RULE 41 - PERFORMANCE STANDARDS vs MATERIAL REQUIREMENTS

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ABSTRACT

RULE 41 - PERFORMANCE STANDARDS
vs. MATERIAL REQUIREMENTS

by

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This thesis was an attempt to delve into the issues surrounding the controversy over Rule 41 of the Uniform Freight Classifications. The controversy involves more than just Rule 41. Carriers must, and wish to, publish the conditions under which shipments will be accepted, a principle portion of these conditions being packaging requirements. There are several sets of Classifications, each with its own requirements, but they are basically modelled after the Uniform Freight Classifications. Since Rule 41 can be viewed as the "original" freight packaging requirement it has become the focus point of a larger controversy. Since the inception of this Rule attempts have been made to discredit the validity of its burst requirements for determining adequate packaging, some urging the use of alternative material requirements, others urging the use of performance standards.

The initial step involves the theoretical aspects, to determine the basic functions the Rule should fulfill. A Freight Rule must be able to accurately determine the ability of packaged products to withstand transportation hazards.

It should be able to allow for the differing packaging needs of various products without unworkable complexity. Test criteria should be simple, standard, and reproducible and should not be biased against alternative materials. The evaluation of any Freight Rule criteria must, overall, be in light of the objectives of the total system, primarily least total costs.

The functions this Rule should fulfill formed a basis of comparison between the effects of various alternatives. Different material requirements varied mainly in their reproducibilities and in their ability to predict damage. Material requirements are inherently unable to account for differing products needs. The performance of one product gives no indication of how another product will perform in a package of the same material. Material requirements are also biased against new and alternative packaging materials and deters their usage. Both the inability to account for varying needs and the bias against alternative packaging materials can prevent the attainment of least total system costs. It was concluded that if a material test is to be retained as a Freight Rule criteria the most suitable tests are edge crush or other compression based tests.

The basic differences between material requirements and performance standards arise because material requirements tell how a product should be packaged and performance standards tell how a packaged product should perform. Performance standards readily account for differing product needs and present no obstacles to the introduction of suitable alternatives to established packaging materials. While it must be acknowledged that performance testing will undoubtedly become more advanced and refined in coming years the current capabilities of performance testing are above the minimum level necessary to make a workable Freight Rule.

It was recommended that the current packaging requirements of Rule 41 be replaced by performance standards, but it was also recognized that for several reasons it may take several years to gain the support necessary for the introduction of performance requirements.

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I. Introduction

Packaging has been defined as ". . .the art, science, and technology of preparing goods for transport and sale[32]." The ideal application of packaging is, as a "means of ensuring safe delivery of a product to the ultimate consumer, in sound condition, at the minimum overall cost[32]." This minimum overall cost will come about, not by treating packaging as a separate step, but by treating packaging as an inter-disciplinary function involved with development, production, marketing, quality control and distribution,. . .in fact, packaging can be involved in virtually every facet of a product, from the point of manufacture to the point of final use. Because of the interrelationships in the system, the success of each step must be measured relative to the entire system. Cutting costs in one area can increase total costs, likewise increased costs in one area can decrease total costs. Any facet of packaging which in any way impinges on the attainment of least costs for the total system is in need of change.

A major portion of many of these packaging distribution systems is transportation by rail or motor freight. The common carriers, including express companies and air lines, as well as railroads and motor carriers, must accept shipments of almost any product presented them. Required by law to post the charges for their services, the carriers have published a multitude of books naming the conditions and fares for which they will perform their services. The requirements for rail are called, Uniform Freight Classifications, and for motor freight are called National Motor Freight Classifications. The freight classifications consist of two parts, one part separates the myriad of available products by their various characteristics, and groups those products of similar characteristics together into classes. To use the Classifications, a product must first be identified by its transportation description, not merely a trade name or generic description. The user then must choose the applicable classifications, generally rail or motor freight, and search the Index to Articles for the applicable classification description. For each article, the index lists one or more item numbers. The Classifications list the items in numerical order, giving for each item its freight rating and various acceptable packages. The second portion consists of the Rules, which state the conditions under which different classes of products will be accepted for shipment. When an item is listed as acceptable in boxes, it means a box as defined in Rule 40, or a fibre box meeting all the requirements of Rule 41, (or Rule 222 of the National Motor Freight Classifications). Many items will be listed as acceptable in certain numbered packages. When referring to a fibre container, a package is a container not meeting all the requirements of Rule 41, but is an authorized container listed in the classifications in a section titled, "Authorized Packages or Shipping Containers." Often a product will be accepted for shipment in more than one type of package, or in one of several designated packages. When confronted with a choice, the user must determine which package best suits his needs by analyzing costs of procurement, potential damage, and preferential freight rates afforded some types of packaging.

In this country the burst requirements, contained in Rule 41 of the Uniform Freight Classifications, are the most widely used criteria for classifying qualities of corrugated and solid fibreboard. These requirements are used to determine if products are adequately packaged. Failing to comply with the regulations can result in refusal of shipment, declined damage claims, or increased freight rates. Since the inception of this rule, repeated attempts have been made to discredit its validity for determining adequate packaging. Some of these attempts urge the replacement of the burst test with another material test, on the grounds that other tests can be of better use in predicting performance. Other attempts have urged replacement of any material test with the concept of performance tests. This analysis of the controversy over Rule 41 will evaluate both types of alternatives to Rule 41's burst requirements to determine which alternative offers the greatest opportunity for the entire system to achieve least total costs. For various reasons, it is felt that the present burst regulations in Rule 41 can in many situations act counter to the achievement of least total costs for the system.

II History

A. Rule 41

The beginnings of Rule 41 date to the same times that fibreboard began gaining acceptance as a means of packaging for freight shipment. The first usage of corrugated in freight shipments was in 1894, and occurred through a technicality. Though the then current classifications did not allow general use of corrugated containers, an exception to the classifications permitted shipment of lamp chimneys in "packages", this technicality permitted corrugated containers to enter into freight shipments. In 1903 an exception to the Official Freight Classification permitted use of corrugated containers for cereals in the Midwest, this exception was extended to the East in 1904. Official Classification 28 give the first official authorization of shipments in solid and corrugated fibreboard on July 1, 1906. Packages were not regulated by size or weight limitations, and no minimum test of board was required, but the packages were subject to a freight penalty of 10%. The freight penalty was the result of pressure from wooden box interests, who were trying to curtail usage of corrugated containers. It is important to note that Western wooden box manufacturers and lumber companies were, and still are, owned by railroads. In 1907 the Official Classifications introduced specifications for thickness of fibreboard containers, imposed a 60 point weight limit, and dropped the 10% penalty on carload lots. During the same year the Western

Classifications #40 Rule 14B set more detailed specifications, including the Mullen test, as a standard of box strength. The next year the Official Classifications adopted more detailed specifications, including the Mullen test, and dropped the 10% penalty on LCL shipments. In 1910, with the cooperation of boxmakers, the Committee on Uniform classification detailed specifications covering test requirements, weight limits, and size limits for corrugated and solid fibreboard boxes. These were included in the Official, Western, and Southern Classifications until 1919, when the three separate classifications were cancelled and the Consolidated Freight Classifications were introduced. Regulations for fibre boxes were included as Rule 41.

