THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

RING CRUSH / STFI TEST METHODOLOGY

Project 2694-12

Report One
A Progress Report

to

CONTAINERBOARD AND KRAFT PAPER GROUP

OF THE

AMERICAN PAPER INSTITUTE

April 26, 1991
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RING CRUSH / STFI TEST METHODOLOGY
Project 2694-12

BACKGROUND

Most linerboard and medium mills measure various properties of their product as part of a program aimed at controlling quality. CKPG sponsors a program in which mill test results are reported to the Institute of Paper Science and Technology bi-monthly. These mill quality data are then reported to the CKPG membership in semi-annual reports. The reports have been useful in indicating industry trends, and in allowing individual mills to compare their results with industry averages.

The results of a recent questionnaire have shown that the procedures used by mills to measure edgewise compressive strength vary considerably. These procedural differences make interpretation of baseline data difficult.

The edgewise compressive strength of the components of corrugated board has, historically, been measured by the ring crush test. In this test, a specimen is cut 6 inches long by ½ inch wide, with the ½ inch dimension parallel with the cross-machine direction of the material. The specimen is then formed into a ring shape and held in a grooved holder so that the compressive failure strength can be measured in the ½ inch dimension.
More recently, a new procedure has been introduced for the measurement of edgewise compressive strength of the components of corrugated board. For this test, the specimen is cut 15 mm wide and any convenient length, usually 3 or more inches, with the longer dimension parallel with the cross-machine direction of the material. The specimen is then gripped between two pairs of clamps separated by a short distance of 0.7 mm.

Movement of the pairs of clamps toward each other exerts a cross-machine direction compressive force on the specimen, and the maximum force sustained by the specimen before failure is measured as edgewise compressive strength. This test is referred to as short-span compression strength or, through common usage in the United States, STFI. The latter refers to the instrument developer.

Most mills today measure ring crush, STFI, or both. Some tests are made in humidity controlled laboratories, and some in unconditioned rooms. Sample conditioning time ranges from a few minutes to many hours. The results for unconditioned samples may, or may not, be corrected to a reference moisture level. In some cases, ring crush values are calculated from STFI measurements or STFI values from ring crush measurements. Some laboratories use a flexible beam tester for measurement of ring crush, in which the ring crush holder rests on a platen supported by a bending beam and
the deflection of the beam is used as an indicator of force on the specimen. Other laboratories use a rigid platen tester in which the holder rests on a platen supported by a strain gage load cell or, alternately, the load cell may sense the force exerted on the upper platen. All or any of these variables may serve to diminish the value of the baseline data.

**OBJECTIVE OF PROJECT**

This study was undertaken with the ultimate objective of maximizing the accuracy and precision of the CKPG baseline data on compressive strength of corrugating components. An important strategy for the initial phase of this project included contracting for the services of Ms. Helen Schuirer. Before her retirement, Ms. Schuirer was manager of the physical testing facilities for Champion International Corp. at their corporate technical center. This position included responsibility for corporate-wide calibration of test instruments and standardization of test methods. She also had many years experience as an active member of the Testing Division of TAPPI (now the Process and Product Quality Division), and as a member of the Test Methods Management Committee of the TAPPI Board of Directors. A significant part of the contents of this report represents her efforts.

The specific objectives for the first phase of this project were developed in meetings between Institute staff, Ms. Schuirer,
and selected members of the CKPG technical committee. These objectives were:

1. Compare the strengths and limitations of the ring crush test (with both flexible beam and rigid platen compression testers: TAPPI methods T822 and T823) and the STFI short span compression test (TAPPI method T826).

2. Compare, objectively criticize, and redraft the various TAPPI methods with the intent of maximizing the accuracy and precision of the data. This analysis will focus on standard conditions.

3. Without significantly compromising the TAPPI procedures developed in objective 2, develop two process control procedures for mill off-machine testing. This effort will focus on developing methods which will provide the machine operator with an off-machine quantification of edgewise compression strength that will be the best approximation of the standard method, standard environment result.

4. Develop a list of secondary issues relating to compression strength testing which arise from this study, and which may be issues for future study.

**INSTRUMENT COMPARISON**

The three methods for measuring edgewise compressive strength of corrugating components; ring crush measured with flexing beam
compression tester, ring crush measured with rigid platen tester, and STFI short span compression tester; were critically analyzed in terms of the advantages and disadvantages of each. Major differences between the three methods which are neither an advantage or disadvantage were also included. The results of this analysis are listed in Table 1 and discussed below.

An important point to remember in this discussion is that the ring crush test and STFI test may not be measuring the same properties of the board. The short span used in the STFI test, 0.7 mm, is shorter than some fiber lengths, whereas the ½ inch span used for the ring crush test is significantly greater than fiber length. Hence, the STFI test is likely to be influenced by fiber properties in a different way than for the ring crush test. This effect may account for part of the within and between grade variance between ring crush and STFI.

