Understanding the Key Characteristics of Linerboard and Medium and Their Impact on Combined Corrugated Board

What's new

- *added lighter weight containerboard*
- *more recycled film source board*
- *TAPPI methods have been added for each physical property*

Third Edition

AICC
THE INDEPENDENT PACKAGING ASSOCIATION

ABOUT THE AUTHOR

Ralph Young

Ralph Young is a well-known speaker and expert on the technical aspects of corrugated packaging and box engineering. He is also an often requested writer for trade publications.

His current consulting company has taken him into the areas of technical expertise in legal placements for foreign manufactures, mergers and acquisitions, developing process improvement programs, and connecting with non-profit organizations.

He earned a BS in Forest Management and an MBA. He consumes life with his wife of fifty years in Roswell, GA where together they invest in the lives of their four grandchildren, and he ministers as an Elder in the Presbyterian Church of America.

Ralph serves as the Technical Advisor to the AICC and is involved in the ASKRALPH membership service. He spent his entire corporate career in the forest products industry investing the last 35 years in the paper and corrugates packaging segment. He has worked in woodlands, primary manufacturing, sales and sales management, marketing, business planning and communications, and four different assignments in product development. He was there when the industry moved to ECT from Mullen. He has been there with the movement to very light weight containerboards and alternative flute profiles. His employees have included Champion International, Georgia-Pacific (Great Southern Paper), International Paper and Mead Containerboard.

He is a member on AICC's behalf in TAPPI, ASTM, IOPP and Chemical Packaging Committee "UN HazMat working group".

What's new *since the Second Edition*

- Retail ready-shelf ready packaging grows
- Significant consolidation
- Growth of domestic test liner production / Mill conversions
- Foreign ownership grows - Imports increase
- Implementation of free on-line learning through AICC's Packaging School
- TAPPI tests methods have been added for each physical property

Introduction/Scope

Understanding the Key Characteristics of Linerboard and Medium and Their Impact on Combined Corrugated Board is the third in a series of training and efficiency guidelines produced by AICC. The first one, "Understanding the Performance Requirements of Your Customers' Packaging", was published in conjunction with the Fibre Box Association (FBA). There is also the Packaging School module "Understanding Combined Board Combinations" and over 50 articles in Box Score. We look forward to providing additional topics in this series which is produced by AICC solely for its independent converting members.

Today, when the corrugated converting industry is facing:

- strong worldwide demand and fluctuating prices of US generated OCC;
- increasing costs for purchased energy;
- a focus on fibre reduction;
- demand for products with reduced Greenhouse Gas (GHG)/CO2 emission;
- requests for corrugated with increased amounts of recovered fibre / Test liner;
- containerboards manufactured with nontraditional fibres, e.g., mixed waste, newsprint, eucalyptus, etc.;
- imported fibres of lower quality;
- new domestically produced ultra light weight test liners.

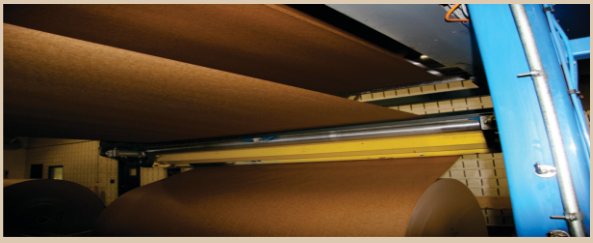
Converters need to know more about every aspect of their operations including obtaining the highest quality linerboard and corrugating medium for the purchasing dollar spent.

Independents are the open-market purchasers of linerboard and corrugating medium in North America either directly or through sheet feeders. Raw material costs such as containerboard or corrugated sheets remain the biggest expense element for converting facilities.

Linerboard and medium cross-direction (CD) compression strengths and their resulting combined strengths through ECT contribute 60-75% of the ultimate performance of the corrugated box. Four point bending or flexural stiffness, sometimes called, bulge resistance, constitutes the other 25-40% of top-to-bottom compression. Therefore, it becomes critical to choose containerboards with the highest ring crush values and converting potentials.

This brochure is intended to provide selection criteria in evaluating current and prospective suppliers. Domestic and foreign opportunities exist to evaluate your purchasing options for your combining operations in the selection of containerboards with the best value. Material selection is becoming more important in meeting customer needs, especially in the area of demonstrating sustainability and creativity in packaging design and engineering. This tool will help independent purchasers to evaluate containerboard on its value and the convertibility (runnability) through their processes.