Prior to 1912 many people, especially in the railroad owned lumber and wooden box industry, regarded fibre containers as inferior substitutes for wooden containers. These interests were making serious efforts at discouraging usage of fibre containers. About 1905 wooden box interests published a propaganda book entitled, The Wooden Box vs. the Substitute, containing carefully selected photos showing seriously damaged fibre containers, damage which was, in most cases, caused by poor handling techniques. These efforts at curbing fibre box usage came to a head in the "Pridham Decision." The Pridham Company planned a fibre box plant in Los Angeles, but discovered that although the Western Classifications had provided for fibre containers since 1906, Western Railroad accepted them only at "class" rates for eastbound shipments, regardless of volume. Fibre boxes being shipped from East to West were allowed "commodity" rates, but eastbound "commodity" rates were applied only to wooden boxes. Since class rates are normally about 20% higher than commodity rates, this acted as a 20% freight penalty on fibre boxes. When the Pridham Company asked the railroad for rates equivalent to westbound goods, he originally got a promise for equivalent rates for fibre boxes. Pressure from lumber and wooden box interests, formidable financial interests at the time, caused the railroads to renege on their promise and the Pridham Company appealed to the I.C.C. The case finally became one where the fibre box industry and active shippers, including Quaker Oats, Postum Cereal, and Ball Bros., sought full acceptance of fibre containers, and the lumber and wooden box industries sought removal of all permittance of fibre boxes from freight classifications. Finally the Commission rejected the arguments of the wooden box interest and ruled there to be no transportation differences between wooden and fibre containers and that rates be set accordingly. The "Pridham Decision" ended the position of the fibre box as a "substitute container."

The Consolidated Freight Classifications still exist, but most functions, including Rule 41, have been taken over by the Uniform Frieght Classifications. With only minor modifications the original Rule 41 continues to regulate fibre box usage. The most significant of these changes were the inclusion, in 1925, of a minimum caliper for mediums, and adoption of basis weight instead of caliper as a criteria for facings in 1944. Specifying by basis weight, instead of caliper, allowed the use of lower weights of kraft linerboard.

B. Controversy over Rule 41

The controversy, over whether or not burst strength forms an adequate basis for judging relative performance characteristics of fibreboard for regulatory purposes, has been going on about as long as Rule 41 has been in force. A report dated April 7, 1919, by A.J. MacKenzie, told of a project in which they attempted to find a relationship between the performance of boxes and the burst test of the board. They concluded the Mullen test gave no indication of the durability of the box as measured by the revolving drum test. Though this project could be questioned for scientific validity, it retains interest as an historical note, dating the Rule 41 controversy.

During the fifties, the puncture test was often referred to as a possible replacement for the burst test. Puncture was supposed to offer several advantages; the equipment is easier to keep in calibration, it avoids the double pop problem of burst tests, and can be used to test triple-wall board. Maltenfort defended the burst test against the puncture test[20] on the grounds that the puncture test is not sufficiently reproducible and could not be predetermined for combined board from properties of the liners. McKee[19] concluded that although the puncture test correlated better with damage than the burst test, it was not enough better to be much of an improvement.

Between 1940 and 1950, there was a growing interest in the importance of the compression strength of fibre boxes in regard to protecting contents. One result was an attempt to have the requirements of Rule 41 amended to include minimum compression strength based on materials, size and shape of boxes. There was much discussion at the "Special Docket of the Consolidated Classification Committee on Rule 41, Fibre Boxes" in 1946, but the effort failed because of anticipated difficulties in enforcement. Some procedure based on compression would seem to be the favorite alternative among those writers commenting on the unsuitability of burst strength as a basis for Rule 41.

One substantial proposal for a change in the boxmakers certificate was put forth by Kivlin[8]. His proposal called for each box to carry four separate ratings, one for each liner, the medium and the adhesive. The ratings were to be alphabetical, with each letter standing for a different quality of material. The various qualities would cover such things as basic weights, stiffness, and degrees of water resistance. If Rule 41 is to continue in a form similar to the present, the number of possible combinations under this method would make it far too cumbersome. But if standards for performance testing are introduced, Kivlin's method offers a means of standardization for the corrugated industry far more useful than burst.

III The Mullen Test

The primary material property requirements of Rule 41 are based on minimum burst strength (lbs/in^2), the major exception being for triple-wall board, which is based on minimum puncture test (in.oz./in of tear). Burst testers in this country are most commonly Mullen or Cady testers, although there have been other American testers, including the Webb tester which was designed for use in the field. Europeans have also developed several burst testers, the most popular being the Schopper-Dolen tester. Since the tester most widely associated with burst testing is the Mullen test, the terms Mullen test and burst test shall hereafter be used almost interchangable. The Mullen tester was developed in 1887 by J.W. Mullen and was quickly adopted for testing by both the paper and fabric industries. Burst was first included as a basis for freight classification in 1907. Burst strength has been included as a criteria for fibreboard in the Uniform Freight Classification since its outset.

The material property requirements contained in Section 3 of Rule 41 are given by Table 1. All of these requirements must be complied with. If necessary to meet tests specified combined weights of facings or component plies must be increased above the minimum. This section also includes the following procedure for burst testing.

> Note 1- (a) Minimum test per square inch referred to in this rule, in separate descriptions of articles, or in descriptions of package numbers, means the bursting strength of materials in pounds per square inch, measured by tests made with the Cady or Mullen tester. The diaphragm used in this tester shall be such that a pressure of 23 to 30 pounds will distend it to a height of 3/8 inch above the diaphragm plate. A motor driven tester of

the jumbo type operating at a constant speed of approximately 120 revolutions per minute shall be used.

(b) In applying Cady or Mullen tests, a specimen of the board shall be clamped firmly in the machine to prevent slippage. If board slips during tests, the results must be disregarded. In testing corrugated board, double pop tests may be disregarded.

(c) Six bursts must be made on unscored areas, three from each side of the board. Only one burst is permitted to fall below minimum test required. Board failing to pass foregoing test will be accepted if in a retest consisting of 24 bursts, 12 from each side of board, not over 4 bursts fall below the minimum test required. When individual bursts in a series are invalidated for reasons described under Paragraph (b), and disregarded, additional bursts shall be made until the total number of valid bursts required to complete the series has been secured.

Section 3 also includes procedures for puncture tests, since puncture is used as a criteria for triple wall board. This section also includes provisions for Referee Test Conditions, size extensions for boxes of less than maximum weight, and multiwall boxes with heavy duty manufacturers joints. Additional notes deal with "Master-Pak" boxes and multiwall boxes over the maximum weight.

The above procedures for burst testing specify diaphragm pressure tolerance and test speed but prescribe no procedure for compliance. Instrument variables, such as indicator calibration or platen condition, are not mentioned, but can affect test results. Clamping pressure is left to the discretion of the operator, except that visible slippage shall be disregarded. Tappi methods T807 and T810 give procedures for burst testing, and vary in that T807 specifies clamping of 100psi, and T810 clamps to prevent slippage.

Table 1: Current Minimum Fibreboard Requirements

		Single Wall		Double Wall		Triple Wall	
Maximum Weight of Box and Contents	Maximum Inside Dimensions (L,W,&D Added)	Minimum Combined Weight of Facings	Minimum Bursting Test of Combined Board	Minimum Combined Weight of Facings (All 3)	Minimum Bursting Test of Combined Board	Minimum Combined Weight of Facings (All 4)	Minimum Puncture Test of Combined Board
20	40	52	125				
40	60	75	175				
65	75	84	200	92	200		
90	90	138	275	110	275		
120	100	180	350	126	350		
140	110			222	500		
160	120			270	600		
275	120					264	1100
For Double Thickness Score Line Boxes							
225	60	138	275	110	275		
300	60	180	350	126	350		

This table does not include figures for solid fibreboard boxes which are included in Rule 41. Weights are specified in pounds, dimensions in inches, burst as lbs/sq.in., basis weights as pounds/1000 sq.ft., and puncture as in. oz./in. of tear.

Source: Fibre Box Handbook, Fibre Box Assoc., Chiz., Il, 1971, p52.