The effect that moisture has on the properties of paper is well known. Generally, paper becomes weaker as its moisture content increases. A value often cited for edgewise compression strength is that a loss of 8% in strength will occur if the moisture is increased 1%; our data suggests this number is a little high and may be closer to 7%; Regardless of the value, good intra- and inter-laboratory agreement cannot be expected unless the moisture level in the sample is controlled. Unfortunately, most
mills cannot function efficiently if samples have to be exposed to the testing atmosphere for many hours before testing. Responses to a recent questionnaire indicated that the actual conditioning time ranges from only a few minutes to several hours, depending on laboratory practice. The STFI instrument is equipped with a sensor which measures the electrical conductivity of the test specimen and then uses this value to estimate the sample moisture content. This moisture content, along with the measured compressive strength and stored coefficients, is used to predict the strength at a reference moisture level, usually about 7 to 7½%. Some laboratories have reported good success with this moisture compensation system, while other have found that moisture content predicted from electrical conductivity is not reliable enough for this purpose.

The ring crush test has been the standard test for measuring edge compression of corrugating components since 1946 when it was first proposed as a TAPPI suggested method. Hence, a significant advantage of this test is the large data base that exists, both in company archives and in the CKPG sponsored baseline program.

Collaborative Reference Program data show that the agreement between laboratories is significantly better for the STFI test than for the ring crush test. For the four month period ending February 1991, the inter-laboratory standard deviation of 42 lb linerboard is 5.9% of the sample mean for the STFI test and 8.6% for the ring
crush test. It should be remembered, however, that the STFI results represent averages of 20 readings and only 10 tests are made for ring crush. An added complication is that some laboratories use a rigid platen, and others a flexible beam, compression tester to measure ring crush. The results for these two types of testers are not segregated in the reports.

An often heard criticism of the ring crush test is that the compressive force is applied to the specimen edges. Hence, any imperfections of the edge, such as might be caused by dull or nicked cutting blades, can lead to suspect results. Another criticism is the difficulty in maintaining parallelism between the various surfaces involved. These include the loading beam, the lower platen which rests on the beam, the bottom and inside surfaces of the ring crush holder, the loading edges of the test specimen, and the upper platen. These surfaces must remain parallel, within the specified tolerances, both in an unloaded state and under load. In this regard, rigid platen testers pose fewer problems than flexible beam testers since they move through a shorter distance during a test. Finally, the ring crush test has been criticized because of specimen behavior during the test. Light weight samples, especially 26# grade, usually fail in a buckling mode rather than in compression. Heavy weight samples, on the other hand, cannot be bent through the required ring radius without bending failure.
The STFI test has been criticized because of the relatively complex calibration procedures. Additionally, the test method requires that the various clamping surfaces have a high level of friction, and that all surfaces be aligned within specified tolerances. A satisfactory procedure for in-laboratory checking of these requirements, and for making adjustments, is not a part of the present method. Finally, the STFI tester is not suitable for other types of compression tests, such as flat crush.
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REVISION OF T822 AND T826

TAPPI test methods for ring crush (rigid platens) and for STFI, T822 and T826, respectively, were critically reviewed by Ms. Schuirer. The review was aimed at detecting any method changes which may improve the precision of the methods, and at making the written methods more user friendly. As part of this review process, and following the proposed revisions to the methods, tests were made in the Institute laboratories to assess the intra-laboratory precision of the method. For this purpose, enough material of the four Collaborative Reference Samples was obtained so they could be tested on eight different days for each of the two methods. The proposed revisions follow this section of the report.

It should be pointed out that none of the proposed revisions affect the basic procedures involved. Rather, they re-orient testing steps in a more logical sequence, add cautionary comments when these seem appropriate, and change words when the new words seem to better describe the instrument component or procedural step.

The present ring crush method, for example, seems to indicate that conditioning does not begin until after the specimens have been cut. The Sampling and Procedural part of the method has been reorganized into four parts and arranged in logical sequence:
Sampling, Conditioning, Preparation of test specimen, and Testing procedure. A requirement was added to measure the moisture content for all samples. The requirement to use rubber or plastic gloves was expanded to include lint-free cotton gloves which are more comfortable. Finally, a procedure was added for calibration of rigid platen testers for which the load cell is in the upper platen.

All of the changes listed above for the ring crush method, except for adding the section on load cell calibration, were also made for the STFI method.

PROPOSED CHANGES / REVISIONS

Ring crush of paperboard (rigid support method)

1. Scope

1.1 The ring crush test correlates with edgewise compression strength of paperboard.

1.2 This method is intended for paperboard between 0.28 mm (0.01 in) and 0.51 mm (0.02 in) thick.

NOTE 1: Caution should be used when testing linerboard less or greater than the specified thickness as the results are less reliable.

