Designation: D 5804 – 97 (Reapproved 2002)

An American National Standard

Standard Test Methods for Zero-Span Tensile Strength ("Dry Zero-Span Tensile")[1]

This standard is issued under the fixed designation D 5804; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides a quick reliable means to measure the zero-span tensile strength of a randomly oriented specimen of fibers when dry.

1.1.1 Similar procedures for determining the zero-span tensile strength of a randomly oriented specimen of fibers when wet are found in Test Method D 5803.

1.2 In this test method, the fibers are tested as a handsheet produced using a standardized procedure such as TAPPI T 205.

1.3 While testing is possible on finished paper materials, information on fiber quality from intermediate steps in the pulping or paper making process, or both, is frequently more useful for improving finished paper quality or improving fiber utilization of, for example, recycled fibers, or fibers subjected to new pulping, bleaching, or finishing processes.

1.4 The modifications of the procedure described in this test method required for testing finished paper is straightforward; however, testing must be done in the two principle directions of the sheet, as required in Test Method D 828, since the finished paper or paperboard will generally have non-random fiber orientation, resulting in different strength properties in the two principle directions of the finished sheet. Testing of sheets having a grammage greater than 100 g/m^2, which includes some paper materials described as paper and many paperboards, is difficult because of problems associated with clamping of individual fibers as the number of fibers per unit area increases.

1.5 Such modifications are not described in this test method, and if they are made, they shall be acknowledged and clearly described in the report as deviations from the standard procedure.

1.6 In addition to a measure of the dry zero-span tensile strength of the specimen of fibers, an index of the cohesiveness of fibers in the sheet is also provided by the ratio of the tensile strength determined using Test Method D 828 and the tensile strength determined using this test method when all testing is done on handsheets having random fiber orientation **(1)**.[2]

1.7 Two instrumental approaches for accomplishing the measurement of dry tensile strength at zero-span are described.

1.7.1 One approach is the use of specially constructed pair of" zero-span" jaws which are used in conjunction with a conventional tensile testing machine.

1.7.1.1 One such design for "zero-span" jaws was proposed by Clark **(1)**. A second design was proposed by Wink and Van Eperen **(2)**.

1.7.2 A second approach is the use of a special instrument incorporating both "zero-span" jaws and measurement and readout devices in a single instrument.[3]

1.7.3 When properly adjusted and calibrated, either of the instrumental approaches may be used to perform this test method.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 586 Test Method for Ash in Pulp, Paper, and Paper Products[4]

D 685 Practice for Conditioning Paper and Paper Products for Testing[4]

D 828 Test Method for Tensile Breaking Strength of Paper and Paperboard[4]

D 1193 Specification for Reagent Water[5]

D 1968 Terminology Relating to Paper and Paper Products[4]

D 5803 Test Method for Wet Tensile Strength at Zero-Span ("Wet Zero-Span Tensile")[4]

2.2 *TAPPI Test Methods:*

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[1] This test method is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

Current edition approved Dec. 10, 1997. Published October 1998. Originally approved in 1995. Last previous edition approved in 1995 as D 5804–95.

[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] One self-contained instrument suitable for making the measurements described in this test method is available from Pulmac Instruments International, Box 50, HCR 34, Montpelier, VT 05602. There may be other sources.

[4] *Annual Book of ASTM Standards*, Vol 15.09.

[5] *Annual Book of ASTM Standards*, Vol 11.01.

T 205 Forming handsheets for physical tests of pulp[6]
T 220 Physical testing of pulp handsheets[6]

3. Terminology

3.1 Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper.*[6]

4. Significance and Use

4.1 The zero-span tensile test measures the tensile strength at the moment of tensile failure of fibers randomly oriented in a sheet.

4.2 One important use of zero-span tensile data is to determine the maximum strength of pulp fibers when beaten under idealized laboratory conditions.

4.3 Zero-span tensile strength is an excellent measure of the" maximum strength" of a pulp, and is almost completely independent of the laboratory beating procedure used.

4.4 Zero-span tensile strength, in conjunction with tensile strength as measured by Test Method D 828 and other physical properties tests, is useful in optimizing new fiber processing techniques and maximizing utilization of new fiber sources such as recycled fibers for the highest possible quality of the end-use paper or paperboard.

