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T 409

BALLOT NO. 04 SARG

DRAFT NO. 03

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WORKING GROUP CHAIRMAN Dennis Crawshaw

SUBJECT CATEGORY Physical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Machine direction of paper and paperboard

(Five-year review of Standard Practice T 409 sp-15)

(Underscores, notes, and strikethroughs show changes from Draft 2)

1. Scope

1.1 This Standard Practice describes several procedures for determining the machine direction of most grades of paper and paperboard. Most of the procedures embody the principle that fibers tend to be aligned in the machine direction of the sheet, and this alignment produces observable effects. However, the extent of restraint used in drying can be very important in determining machine direction.

1.2 Application of the procedures in this Standard Practice to certain grades of paper, such as sheets laminated to film, creped papers, extensible papers (where it is not unusual for the machine direction tensile to be relatively low and the stretch to be relatively high), and papers reinforced with textile materials, usually result in unreliable determinations. Tearing resistance and folding endurance may be used to determine machine direction for

paper known to have been made on a cylinder machine. Tearing resistance should not be used for paper made on a fourdrinier machine, and folding endurance should be used only as specified in Section 7.7.

1.3 During manufacture of paper, cross flows coming from the headbox and the forming section may cause preferential alignment of fibers at an angle to the machine direction. Since the procedures in Section 7.11 are affected by fiber orientation, differences as great as 15° may be expected for sheets of uncertain orientation.

2. Summary

This method describes several procedures for determining the machine direction of paper and paperboard. Some of these procedures employ standard test equipment; others require only the simplest of apparatus.

3. Significance

3.1 The determination of the machine direction of paper is essential for the correct folding of pages in books and pamphlets and for scoring and creasing of folders, labels, and cartons.

3.2 Determination of machine direction is necessary, in many instances, to properly report and identify tested properties. For example, identification of the machine direction is required to correctly determine and report directional brightness, gloss, tear, tensile properties, folding endurance, edge crush, coefficient of friction, and bending properties.

4. Definitions

4.1 The two directions of paper or paperboard are defined as:

4.1.1 *Machine direction*, the direction of a paper or paperboard corresponding or parallel to the direction of flow of the stock along the paper machine.

4.1.2 *Cross direction*, the direction of a paper or paperboard at right angles to the machine direction.

5. Apparatus

5.1 *Bursting tester*, meeting the specification set forth in TAPPI T 403 “Bursting Strength of Paper.”

5.2 *Tensile tester*, meeting the specifications set forth in TAPPI T 494 “Tensile Breaking Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus).”

5.3 *Tearing resistance tester*, meeting the specifications set forth in TAPPI T 414 “Internal Tearing Resistance of Paper.”

5.4 *Folding endurance tester*, meeting the specifications set forth in TAPPI T 423 “Folding Resistance of Paper (Schopper Type Tester)” or TAPPI T 511 “Folding Endurance of Paper (MIT Tester).”

5.5 *Drying oven or desiccator.*

5.6 *Other equipment*, indelible pencil, shallow glass or metal pan, microscope.

6. Sampling and test specimens

6.1 Obtain a sample of the paper in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product." From each test unit of the sample prepare specimens as follows:

6.1.1 *For Procedures 7.1 and 7.8:* for purposes of identification, draw a line through adjacent parts of the paper and the specimen to be cut, the line to be visible on both paper and specimen. Cut circular specimens approximately 25 mm in diameter or square specimens approximately 25 mm on a side. For square specimens, the sides of the specimen must be cut parallel to the sides of the test unit sheet.

6.1.2 *For Procedures 7.2, 7.4, and 7.7*: cut two test specimen strips 15 × 250 mm. Cut them at right angles to each other and parallel to the edges of the test unit sheet.

6.1.3 *For Procedures 7.3, 7.5, 7.9, and 7.12*: use the test unit sheet as is.