A template at the end of this brochure should simplify communications with suppliers. They can then report the comprehensive characteristics of the containerboards being purchased. Should a supplier be unable to evaluate a physical property at the mill-site lab, independent third party testing labs are available to perform the proper tests and then report the results. Call AICC for recommendations.



IH 2017 AF&PA Reporting Mills' Low and High CD Ring Crush Values and STFI Values for Selected Grades 26# Liner and above.

In the following chart we have added a column for Short Column Test.
Values for 13-23# have come from mill spec sheets. SCT is a better indicator of strength for lower caliper grades.

Basic Weight #/ MSF	Range SCT	CD Ring Crush Range	Percent Variation SCT or RC
18# Test Liner	10	N/A	N/A
21# Test Liner	11.2 - 11.9	N/A	2%
23# Test Liner	13 - 14.1	N/A	9%
26# Liner	10.5 - 16.6	36-49	29%
30# HPL	14.1 - 18.9	54-61	29%
33# Liner	15.6 - 21.5	61-71	35%
33# HPL	16.5	62-79	11%
35 # HPL	17.0 - 24.3	69-82	28%
42# Liner	19.3 -25.3	81-100	34%
45# HPL	21.9 - 28.4	91-100	15%
55# HPL	29.4 - 34.3	116 - 131	5%
69# Liner	30.0 - 38.4	135 - 149	12%
75# HPL	38.7 - 43.1	166 -185	17%
90# Doble Liner	39.1 - 47.8	175 - 184	23%
23# Medium	9.9 - 14.4	27 - 36	59%
26# Medium	10.9 - 15.9	31.5 - 41.7	63%
33# Medium	15.6 - 20.7	46.5 - 69	49%
33# HPM	17.7 - 19.7	69 - 73	9%

One would expect some variation of ring crush /SCT within a basis weight given the number of machines and process variables that occur.

However, the very wide differences in corrugating stacking strength potential, while not surprising, is a warning. Under ideal engineering design the fluted corrugating medium should contribute 50% of the vertical compression strength in a combined sheet and corrugated box. However, this is not the case today as medium typically supports 30-35% of the vertical load sharing in a corrugated box. It becomes a very cost-effective engineering component option when seeking to improve stacking strength in the finished corrugated box.

With these differences in performance, the onus is on each corrugated facility to purchase those containerboards which develop the maximum combined board strengths for the least cost.

Theory of Corrugator Effective Yields:

Over 250 Combined Board Quality Audits spanning OVER twenty years, plus studies such as the AICC's Degradation Study, indicate that different corrugators produce ECT variations as large as 40% from the same ring crush / SCT components. Here is a look at how this might break down:

CORRUGATOR EFFECTIVE YIELD	VARIATION FROM ECT PREDICTION
1st. Quartile	+5 to +15%
2nd Quartile	+5 to -5%
3rd Quartile	-5 to -15%
4th Quartile	-15 to -25%

A facility needs to determine its own unique corrugator effective yield rating. With this information, independent converters may be able to adjust the amount of fibre (up or down) depending on the performance needs of the customer. By use of designed experiments an operation can predict the ECT outcomes from their operations from the strength levels of the containerboards consumed.

Understanding the Key Characteristics of Linerboard and Medium and Their Impact on Combined Corrugated Board

The American Forest & Paper Association's semiannual publication of the Continuous Baseline Study tracks six liner and six medium properties from 77 paper machines representing 43 mills. They have given AICC permission to use the high and low values from their study as data points in this project. We have also taken additional physical property values from individual mill spec sheets and developed Best in Class scenarios for each linerboard and medium grade.

RESOURCES:

There are several web sites you can visit where domestic and European containerboard manufacturers openly share "DNA" profiles of their products. With these transparent views, an operation can decide the quality description of the physical properties and the values for each grade, basis weight, or substance.

For more information about the five part series on Containerboard and Expected Values of Combined Board in previous issues of BoxScore, contact Ralph Young at ryoung@aiccbox.org

GLOSSARY:

"As tested": results refer to test results done at the end of the paper machine at the mill site. These can sometimes be sufficient, but it is important to know the real minimum and/or maximum value depending on the characteristic. Mills that do not use a "specification" to describe a physical property will often use this method to report infrequent tests, random tests or customer requested tests.