5. Apparatus

5.1 *Zero-Span Jaws*, comprised of two adjacent, spatially aligned clamping jaws in initial intimate contact ("zero-span"), which reliably and reproducibly exert a very high, optimum, and uniform clamping pressure on fibers in a test specimen. The essential elements that must be incorporated into any zero-span tester are shown in Fig. 1.

5.1.1 The clamping pressure required ensures a maximum clamping effect, but cannot totally prevent the microslippage whereby the tensile load transmitted in the clamped fibers is dissipated by frictional shear into the clamping jaws. This microslippage means that the ends of some fibers will slip out from beneath a clamping jaw, thereby diminishing the number of fibers carrying the load at tensile failure. For this reason, careful interpretation of zero-span tensile strength values shall be exercised in order to separate effects due to the relative number of fibers which are carrying the load at failure and the effects due to the average tensile strength of the individual fibers present in the aggregate.

5.2 While firmly clamping the specimen, the clamps shall be able to separate at a defined uniform rate of loading until the sample fails.

5.3 There are two adjacent clamping jaws which, in an unpressurized configuration, allow a test strip to be inserted between them. In the pressurized configuration, both jaws come together to apply a very high and uniform clamping pressure to the test strip. This securely clamps the fibers in the specimen that cross the clamping line defined by the intimate and very accurate spatial alignment of the two jaws at zero-span.

5.4 A suitable clamping arrangement for either of the two clamping jaws is illustrated in Fig. 2. The required clamping dimensions include a clamping width of not less than 15.0 mm and a clamping length of not less than 0.060 mm. Clamping widths as great as 22.0 mm and clamping lengths of 0.80 mm have been found satisfactory. It is extremely important that the clamping width be accurately determined to the ±0.01 mm, using a digital caliper or similar device with calibration accuracy traceable to NIST or equivalent national standardizing body, and that the two clamps making up a pair have identical clamping widths to the same tolerance. The exact length of the clamp is not so critical, but pairs of clamps shall have widths identical to the specified tolerance; ±0.01 mm. The clamping jaws should come together to provide a clamping pressure which is uniform across the clamping width to better than 1 part in 1000. The clamping jaws should be manufactured to ensure the maintenance of such precision over an extended period of repetitive high pressure clamping in a wet environment (stainless steel or other rust-resistant alloy).

5.5 The spatial alignment of the two jaws is illustrated in Fig. 3. The top and bottom clamping surfaces of both sets of jaws shall come together in the clamped arrangement so as to create the two precision planes illustrated. When clamped, the

[6] Available from the Technical Association of the Pulp and Paper Industry (TAPPI), Technology Park/Atlanta, P.O. Box 105113, Atlanta, GA 30348.