During a burst test, as pressure is applied to the specimen, bending and shear stresses are induced in the specimen as well as direct tension stresses in the middle plane of the specimen due to stretching. For thin sheets at large deflections bending and shear are small in comparison to direct tension. Bursting strength is primarily dependent on tensile strengths and stretches of sheet in machine and cross directions. Relationships between burst and other properties have received much attention. Due to various assumptions most results are applicable only to thin sheets of paper, not to corrugated boards. Whittsitt covered numerous theories relating burst strength to tensile strengths and breaking strains[1]. The following formula is indicative of these theories and is attributed to Vanden Akker.*

(1) $P=(2\sqrt{6} \times \sqrt{e} \times T)/r$
P=burst strength
e=breaking strain
r=radius of orifice
T=average of machine and gross direction tensile strength

As a good approximation, burst is proportional to the product of average tensile strength and the square root of breaking strain in the least extensible direction, normally machine direction. Assuming failure occurs in the machine direction, the strain, meaning that cross direction tensile force at rupture will be less than maximum in the tensile test. Defining T as average of machine and cross direction tensile

*Whittsitt refers to this formula (1) and attributes it to an unpublished work of Vanden Akker at the Institute of Paper Chemistry in 1937-38.

strength fails to take this into account. Another weakness is that burst tests involve biaxial strains while tensile tests involve uniaxial strains. In a tensile test lateral contractions of the specimen can occur, but cannot occur in a burst test, so the force required to induce a given strain in a burst test will be greater than that to induce the same strain in a tensile test. For most purposes it is sufficient to assume burst is proportional to tensile and square root of breaking strain.

Proper calibration of a Mullen tester is important and somewhat controversial, with deadweight testers normally used in calibration it is difficult to simulate the inertial effects causing most guage error. It is felt that electronic indicator systems may offer some advantages in that they better maintain calibration.

Rule 41 gives no requirement for clamping pressure when performing a burst test. Vanden Akker's formula relating burst to tensile strength indicates burst is inversely proportional to the radius of curvature of the sample at rupture. The lower the clamping pressure the greater the degree of slip or stretch in the clamp area, causing a decrease in the radius of curvature and hence an increase in bursting strength. As clamping pressures increase, slippage or stretch decreases. After the point where slippage approaches zero, further pressure increases have little effect on results. Specification of high clamping pressures minimizes variations in burst due to variations in clamping pressure. On the other hand, at very high pressures the flutes are crushed, and significantly lower results are obtained. At present there is no standardization of clamping pressure, but it seems best to use a clamping system assuring even pressure on each sample, such as a pneumatic or hydraulic. Results can be affected by variation in the conditions of clamping surfaces, due to changes in the amount of the coefficient of friction, causing changes in the amount of slippage. Variations in the radius of the orifice affect results by changing the radius of curvature at rupture.

Other sources of variation come from air in the hydraulic system, or changes in the rate of loading. Considerable variability can be gained from variations in diaphragms. There is a diaphragm specification written into Rule 41, but there is no published information relating this tolerance to variations in bursting strength.[2] The Mullen test also has variability between laboratories and methods often used to check interlaboratory calibration are of doubtful use.[6]

In performing these tests it is occasionally possible to audibly detect double-pops, especially when testing double-wall board. Results of double-pop tests are allowed to be discarded. Actually when testing corrugated the two facings rarely break simultaneously, even if no double-pop is detected. The variance lies in the time interval between ruptures, for short intervals the difference between pops is not detectable audibly.

IV Rule 41

A. Content of Rule 41

The controversy over Rule 41 has centered primarily on the burst requirement contained in Section 3, less controversial are sections giving requirements for aspects of fibreboard packaging ranging from cushioning for fragile items to methods of closure.

Section 1 gives rates for conforming, non-conforming, and "other than Rule 41" boxes.

Section 2 gives provisions for use of solid and corrugated fibreboard. Both must possess proper bending qualities and be firmly glued together. Corrugated must have a water resistant outer facing and a corrugating medium not less than .009 inch thick and weighing not less than 26 lbs/1000 sq.ft. Provision is made for hand holes, ventilation holes and perforations. Terms such as proper bending qualities and water resistance are defined in Section 14.

Section 4 gives regulations for the use of familiar boxmakers certificate. Each box must bear a legible certificate bearing information from Section 3 applicable to that box, plus the name and location of the box maker. This Section also describes the certificates for special numbered packages for fragile items covered in Section 5.

Section 5 gives provisions for packaging of fragile articles including glass and earthenware. Detailed specifications provide requirements for weights, capacities, mediums, facings and interior separators and pads.

Descriptions of general styles of boxes are given in Section 6. Sections 7 and 8 deal with acceptable methods of closing boxes, and Section 11 gives acceptable methods for forming manufacturer's joints. The concepts contained in 5, 7, 8 and 11 are very important in assuring safe transit of boxes, and possibly prevent more damage than the burst requirements of Section 3. If other material requirements were substituted for the burst requirements of Section 3, the remaining Sections of Rule 41 would remain virtually intact, most changes being where material is specified by pounds burst. However, if performance standards are substituted for burst requirements, virtually all of Rule 41 will be replaced. Most sections contain requirements attempting to assure proper performance, with performance standards this would be assured by required tests.

Besides Rule 41, fibre board packaging is provided for by the numbered Special Packages, or under provisions of Rule 5. If a shipper feels he has an adequate package that is not allowed in the above provisions, he can often arrange for experimental shipments under the provisions of Rule 49.

B. Reasoning and Effects of Rule 41

1. Theoretical: What Freight Rule Requirements Should do

Before it is possible to evaluate the alternatives for freight rule requirements, it is necessary to have an understanding of the functions these requirements should fulfill.

Any freight rule requirement should be of broad applicability. While ideally this would entail having a single set of requirements for different product classes, what must be avoided are requirements stipulating exactly how each product must be packed, the myriad of available products would make such requirements unworkable. The standards set as freight rule requirements would be meant to serve as general guidelines not as packaging specifications.

Requirements that are set up must be based on a method capable of giving accurate prediction of expectable damage. Any test being used as a basis should be such that there be a significant relationship between the level of the test, and aspects of normal usage, and such that when any package fails to give the required test results there arises serious question of the ability of the affected package to bring its contents to their destination in good condition. Basing requirements on methods capable of accurate damage prediction, gives a basis for refusing shipment for those containers not prepared to make transportation reasonably safe and practical, and a basis for paying damage claims in instances where damage results from carrier negligence. Herein lies the issue which could prevent a single set of requirements from applying to all packages. What level of damage can be accepted, while still calling transportation safe and practical? A damage level completely acceptable for shipments of commercial flour or cereal, would be unthinkable for exotic electronic equipment or harsh chemicals. Before any requirements can be set, it is necessary to determine what levels of damage are acceptable for different product types.

Besides giving a good indication of the performance of the container in the conditions it will meet in transportation, test criteria should be limited and relatively easy to understand. Test criteria should be limited because of the costs of testing, and the more complex requirement are, the more difficult the judgement of compliance becomes. Making test criteria simple, standard, and reproducible, gives all parties to any controversy a common standard of reference, allowing each to verify compliance, or non-compliance, using readily available equipment.

Criteria should be able to differentiate where pertinent differences exist, but some controversy can evolve over which differences are pertinent to transportation. Clearly ability to discern differences in ability of a package to withstand transportation hazards will be necessary, but it is not necessary for freight rule requirements to differentiate material qualities. While standardized material grades are necessary for consistency, discerning these qualities is not a direct concern of a freight rule. The direct concern of a freight rule is the ability of packaged products to withstand transportation hazards.

Evaluation of any freight rule criteria must be made in light of the objectives of the total system, mainly, least total costs. Shippers should be allowed to use the cheapest available method of obtaining low damage. The criteria should not prevent the usage of new material developments. Requirements designed so that only certain materials are able to meet them will act in a manner restricting usage of other materials. For any product there is a point where the costs to obtain reductions in damage become greater than the costs of the damage prevented. This point will not be the same for all products. In other words, least total costs can be attained at a higher damage level for low value products than for high value products. Of course exact determination of these costs is impossible, since many costs are intangible, but any criteria able to take this concept into account will offer substantial advantages in attaining least total costs.