Average: This is the sum of the values in the test group divided by the number of samples tested. No one can argue with this mathematical term, but some mills have decided not to submit to this very common statistical method.

Specification: This is used to define manufacturing process parameters and gives almost absolute value clarity to the containerboards produced.

Typical: This is like "average," but usually includes wider variation parameters. A converter should seek a detailed numeric definition with variation limits from the supplier.

Two Sigma Variations: This is the usual statistical measurement to describe 95% of the values falling around an average. Six sigma would be one value out of one million falling outside the stated parameters. Processes that are under control will use this measurement term to describe physical properties.

Reject Limit: This can be an upper or lower control value that the mill will use as a pass/fail point to not ship roll stock. This is not the same as minimum or maximum.

CHARACTERISTICS COMMON TO BOTH LINERBOARD AND MEDIUM

Basis weight T410: This is a measurement of the weight in English or Metric measurements expressed in pounds per 1000 square feet of material or grams per square meter. Variability in this parameter will manifest itself as nonconformity in moisture content, porosity, compression factors, and the tare weight of the resulting boxes. To an extent all other measurable containerboard properties are dependent on basis weight.

Tensile Strength T494: Tensile strength is indicative of the strength on linerboards and medium derived from factors such as fiber strength, fiber length, and bonding. Tensile strength can also be used as an indication of the potential resistance to web breaking. When evaluating this property also consider the stretch and the tensile energy absorption. Both the machine direction and cross direction values are important as well as the ratio MD/CD.

LINERBOARD

Bursting strength or Mullen T807: This is a measure of the resistance to rupture and is used for both the linerboard and combined corrugated board.

Caliper, Hard T411: This is the thickness of the material. Uniformity of linerboard thickness in both the Machine Direction and the Cross Direction (CD) is significant in both combining and converting operations. Variations in linerboard caliper uniformity will affect web tension control and warp in the combined board can be the result.

Cobb/ water absorption/penetration T441: This is a measure of the mass of water absorbed in a specific time by one square meter of linerboard or combined corrugated board. Whether using the Cobb or Hercules Size Test method, the felt and wire side rates of water movements into the linerboard impacts pin adhesion, glue lap strengths, ink consumption, color densities and the customer's case sealing operations. Proper sizing at the mill also impacts the ability to not exceed the maximum Cobb limit for UN boxes.

Coefficient of friction (COF) T549: This property measures the angle in degrees at which two surfaces will begin to slip with an incline surface tester. The COF impacts the safe handling of heavy and potentially dangerous roll stock following its manufacture. The linerboard and corrugated business is a material handling business. Roll stock needs to travel safely and properly to avoid damage and the costs associated with wasteful damage to the linerboard. Similarly, corrugated sheets must travel efficiently and without much slipping through converting operations and later through customer filling operations. The COF of linerboard affects all these operations and must therefore receive understanding and constant attention during linerboard manufacture.

Compression strength T818/T826: This test can be used to correlate the edgewise compressive strength of containerboard directly to the Edge Crush Test and Box Compression Test. Either ring crush measured in pounds of force per 6 inch linear strip or the Short Compression Test (0.7 mm) measured in SFTI units are used to predict edge crush (ECT) values when combined on the

Ring Crush Testing

corrugator. These values can then be compared to actual ECT values after running the combined board through converting operations such as printing, die cutting and folding/gluing. (Refer to the AICC 2008 ECT Degradation Study.)

Internal bond strength/Z direction tensile T541: This method measures the energy required to rapidly delaminate a sheet through its thickness, or “Z” direction. Low internal bond strength can contribute to weakness of the corrugated box's glued joint (manufacturer's joint). Low bond can contribute to peeling. Low bond can also contribute to low compression strength.

Moisture content T412: This reports the percent of the free moisture in the board. Variations in linerboard moisture content -- both high and low -- can lead to warp and bonding issues on the corrugator and to difficulty with the folding

This is an IR oven which completely dries the sheet and determines the Moisture content.

properties of the combined board. Moisture control and the reporting of actual moisture content profiles are critical in both the machine direction (MD) and cross direction (CD).