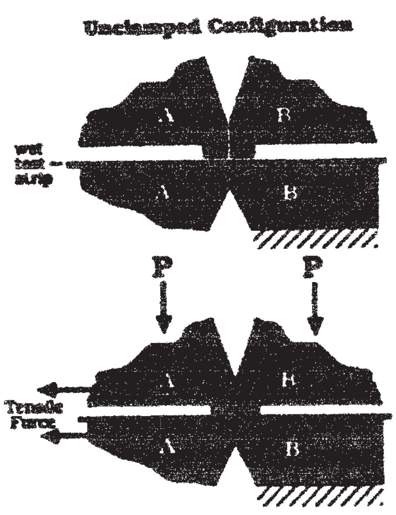


FIG. 1 Essential Elements for Any Wet Zero-Span Tester

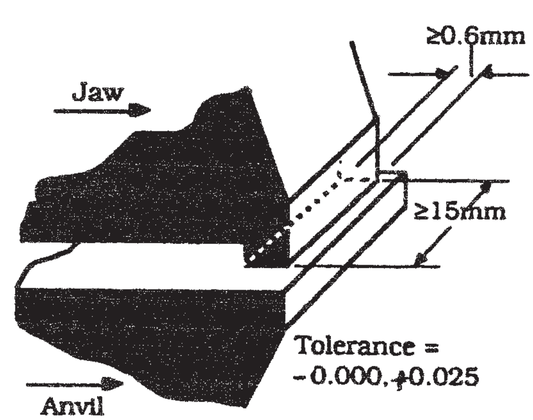


FIG. 2 Suitable Clamping Arrangement for Either of the Two Clamping Jaws

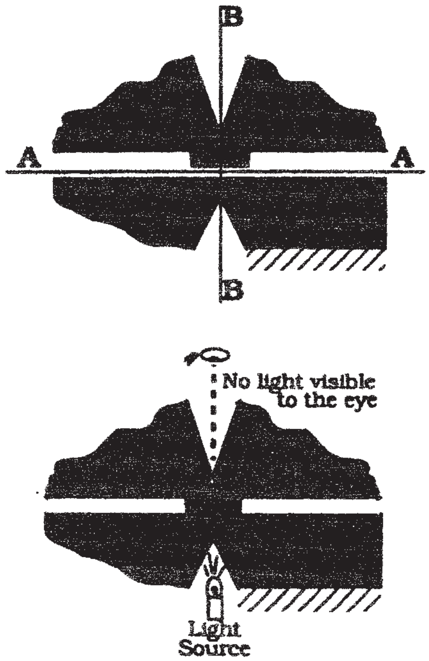


FIG. 3 Spatial Alignment of the Two Jaws

horizontal surfaces of both jaws shall conform to Plane A to a tolerance of 0.005 mm or less. When clamped, the vertical surfaces which are in contact at zero-span shall conform to Plane B with a tolerance such that a light beam is completely interrupted when the jaws are in clamped zero-span contact.

5.6 The apparatus shall provide the capability to cause both clamping jaws to come together so as to induce an adjustable range of measurable clamping pressures sufficient to demonstrate optimum clamping of the fiber test strip.

5.7 Increasing the jaw clamping pressure from a low value improves clamping efficiency, resulting in an increase in the observed zero-span tensile failure load of the fiber aggregate. Such increases will continue until the clamping pressure reaches a level which causes fiber damage, after which the zero-span tensile failure load of the fiber test strip will be observed to decline. The clamping pressure which maximizes the zero-span tensile failure load of the fiber test strip is the optimum clamping pressure.

5.8 There are at least three zero-span jaw systems complying with the requirements in Section 5. These are the specially designed zero-span jaws of Clark **(4)**, and those of Wink and Van Eperen **(5)**, either of which can be used with a conventional tensile testing instrument such as is described in Test Method D 828, and a self-contained unit comprised of a tensile measuring system and zero-span jaws.[3] No further description of the jaws incorporated in the self-contained unit is required beyond that in 5.1 through 5.7. The description of the separate jaws which may be attached to a conventional tensile testing machine (5.2.2) is as follows:

5.9 *Zero-Span Jaw Attachment (*Fig. 4 *and* Fig. 5*)*[3]:

5.9.1 The generally available zero-span attachment jaws for use with conventional tensile testers (5.2) are pairs of jaws with flat tips made from hardened steel and of one of the two shapes shown schematically in Fig. 3. Provided that the attachment jaws are very carefully made so that the fit and alignment of the tips of the jaws is as described in 5.5, the general designs of the attachment appear to have no appreciable effect on the test results.

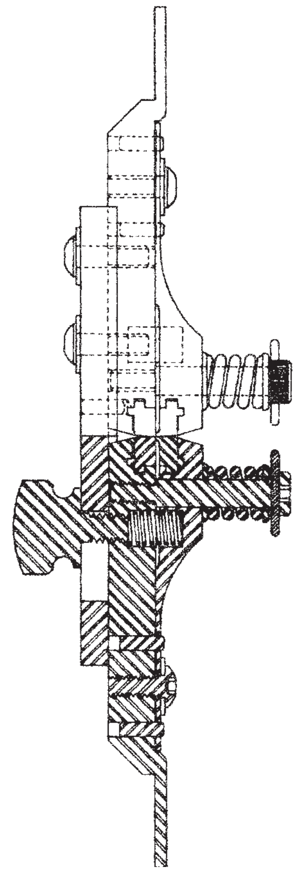
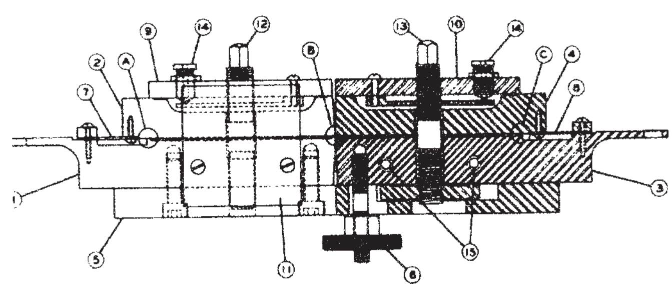


FIG. 4 Clark Attachment



Legend: A, B, C = clamping surfaces
1, 2 = jaw members,
3, 4 = movable jaws,
5 = base plate,
6 = knurled locknut,
7, 8 = flat spring stock,
9, 10 = loading beams,
11 = guide plate
12, 13 = differential screw,
14 = electrical contactor
15 = knurled nuts.

