25,4 mm ± 0,2)

NOTE 1 ASTM D 3330/D3330M-0,4 (2010) (= 56 N/100 mm) is used by many, but the specification does not give the same precision as the FINAT method.

NOTE 2 In the list below, examples of tapes are given that fulfil the above requirements:

— Nitto P-50TM[1)];

— Tesa tesafix 4961TM[1)];

— 3MTM[1)] type 410 M.

The customer and supplier should agree which adhesive tape, of those fulfilling the above requirement, is to be used.

5.2.5 Test piece

The test piece size shall be 25,4 mm ± 0,2 mm edge length

1) This information is given for the convenience of user of this International Standard and does not constitute an endorsement by ISO of these products.

6 Sampling

If tests are being made to evaluate a lot, the sample shall be selected in accordance with ISO 186. If the tests are made on another type of sample, make sure that the specimens taken are representative of the sample received.

7 Conditioning

Conditioning shall be carried out in accordance with ISO 187.

8 Preparation of test assemblies

8.1 From each test specimen, cut strips (25,4 ± 0,2) mm (see 5.2.5) wide of sufficient length to fit the preparation device in use.

NOTE Commercially available preparation stations typically require strips 140 mm to 178 mm long.

Handle the strips by the extreme ends only and discard any that exhibit creases, wrinkles or other abnormalities.

8.2 Load the preparation station with adhesive tape, test strip, anvils and platens in accordance with the manufacturer's instructions, ensuring that the anvils and platens are free from adhesive and fibre residue from previous tests.

8.3 Operate the preparation station so as to apply one of the pressures below for the specified period.

For some materials, it may be necessary to use a different pressure and pressing period.

Pressure: Low — (400 ± 13) kPa

Medium — (690 ± 20) kPa

High — (1 035 ± 34) kPa

The pressing period for these is 3 s ± 0,5 s.

For rough and/or compressible boards (e.g. core boards), pressure 400 kPa and pressing period 15 s ± 1 s is used.

The pressure and the pressing period should be agreed between the buyer and seller.

8.4 Use a knife or inbuilt cutting device to separate the individual test assemblies. If necessary, trim the edges of the test piece/tape sandwich to remove any overlap.

9 Calibration

Calibrate the preparation station and the test instrument at required intervals in accordance with the manufacturer's instructions and/or the procedures given in Annex A.

10 Procedure

10.1 Carry out the tests under the same atmospheric conditions as those used to condition the test pieces.

10.2 Select an instrument range appropriate for the material being tested.

10.3 Latch the pendulum in the horizontal position. On instruments with mechanical indication, ensure that the pointer is swung in a direction opposite to that of the swing of the pendulum at the time of impact until it comes to rest against the pendulum latch pin.

10.4 Take the first test assembly, consisting of an anvil, test piece/tape sandwich, and aluminium platen, and place it in position in the pendulum strike zone. Secure the test assembly firmly in position using the fixtures provided.

10.5 Operate the pendulum release mechanism and allow the pendulum to strike the aluminium platen, rupturing the test piece. If possible, capture the platen to prevent damage to it by contact with hard objects.

10.6 Examine both surfaces of any test piece rupture. Discard results of tests that exhibit partial delamination, tape to tape bonding, tape show-through or tape to metal peel at the leading edge of the rupture.

10.7 Note the test value. If appropriate, re-latch the pendulum, remove the test assembly and reset the instrument for the next test.

10.8 Make at least five tests in each principal direction of the test material.

10.9 If tape to metal peel is observed with samples of high internal bond strength, it may be necessary to increase the clamping pressure to 1 035 kPa. Care shall be taken to ensure that there is no tape bonding or show through of tape at either of the rupture surfaces following the test piece rupture.

11 Expression of results

11.1 For each direction tested, calculate the mean value of internal bond strength to three significant figures.

11.2 For each direction tested, calculate the standard deviation or coefficient of variation of results to two significant figures.

