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A MATERIAL COST AND WEIGHT COMPARISON OF SHIPPING
CONTAINERS USING ECT VERSUS BURST STRENGTH FOR
ROOM AIR CONDITIONERS.

BY

ANNE MARGARET MCSWEENEY

A THESIS SUBMITTED TO THE DEPARTMENT OF
PACKAGING SCIENCE
IN THE COLLEGE OF APPLIED SCIENCE AND TECHNOLOGY
OF THE ROCHESTER INSTITUTE OF TECHNOLOGY IN
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1993

DEPARTMENT OF PACKAGING SCIENCE
COLLEGE OF APPLIED SCIENCE AND TECHNOLOGY
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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE DEGREE

The Master of Science degree thesis of
Anne Margaret McSweeney
has been examined and approved by the thesis committee
as satisfactory for the thesis requirements for the
Master of Science Degree

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Using ECT Versus Burst Strength for Room Air Conditioners.*

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ABSTRACT

A MATERIAL COST AND WEIGHT COMPARISON OF SHIPPING CONTAINERS USING ECT VERSUS BURST STRENGTH FOR ROOM AIR CONDITIONERS.

By

Anne Margaret McSweeney

This research compares the material cost and weight of using edge crush specifications for the selection of a Whirlpool Corporation room air conditioner shipping container verses Mullen burst strength specifications. For the purposes of this thesis, the air conditioner studied is referred to as Product "M".

The following presumptions are made. The material cost of using an ECT performance specified container is lower than the material cost of a Mullen specified container. The material weight is less using an ECT specified shipping container rather than a Mullen specified shipping container.

The data generated first are the strength of the product and its interior packaging. This is determined through the use of vertical compression methods. After the internal product and package

strength is determined, the stack height and safety factors required are used to calculate the necessary shipping container strength.

The findings of this study on Product "M" are as follows. First, ECT specified material is 4.3% more cost effective than Mullen specified material. Second, ECT specification results in 17.5% less material by weight than Mullen specification. Using a hypothetical product volume of 250,000 units per year, the savings of \$0.06 and 0.73 pounds. per unit, would equate to approximately \$15,000.00 and 182,500 pounds. savings on Product "M" per year. In summary, the presumptions for Product "M" are proven correct.

Currently there is no legislation requiring material source reduction in shipping containers. In this study, when comparing the final reduction in material for the ECT container versus the Mullen container, it could be concluded that the ECT container is more "environmentally friendly" than the Mullen container due to the use of less material in the container. To eliminate the use of material up-front is generally thought of at Whirlpool Corporation to be better than trying to recycle, reuse or incinerate materials used in products or packages.

FUTURE CONSIDERATIONS

Theoretically, this study has proven that an ECT specified container is more economical and uses less material by weight than a Mullen specified material. The logical next step in the study of this problem is to construct actual samples of this material for testing and evaluation. If the new material performs as predicted by this study then it could be considered for possible production at a future date.

Other factors which may influence the performance of the materials selected in this study are the use of handholes in the shipping container, the effect of printing, and the use of other materials such as double-wall. The influence of these factors should be investigated before materials are chosen for final production.

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CHAPTER 1

INTRODUCTION

This research compares the cost and material weight of an edge crush specified (ECT) shipping container for a specific Whirlpool Corporation room air conditioner (RAC) verses a Mullen burst strength specified shipping container. The product studied will be referred to as Product "M". The results of this study include a proposal for shipping container material performance (ECT) requirements, a cost comparison between ECT and Mullen materials, and approximate weight reduction between the ECT and Mullen materials.

The first task in this study is to identify what vertical compression strength is required for the shipping container. The second task is to identify what material specification, ECT and Mullen, is needed to meet the vertical compression requirements and the cost of each material. The theoretical material weight differences between the ECT and Mullen specified shipping containers will also be reviewed.

The following suppositions are made. The material cost of using ECT performance specified containers is lower than the material cost of the current Mullen specified containers. The material

weight is less using ECT specified shipping containers rather than Mullen specified containers.

This study will not include research in the following areas.

- Evaluate the accurateness of the current specifications for the Mullen room air conditioner shipping containers.
- Review the history of Mullen burst or edge crush testing.
- Evaluate the testing required to obtain the liner and medium combinations that make up the ECT specified materials.
- Evaluate the correctness of the current interior packaging for efficient design or use of materials.

The study's assumptions are as follows. There is a need for a performance based (compression) specification for room air conditioner shipping containers. The ECT information generated by Inland Container Corporation is accurate and representative of ECT materials, as much as possible. The cost information generated by Inland Container Corporation is representative of general industry structures for corrugated prices.