FIG. 5 IPC Attachment

5.9.2 One of the attachment jaws is fixed to a plate having a tang to fit into a universal coupling or grip of the tensile tester. The other of the jaws forms a sliding member with the tensile tester. The sliding member is constrained to move parallel to and against the plate and is arranged to be clamped to the plate by means of a knurled screw. When the screw is loosened, this member is enabled to slide without restraint along guides attached to the plate, thus moving its jaws away from the jaws fixed to the plate, and so to rupture the specimen.

5.9.3 The outer jaw of each pair is movable outward and is arranged to be clamped against its mating jaw by means of a screw. The applied closing pressure is controlled either by means of a heavy spiral spring having an adjustable compressed length, or else in an alternative form of attachment **(2)** by means of a cantilever arrangement having electrical contacts to signal when a prearranged pressure has been reached.

5.9.4 The effective dimensions of the tips of the jaws gripping the specimen are 0.6 ± 0.1 mm long and 15.0 ± 0.05 mm wide. By means of either a shim or preferably by a portion of the specimen to be tested, inserted at the far end of each pair of jaws, the faces of the jaws are 1 or 2 µm nearer together than the rear edges.

5.9.5 Arrangements are provided to adjust the clamping pressure on a gripped specimen up to about 1000 kg/cm, which corresponds to about 90 kg on the faces of a pair of 0.6 by 15.0 mm jaws.

5.9.6 The attachment is designed and fitted into the jaws of the tensile tester in such a way that the applied load passes along the plane of the specimen being tested. When so mounted without a specimen, and the knurled screw holding the movable pair of jaws to the plate is loosened, it is important that no misalignment of the jaws be observable.

5.9.7 When tightened, the jaws are required to lie within 12 µm (0.0005 in.) of a common line in a plane of the specimen, as observed with a microscope. The outer surfaces (sides) of the jaws are required to be in alignment to within 25 µm (0.001 in.). However, it is almost impossible to check the fit of the jaws with a microscope; this should be done by their performance in use.

5.9.8 Because of the close tolerances necessary, any rusting of the tips of the jaws may impair the accuracy of the test. When not in use, the attachment should be oiled with a light, noncorrosive machine oil and kept in desiccator or a container with a quantity of anhydrous silica gel. Carefully wipe the jaws and clean them with solvent to remove any excess oil or debris before use.

5.9.9 Do not tap the pairs of jaws together when closing them. If the jaws are continually tapped together, their edges may become peened into a sharp ridge, which will cut into and weaken the specimens.

5.10 *Testing and Measuring System*:

5.10.1 The apparatus shall provide the means to exert and measure an in-plane tensile force within the clamped fiber test strip and to increase this force at a controllable rate until tensile failure occurs.

5.10.2 In cases where a combined instrument providing zero-span jaws complying with 5.1 incorporated into an integrated measuring and recording system is used (1.8.2), the means for exerting in-plane tensile force incorporated in that instrument complies with 5.2. The controlled increase in tensile force shall be at a rate of 25 ± 2 N/s/cm of jaw width, unless reported to the contrary as a deviation from this test method in the report.

5.10.3 In cases where separate zeros-span jaws complying with 5.1 are used (1.8.1), the means of incorporating in-plane tensile force shall be a constant rate of elongation type tensile tester complying with Test Method D 828, having a range of at least 20 kg (45 lb), and adjusted to apply a gradually increasing load so as to break the specimen in 2.5 ± 0.5 s.

5.10.4 A measuring system is used to record the tensile load carried by the specimen at the moment of the tensile failure.

5.10.5 There are no special requirements for the electronic measurement system beyond that generally found in equipment complying with Test Method D 828 or similar measurement systems incorporated in self-contained zero-span tensile testers.