NOTE Comparisons of test data from the mechanical Scott Internal Bond Tester with data from later electronic versions pose two problems. First, the upper and lower ranges on earlier instruments that use removable weights to increase the range of the pendulum do not agree. The weight additions shift the pendulum's centre of percussion, thereby, affecting both its range and internal vibrational losses. To correct this problem, later, electronic instruments use an extrapolated lower range scale when extending the range of the instrument. While correlations and agreement with low range scale (without additional pendulum weights) data are straightforward, it is not possible to correlate electronic instrument test results with data taken on a mechanical instrument that is in the high range configuration.[11]

12 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 16260;

b) the date and place of testing;

c) all the information necessary for complete identification of the sample;

d) the type of instrument used;

e) the temperature and relative humidity used for the test;

f) the number of test pieces tested in each direction;

g) the pressure used in preparing the test assemblies, in kPa;

h) the time that pressure was applied in s;

i) the type of tape used;

j) the arithmetic mean results, as calculated in 11.1;

k) the standard deviations or coefficients of variation, as calculated in 11.2;

l) any deviations from the procedure described in this International Standard that may have influenced the results.

Annex A
(normative)

Maintenance and calibration

A.1 Test assembly preparation station

A.1.1 Inspect the aluminium platen(s). They shall be free from dents, scratches and adhesive residue. Contact surfaces shall be flat and edges free from burrs. Verify that the dimensions of the tape contact faces are (25,4 ± 0,2) mm × (25,4 ± 0,2) mm. The physical properties of aluminium differ for different alloys, thus, affecting the coefficient of restitution between the aluminium platen(s) and the steel sphere impact point on the pendulum. Use the alloy specified in 5.2.2.

A.1.2 Use a load cell, pressure gauge or other suitable device to verify that any device employed to prepare the test assembly can apply a pressure according to 8.3.

A.2 Pendulum and associated fixtures

During the test, the potential energy of the pendulum is distributed in several ways as follows:

a) energy to rupture the test piece;

b) energy in the pendulum excess swing;

c) frictional losses proportional to the excess swing;

d) vibrational losses due to pendulum construction;

e) energy to move the aluminium platen.

A.2.1 Ensure that the pendulum spindle is horizontal and the bearings are maintained according to the manufacturer's instructions.

A.2.2 Determine the mass of the pendulum by weighing or reference to the manufacturer's specifications.

A.2.3 In the case of pendulums fabricated from multiple components, verify that there is no relative movement between components.

A.2.4 Verify that the pendulum is horizontal when held in the latched position and that the release operates smoothly without imparting any upward displacement to the pendulum on release.

A.2.5 Verify that the instrument is equipped with mechanical or electronic means to subtract energy loss through friction, vibration and moving the aluminium platen from the total energy lost during the test.

A.2.6 Instruments in current use calculate energy losses from measurements of pendulum angular displacement and constants such as the pendulum mass and centre of mass location. Angular displacement is determined by a mechanical friction pointer or now more commonly by an optical encoder.

Ideally, the instrument should be verified by independent measurement of the pendulum displacement and calculation, comparing the calculated values of internal bond strength with those indicated by the instrument. In practice, the average user may not have the required equipment available.

An alternative calibration system offered by some equipment manufacturers consists of sets of metal weights of various sizes and a mounting fixture designed to replace the normal test assembly. A weight is placed in the fixture and struck by the pendulum. The indicated value of internal bond strength from the instrument is compared with the value assigned to the weight by the manufacturer. Such verification systems, which imply the existence of a master instrument, are usually specific to one maker of instrument.

Annex B
(informative)

Precision

B.1 General

The precision statement was obtained from a round robin test that was conducted over the months of June thru September 2012 using four grades of paperboard and a uniform source of double-sided tape. The results are as follows.

Each laboratory was instructed to run 10 tests on each sample for both machine and cross-machine directions for a total of 20 test results per sample.

The tests were run at the (medium) pressure 690 kPa ± 20 kPa and pressure time 3 s (see 8.3).

Sample A: Manila envelope stock, 108 g/m^2, pulp – virgin kraft.

Sample B: Liner board, 205 g/m^2, pulp – virgin kraft.

Sample C: Coated cylinder board, 384 g/m^2, pulp – recycled old newsprint.

Sample D: Coated folding box board, 303 g/m^2, pulp – unbleached sulphate.

B.2 Results

The data are presented in Tables B.1 and B.2.

The calculations were made according to ISO/TR 24498[5] and TAPPI T 1200[9].

The repeatability standard deviation reported is the “pooled” repeatability standard deviation, that is, the standard deviation is calculated as the root-mean-square of the standard deviations of the participating laboratories. This differs from the conventional definition of repeatability in ISO 5725-1[3].