This study is important because some of the packages designed under Mullen specifications lack vertical compression performance, while others are over-packaged. This study also serves to evaluate the possibilities of reducing the amount of material used in room air conditioner shipping containers for reasons of cost and effective use of natural resources. Only data

gathered in accordance with the test plan (Appendix A) is permitted for use in this study. The data in this research includes the vertical compression strength results of the air conditioner product identified as Product "M". This data is required for use in the specification of the ECT material by Inland Container Corporation.

All packaging used to generate vertical compression data is production packaging or prototypes which are production-like. The research is generated using a minimum of three samples of each room air conditioner product identified above. All data is generated by using either Whirlpool Corporation test specifications or ASTM test specifications. The specifications used have been developed and modified by Whirlpool Corporation to represent the specific distribution system that RAC product is exposed in the "real world".

CHAPTER 2

REVIEW OF THE LITERATURE

Many of the package designs for Whirlpool room air conditioners were designed and released over five years ago. Before starting the necessary work to evaluate the change from Mullen specified shipping containers to ECT specified shipping containers, the changes in the world of room air conditioner sales and distribution over the past five years needed evaluation and updating. Basically we needed a plan, a packaging strategy. What is it that we want and need from this product's package?

The modern history of a package's function is quite remarkable. In the first half of the twentieth century the transformation of packaging into that of a salesperson began. After the second world war the era of mass merchandising came into being. With the advent of the supermarket, packaging began to influence the way consumers purchase goods. The package became a powerful instrument which could both attract potential buyers and sell them. Retailers built stores around packaging displays of products and allowed this to sell the product rather than the

traditional sales clerk.¹ In the decade of the nineties, this type of sales environment for goods is not going away and is seen throughout all of retailing: supermarkets, hardware stores, clothing stores, sporting stores, department stores, the list seems to be endless. Anyone can look around them and confirm this statement to be accurate.

The modern era has also seen a change in the family unit. Not only have there been the obvious changes in marriage patterns, but there have been changes in the way families live together. There are more and more single parents, more women are active in the work force, and there are increases in the number of single head of households.² The environment for the sale of Whirlpool room air conditioners has experienced these changes in retailing, consumer buying habits, and installation of our products.

Focusing more narrowly on Whirlpool Corporation and the needs of the product studied, the outcome of a joint engineering and marketing meeting showed that the market for distributing and selling room air conditioners has changed. Our dealers and distributors are telling us that they do not want to invest in product inventory but they still want product on the sales floor

¹Arthur W. Harckham, PDC, Packaging Strategy Meeting the Challenge of Changing Times (Pennsylvania: Technomic Publishing Company, Inc., 1989), 1-2.

²Ibid., 4.

whenever they need it. As of about two years ago, many of the sales for room air conditioner product were made through outlets such as Sears and Lowes. In this type of retail environment, the actual product was displayed on the sales floor, and a “knowledgeable” sales person helped the buying consumer with decisions on product size and features. Because of dramatic changes in the distribution and sales environment, the requirements for the package must also change to meet the new needs of this environment. A few of the requirements that have changed are storage time, shipping modes, sales volume, expectations of the package performance from point of production through the end user (consumer), and the role of the package from a marketing and sales viewpoint.

MARKETING PERSPECTIVE

To elaborate on the changing roles and expectations of the Whirlpool Corporation RAC package, let us begin by looking at the package from a marketing perspective. The role of the package in the past for RAC built by Whirlpool Corporation was one which was strictly traditional. The package was needed for distribution: to get the product from the production facility through the distribution channels to the end user (consumer) without product damage. With the evolution of mass market retail outlets such as Wal-mart, Home Depot, and Circuit City the package took on a new responsibility - sales. This product has

gone from having a dedicated sales representative who was knowledgeable about the product and its features to either having no sales person support, or no knowledgeable sales person support. This has put the burden of selling the product on sales brochures (when they are used by the retail outlet), on advertising, and most importantly on the package. The room air conditioner appliance package has evolved into the role of a "silent salesman". Due to this fact, the package has changed from a brown box with only the logo and required legal information such as product identification and address line to a package using clay-white outside liner material and enhanced graphics including screens, four colors, and heliographs. Product illustrations and pictures are incorporated with features, warranties, sizing information, and the like.