6. Reagents

6.1 *Distilled Water*—Any of the four grades of water described in Specification D 1193 are suitable for making the measurements described in this test method.

7. Sampling

7.1 The sampling and number of test specimens taken depends upon the purpose of the testing.

7.2 Samples shall be taken at various points in the production process, depending upon the information required or agreement of parties involved in the testing.

8. Sample Preparation

8.1 This test method requires a random aggregate of fibers in sheeted form for testing. Even when the sample is obtained in sheet form, it must be reformed into a fiber slurry and then reformed into a randomly oriented sheet following standardized procedures such as TAPPI T 205.

8.2 Forming of the fiber slurry may be done by the method of user choice. The method used should be reported.

8.3 As required in TAPPI T 205, the resulting handsheet will have a grammage of 60 g/m^2, with a tolerance of ±5 %. This is the grammage required in 11.1.

8.3.1 If the test sheets are roll-couched, as described in TAPPI T 205, there will probably be an appreciable degree of orientation. Arrange to apply the two couching blotters with their grain crossed and the lower blotter with its grain in the direction of rolling. Mark each sheet with this direction and also the specimen disks. Make half the determinations in this direction and the other half perpendicular to it. This precaution is not necessary with air-couched sheets as described in TAPPI T 205.

9. Calibration and Maintenance

9.1 *Calibration (General)*—Use the calibration procedure that is specified by the manufacturer. If no procedure is specified use the following procedure: Calibrate load measuring mechanism. Zero-span jaws, mounted vertically, may be calibrated using a dead weight or force gage traceable to NIST (similar to a conventional tensile tester). It is preferable to use a force gage on zero-span jaws that are mounted horizontally. Obtain readings at six points throughout the usable range of the load measuring mechanism. Applied values should agree with measured values to within 0.5 %.

9.2 *Maintenance (General)*—Make sure that light passing between the jaws is totally absent when the clamping jaws are brought to zero-span contact. Careful and regular cleaning of the jaws is required to maintain the jaws in this state. It is particularly important to prevent fibers or solid deposits from forming between the lower jaws, as their presence will affect jaw performance and test results.

9.3 *Calibration of Separate Zero-Span Attachment Jaws in* 5.9:

9.3.1 For reliable results, the procedure given for the calibration and use of the jaws should be carefully followed, and special care taken not to damage their tips.

9.3.2 Loosen the knurled screw a quarter of a turn and slide the movable jaws back and forth on the plate. Check that friction is absent but that there is merely a sliding fit with no lateral looseness of the movable jaw member in the slide.

9.3.3 Gently push the two sets of jaws into contact and firmly press their tips together (usually with one tang against the chest or a desk top and the other tang in one hand). Tighten the knurled clamping screw with the free hand. Close the jaws and place the assembly under a microscope with a magnification of 50 times or greater. Check that the tips of the two pairs of jaws make uninterrupted contact at their edges within the tolerances specified in the previous section.

9.3.4 Loosen the jaw clamping screws and adjust the extent of the jaw openings are from 1 to 1.5 mm wide. Insert a strip of book or writing paper between the opened jaws with a preset pressure of about 1000 kg/cm^2. Loosen the clamping screws, remove the strip of paper, and examine the imprint of the jaws on the paper with the microscope. If properly made, there will be no discernible ridge in the paper corresponding to the common line where the edges of the two pairs of jaws meet. The imprints made by the jaws should be uniform in translucency and appearance.

9.3.5 Adjust the load on the clamping screws so that when tightened to their stops or to their indicated positions approximately equal pressures are exerted. Test the adequacy of the applied pressure as follows:

9.3.5.1 Clamp the attachment in the tensile tester and check its alignment. Carefully follow the test procedure as later described, and obtain an average reading in the machine direction of five strips of a good quality of draft wrapping paper.

9.3.5.2 Repeat the test procedure with extra clamping pressure applied, and note if the average test is now statistically higher or lower. If higher, increase the pressures further, again carry out the test and continue to increase the pressure until the test results show no further increase. Normally this pressure will not need to be decreased for subsequent weaker specimens; if lower, reduce the clamping pressure slightly after ensuring that the jaws are gripping perfectly.

9.3.6 Loosen or disconnect the upper jaws and knurled clamping screw from the attachment and, unless the tensile tester indicator can be adjusted to zero, weigh, and record the combined weights to the nearest 0.05 kg (0.1 lb) so that this weight, which otherwise would be included in the indicated loads, may be subtracted from the average load after each test.