2. What Rule 41 Actually Does

The actual effects of the burst requirements can be quite different from the theoretical functions outlined above. The freight rules, (including Rule 41) are written with the assumption that packaging will take place in metal, wood, corrugated, or fibreboard. At the time of inception of the rules this was true, but now other alternatives have been developed, including plastic corrugated and shrink films. The most common form of exterior packaging is the box, by the definition of a box contained in Rule 40 and 41 a box must be wood, or fibreboard, meeting certain burst and basis weight restrictions. Regardless of how satisfactory they may be, the only manner by which a shipper can use a plastic board or film outer container is through an exception. Since the current phrasing of the rules stipulates the material of which a box must be made it discriminates against new package developments.

There is considerable doubt as to whether the burst requirements, by themselves, are capable of determining whether packages are adequate. The requirements, as given, do not take into account product differences. Section 5 of Rule 41 contains additional requirements for fragile articles but even these fail to take into account differences between fragile articles. The result is that some products must be grossly over packed in order to meet requirements, while others can meet requirements to the letter, and still be inadequately protected. Since damage claims are paid on the basis of whether or not a package meets the requirements of Rule 41, a shipper who has determined his product is well protected in a non-conforming container, will be unable to collect claims on damage, even if caused by carrier negligence.

The present requirements of Rule 41 can prevent the achievement of least total system costs for some products. Even if a company determines that by shrink wrapping their canned goods, instead of using corrugated containers, they can achieve lower material and handling costs, and equal or lower damage levels, they cannot ship these products on a common carrier. By requiring shipment in fibreboard the carrier prevents potentially substantial savings, potential savings which could result in lowered prices, or averted price increases. If a company finds its product sustains almost zero damage in a container made of board equivalent to 125 lb. test, but the size and weight of the container require 200 lb. test board to meet the regulations in Rule 41, he can avoid the potential problems of ignoring Rule 41 only at an increased cost to himself. In either case, acting in accordance with Rule 41 results in additional costs to the concerned product system.

One of the requirements of a test, forming the basis of a freight rule, is good reproducibility. Because of uncontrolled variations in machines and nonstandardized procedures covered in an earlier section, the Mullen test has a reproducibility of only 20%, or worse, a very marginal performance when used for purposes requiring good reproducibility. Additionally, the Mullen test is unable to detect some differences pertinent to the ability of packaged products to withstand transportation hazards. A fair correlation can be shown between level of burst and performance for one package, but this offers no guarantee of correlation between the performance for a certain burst level with that package, and the performance of a different package made from board of the same burst test. Ideally, a test criteria for a freight rule should be such that any package, giving a certain result in the test, can be expected to give approximately the same performance in actual conditions.

V Sources of and Prediction of Damage

As stated under the theoretical requirements for a freight rule, any tests being considered should give a good indication of the performance of the fabricated container under the conditions it will meet in the field. In order to determine which tests give results best indicating performance, it is necessary to have data in two areas:

1) what are the types and causes of damage being experienced
2) which tests give results having high correlation between predicted performance and actual performance, based on observation.

It is often stated that damage in shipping comes from three primary sources: 1) impact, 2) stacking, and 3) vibration. Damage resulting from stacking occurs primarily in warehouses where pallet loads are stacked three and four high. With parcel post shipments the worst damage problem is with packages breaking open on impact.* In establishing requirements to assure that packages are adequately protected against hazards they will encounter during transportation, a freight rule need only be directly concerned with those hazards to be encountered during transportation. The freight rule should require a package to withstand the forces of impact and vibration to a degree which can be reasonably expected to occur, but except for the degree that resistance properties are interrelated,

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* From a conversation with Dr. Goff, Director, School of Packaging, MSU.

it need not assure performance under conditions not present in shipping, i.e., warehouse stacking. Those companys using warehouse stacking may incorporate additional standards, if they desire, but those not using warehouses should not be required to protect against situations to which they will not be subjecting their products.

The aim sometimes stated for laboratory testing, is the simulation of some ill-defined, "conditions in the field," in effect, to simulate the forces present in impact, stacking and vibration, in an attempt to achieve the same damage levels and types. The data on damage levels and types are based on field trials, whose results are the average of widely varying damage levels from a large number of samples. A better aim for lab testing, other than simulation, is, after determining which container styles, materials, and material properties offer protection, to differentiate between these qualities where differences exist.

Writings on research projects, seeking to determine correlations between test results and damage during shipment trials for boxes of various grades of corrugated, were found to give results pertinent to the issue of a test basis for Rule 41. One of these was performed by the Reed Paper Group of England[10], and the other by the Swedish Packaging Research Institute[25].

A. Reed Paper Group Project

Experiments were performed by the Reed Paper Group, to correlate damage levels from field trials for rail and truck, to test results obtained from various lab tests. They tested cases in two separate groups. One group was filled with cans to represent cases whose products support most of the load. The other group was filled with cartons, representing products whose cases must bear a high degree of the load. They tested cases of eight different qualities, based on various grades of liners and medium. Their primary interest was differentiating damage levels to the contents, not to the containers. In the carton field trials, the road tests consisted of full trailer loads transported across London, stored for a week than transported to a factory, a total distance of 80 miles. The rail trial consisted of a full load taken about 80 miles, with a final short journey in a delivery van of mixed goods. The can trials consisted of pallet loads, which were stored for two weeks, then shipped 250 miles, half of the pallets by rail and half by truck.

Damage coefficients were computed for each container grade for cartons and cans. These damage coefficients were correlated with data obtained from various laboratory tests, including compression, drop tests, incline impact, flat crash, burst, puncture and vibration. For cases carrying cartons, the best correlation with performance, as indicated by degree of carton damage, was for drop tests, followed closely by compression tests. These two tests gave the only good correlations with damage. Field test damage to cans had low levels; and there were no significant differences in damage levels to the cans between cases of different qualities, but there were significant differences in the amounts of damage sustained by the cases. This indicates that cans probably do not need a container affording protection as much as they need a means to be held together. Laboratory tests for cases of cans were therefore restricted to those testing the ability of the board to resist tearing and to contain the cans. The only good correlation between laboratory results and field trials was for burst tests. It was not noted which tests were included, but it most likely excluded compression tests and edge crush tests, whether or not drop tests were included was impossible to discern.

B. Swedish Packaging Research Insititute Project

The Swedish Packaging Research Institute Project[25] was set up primarily to determine which corrugated board properties are most significant for determining the level of protection the container affords the packaged product. They chose three different classes of products; products that can stand limited loads, represented by cartons; products that can withstand pressure and impact but exert destructive forces on packages, represented by vacuum cleaners. They chose twelve grades of corrugated based on different values of burst, edge crush, puncture and flat crush. Four grades were chosen to keep the bursting strength relatively constant while other properties varied and four were chosen to keep flat crush relatively constant while the other properties varied. The final four were chosen to correspond to commercial corrugated. Transport trials consisted of three seasonal shipments to each of seven countries to assure that the trial shipments were subject to all types of encounterable hazards. The destination countries included the United States and six continental countries. Upon receipt all containers were checked for damage with regard to type, location, and extent. Analysis of the damage showed, as expected, widely varying damage levels between the routes, but differences between the various grades were the same regardless of the destination.* These high correlations allowed the various data to be combined into average values.

Six material tests; compression resistance, bending stiffness, bursting strength, puncture, edge crush, and flat crush, were chosen for detailed study because of their pertinence to the investigation. These six material properties were analyzed to see which were dependent and which were independent. Compression resistance, edge crush, and bending stiffness showed high correlation with each other and were adjudged dependent variables. Further analysis in this project was restricted to edge crush, puncture, burst, and flat crush.