2. Significance
The edgewise compression strength of corrugated board is the principal element in determining the dynamic compression strength of the container made from that board. Since fiberboard shipping containers are frequently subjected to loads which are resisted by compression strength, this property is an important measure of the performance characteristics of corrugated board, useful in controlling the manufacturing process and in measuring the quality of the finished product. Since edgewise compression can be estimated by a summation of the ring crush strengths of the liners and the medium, this test becomes a useful one for the corrugated boxmaker.

3. **Summary**

A compressive force is exerted on a specimen held in ring form in a special sample holder and placed between two platens of a compression machine by causing a driven platen to approach the rigid platen at a uniform speed until the specimen collapses.

4. **Apparatus**

4.1 Compression machine having the following:

4.1.1 An upper and lower platen, one rigidly supported and the other driven. Each platen shall have a working area of at least 100 cm². The platens are required to have not more than 0.050 mm (0.002 in)
lateral movement and the rigidly supported platen not more than 0.150 mm (0.006 in) vertical movement, within a load range of 0 to 2500 N. Within a 100-cm² working area each platen shall be flat within 0.0025 mm (0.0001 in) of the mean platen surface and the platens shall remain parallel with each other within 0.0125 mm (0.0005 in) throughout the test.

4.1.2 A means for moving the driven platen to achieve an initial platen separation of at least 60 mm (2.25 in). Within a range of platen separation of 0 to 60 mm and within a load range of 0 to 2225 N, the speed of the driven platen shall be controllable at 10 ± 0.2 mm (0.4 ± 0.008 in) per minute. (Note: for convenience, the test machine should be capable of rapid return and automatic, settable positioning).

4.1.3 A capacity of at least 2225 N.

4.1.4 A means for measuring and indicating the maximum load sustained by the test specimen within 2.5 N (0.5 lbf.)

4.1.5 An indicating mechanism that can be checked accurately with dead weight load, load cell, or proving ring. The accuracy required is 0.5% or 2.4 N (0.5 lbf) whichever is greater.
NOTE 2: For machines where the load cell is the upper platen see Appendix A.

4.2 Specimen holder, composed of a circular block having an annular square cut groove, 6.4 ± 0.25 mm (0.25 ± 0.01 in) deep and 49.2 ± 0.035 mm (1.940 ± 0.001 in) outside diameter. The bottom of the annular groove is required to be parallel with the base of the block ± 0.01 mm (0.0004 in), with the sides of the groove at right angles. A branch groove tangent to the annular groove, of the same depth and extending to the edge of the block, is provided to insert the specimen and is not wider than 1.27 mm (0.050 in) at its entrance to the annular groove. The center "island" created by the annular groove is removable and replaceable with disks of different diameters, so that the width of the groove may be adjusted to be at least 150% but not more than 175% of the nominal caliper of the specimen being tested. Each disk has a central hole to fit a receiving pin central to the annular groove and is free to turn as the specimen is inserted through the branch groove.

4.3 Scribe or otherwise mark one point on the perimeter of the annular groove at some distance, preferably
0.5 in away from the branch groove.

4.4 A precision die cutter capable of accurately cutting the test specimens to exact dimension with clean parallel edges.

5. Sampling

Samples should be selected and gathered in accordance with TAPPI T400 "Sampling & Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Products."

NOTE 3: This test is extremely sensitive to moisture. As soon as samples are gathered, they should be promptly picked up or delivered to the test lab.

6. Conditioning

Due to possible dimensional changes samples should be preconditioned and conditioned before cutting test specimens in an atmosphere in accordance with TAPPI T402, "Standard Conditioning & Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products."

7. Preparation of Test Specimens

7.1 Carefully die-cut test specimens felt side down 12.700 + 0.000 - 0.025 mm (0.500 + 0.000 - 0.001 in) wide 152.4 + 0.00 - 0.2 mm (6.00 + 0.00 - 0.01
in) long. Cut so that the long dimension is parallel with the machine direction of the board for CD specimens and the long direction is perpendicular to the machine direction of the board for MD specimens.

**NOTE 4:** Once test specimens are cut, be careful not to place them near high humidity, heat or any other condition that may change the moisture content of the test specimens.

In cutting the specimens take care to ensure that:

7.1.1 The long edges are parallel, such that the widths at opposite ends are within 0.015 mm (0.0006 in) of each other.

7.1.2 The long edges are parallel (perpendicular for MD tests) with the machine direction of the board.

7.1.3 The edges are cleanly cut without tears or frays.

**NOTE 5:** Die cutting of single sheets is the proper way to cut the test specimens, meet the requirements of this section, and give test results within the precision stated.