10. Conditioning

10.1 Condition the specimens and test in an atmosphere in accordance with Practice D 685.

11. Procedure

11.1 Weigh each test handsheet to determine grammage in accordance with TAPPI T 220. As specified in 11.7, grammage of the prepared handsheets shall be 60 g/m^2 with a tolerance of ± 5 %. Handsheets outside this tolerance range are not to be used for testing.

11.1.1 By making lighter sheets than 60 g/m^2, (for example, 30 g/m^2), it is possible to raise the zero breaking length appreciably; however, such sheets and their testing do not comply with this test method.

11.1.2 If enough pulp is not available and the test is for other than referee purposes, it may be convenient to use the remnants of the strips from a conventional tensile test on a handsheet made from the specimen pulp. Avoid the areas immediately adjacent to the breaks, testing them at right angles to their lengths.

11.1.3 Unless the formation and uniformity of the test sheets are excellent, more exact results may be obtained by preparing the specimens as disks as follows: With a sharp paper punch of about 17 mm (¾ in.) diameter, punch out circular specimens from conditioned samples. Measure the diameter of the punched disks to within 0.025 mm (0.001 in.). Weigh the specimen disks on a sensitive analytical balance and calculate their average basis weight (moisture free) in g/m^2 to three significant figures. Alternatively, squares may be cut for weighing, using a double knife cutter of known width (0.500 in. wide, 0.750 in. wide, etc).

11.2 Cut each test sheet into test strips of a size to suit the zero-span tensile jaws which will be used (for example, 11 by 2 cm). Cut the test strip to a width exceeding the width of the clamping jaws so that when a strip is located in the test position, it extends beyond the jaws in both directions by about 2.5 mm (for example, a 15-mm jaw specimen width should be at least 20 mm).

11.2.1 Because the exact dimension of the fracture in the specimens is controlled by the width of the jaws (15 mm), provided that the length of each specimen is such as to enable it to be securely clamped across the entire line of fracture, the actual length of the specimen is immaterial provided that the specimen width exceeds the jaw width. Any portion of the specimen protruding from the sides of the jaws will not significantly affect the results. Use of a specimen wider than the jaw width guarantees that the fiber aggregate is uniformly clamped over the whole jaw width, with no edge effects. This is because no stress is applied to these projections until the fracture of the gripped portion has occurred.

11.2.2 It is possible to make successive determinations on a strip 15 mm long, if desired.

11.3 Determine the zero-span tensile strength as described in either 11.4 or 11.5.

11.4 When using an integrated testing apparatus such as is described in 5.10.2, proceed as follows:

11.4.1 Place the test strip onto the test position in the instrument following the manufacturer's instructions.

11.4.2 Activate the tester to conduct the zero-span tensile test following the manufacturer's instructions. Record the zero-span tensile load at failure in Newtons per centimetre, or units which may be converted to Newtons per centimetre, or as agreed upon by parties involved in the testing.

11.5 *Preliminary Instructions*—Determine the zero-span tensile strength of the specimen using a separate zero-span attachment and tensile tester as described in Test Method D 828 as follows:

11.5.1 Usually it is desirable, (resulting in higher test results which should be checked) to cover one of the gripping surfaces of each pair of clamping jaws with a good quality of cellophane adhesive tape as follows: Loosen the knurled screw slightly and without tapping, firmly press the tips of the jaws together. While still under pressure, tighten the knurled screw as in 9.3.3.

11.5.2 Cut a short length (5 to 8 mm) of a strip of cellophane or other thin hard adhesive tape made from a strong film material, and center the short length between the opened jaws. The grain direction of the tape (the strongest direction) will then be parallel to the length of the attachment. Close the jaws and apply the preset pressure with the clamping screws. Place the attachment in the tensile tester. Loosen the knurled screw. Apply tension and break the tape. Remove the attachment and with a razor blade, shaving off the cellophane protruding from the sides and abutting edges of both pairs of jaws. The attachment is now ready for use. Normally, the facing is good for 20 or more tests, unless the specimens to be tested are particularly strong. The facing should be inspected after each set of tests and renewed if it appears to be frayed.