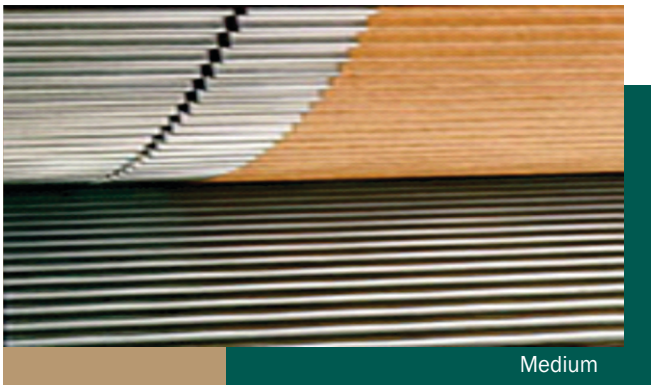
Porosity/air resistance T460: This test measures the amount of time required for a certain volume of air to pass through a test specimen using air pressure generated by a gravity-loaded cylinder. Porosity can influence the rate of water transmission thru the sheet of linerboard and the receptivity of the sheet to adhesives. Porosity may also affect ink and glue absorption rates. Porosity will affect the end user's vacuum-style box handling equipment and case sealing operations.

Smoothness/roughness T538: The purpose of this test is to measure the extent to which the surface of a specimen deviates from a plane, as determined by the depth, width and number of departures from that plane. The measured flow rate of the leakage of air is an indirect measurement of surface roughness. While the most significant impact of smoothness/topography is on print quality, this property compares to COF discussed above. Measurements are performed in one of six ways: Sheffield, Emveco, Bendtsen, Belk, Parker Print Surf and Gurley. Knowing this characteristic allows us to adjust our processes so that we will not exert excessive pressure at the press leading to reduced flat crush and compression and ultimately ECT degradation.

Other properties: Other physical properties less commonly measured but instructive to know include Dennison wax pick, scuff/peel, surface dirt count, sheet formation, fibre lengths and types, and luminance reflectance. All these are explained in the TAPPI Test Methods.* All these methods are set up for regular peer reviews. While some characteristics are more important than others, they must all work together for maximum runnability and combined board strength.

CORRUGATING MEDIUM

Even before the alternative Rule 41 and Item 222 options of using linerboard made to a ring crush specification, astute combiners began to become aware of the significant value of shifting combined board vertical compression designs into the center of the structure. But along with the theoretical possibility of redistributing the load sharing in the



Medium

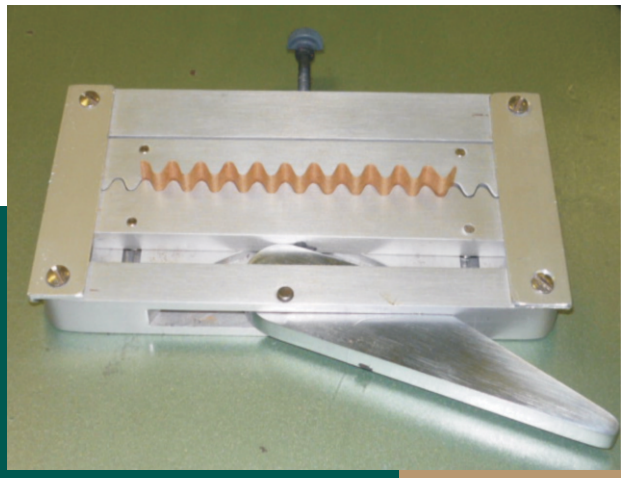
corrugated structure there is the realization that corrugators generate very different corrugated strengths in combining the same containerboard rolls.

Caliper, Soft T551: This measurement for the thickness of a single sheet of paper or paperboard uses soft synthetic rubber platens against the paper to minimize the effect of surface roughness. This is the true measure of the thickness of medium. Variations from roll to roll will generally lead to poor bonding runnability and bonding. There are wide variations among mills on the gap between hard and soft calipers. Not addressing the compressive differences in corrugating medium calipers among suppliers can lead to inconsistent flute formation and strength retention in the corrugating labyrinth.

Caliper, Hard T411: This is the thickness of the material using steel anvils. This is the traditional caliper measure of board thickness using an automatic clamping system. Variations in CD profiles can cause web tension differentials and web breaks.