Analysis to correlate damage to material properties assumed the following relationship between material properties and amount of damage.

(2) $Y = k \cdot x_1^{\alpha} \cdot x_2^{\beta} \cdot x_3^{\gamma} \cdot x_4^{\delta}$

Y = amount of damage

k = constant

x_1 = bursting strength - kp/cm^2

*With a 95% probability

Table 2: Correlations of Material Properties

Material Property	Correlation Coefficients					
	Compression Resistance	Bending Stiffness	Bursting Strength	Puncture	Edge Crush	Flat Crush
Compression Resistance	1.00					
Bending Stiffness	0.94	1.00				
Bursting Strength	0.58	0.54	1.00			
Puncture	0.77	0.93	0.54	1.00		
Edge Crush	0.93	0.94	0.41	0.82	1.00	
Flat Crush	0.56	0.74	0.09	0.77	0.81	1.00

Source: "Transport Trials with Corrugated Board Boxes to Europe and U.S.A.", Johnson, G., Research Project, Swedish Packaging Research Institute, p 14.

x_2 = puncture - kp/cm

x_3 = edge crush - kp/cm

x_4 = flat crush - kp/cm^2

$\alpha \rightarrow \delta$ = exponents

Multiple regression analysis was performed to determine the exponents. Since the object is to reduce Y to as low a value as possible the property with the most negative exponent can be considered most important as an indication of performance, a positive value would indicate a property that allows more damage as it increases. These analyses were performed for the various seasonal shipments, type of damage, and type of product. Overall it was concluded that the most important measure of protective capacity of corrugated was edge crush, and hence indicating importance of compression resistance and bending stiffness. Also giving some degree of measure of protective capacity for both cartons and cans was the bursting test. Puncture was deemed to also be an important quality with regard to products similar to cartons, but proved a poor indication of container quality for tin cans. It was determined that in all cases flat crush should not fall below a minimal level. They strongly emphasized that no single material property was of decisive importance and that it is necessary to have a thorough knowledge of packaged products to properly select corrugated board boxes.

C. Indications From Research Projects

Several interesting points can be derived from these two projects.

1) Both projects concluded that of the material properties tested, compression and compression type tests gave the best overall indications of performance.

2) The situation which included the drop test, a performance test, gave a higher correlation with actual performance than any individual material test.

3) The project by the Swedish Packaging Research Institute concluded that performance is based on a combination of properties, and that even though some properties are shown to be better indicators of performance, none are of decisive importance in all situations. The combination giving best performance varies, since each product exhibits different characteristics. The relative importances they found were determined for overall damage levels, the importance of each property was found to change if particular types of damage were to be avoided.

VI. Discussions on Possible Freight Rule Requirements

A. Burst Test

1. Defense of the Burst Test

In this section it is sought only to present arguments which have been offered in defense of bursting strength as a freight rule requirement. The validity of these arguments will not be questioned in this section, but will be scrutinized in later sections on performance tests, and compression tests. The first few of these positions actually could be applied to any material property to be used as a basis for a freight rule.

A freight rule should be written so as to apply to all containers offered for shipment, therefore, containing only specifications of broad general nature, such that when the test results do not meet the requirements, there arises serious question of the ability of the affected package to bring its contents to their destination in good condition. Keeping requirements of a broad general nature precludes the possibility of making a freight rule an encyclopedia of packaging specifications, covering all aspects and situations.

A freight rule should not assure the safe delivery of all packages, but should provide a degree of protection assuring safe delivery of the broad group of easily handled products, and give basis for refusing for shipment those containers not so prepared as to make transportation reasonably safe and practical. Products vary widely in their need for protection; a requirement strong enough to assure safe-delivery of all products would result in great waste of costly materials, since most products would be over packaged.

2. Specific Advantages of Burst

The defenders of the burst test as a freight rule criteria, most notably Maltenfort, have pointed out several characteristics, which they feel make the burst test a more advantageous criteria, for a freight rule, than other tests.

First, they claim that the burst test is the only test that can adequately assure a predetermined strength in the combined board, by properties measurable at the mill on pre-combined materials[20]. By measuring the burst strength of the liners, and adding the strength of the liner after adjusting for the take up factor, the burst strength of the combined board can be predicted, with good accuracy. This offers advantages over tests such as the puncture, for which no method is known to assure a given test level before the materials are fabricated.

Secondly, the burst test can be run on damaged boxes, with results very close to that of the original board[20]. Since compliance to the Rule is questioned, most frequently, upon the occurance of damage in transit, and the only available information for judging compliance are the damaged box and its contents, a test which need not be run on factory fresh boxes or materials offers distinct advantages.

Thirdly, most strength properties of board diminish with time after fabrication. Puncture levels, or compression strengths of board which has been stored for 6 months will be significantly less than that of the initial levels. If compression were used as a criteria, it could be difficult to determine if board, which had been in storage, had originally complied with requirements. Conversely, burst levels are maintained much better than other properties over time, making it immensely simpler to determine if questioned board had originally complied with requirements.

3. Specific Arguments Against Alternatives

In addition to pointing out specific advantages of the burst test, defenders have pointed out specific disadvantages of its principle alternatives. A major argument offered against either compression or performance tests, is that properties reflected by these tests are properties of the fabricated container not of the material itself[21]. In testing compliance with burst requirements the test needn't be run on every box style. Since several box styles are run at the same time, it is only necessary to test each run, testing compliance to compression, or performance tests would require the testing of each different box style produced. In addition to requiring more testing, the testing involved for compression or performance tests is more complex, consequently establishing compliance for either of these alternatives could prove considerably more than checking compliance for burst tests. Maltenfort also claims most products will arrive in good condition packed in boxes which would not be in compliance with compression standards[7]. It was claimed that since meeting these compression standards would have entailed additional expense where it was not required, these standards would result in considerable overpacking, and consequential waste. It should be noted that no statement was made to point out the compression standards used, or how far out of compliance the boxes were.

4. Disadvantages of Burst Tests

In opposition to the claimed advantages of the burst test presented above, this test also has several widely recognized disadvantages. The first of these is the Mullen test's inadequacies for testing multiwall board. The ability of this test to measure strength properties of triple wall board is of such a low magnitude that requirements for this material are based on the puncture test. The inabilities of the burst test in testing triple wall board lie in two areas. First, the strength of this material is outside the range testable by most burst testers. Secondly, even if an available tester is capable of providing the pressure necessary to burst seven layers of material, it is exceedingly difficult to get them to burst simultaneously, a phenomena referred to as "double-pops". This double-pop problem plagues testing of double wall board, even though the burst test is retained for double wall requirements. The burst test is, therefore, virtually incapable of providing standards for multiwall board. This problem places the Mullen test at a disadvantage with any desire to establish one set of requirements applying to all situations.

A second problem associated with the Mullen test is the equipment. As discussed earlier, the equipment must be carefully calibrated to achieve any level of reproducibility, and there are several factors hindering the maintenance of closely correlated calibration from one machine to another. Since this maintenance of calibration is difficult, it often could be done inadequately. The level of reproducibility of the Mullen test, under the best conditions, assuming here that tests to determine the reproducibility are performed on well calibrated machines, brings doubt to the capability of the test in assuring that two fabricators, applying the same ratings to their boards, will actually be producing board of the same strength. If, in fact, the testers are not well calibrated the situation can only worsen.

A third and major weakness of the Mullen test is that the burst strength is independent of the quality of fabrication whereas the quality, strength, and performance characteristics of corrugated are closely tied to the quality of fabrication. The bursting strength of a sample of corrugated is equal to the sum of the strengths of the liners, plus an increment for the medium. No provision is made for the quality of the fluting or glue, either of which can affect final strength and performance characteristics of corrugated.