11.6 *Procedure with Clark Attachment (*Fig. 4*)*:

11.6.1 With the knurled screw, clamp the pairs of jaws together and open each as before. Inspect the translucency of each specimen before inserting it to ensure that the portion to be tested does not include a particularly light or heavy area or defect. Insert a disk or an end of the specimen test strip between the opened jaws so that it projects beyond the other side, and adjust its position over the clamping surfaces. Tighten one of the clamping screws finger-tight to hold the strip in position. With the key provided, tighten the other screw all the way in until the preset pressure has been applied, then similarly tighten the first screw.

11.6.2 Set the jaws of the tensile tester about 185 mm (7.4 in.) apart. Place the attachment, with the specimen in place centrally in the grips, and clamp firmly in position. Should the jaws of the tensile tester be made for a specimen width greater than 15 mm, it is desirable to attach a stop in the jaws to center the tangs automatically. If they are made for narrower strips, it will be necessary to reduce the width of the tangs to suit. In any case, the attachment shall be clamped so that its center line coincides with the center line of the jaws of the tensile tester.

11.6.3 Using the tensile tester controls, set the tester to hold the maximum load measured during the test. Set the auto return, if there is one, to "OFF," or otherwise program the tensile tester to" STOP" the cross-head travel after the peak load is achieved. This setting is very important. If the cross-head returns in an automatic mode at the end of the test, damage to the tester, the zero-span attachment, or both, is possible.

11.6.4 Activate the tensile tester and apply the load at such a rate that the specimen will break in 2.5 ± 0.5 s. This time to break is achieved by a very slow cross-head speed, and shall be determined by trial and error. Just as the tensile tester is activated, loosen the knurled clamping screw a quarter turn. When the specimen breaks, immediately stop the stressing jaw of the tensile tester; if the stressing jaw moves 5 or 6 mm further by the construction of the attachment, the pendulum will be further loaded and the proper indicated reading lost.

11.6.5 Record the indicated breaking load to the nearest 0.1 kg (0.2 lb). Loosely tighten the knurled clamping screw to prevent the jaws from subsequently sliding together and tapping each other. Remove the attachment from the tensile tester.

11.6.6 Reset the tensile tester cross-head to its initial starting position, using the manual return controls or similar controls.

11.6.7 Loosen the jaw clamping screws of the attachment and remove the broken specimen, or pull the specimen strip along to a new place beyond the fracture, taking care that no debris is left. A hand-operated rubber bulb blower or aspirator is effective for cleaning the jaws. Loosen the knurled clamping screw, press and clamp the zero-span jaws together, and repeat the steps in 11.6 to test the required number of specimens.

11.7 *Procedure with IPC Attachment (*Fig. 5*)*:

11.7.1 Insert the attachment into the tensile tester and prepare for testing as in 11.6.2 and 11.6.3.

11.7.2 After making the electrical connections to indicate the required maximum pressure, detach the bottom tang from the lower coupling. Release the guide plate and movable pairs of jaws by loosening the knurled nuts to ensure lateral alignment, then tighten the knurled locknut. Attach the lower tang to its coupling; then open the pairs of jaws by turning the loading screws counter-clockwise with the key provided. Insert the test specimen between the abutting jaws and a portion of the same specimen at the far ends of the jaws. With the key, lightly tighten each pair of jaws: Continue to tighten the jaws in small increments alternately, until the signal lights go out indicating that the specimen is gripped with the preset clamping pressure.Fig. 6

11.7.3 Release the guide plate by loosening the knurled nuts sufficiently to ensure frictionless motion. Follow the procedures described in 11.6.3 through 11.6.7.

11.8 Make at least ten replicate determinations on each sample.

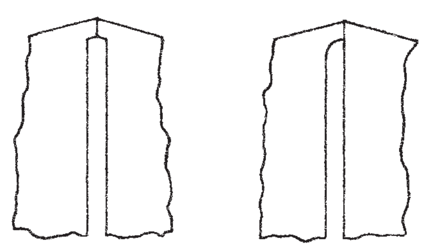


FIG. 6 Jaw Shapes

11.8.1 Average the readings, and unless the indicator has been compensated, subtract the weight of the upper zero-span jaws and knurled locknut from the result to give the actual zero-span breaking load.