7.2 For the purposes of this method, test a minimum of 10 specimens of each test unit for each direction.

7.3 Periodically inspect a cut specimen under a low
magnification to check for proper dimensions (7.1) and to insure that cuts are clean and sharp. Any damage to the edges indicate the die-cutter should be checked for sharpness, nicks, or burrs.

8. Testing Procedure

8.1 Rubber, plastic, or disposable lint-free cotton gloves should be worn throughout the entire test procedure.

NOTE 6: Contaminants on hands especially moisture has an adverse effect on test results.

8.2 Determine the average thickness (caliper) of the sample to be tested in order to select the proper disk insert (4.2).

8.3 Wearing gloves, carefully insert the test specimen in the sample holder, locating the ends so that they are at the scribed mark (4.3) and they do not coincide with the tangential groove. Place the specimens in the holder so that half are tested with the felt side facing inward, and half with the felt side facing outward.

NOTE 7: If the sample buckles on insertion or the disk rises
allowing the specimen to get beneath the disk (see NOTE 1). If this condition is present throughout the testing sequence, it should be noted in the report as test results tend to be low.

8.4 Place the holder with the test specimen on the center of the lower platen of the compression machine. It is desirable to fix stop blocks on the lower platen to insure proper placing of the holder, but the holder can always be centered if the platens are marked or scribed. Position the holder so that the meeting specimen ends are always in the same position, i.e., directly in front of the operator.

8.5 Apply a load to the specimen by activating the driven platen at a speed of 10 mm/min until a maximum force is sustained. Immediately after reaching the maximum, the specimen will fail in the area projecting above the holder. Record this maximum load value.

8.6 For 152.4 mm (6.0 in) test specimens to convert test values to kilonewtons per meter multiply, readings in pounds force (lbf) by 0.0292. Multiply readings in kilograms force (kgf) by 0.0644, and multiply readings in newtons by 0.00656.
8.7 Collect the test specimens and determine their moisture content as a composite reading according to TAPPI T412 "Moisture in Paper".

NOTE 8: The ring crush is extremely sensitive to the moisture content of paperboard under test. Since paperboard does not always condition to identical moisture contents, knowledge of the latter will sometimes explain differences in between-laboratory results.

9. Report

9.1 Report separately the CD and MD test results (each an average of a minimum of ten determinations) of the force per unit specimen length required to crush the specimens in kilonewtons per meter to three significant figures (or in pounds force for 6 in. specimens to the nearest pound).

9.2 Include, for a complete report, the total number of specimens tested.

9.3 Report the moisture content of specimens tested.

10. Precision

10.1 Repeatability (within a laboratory) = 6%

10.2 Reproducibility & Comparability = Not known in accordance with the definitions of these terms in
TAPPI T1206. "Precision statements for Test Methods".

10.3 Repeatability was determined using test results from one laboratory for randomized samples of 26 lb medium and 26, 42, and 69 lb linerboard on eight (8) different occasions.

11. Additional Information

11.1 Effective date.

11.2 Related method: TAPPI T818 "Ring Crush of Paperboard" uses a deflecting beam tester operating under a loading rate of 25 lbf/s but in all other respects is identical.

NOTE 9: This tester is no longer manufactured.

APPENDIX A LOAD CELL CALIBRATION (load cell in upper platen)

A.1 Insure the instrument has been on for 15 minutes to allow the electronics to stabilize.

A.2 Adjust lower stop on Crush Tester to a position that will allow the load cell calibration device to be placed between the platens.

A.3 With MEM OFF, adjust the display to read zero. Place switch into CHECK position and compare
display reading with yellow check label. Adjust CAL Potentiometer so that display and check value are equal.

A.4 Check digital transducer for zero reading and adjust.

A.5 Place load cell calibration device in gap of Crush Tester.

A.6 Check to see if switches are in the following positions:

A.6.1 Range 0 - 1000 lbs.
A.6.2 MEM OFF
A.6.3 Var. Speed (Variable speed should be set at 00.0)

A.7 Press LOAD switch and increase variable speed until load cell is almost in contact with the upper platen. SLOWLY increase variable speed and stop at 50 - 75 lb increments and note display readings and adjust CAL potentiometer if needed. Repeat to verify calibration.

A.8 After calibration is complete check the check value. If the check value differs from the original make note of the change.

A.9 Turn MEM ON and return platen and speed to test position.
Literature Cited


PROPOSED CHANGES / REVISIONS

Short Span compressive strength of paperboard

1. **Scope**

   1.1 This method describes a procedure for determining the edgewise compressive strength of paperboard.

   1.2 This method is intended for paperboard between 0.14 mm (0.006 in) and 0.70 mm (0.03 in) thick.

2. **Significance**

   The edgewise compressive strength of corrugated board is the most important property governing the compressive strength of corrugated containers. Research has shown that the short span
compressive strengths of linerboard and medium are well related to the compressive strength of the corrugated board and, hence, to box compressive strength (2,3). For example, summations of the compressive strengths of the components correlate highly with combined board edgewise compressive strength.