A fourth disadvantage of the burst test is somewhat interrelated with its inability to account for variance in fabrication. The burst test, by itself, is not capable of accurately predicting performance. Even the requirements in Rule 41 take this into account in setting guidelines for closing packages and forming manufacturer's joints. All other things equal, burst strength can give an adequate correlation with performance. In actual situations, though, all other things are not equal, boxes do not all receive like qualities of fabrication, set-up, and closing. Products do not share like characteristics. The high degree of independence shown between various material properties indicates that two samples, with identical bursting strengths, may not have the same actual strengths. The burst test may be able to give some measure of relative performance within one box style and product, but becomes wholly inadequate for predicting actual performance, especially if it is desired to achieve like levels of performance for a range of products.

B. Possibilities of Performance Tests

If a freight rule requirement is based upon a material property, such as burst, it cannot be expected to assure safe delivery of all packages, without resulting in a great waste of materials. A broadly applicable material property specification attempts to provide a degree of protection assuring safe delivery of some non-existant "average" product, on the assumption that there exists a single, measurable property offering a high correlation with the performance of a fabricated container. Real-life works not so smoothly, the measure of the strength of a fabricated container is dependent on several material properties, each contributing to a different degree, as well as the fabrication of the board and container. Additionally, factors unrelated to the container's material contribute to final performance. Since products need protection from different forces in different degrees, the product to be placed within the container has a large influence on container performance. Even the orientation of the product within the container can influence final performance. For cartons, compression strength is generally considered greatest when cartons are stacked upright, but in addition to influencing compression, a study at Pillsbury indicates that the orientation of cartons within a case can also influence resistance to damage from impact.[29] Regulating containers, on the basis of a material property, cannot take into account factors influencing performance which are unrelated to the container itself. Material requirements basically dictate how products are to be packaged, and are inherently incapable of retaining generality, if they are to account for the individual needs of products. On the other hand, performance standards do not dictate how products are to be packaged, but rather, dictate what a package in general is expected to do. A package meeting performance standards automatically accounts for the individuality of the product. Allowing package strength to vary with the needs of the product will eliminate "forced" overpackaging, and consequential waste of materials.

In addition to eliminating the overpackaging, frequently necessary if one is to adhere to present requirements, performance standards will halt discrimination against new packaging materials. Unless one is shipping under the provisions of Rule 49, a box must be either wood or fibreboard to meet the specified material requirements. At the time the rules were written, there weren't suitable alternatives, with the possible exception of metal containers or paper sacks. In the last few years, the availability of suitable packaging materials has broadened. Plastic corrugated, shrink wrapping, and foam packages are all available, and, in some situations, can result in lowered packaging costs, lowered damage levels, or both. But, unless the requirements for a package contained in the Uniform Freight Classifications are changed, these, and other developments can be permitted only as exceptions, and at the discretion of the Committee. Conversely, under the auspices of performance standards, any new packaging material could be accepted for shipment, providing it is shown to provide the level of performance required for the concerned application.

Ideally, the Uniform Freight Classifications should allow the optimum package for each product. Though the achievement of an optimum situation cannot be realistically expected in all situations, the following procedures, if followed, would result in a package approaching the optimum for each product:

1) For each product it should be determined, which of

the external forces it may be subjected to can damage the product, or hinder proper functioning of the container.

2) The type and severity of the damage caused by the various external forces should be determined.

3) The destructive forces exerted on the container, by the product, should be known.

4) The properties of the alternative materials, and material combinations, must be analyzed, to determine the degree to which they protect against the various destructive forces.

5) For each product, an understanding of the trade-off curves between damage costs and packaging costs should be achieved.

6) Finally, for each product, the container should be of the material combination giving the amount of protection against the forces to which it and its product are susceptible, offering the best balance between packaging costs and damage costs.

These six steps will be basically followed by any company attempting to minimize their packaging costs. Because of the nature of the transportation and distribution network, it is not quite possible to gain a perfect understanding of the forces acting on any certain package. While the exact forces acting on any single shipment cannot be predicted, the range of forces to which the shipment could be exposed is pretty well understood. If a product is susceptable to damage from impact, the level of force at which damage becomes apparent should be known; if a product can be damaged by vibration, the frequency range liable to cause damage should be determined. The type, and severity of damage by different forces becomes petinent in a case where two different forces can damage a product, if impact can render the product unsalable, but vibration only scuffs the carton, priority should be placed on eliminating the most severe damage. Knowing the forces exerted by the product on the container is important with products such as books, which are known to create particular problems.

These first three steps will not be much affected by any requirements in the Classifications. Companies should analyze potential hazards the same, packaging will be subjected to the same shipping hazards if it must adhere to material property requirements as it will if it must adhere to performance requirements. The difference between the two types of requirements arises in step 4. If a freight rule is based on a material requirement (burst strength), the packager's analysis of potential materials is limited to those capable of meeting the requirement (fibreboard). On the other hand, under performance requirements, which do not specify a material type, the analysis of alternative materials is not limited to certain materials. With the present burst requirements, if the material offering the least total cost desired in step 6, is not fibreboard, the shipper is prevented from achieving his least cost figure, with no gain in utility whatever. Since performance tests do not restrict the materials analyzed in step 4, the least total cost desired in step 6, is much more likely to be achieved.

Step 5 contains the key to deciding what levels of protection are desired. In most cases, a company will not be interested in increasing material costs by 3 cents a unit to eliminate damage costs of 2 cents per unit. Actual packaging costs and damage costs are easily determined, indirect costs, such as loss of consumer confidence, are harder to determine. Companies will not always be able to chose damage levels solely on the basis of packaging costs. With shipments of hazardous materials any damage whatever is unacceptable.

1. Acceptability of Performance Tests

Though the primary present requirements for boxes are the burst requirements of Rule 41, there are numerous precedents for performance tests. The Uniform Classification Committee currently accepts performance test data in support of test shipment permit applications for non-complying boxes. Various performance tests, most frequently drop tests, are included in the specification for packages for many hazardous articles, and are included for some packages in Rules 40, 41 and 51. Performance tests are spelled out for a number of the Numbered Package Series. Whether specified by performance tests or not, the theory behind the special numbered packages is performance, these packages prove adequate even though they do not meet other requirements. In each of the instances outlined above, performance tests are included in specifications, through the recognition that for the concerned application, burst strength alone cannot and does not assure adequate container strength.

All of the advantages of performance test previously discussed are under the assumption of the existence of suitable methods of performance testing. All prior arguments remain theoretical in the absence of suitable testing methods. Performance tests do not have to simulate exactly conditions in distribution, but instead, should indicate the performance of each potential package for a product, relative to the alternative packages for that product. Even though exact simulation of the distribution environment is not expected, the test used must indicate resistance to potentially damaging forces. If several different hazards are potentially damaging, it is possible several tests may be needed. Much doubt of performance testing arises through questions of the ability of present methods to indicate resistance to actual forces. Some of the earlier rough handling tests, such as the rotating drum test, the incline impact or vibration tests such as ASTM D-999-68(1973),do have questionable or limited applicability. The rotating drum test does not correlate well with any actual hazards. The incline impact was designed to simulate shocks occuring in boxcars, particularly from impacts due to humping, but, because of dissimilarities between the shocks produced by rail impacts and test machines, or between two different test machines, this test does not approach any sort of simulation to humping shocks. The vibrators designed for ASTM vibration tests are capable of bounce tests, but lack the frequency ranges necessary for determining resonance points. In spite of the limitations of many tests, there are tests and equipment capable of indicating performance under various situations. These are covered in depth in Henzi's survey of methods.[30] With the development of programmable shock testers and more sophisticated vibration tests, along with the classic rough handling test, the drop test, and several specialized test, performance tests cannot be opposed on the grounds of inadequacy.