11.8.2 Calculate the average moisture-free basis weight of the specimens in grams per square meter.

12. Calculations

12.1 Correct each result to target grammage of 60 g/m^2(oven-dried equivalent: see TAPPI T 205):

$$\text{Corrected zero-span value,} \\ N = \text{measured value, } N \times (60/\text{strip grammage}) \quad (1)$$

12.2 For test results determined using the procedure in 11.6 *only*, the results must be corrected for the apparent force equivalent to the mass of the upper zero-span jaw and knurled locknut. This may be most easily done by adjusting the instrument readout to zero with the zero-span attachment in place and the knurled locknut loosened.

12.2.1 An alternative procedure is to remove the upper jaw and knurled locknut from the rest of the assembly, weigh the removed components on a balance to the nearest gram, convert that force from grams-force to Newtons by multiplying by 9.80665×10^{-3}, and subtract that value from the result in Eq 1.

12.3 Calculate the zero-span tensile test value of each result corrected to 60 g/m^2(oven-dried equivalent), in Newtons per centimetre (to one significant figure after the decimal point) using Eq 2: Corrected wet zero-span value,

$$N/cm = \frac{\text{measured value, } N \times (60/\text{strip BW})}{\text{jaw width from 5.4, cm}} \quad (2)$$

12.4 Calculate the average zero-span tensile strength for each sample from all of the results from 12.3 for each sample tested.

12.5 If the original pulp sample contained filler or additive, or both (typically from broke), correct each zero-span tensile result to account for its presence (see Test Method D 586) using Eq 3:

$$\text{Ash corrected wet zero-span value,} \\ N = \text{uncorrected value} \times [100/(100 - \%\text{ash}), N] \quad (3)$$

12.6 If desired, calculate the ratio of the normal tensile strength to the zero-span tensile strength for the same specimen and determined on specimens at, or corrected to, a grammage of 60 g/m^2. Report as the bonding index.

12.6.1 Although useful as an indication of fiber cohesiveness, the bonding index is not a true measure of the bonding characteristics of the fibers.

13. Report

13.1 Report the following information:

13.1.1 The average zero-span tensile result from 12.4 or 12.5.

13.1.2 The range and standard deviation for results on specimens from each sample.

13.1.3 Any deviations from the requirements of this test method.

14. Precision and Bias

14.1 *Precision for Procedure in* 11.4:

14.1.1 *Repeatability (Within One Laboratory)*—The estimated repeatability of this test method, calculated as the standard deviation of repeated tests on pulps with results between 75 and 95 Newtons/cm when tested as described in 11.4, was 1 % of the measured value. The 95 % repeatibility limit was 3 % of the measured value.

14.1.2 Reproducibility studies using the self-contained zero-span unit described in Section 5, are in progress.

14.2 *Precision for Procedure in* 11.5:

14.2.1 *Repeatability (Within a Laboratory)*—Previous estimates of repeatability based on testing 30 samples in three laboratories using either of the styles of zero-span jaws described in 5.9 in conjunction with a conventional tensile tester were a standard deviation of 1.8 % of the measured value, and a repeatability limit of 5 % of the measured value.

14.2.2 *Reproducibility (Between Laboratories)*—Previous estimates of reproducibility based on testing 30 samples in three laboratories using either of the styles of zero-span jaws described in 5.9 in conjunction with a conventional tensile tester were a standard deviation of 3.6 % of the measured value and a repeatability limit of 10 % of the measured value.

14.2.2.1 These values are estimates based upon tests of over 30 samples in three laboratories, using the two different designs of jaws described in 11.5.

14.3 The zero-span test performed using the jaws described in 5.9 and a conventional tensile tester has an estimated precision stated only if care is taken to finish and calibrate the attachment accurately, and to carry out the procedure exactly as prescribed. The highest skill and care are required in making the attachment; unless exceptional facilities and workmanship are available, attempts to produce a "homemade" attachment will probably result in failure to obtain reliable test results.

15. Keywords

15.1 fibers; paper; paperboard; zero-span tensile

APPENDIX

(Nonmandatory Information)

X1. DIRECTIONALITY EFFECTS ON ZERO-SPAN TENSILE

X1.1 In a randomly oriented test sheet, it is reported that the zero-span breaking load is three-eighths of what it would be if the fibers were all aligned in the direction of the applied load **(4)**. In practice this ratio appears to be high **(5)**, possibly because some fiber ends are in or their lengths adjacent to the line of rupture and by other causes.

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