6.1.4 *For Procedure 7.6*: cut the required plies (T 414) 63 mm long in the tearing direction and 75 mm wide. Cut one set of plies with the tear direction parallel to the long edges of the test unit sheet, and another set at right angles to this direction.

6.1.5 For procedure 7.11: cut square samples at least 230 cm on a side with one axis cut parallel to the known machined edge.

7. Procedures and interpretations of observations

7.1 *Axis of curl procedure.* Induce curl in a square or circular specimen by floating the specimen on tap water in a pan, or moisten with a sponge one side of each of two test strips cut at right angles to each other. Observe the curl before water penetrates completely through the specimen(s). Papers with a high degree of dried-in strain may first exhibit an axis of curl in the cross direction. After strain relaxation, the curl axis changes and parallels the machine direction. The axis of curl will be parallel to the machine direction of the paper. Note or mark with an indelible pencil the axis of curl. This procedure may give misleading results with papers with high polar angles.

NOTE 1: If paper absorbs water readily, do not expose it to the water for more than a few seconds. This procedure is generally not suitable for highly absorbent or unsized papers.

7.2 *Bend procedure.* Place the two specimen strips together, one on top of the other, making sure they are aligned. At one end grasp the two specimens between the thumb and forefinger and hold them horizontally so that they are free to bend of their own weight. Repeat, placing the bottom specimen on top. Observe which specimen bends more when it is placed on the bottom. The specimen cut with its length parallel to the cross direction will bend more because of the lesser cross-direction stiffness and will, when on the bottom, fall away from the specimen cut with its length parallel to the machine direction.

NOTE 2: This procedure is not applicable unless the edges of the test unit sheets from which the test specimens are taken (6.1.2) were cut parallel to the machine and cross directions. When the orientation of the test unit sheets is uncertain, see 7.11.

7.3 *Bursting test procedure.* Perform a bursting test on the test unit sheet in accordance with T 403. Remove the test unit sheet from the bursting tester and observe the principal line of rupture. This line, with approximately perpendicular fractures at either end, will be perpendicular to the machine direction.

NOTE 3: The bursting test is convenient for papers with a "normal" distribution of tensile and stretch characteristics; however, there are numerous exceptions to this. The principal line of rupture is parallel to the direction with the higher stretch. In those papers where there is no significant difference in the stretch for the two directions, the rupture tends to be more random and less positive.

7.4 *Tensile test procedure*. Perform tensile tests on the specimens in accordance with T 494 ~~or T 404~~. The specimen cut with its length parallel to the machine direction will usually have the greater tensile strength and the lesser stretch.

NOTE 4: See Note 2 above.

7.5 *Surface fiber procedure.* Observe the orientation of the fibers on the surface of the paper. To view the paper, hold it horizontally with the light incident at an angle of about 45° to the surface of the paper. Observation of the paper surface under a microscope is helpful. The direction in which most of the fibers are oriented, especially on the wire side, is the machine direction. Dual-ply sheets may give misleading results.

NOTE 5: This test is reliable only for one very experienced in its use.

7.6 *Tear test procedure.* Perform tearing tests on the specimens in accordance with T 414. The specimen with the tear line in the machine direction may have the lesser tearing resistance.

NOTE 6: This procedure is reliable only for papers known to have been made on a cylinder machine. See 1.2 above. Also see Note 2 above.

7.7 *Folding endurance procedure.* Perform folding endurance tests on the specimens in accordance with T 423 or T 511. If the average number of double folds found in the specimens cut in one direction is at least two times that found in the specimens cut in the other direction, the specimens with the higher number of folds are probably cut with the length in the machine direction.

NOTE 7: See 1.2 and Notes 6 and 2 above.

7.8 *Drying procedure.* Place the specimen in a drying oven at approximately 100°C or in a desiccator over a suitable drying agent. Expose the two sides of the specimen equally to the drying atmosphere and suspend or otherwise hold it so that it can curl without restraint. Any pronounced curl due to drying will usually have its axis parallel, or nearly parallel, to the machine direction of the paper.