Drop tests provide an interesting point in testing, they are probably the earliest form of performance testing, yet remain one of the most reliable. The Reed Paper Group's experiments[10] showed drop tests to give the highest correlation with actual performance of any commonly used lab test. J.C. Penney Co. has developed a testing procedure, based mainly on drop tests, which has cut damage levels to considerably less than one percent, even on fragile articles.[31] Moreover drop tests are simple and inexpensive to conduct.

Even though methods and equipment capable of accurate performance tests are available, it will still probably take time for them to become widely adopted. First, since performance tests will no longer require fibreboard packaging, considerable opposition can be expected from fibreboard box interests, in the same manner that wooden box interests opposed the acceptance of fibreboard boxes. Secondly, test procedures and conditions need to be carefully standardized. Standardized procedures must be worded carefully, since frequently particular product characteristics determine proper test procedures, such as placement of accelerameters for shock and vibration testing, or determining the face or corner of a container most likely to damage the product during impact. In order to simplify requirements test procedures will have to rely on the ability of manufacturers to determine weak points of their products. As it is, there will be resistance from manufacturers not wishing to purchase additional test equipment or testing services, even though, in most cases, costs could be cut in the long run. Probably the biggest obstacle to the acceptance of performance requirements is the resistance to change, unless a manufacturer is aware of specific applications in which performance requirements could save money, they would prefer to leave well enough alone. It will take time for performance standards to gain stronger support and wider acceptance.

2. Workings of Performance Standards

Discussion of performance tests, so far, has centered primarily on their suitability; more than just this knowledge is necessary before implementing freight requirements. Performance standards must be written with the proper objectives in mind. It is not sufficient merely to seek minimized damage and packaging costs, it is the total cost of the packaging-transportation function which should be minimized. While the packaging-transportation function does add considerable economic value to products through time-place utility, the amount of additional value gained is inversely affected by the costs of this function. The costs involved in packaging-transportation function include more than just damage costs and material costs. Also of concern to carriers and users are costs occuring due to testing, the inspections required to determine damage, litigation when responsibility for loss is not clear, and freight bills. When carriers are setting up freight regulations, their direct concern will be to minimize <u>their</u> costs of moving freight and handling claims. They must bear in mind that their users also are attempting to minimize costs, and therefore freight regulations should contain ample leeway for individual firms to minimize their costs.

Below is included one possible method of including performance tests in freight regulations. This method utilizes a combination of rates, testing levels, and liability levels allowing each firm to chose the combination offering them the least total costs. This is meant as a simplified model involving only two levels, because the wide variety of products create wide ranges of need, the actual application of performance tests to freight requirements may have to involve more specialized catagories.

1) Level one would involve reduced claims liability for the carriers, and reduced rates for users. Minimum test levles for level one would be set up to assure that the package itself will not fail, spilling product or creating undo hazards for other packages, equipment, or labor. The direct concern will not be prevention of damage to the product itself. A likely candidate for level one testing would be a rough handling test such as drop testing. Because products shipped under level one could be more susceptable to damage, they would be accepted for shipment at a reduced liability level. The carrier would retain liability for most catagories of loss, theft, or delay in shipment, but unless gross negligence is shown, the carrier will not be liable for product damage. In return for accepting reduced liability, the user would receive reduced freight rates.

2) Level two would couple higher freight rates than level one, with more complete claims liability. Testing involved for level two would be full range testing including shock and vibration tests as well as rough handling tests. The more extensive test program for level two assures that, not only is product unlikely to spill from its container or pose hazards to other packages, equipment or labor, but also is unlikely to sustain damage within its package. A product-package meeting the requirements of level two could be assumed to offer ample protection against foreseeable hazards, therefore, when damage does occur, the carrier is liable. In return for accepting greater liability levels,

the carriers would receive higher freight rates.

The lower freight rates for level one can be offered by the carriers, primarily, through reductions in the costs of handling liability claims; specifically, the costs of litigation, inspection, payments for damage and insurance. This same level is potentially attractive to companies who compute that the savings in freight bills and claims handling will more than offset the absorbed damage losses. Level two also offers economic attractions. The package testing required for level two is better able to determine optimal packaging for a particular product than tests for level one. Because packages meeting the requirements of level two will experience minimal damage, the costs inherent in claims handling will be reduced. Level two testing also minimizes the risk to carriers, that they will be paying claims for damage whose actual cause was inadequate packaging, not improper handling.

It is important to note that the test levels required under levels one and two are minimum levels, any company wishing to implement more exacting standards for its own products, will be free to do so. The most obvious application of this would be where a firm accepts the reduced rates and carrier liability of level one, but also uses full range testing to minimize damages. For some products, such as cartons or tin cans, the tests required for level one, may be able to do an adequate job of determining product protection. For other products, such as electronic equipment, level one testing may assure the carrier he will not experience undue hazards in handling the product, but are not apt to assure the shipper his product will not suffer damage within the container.

There is a potential problem with level one reducing carrier liability for damage. Since carriers would no longer face direct costs from damage their incentive for maintaining damage reducing handling procedures is reduced.

Another option open to shippers is, to accept limited liability on return for reduced rates, then in turn, purchase insurance to cover losses for which the carrier is no longer liable. The nature of insurance companies being as it is, firms employing full range testing would pay lower premiums than those employing limited testing.

In most cases, product packages will not be required to be tested at a certain level, since only the firm itself has adequate information on its product to determine a cost minimizing approach. Product packages, which would upon failure create extreme hazards to other products, equipment, or labor, may have to be required to undergo more extensive test levels.

3. Showing Compliance with Requirements

In addition to the design of performance standards, concern must be also granted to the manner in which compliance will be shown. The major problem arising in this area is that performance tests provide nothing a shipper can directly translate into the material specifications suppliers require.

The parties concerned with packaging materials can be divided into three groups, suppliers, users, and carriers, each of which has different concerns toward the materials. Under Performance standards carriers primary concern with materials should be whether they impart adequate performance to the package. In most cases, carriers should have no direct concern with the material specifications of the packages they handle. The direct concern of suppliers lies in imparting to materials those qualities users have specified, any concern shown by suppliers toward performance of individual containers, would arise through their desire for good customer relations. The users will occupy a position directly between carriers and suppliers. They must design packages that can provide the performance required by carriers, and be translated into the material specifications needed by suppliers. Performance standards will make little change in the concerns of suppliers, they do and will try to meet the specifications of their customers. Most users presently make efforts to design packages with adequate performance, if carriers switch to performance standards, users design processes will be effected in two ways, they no longer have to act within the constraints of material requirements, and the performance levels and tests utilized will be uniform among the various firms. To show that a package design complies with requirements, a firm will need to show that the material specifications for that design consistantly provide adequate performance for the product and package. To show that an individual package complies with performance standards, a firm must show that, not only does the package, as specified, provide required performance, but also that the package itself meets the specifications. Problems in showing specifications will consistently provide performance, can arise with materials such as corrugated, especially if it is attempted to specify it by a single material property. The more complete the specification drawn up, the better the chance that materials such as corrugated will provide performances as consistent as materials such as plastics or metals. It is immensely easier to impart uniform properties to plastics or metals so firms using these will not have the same problems showing that specifications provide consistant performance that corrugated users face.

Once it has been established that the materials, as specified, will afford adequate protection to the packaged product, most subsequent orders need only be tested for compliance to specifications, requiring less expensive testing than necessary to recheck performance of filled packages. Users will of course, be expected to occasionally retest performance, with the most frequent retesting being performed for the materials showing the least uniformity. In situations where compliance is in question, the shipper will merely have to show evidence that the package, as specified, complies with requirements, and the package, as constructed, complies with specifications. To discourage attempts at shipping non-complying packages, carriers should impose penalties, such as freight penalties and liability for any costs incurred by the carrier because of the non-complying packages.