3. **Summary**

A test specimen, normally 15 mm wide, is clamped in two clamps, 0.7 mm apart. The clamps are forced towards each other until a compressive failure occurs. The maximum force causing failure is measured.

4. **Apparatus**

4.1 Compression Tester having the following:

4.1.1 Two clamps for holding a test specimen 15 mm (0.5906 in) wide (Fig. 1). Each clamp has a stationary and a movable jaw. The clamps shall be 30 mm (1.18 in) deep and have a surface of high friction, for example, a sand-blasted surface. The clamps shall grip the test specimen firmly over its full width. The stationary jaws shall be on the same side of the test specimen. The clamping surfaces of the movable jaws shall be in the same plane and parallel with those of the stationary
jaws (see Appendix A).

4.1.2 The clamps shall be able to grip the test specimen with a constant clamping force of 2300 ± 500N.

4.1.3 A means for indicating the clamping pressure exerted by the clamps.

4.1.4 At the start of the test, the free span between the clamps shall be 0.70 ± 0.05 mm (0.0275 ± 0.0020 in). After the test is started, the clamps shall move toward each other at a speed of 3 ± 1 mm/min (0.12 ± 0.04 in/min), the deformation of the load cell being considered.

4.1.5 A means for measuring and indicating the maximum load sustained by the specimen which can accurately be checked with dead weight loads or equivalent means. The accuracy required is ± 1% of the test reading when this is within 10-100% of the full scale range.

4.2 A precision die-cutter capable of accurately cutting a test specimen to a width of 15 mm (0.5906 in) and a length of 150 mm (6 in).

4.3 Some machines may be equipped with means for measuring the moisture content of the specimen being tested. Refer to Appendix B and the manufacturer's instructions for use of this feature.
5. **Sampling**

Samples should be selected and gathered in accordance with TAPPI T400 "Sampling & Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Products."

*NOTE 1:* This test is extremely sensitive to moisture. As soon as samples are gathered, they should be promptly picked up or delivered to the test lab. Be careful not to handle the test areas with bare hands.

6. **Conditioning**

Due to possible dimensional changes, samples should be preconditioned and conditioned before cutting test specimens in an atmosphere in accordance with TAPPI T402 "Standard Conditioning & Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products.

7. **Preparation of test specimens**

7.1 Carefully die cut test specimens felt side down to a width of 15 mm (0.5906 in) and a length of 150 mm (6 in). Cut CD specimens so that the long direction is perpendicular to the machine direction of the board. MD specimens are cut so the long direction is parallel with the machine direction of the board. Be careful not to touch test areas with bare hands.

*NOTE 2:* Once test specimens are cut, be careful not to place them
near high humidity, heat, or any other condition that may change the moisture content of the test specimens. In cutting the test specimens take care to insure that:

7.1.1 The long edges are parallel, such that the widths at opposite ends are within 0.1 mm (0.004 in) of each other.

7.1.2 The long edges are parallel (perpendicular) to the machine direction of the board.

7.1.3 The edges are cleanly cut, without tears or frays.

7.2 For the purpose of this method, make a minimum of 20 tests per each direction.

NOTE 3: Multiple tests can be run on one test specimen under the following conditions a) test areas must be spaced apart at least 12.7 mm (0.5 in) and b) any moisture sensing device is not in use. If a moisture measuring device is in use see Appendix B, on how to proceed.

8. Testing Procedure

8.1 Rubber, plastic, or lint-free cotton gloves are recommended during testing. If gloves are not worn, extreme care should be taken in handling the test specimens by the ends.

8.2 Select the program for the grade to be tested if this feature is available and follow the prompts. Confirm that the clamping pressure is at the prescribed level.
8.3 Handling the test specimen by its ends, insert the test specimen in the sample slot.

8.4 Activate the clamps so that the prescribed pressure is applied. The test specimen will fail when the maximum load is reached. Record the maximum load.

**NOTE 4:** On some heavy boards, it might be necessary to increase the clamping pressure to prevent slippage. If this is the case, the increased pressure must be noted in the report.

8.5 Determine the moisture content of the sample being tested.

9. **Report**

9.1 Report separately the CD and MD test results (each an average of 20 determinations of maximum compressive force per unit width) in kilonewtons per meter (or in lbs. force per inch) to three significant figures.

**NOTE 5:** Results in lbs force per inch may be converted to kilonewtons per meter by multiplying by 0.17513

9.2 Report the standard deviations of the CD and MD compressive loads separately.
9.3 Include for a complete report, the number of determinations in each direction.