Compression strength T818/T826: This test measures the edgewise compressive strength of containerboard, and when combined with the linerboard values relates directly to ECT and BCT. Either ring crush or STFI are used to predict ECT values through the corrugator and then compare them to ECT losses through the converting operations.

Corrugated flute crush T824: This test evaluates the ability of corrugating medium to contribute to



Fluted Edge Crush

the compression strength of a corrugated box. It is a procedure for measuring the edgewise compression strength of a laboratory-fluted strip of corrugating medium in a direction parallel to the fluted tips. This test helps to predict the formability of the medium and the impact formability has on the potential ECT results of the combined board coming off the corrugator.

Hot coefficient of friction: Unfortunately this is not a widely commercially available test procedure. This surface characteristic of corrugating medium has an impact on its ability to form properly in the corrugating labyrinth without fracturing, decapping or shearing.

Flat crush of corrugating medium/Concora T809: This measures the rigidity of the formed medium to crush resistance perpendicular to the flute tips. Through this test one can predict the rigidity of the fluted structure of the combined corrugated board. From flat crush testing it's known how well the corrugated sheet will survive the degradation in the converting process.

Insoluble ash T244: The results here measure the amount of silica, trash and grit in the sheet that are harmful to the life of the corrugating rolls, punches, dies, and knives.

Moisture content T412: This reports the amount in weight or percent of the water (moisture) in the board. The moisture content of the medium affects the ability of the medium to achieve good flute formation and accept additional moisture. CD moisture variations in medium cause warp.

Porosity/air resistance T460: This method measures the amount of time required for a certain volume of air to pass through a test specimen using air pressure generated by a gravity-loaded cylinder. Porosity influences the ability of the medium to absorb or release moisture.

Tensile strength T494: This is a measure of the amount of energy required to rupture a piece of board by pulling it apart. It is derived by such

Tensile strength

factors as fibre strength, fibre length and bonding. Tensile strength is a critical feature of corrugating medium in the both the machine direction (MD) and cross direction (CD) profiles. The MD strength is a measure the ability of the

corrugating medium to withstand the stresses of flute formation. Tensile strength of the medium is a measure of resistance to tearing and breaking from the acceleration and tension forces of the web as it travel through the single facer operation.

Stretch T494: This is the maximum strain in a piece of board before rupture occurs and is measured at the time of tensile testing. This MD characteristic is important to proper flute formation and maximizing running speeds.

Water absorption/penetration T432/831/835: The ability of corrugating medium to absorb water is measured by releasing a drop of water on the surface of a specimen and determining the time in seconds for the drop to penetrate through the sheet and wet the lower surface. The ability of corrugating medium to absorb water varies with age. Aged corrugated medium is less absorbent and therefore less resistant to picking up moisture. Medium under six months old is usually acceptable. Rolls six months to one year old are less absorbent. Rolls over one year old can greatly impact corrugated speeds and bonding development. Tests predicting rapid water absorption through the use of Float Curl or Water Drop tests are thus important. Poorly absorptive corrugating medium will lead to improper flute formation and poor bonding in the combined board.

Water Drop

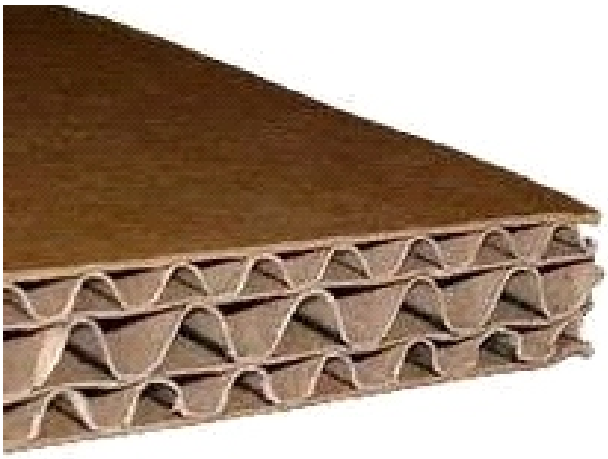
WHAT YOU CAN DO WITH THIS INFORMATION AND TEMPLATE

All this is provided so that independents can begin discussions with their containerboard suppliers and sheet suppliers to better understand the performance properties of the materials they purchase. Since the industry does not utilize a graduated pricing structure in North America for the different containerboard strength levels, each plant operation must determine its own value in the raw materials it purchases and its own combining efficiencies.