With the adoption of performance testing as a freight rule requirement, the classic manufacturers stamp would become archaic. It would no longer be useful from the point of view of the carrier to identify grades of materials, but some method of identity should be required to facilitate procedures in case of questioned compliance. Such identity should include the manufacturers name and location, and possibly a date and batch or order number to provide linkage between packages and test data. Even though grading of materials would not be required explicitly by the freight rules, some kind of standardized grading would offer many advantages to suppliers and users, and for materials where no adequate grading system now exists, it should be encouraged that one be adopted.

C. Discussions on Compression Requirements

Even though it is felt that performance tests offer a more adequate basis for freight requirements than the current burst and related material requirements, discussions on the advantages of Compression Standards over burst standards as a material strength requirement are included also. These discussions are included primarily for two reasons:

1) There is, at present, inadequate support for the implementation of performance requirements. Part of the

extent of support is due to the lack of understanding of the advantages offered, part is also due to the opposition of certain special interest groups. Whatever the case, it is likely that some kind of material requirement will be in effect for some time.

2) Even after the adoption of performance requirements, some material requirement could be retained in an either/or manner, for shipments whose size or value does not warrent testing. Inclusion of alternative material requirements could also eliminate opposition from shippers who, for some reason, do not wish to use performance testing.

It is felt, that if some form of material requirements are to be retained, some method, based on compression is a more logical choice because of several inherent advantages over bursting strength. Tests by the Reed Paper Group[10] and the Swedish Packaging Research Institute[25] offer evidence that compression-type tests provide better correlation with performance than bursting strength. Measurement of compression-type properties also is affected by variables introduced during fabrication, variables which can significantly affect the final performance of the package. Bursting strength is not affected by the quality of fabrication, and can be computed directly from the bursting strengths of the outer liners, making this test incapable of predicting changes in performance due to differing qualities of fabrication.

One of the primary arguments against compression-type requirements is that, as commonly measured, compression is a property of the fabricated container, not of the material itself[41]. It is envisioned that meeting a compression requirement would entail the testing of each box style or each run, and hence, would be prohibitively expensive. Measuring the compression strengths of set-up boxes also does not provide a unit of comparison between different qualities of board. Some unit of comparison between qualities is necessary for requirements based on a material property. A compression-type requirement need not be based on compression measured from the completed box. One alternative is, to simply use the edge crush strength, which has been shown to be highly correlated with compression strength.[25] A second alternative would be to compare compression strengths of standard sized boxes. A third alternative would involve the computation of compression strength from other properties. There have been several theories advanced on the computation of compression strength from material properties, probably the most accurate of which is the exponential method, advanced by McKee[14] and Buchanan[12]:

where: (1) $P = n\, P_m\, h^{\frac{1}{2}}\, z^{\frac{1}{2}}$

P = total compression strength
P_m = edge crush strength
h = caliper
z = perimeter
n = a constant, varying with the units desired and the method of measuring edge crush.

To obtain a unit of comparison between grades, the term for perimeter is dropped, giving a measure of compression/unit length:

where: (2) $P_u = n, P_m h^{1/4}$

P_u = compression/unit length

Since total compression varies with the square root of perimeter, the differences between the utilization of strength must be accounted for during the writing of requirements, by calling for greater strength/unit for boxes of larger perimeters.

Maltenfort and Kellicutt also have developed theories for computing compression from material properties[13,31]. These theories, as well as exponential theory of McKee and Buchanan, were analyzed, using data developed by Mirasol[15], comparing computed compression with measured compression for six different perimeters. Figures, computed from Maltenfort's and Kellicutts formulas show a greater range in results, (comparing the ratio of theoretical compression to measured compression for differing perimeters), but also show a definite trend toward less accuracy as perimeters increased. The McKee and Buchanan formulas showed considerably less variation, with the existing variation being random. Mirasol's data showed McKee's formula to give results ranging from 70% to 73% of measured compression, results varying almost by a constant. When using McKee's formula, Mirasol used the same constant used by McKee, but failed to realize its source. McKee determined the constant by regressional analysis on data obtained with his method of determining edge crush. Mirasol used the same constant, but a different method of determining edge crush. Implementation of any requirements based on formulas (1) or (2) will necessitate the computation of constants (n,n,) consistant with a standardized method of computing edge crush (pm).

One of the advantages often cited for burst is, it is the only test which can be run at the mill, on pre-combined materials, to estimate a predetermined strength in the combined board. Edge crush can also be estimated from properties of the precombined board by the following formula:

$$\text{ECT} = \sum \text{RCT}(\text{liners}) + a \cdot \text{RCT}(\text{fluting}) \quad (3)$$

where:
RCT= ring crush test level
ECT= edge crush level
a= constant (or take up factor) depending on flute size

For either burst or edge crush, it must be recognized that the estimations have inherent inaccuracies.

Other advantages cited for bursting strength are that it can be measured on damaged boxes, and that it maintains its level better over time. It is known that the real strength of a package (as indicated by actual performance) diminishes with time, handling, and previously incurred damage. A property not reflecting these losses in strength is not capable of reflecting real conditions. Maltenfort also argues that most products will arrive in good condition packed in boxes which would not be in compliance with a compression standard, but failed to point out the compression standard used, or how far out of compliance the boxes were. This argument can be discarded merely by examining the nature of material requirements. Material requirements are limited to protecting some nonexistant "average" product against reasonably expected hazards. Since the standards are set up to assume that a large majority of boxes will arrive with the contents in good condition, it can be assumed that most cases only slightly out of compliance will also arrive with contents intact. If the boxes Maltenfort refers to were out of compliance by a high degree it is likely that the standards were not set at a reasonable level.

Freight packaging requirements based on compression are not without serious short comings though. These shortcomings arise, primarily, because, as outlined above, these compression requirements would be a material property requirement and will present the same problems involved with material property requirements discussed earlier. In brief these are:

1) The requirements must be aimed at broad groups of products, or an "average" product, and cannot take into account the individual product differences contributing so significantly to package performance.

2) Material property tests and related requirements are normally meaningful for only one type of material, hence prohibiting alternative materials. Both burst and compression testing are aimed at fibreboard. Requirements, based on these test, discriminate against other, more recently developed packaging materials.

3) Because they fail to account for individual product differences, and because they discriminate against alternative packaging materials, material property requirements can

frequently prevent a firm from minimizing the cost of their packaging-distribution system. This is, by far, the weakest point of any material property requirement.

Finally, even though there are serious drawbacks to requirements based on compression, compression is better suited for Freight Rule requirements than is bursting strength. The advantages being achieved primarily through better correlation with actual performance. If some sort of material requirements are to be retained, either on an interim basis, or as an alternative to performance testing, it is urged that these requirements, in some way, be based on compression strength.

VII Recommendations

A. It is recommended that every effort be made to urge the Uniform Classification Committee to adopt performance tests for freight rule requirements, instead of burst tests or other material tests. The major reasons for urging this switch are:

1. Performance standards will allow packages to be designed to meet the needs of the individual product.

2. Performance standards will not force products to be packaged in fibreboard.

3. Primarily because of the above reasons, performance standards can allow firms to achieve the least total costs for packaging and transportation.

B. Since forces opposed to performance standards may delay their adoption, it is recommended that a compression standard be adopted, as an interim requirement for corrugated board. The major advantage compression offers over burst is a higher correlation with actual performance.

1. Since direct comparison between cases in inadequate for the needs of a freight rule, it is recommended that a unit of comparison be adopted to separate board into qualities. These methods offer good possibility here:

a) The edge crush test
b) Compression strength for a standard box size
c) Compression per unit of perimeter as computed by exponential method devised by McKee and Buchanan

C. If it is found advantageous to retain a material requirement for some applications after the adoption of performance standards it is recommended that interim compression standards be retained.

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