9.4 Report the moisture content.

10. Precision

10.1 Repeatability (within a laboratory) = 5%

10.2 Reproducibility & Comparability = Not known in accordance with the definitions of these terms in TAPPI T1205, "Precision statements for Test Methods."

10.3 Repeatability was determined using test results from one laboratory for randomized samples of 26 lb medium and 26, 42, and 69 lb linerboard on eight (8) different occasions.

11. Additional Information

APPENDIX A - SPECIFICATION FOR THE CLAMPS (4)

A. 1 The four jaw edges in contact with the test specimens in the 0.7 mm span shall not be blunted. The difference in the free span at the top and bottom of the jaws shall be less than 0.03 mm.

A. 2 Those parts of the two surfaces of the stationary jaws that grip the test piece close to the free
span shall lie between two parallel planes, 0.01 mm (0.0004 in) apart. All points of the two surfaces, 30 mm in each direction from the free span, shall lie between two parallel planes, 0.2 mm (0.008 in) apart (Figure 2).

A. 3 All points of the bottom surfaces of the jaws shall lie between two parallel planes 0.1 mm (0.004 in) apart (Figure 3).

Fig. 2 Specifications for the maximum permissible departure from parallelism of the clamping surfaces (4)

Fig. 3 Specifications for the maximum permissible departure from vertical alignment of the clamps.
APPENDIX B - MOISTURE DETERMINATION AND LOAD CORRECTION

B. 1 Test machines complying generally with the requirements in Section 4 are available which also incorporate means for measuring the moisture content of the specimen under test and in some instances, correcting the load readings at a given moisture content to the load which would be obtained at a specified moisture content, usually 7.5%.

B. 2 The moisture measurement system shall have the following:

B. 2.1 Moisture measurement sensors which firmly contact the specimen under test.

B. 2.2 Means for indicating the moisture content of the specimen under the test within ± 0.25%.

B. 3 Calibrate the moisture indicating system for the sample lot tested following the manufacturer's directions.

NOTE 6: Experience indicates that the moisture systems employed are sensitive to many factors such as furnish, basis weight, calendering, and impurities in the test material. For this reason it is necessary to calibrate the sensor systems for the material being tested to obtain accurate results.
B. 4 Load Correction. Some machines have a microprocessor system for estimating the failure load at a specified moisture content, usually 7.5% from the load and moisture content at the time of the test. In this case, it is necessary to determine the relationship between the failure load and moisture content for the material being tested.

B. 5 When employing the moisture correction system, carry out the tests following the procedures in Section 7 (see NOTE 3). If replicate tests are made on one specimen, avoid having the moisture sensors contact any previously tested area. Report the following:

B. 5. 1 The maximum compressive force per unit width and standard deviation at the test moisture content and at the specified moisture content in kilonewtons per meter (or in lbs. force per inch) to three significant figures.

B. 5. 2 The moisture content at the time of the test and the specified moisture content.

B. 5. 3 The moisture and load correction factors used.

B. 5. 4 The number of test determinations in each direction.
Literature Cited


2. Whitsitt, W.J., Compression Symposium, Forest Products Laboratory, Madison, WI, October 1-3, 1985.

3. Seth, R.S., TAPPI Journal 68 (3) 98 (1985)


PROCESS CONTROL METHODS

TAPPI test methods are often not suitable for testers in a mill laboratory. Much of the detail needed to describe instrumentation and calibration is not needed, and may be confusing to the mill tester. Additionally, there are many precautionary comments which are not needed in the TAPPI method but which can be helpful to the mill tester. Some requirements of the TAPPI method are not amenable to mill operations. A good example of this is the TAPPI method requirement to fully condition samples. Most mill laboratories use a shortened conditioning time in order to keep up with production requirements.
As part of this project, Process Control Methods were developed for both the ring crush and STFI tests. These methods are intended to serve two functions. First, they provide a simplified procedure for mill testers. Second, they should help eliminate differences in procedure throughout the industry and, thus, improve the precision of the CKPG baseline.

PROCESS CONTROL METHOD FOR MILL USE

Ring Crush of paperboard (rigid support method)

**Definition**
The ability of paperboard to withstand deformation forces to the edges of a test specimen.

**Scope**
This method is intended for paperboard between 0.28 mm (0.01 in) and 0.51 mm (0.02 in) thick.

**NOTE 1:** *Caution should be used when testing linerboard less or greater than the specified thickness as the results are less reliable.*

**Significance**
Summations of the compressive strengths of the components correlate with combined board edgewise compressive strength which is the most important property governing the compressive strength of corrugated containers.
Apparatus

Ring Crush Tester (rigid support)
Precision Punch Die Cutter
Sample Holder
Disc Inserts
Rubber, plastic, or disposable lint-free cotton gloves

NOTE 2: Studies have shown that the use of a double edge blade cutter or a table top square cutter can damage the test edges of the test specimen not visible to the eye and lower test results.