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 may not be valid for different materials or different test conditions. Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77.

NOTE 1 The repeatability standard deviation and the within-laboratory standard deviation are identical. However, the reproducibility standard deviation is NOT the same as the between-laboratories standard deviation. The reproducibility standard deviation includes both the between-laboratories standard deviation and the standard deviation within a laboratory, as follows:

$$s^2_{\text{repeatability}} = s^2_{\text{within lab}} \quad \text{but} \quad s^2_{\text{reproducibility}} = s^2_{\text{within lab}} + s^2_{\text{between lab}}$$

NOTE 2 $2{,}77 = 1{,}96\sqrt{2}$ provided that the test results have a normal distribution and that the standard deviation, s, is based on a large number of tests.

Table B.1 — Estimation of the repeatability

Sample	Number of laboratories	Mean internal bond strength J/m^2	Repeatability standard deviation s_r J/m^2	Coefficient of variation $C_{V,r}$ %	Repeatability limit r J/m^2
A	7	539	65,5	12,2	182,0
B	10	389	33,3	8,6	92,3
C	10	160	17,2	10,8	47,7
D	10	157	10,4	6,6	28,8

Table B.2 — Estimation of the reproducibility

Sample	Number of laboratories	Mean internal bond strength J/m^2	Reproducibility standard deviation s_R J/m^2	Coefficient of variation $C_{V,R}$ %	Reproducibility limit R J/m^2
A	7	539	85,0	15,8	235,6
B	10	389	41,2	10,6	114,2
C	10	160	21,1	13,2	58,5
D	10	157	17,9	11,4	49,6

Annex C
(informative)

Verification of device compliance with a standard

An impact device for checking the standard is shown in the form of a drawing in Figure C.1 and in the form of a photograph in Figure C.2. Pre-defined cylindrical mass pieces are positioned in the device such that, at the centre of percussion, the tip of the pendulum bob strikes the centre of the circle at 0° deflection. This absorbs the pendulum energy which the impact then transfers to the test piece.

Figure C.1 — Impact device with a cylindrical mass piece in 3D

Figure C.2 — Mounted impact device with a cylindrical mass piece and pendulum bob

For devices from different manufacturers, there is an adapter that ensures that the cylindrical mass pieces will be reliably struck in the centre by the pendulum bob at 0° deflection. The test pieces are available in gradations of 10 g, the weight being determined by the length of the cylinder.

Similar pendulum designs shall supply the same values when the same mass pieces are struck. This circumstance gives rise to the values in Table C.1 which, for physical reasons, differ for measuring range 1 and measuring range 2.

Identical results of measurement will never be obtained when the same material is tested in two measuring ranges.

Table C.1 — Table of values for measuring ranges 1 and 2

Test piece weight g	Measuring range 1 J/m^2	Measuring range 2 J/m^2
20	130	
30	205	230
40	260	320
50	310	400
60	360	460
70	400	510
80	440	580
90	465	630
100	500	680
110		710
120		740
130		770
140		800
150		815
160		830
180		870
200		910
220		950
230		970

To check a measuring instrument to determine whether it complies with this International Standard, measurements are conducted in the measuring range using the impact device and the test pieces cited in the respective table, the measured values being noted.

Five measurements are to be performed using each test piece and the results averaged. Obvious faulty measurements shall be discarded and replaced by a repetition of the test with a new value.

A device complies with this International Standard if, and only if, the average values from five single measurements coincide with the values in Table C.1 while observing a tolerance.

Deviations of ±3 % of the value in Table C.1 are permissible for devices built in 2011 or later. Deviations of ±10 % of the value in Table C.1 are permissible for older models.

The tendency of any deviations from the values in Table C.1 is the same for all test pieces. This means that the results obtained with one device and in one measuring range will always tend to be higher or lower than the corresponding values in Table C.1.

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[2] ISO 4288, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

[3] ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

[4] ISO 15754, *Paper and board — Determination of z-directional tensile strength*

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

[6] ASTM D3330/D3330M-04(2010), Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape

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[10] Blockman A.F., & Wickstrand W.C. Interfiber Bond Strength of Paper. TAPPI. 1958, **41** p. 191A

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