Several of these properties and their values are voluntarily reported by the mills to a third party and then published twice a year by the AF&PA in their Continuous Baseline Study. Contact Ralph Young about these if you desire to have a deeper understanding of the range in test values.

The template on the last page summaries in one chart all that we have discussed. It is intended for your use with both current and potential suppliers in evaluating the values of their product offerings.

For additional information or assistance, contact AICC Technical Advisor Ralph Young at ryoung@aiccbox.org. AICC looks forward to being of continued service to its members and associates.



LINERBOARD

PHYSICAL PROPERTIES	Measurement
Basis Weight min/target/max	#/MSF
Burst-Mullen average	lb-f/in^2
Caliper, Hard min/target/max	0.001 inches
CobbBottom 2 minutes min/max	g/m^2
Compression RC/SCT equiv min/target	lb-f/6 in or STFI units
Dirt/Speck Count	mm^2/m^2
Internal Bond Scott (Ztensile) min	lb-f/in^2
Luminous Reflectance average	L value
Moisture Content min/target/max	percent
CD variation	percent
moisture streak	percent
Porosity-Gurley min/max	sec/100 cc
Slide Angle MD min	degrees
Scuff min	# strokes
Smoothness-Sheffield/EMVECO target/min	units
Tensile min	lb-f/in
Wax Pick min	Dennison units
Date of Document	

MEDIUM

PHYSICAL PROPERTIES	Measurement
Caliper, Hard min/target/max	#/MSF
Basis Weight min/target/max	0.001 inches
Caliper Soft min/target/max	0.001 inches
Corrugated Flute Crush (CFC) target/min	lb/f
Compression RC/SCT equiv min/target	lb-f/6 in or STFI units
Flat Flush Concora (CMT) min/target	lb/f
Hot Coefficient of Friction	
Insoluble Ash average	percent
Moisture Content min/target/max	percent
CD variation	percent
moisture streak	percent
Porosity-Gurley min/max	sec/100 cc
Stretch MD min	percent
Tensile MD min	lb-f/in
Water Absorption-WaterDrop or Float Curl min/max	seconds
Date of Document	

History of this Brochure

While this is the third update of this AICC document, the start of this compilation work began in the earlier 1990's when the industry was moving from Mullen based linerboards and semichemical mediums made with virgin softwood and hardwood fibres to compression strength containerboards made more and more with recovered fibre.

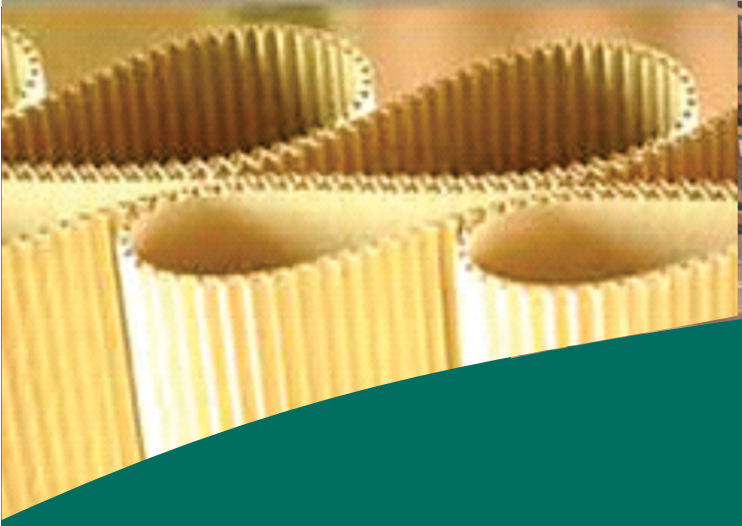
The emphasis for this particular work began in 2009 when the AICC set out to survey its members' range in obtained and retained ECT combined board strength based on the strength values of the components. We continue to remember those who participated almost a decade ago. Their contribution was significant. RAY

Recommendations:

Edge Crush Test: Application ans Reference Guide for Combining Corrugated Board - FBA
How to get Best Box - FBA / AICC
Understanding Box Performance FBA / AICC

References:

European Corrugated Packaging Association FEFCO
Technical Association of the Pulpand Paper Association TAAPI
Confederation of European Paper Industries CEPI
American Pulp and Paper Association



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