Sampling

As this test is extremely sensitive to moisture, samples should be promptly picked up or delivered to the test lab.

NOTE 3: Be careful to avoid high humidity, heat or any condition that may change the moisture content of the samples.

Conditioning

For precision and accuracy of test results TAPPI T822 states TAPPI T402 "Standard Conditioning & Test Atmospheres for Paper, Board, Pulp Handsheets and Related Products" must be followed.

NOTE 4: Some mill labs have rapid conditioning systems and this
step should be followed. In any case, a composite moisture content of the paperboard under test, along with the temperature and humidity of the test lab should be taken and recorded. This knowledge can sometimes explain significant differences in test results on a specific grade at various times of testing.

**Calibration**

The operational mode of the instrument must be verified before testing. For daily routine checks, control samples can be used. These control samples should be selected by the supervisor on one or more grades. They should be kept in a moisture free plastic bag with the date the grade was tested, the high/low and average reading along with the moisture content of the sample and the room conditions. **Take the required number of tests and check to see if the results are within the range provided by the supervisor. Check the "zero setting and re-zero if necessary."**

**NOTE 5:** If the load cell supports the lower platen, the sample holder MUST be centered on the lower platen when checking zero.

When you are assured the instrument is in proper
calibration, you are ready to begin testing.
For complete in-depth calibration, the proper procedures can be found in the manufacturer's operating manual and should be followed at regular intervals.

<table>
<thead>
<tr>
<th>Procedural Steps</th>
<th>Caution Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Rubber, plastic, or disposable lint-free cotton gloves should be worn throughout the entire test procedure.</td>
<td>a) Contaminants on the hands especially moisture has an adverse effect on the test results.</td>
</tr>
<tr>
<td>b) With the felt side of the sample down and using a precision punch die cutter (width 0.5 in &amp; 6.0 in length) cut the required number of CD test specimens. The long dimension is parallel with the MD for CD test specimens. If MD testing is required, cut so that the long dimension is</td>
<td>b) Use of a double blade cutter or a table top square cutter can damage test edges not visible to the eye and lower test results. Make sure the sample is in true MD and CD direction. A skewed sample will produce questionable results, as both CD and MD strengths will be reflected in test results.</td>
</tr>
</tbody>
</table>
perpendicular to the MD of the board.

Edges must be cleanly cut without visible tears and frays. This requires periodic checks on the die-cutter.

Die cutting of single sheets is the proper way to cut test specimens.

c) Select the proper disc insert for the sample holder by determining the thickness of the sample to be tested.

c) Groove width should be at least 150% but no more than 175% of the average thickness of the specimen being tested. Be careful not to drop or damage the sample holder or disc inserts as it will affect test results.

d) See "a" and carefully insert the test specimen in the sample holder making sure the ends of the test specimen meet at a scribed mark on the perimeter of the annular

d) Place the test specimens in the sample holder so that half are tested with the felt side inward and half with the wire side inward.

If the sample buckles on
groove away from the branch groove.

insertion or the disc rises allowing the specimen to get beneath the disc, the test should be repeated. Before continuing, check to see you have selected the proper disc and change if necessary. If this is not the case, continue testing. However, if this condition is present throughout the testing sequence it should be noted in the report. SEE NOTE 1

e) Place and center the sample holder on the lower platen. Position the sample holder so that ends are always in the same position.

e) Fixed stops on the lower platen will ensure that the sample holder will always be correctly positioned. Check the zero and re-zero if necessary.

SEE NOTE: 5 if lower platen is supported by the load cell.

f) Apply the load to the

f) The correct speed of 10 mm/min
test specimen by activating the driven platen until the specimen fails. Record the maximum load value.

g) Return the driven platen to allow the next specimen to be tested.

g) Some instruments are set for automatic return.

h) Repeat steps "d through g" for the remainder of the test specimens.

REPORT

1. Report as required the individual and average of CD and MD results.

2. Report the moisture content of the sample tested or the moisture corrected ring crush values.

3. Report size of disc insert used.

4. Report the temperature and humidity of room during testing if there is any deviation from TAPPI room conditions.
PROCESS CONTROL METHOD FOR MILL USE

Short span compressive strength of paperboard

**Definition**  The ability of paperboard to withstand deformation forces applied to the span of the test specimen.

**Scope**  This method is intended for paperboard between 0.14 mm (0.006 in) and 0.70 mm (0.03 in) thick.

**Significance**  Summations of the compressive strengths of the components correlate with combined board edgewise compressive strength which is the most important property governing the compressive strength of corrugated containers.