NOTE 8: The same papers (See 1.2) that fail to provide reliable information on the tear and fold tests may also fail on this test.

7.9 *Hand tearing procedure.* Hold the sheet of paper or paperboard in both hands and tear the sheet with firm, even pressure, from the top edge towards the bottom edge for a distance of approximately halfway. Rotate the sheet a quarter turn so that the untorn sides are now at the top and bottom. Repeat the tear procedure so that the two tear lines almost intersect. The straightest line of tear will be parallel to the machine direction. The cross machine direction of tear will not be as straight and will be more ragged with a pronounced feathering along the tear line.

NOTE 9: See 1.2 and Notes 6 and 2 above.

7.10 *Wire marks procedure.* Observe the wire marks, if visible. In many cases the wire marks are sufficiently clear to determine the direction of the most prominent lines. The most prominent lines usually will lie at right angles to the machine direction.

NOTE 10: The majority of wires or forming fabrics have cross-direction strands on the outside. They have more contact with the paper, thus the prominent lines in the cross direction. This procedure is based on properties of the wire.

7.11 *Hand flexing procedure.* Holding the square specimen by two parallel sides, bend or flex the specimen but not to the point of creasing it. Then turn the specimen 90° and flex it again. When flexing in the less stiff direction, the axis of curl is parallel to the machine direction. This procedure works well with paperboard grades, liner and medium, but not well with light materials.

7.12 *Ultrasonic tester procedure.* Use an ultrasonic instrument to measure the speed of ultrasonic pulses in the plane of the paper. The paper will have a greater ultrasonic pulse speed (sometimes reported as tensile stiffness index) in its machine direction than in its cross- machine direction.

NOTE 11: Laboratory ultrasonic test instruments are available from suppliers listed in "Test Equipment Suppliers for TAPPI Test Methods".

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7.13 *Uncertain orientation of test unit sheets.* Use one or more of the procedures 7.1, 7.3, 7.5, 7.8, or 7.10 when the test unit is not in square-cut sheets or it is uncertain that the edges of the sheets are parallel to the machine and cross directions. Alternatively, as specified for the procedure, cut consecutive test specimens at 0°, 30°, 60°, 90°, 120°, and 150° from an arbitrarily selected reference line, and use one of the following modifications of the other procedures:

7.13.1 *Modified bend procedure.* Following 7.2 above, compare each pair of consecutive test specimens in turn (0-30, 30-60, 60-90, 90-120, 120-150, and finally 150-0). The specimen that bends more than both of its nearest neighbors can be considered to have its length closest to the cross direction.

7.13.2 *Modified tensile test procedure.* Following 7.4 above, determine the tensile strength of each of the consecutive test specimens. The specimen having the greatest tensile strength may be considered to have its length closest to the machine direction.

7.14 *Use of more than one procedure.* It is recommended that any conclusion drawn from the application of one of the above procedures be verified by another procedure, especially by one of the first four procedures listed. Before drawing a firm conclusion as to the machine direction, note the unreliability of the procedures for certain materials, as stated in 1.2 and in the Notes.

8. Report

When required, report the procedure or procedures used for determining the machine direction.

9. Precision and accuracy

No precision and accuracy statement is required for this Standard Practice.

10. Keywords

Paper, Paperboard, Machine direction

11. Additional information

11.1 Effective date of issue: To be assigned.

11.2 The 2003 edition was issued as a Standard Practice in accordance with test method guidelines. During the 2009 revision, Section 8.11 was added as a new procedure for use with corrugated and board materials. All changes in the 2015 edition were editorial. The ~~2021~~ 2023 edition was modified to add the ultrasonic tester procedure, and clarify the hand flexing procedure described in Section 7.11.

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11.3 It is recommended that experience in these procedures be obtained by practicing with specimens of known machine and cross directions.

11.4 Related methods: Canadian, PAPTAC D.1; Scandinavian, SCAN-P9.

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