**Apparatus**  Compressive Tester

Precision Punch Die Cutter

**Sampling**  As this test is extremely sensitive to moisture, samples should be promptly picked up or delivered to the test lab.

**NOTE 1:**  Be careful to avoid high humidity, heat or any condition that may change the moisture content of the samples.

**Conditioning**  For precision and accuracy of test results TAPPI T822 states TAPPI T402 "Standard Conditioning &
Test Atmospheres for Paper, Board, Pulp Handsheets and Related Products" must be followed.

NOTE 2: Some mill labs have rapid conditioning systems and this step should be followed. In any case, a composite moisture content of the paperboard under test, along with the temperature and humidity of the test lab should be taken and recorded. This knowledge can sometimes explain significant differences in test results on a specific grade at various times of testing.

Calibration The operational mode of the instrument must be verified before testing. The manufacturer's operating manual lists daily routine calibration steps.

Control samples can also be used. These control samples should be selected by the supervisor on one or more grades. They should be kept in a moisture free plastic bag with the date the grade was tested, the high/low and average reading along with the moisture content of the sample and the room conditions.

Take the required number of tests and check to see if the results are within the range provided by the supervisor. When you are assured the instrument is
in proper calibration, you are ready to begin testing.

For complete in-depth calibration, the proper procedures can be found in the manufacturer's operating manual and should be followed at regular intervals.

**Procedural Steps**

**Caution Statements**

a) Rubber, plastic, or disposable lint-free cotton gloves are recommended throughout the entire test procedure. Note that if gloves are not worn extreme care should be taken when handling the test specimens.

b) With the felt side down and using the proper precision die cutter, cut the required number of CD test specimens. The long dimension is perpendicular to the MD for CD test specimens.

If MD testing is required,

a) Contaminants on the hands especially moisture has an adverse effect on the test results. In any case, the test specimens must be handled by the ends of the test specimen. The test area must not be touched by bare hands.

Make sure the sample is in the true MD and CD direction. A skewed sample will produce questionable results, as both the CD and MD strengths will be reflected in test results.

Die cutting of single sheets is the proper way to cut test
cut so that the long dimension is parallel with the MD of the board.

c) Select the program for the grade to be tested if this feature is available. Confirm that clamping pressure is at the prescribed level.

c) If a program is available, follow the prompts.

d) **Handling the test specimen by its ends**, insert the test specimen in the sample slot.

e) **Start the test.** The test specimen will fail when the maximum load is reached.

e) On heavy boards, above 69#, it might be necessary to increase the clamping pressure to prevent slippage. If this is the case, the increased pressure should be in the report.

**NOTE:** 3 After using increased clamping pressure make sure
instrument is returned to the prescribed clamping pressure.
Record the maximum load.

f) Repeat steps "d and e" on the remaining test specimens.

REPORT
1. Report as required the individual and average of CD and MD results.
2. Report the moisture content of the sample tested or the moisture corrected values.
3. Report the temperature and humidity of room during testing if there is any deviation from TAPPI room conditions.

RECOMMENDATIONS
The following is a list of considerations on edge compression of liner and medium which might be addressed in a continuation of this project.

1. Should there be a separate study (procedures) for high performance board? This question was raised by a member of the committee.

2. Is there a way to expand the useful basis weight range
for the ring crush test? How can we go to lower basis weight specimens and still maintain precision?

3. Should the diameter of the ring crush specimen be adjusted for different weight materials?

All of the above are important questions and may need to be explored in future studies. However, they do not fall within the context of the objectives of the present study.

4. What is the correlation between moduli measured by ultrasound techniques and compressive strength measurements?

5. How can the prediction of ECT based on component compression strength measures be improved?

These two issues are integral parts of other ongoing CKPG projects.

6. What is the effect of testing speed on the STFI test, and on ring crush measurements made with rigid platen testers.

The effect of speed on the STFI test is not presently known. Such knowledge is a necessary part of our understanding of the
crush, the testing speed of 10 mm per minute was arbitrarily selected based on ECT data. Several companies have reported that this speed is too fast to achieve correlation with flexing beam testers. Collaborative Reference data seem to support this.

7. Should a standard procedure be developed for calibrating and standardizing the compression testing equipment?

Not all components of the STFI and ring crush measurements systems are traceable to recognized standards. Hence, we need to rely on a standardization system which must include:

* Instrument calibration
* Preventive and corrective maintenance
* Well defined testing procedures
* Reference samples
* Technician training

Parts of this system are already provided for through methods included in this report, through Collaborative Reference Data, from instrument makers' instruction manuals, and with in-house expertise.

Our evaluation has indicated that suitable calibration techniques and technician training are not presently available on an industry-wide basis.
THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

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