The end user (consumer) of this product has also changed his/her expectations. The product package has to communicate product features, installation information, and sizing information to experienced installers, the do-it-yourselfer, as well as single mothers and the older consumer. Consumers are demanding education before the purchase of a product. Product image is also very important to the consumer. Because this product is sold on the "floor", the consumer will not purchase a product which is packaged in a shipping container that is creased, tattered, or torn. And rightly so, since this type of box certainly does not portray an image of quality, no matter how superior the product is inside.

It is a fact that Whirlpool Corporation has some of the finest quality numbers in the appliance industry—but the consumer does not seem convinced of this when the shipping container looks to be of poor quality, no matter if the product inside is damage-free or not. The end user (consumer) demands have migrated in an upward direction and have now become the demands of our dealers and distributors. Along with all the above criteria, the consumer is becoming knowledgeable and aware of packages which they are able to recycle. They want to have the opportunity to take the package to the recycle center. The consumer is also sensitive to over packaging. Whether the product is truly over packaged or not, there is consumer perception at work with the issue of over packaging.

STORAGE AND SHIPPING DEMANDS

During the same time period that the marketing requirements were changing, the requirements for physical distribution were becoming equally complex. Traditionally, there have been two brands of room air conditioners made by Whirlpool Corporation, the Kenmore brand for Sears Roebuck and Co. and the Whirlpool brand. Production was primarily from September through April. It was not uncommon to have the product sell out by the end of the shipping season. At that period in time, most product was shipped full trailer load (FTL) directly to its destination where it would be unloaded and sold to the end user (consumer). Packaging

designs under those conditions were relatively simple. The package was exposed to a minimum amount of hazards such as humidity, storage time and handling; thus, there was not a significant amount of robustness needed to compensate for those factors and the package could be made using fairly inexpensive materials.

The number of RAC brands produced by Whirlpool Corporation has grown from two to twelve. Due to this demand on production facilities, the length of the production season has increased twofold. Because of outside influences such as weather patterns and the economy, exhaustion of product inventory produced is not always guaranteed. Whirlpool has also developed and implemented "Quality Express", a just-in-time (JIT) distribution system, whereby dealers and distributors are given the flexibility to order product by the trailer load or in single units with overnight delivery service. With these facts, the package design now has to support longer storage times, longer exposure to things such as humid conditions and bad stacking, and an increased amount of handling. Many dealers, distributors, and retail outlets in trying to cut down on their storage costs, the amount of product they could potentially damage, and the effects of an uncertain economy, no longer want a full trailer load of product in their facility and have readily embraced "Quality Express" The participating distributors and dealers have restructured their distribution and retail systems to

accommodate the more JIT delivery schedule that is inherent to "Quality Express". Quality Express has changed the overall distribution modes to include more and more less-than-trailerload (LTL) type shipments. Along with the increased volume of product being produced comes a requirement from physical distribution for higher and higher stack heights to better utilize the current warehouse space. Better utilization of the current warehouse space will help prolong the move to more warehouses, which in the long term will save warehousing capital cost.

With the growth of Whirlpool as a corporation, there has emerged a surge of activity, by Whirlpool, in overseas markets. Shipping overseas has introduced the variables of overseas temperature, humidity, and container transport into the equation. Product and package designs have to accommodate the sub-zero temperatures of Canada to the hot and humid port facilities of the Middle East and Asia, as well as everything and everywhere in-between.

SELECTION OF REQUIREMENTS

So now that the environment has been established, a strategy for packaging design and development can be created. The following discussion explores the specific package design requirements which were developed in cooperation between product engineering, physical distribution, and marketing. This list of

design requirements initially will disregard things such as cost and material limitations. Due to the nature of this “wish” list, not all of the wants and wishes are realistic. To start, it was agreed that the product should reach the consumer (end user) damage free, if and when it was subjected to the “design specifications”. In other words, packaging engineers are not designing the product with its package to be dropped from a second-story window, and as such would not expect it to be damage free if it was dropped in this manner. The shipping container should be clean and undamaged. The product inside the package should be transportable in a personal vehicle without sustaining damage. The product should be easy to remove from the package. The shipping container should be easy to handle by the consumer. There should be appropriate instructions printed on the shipping container to indicate things such as proper handling, unpacking and disposal. All graphics and labels should be easy to read. The shipping container should not show “dirt”. Materials used for the package should be either recycled or recyclable. The package footprint should be as small as possible. The packaged product should be easy to handle with clamps, forks or a hand truck. The packaged product should be easy to stack. The packaged product should be able to be stacked to the warehouse ceiling (thirty feet). The packaged product should be robust, that is, able to withstand handling which exceeds the manufacturer’s specified limits. The shipping container should be clean, square, well sealed, and have no loose flaps.

After the above expectations from the production facility through the consumer (end user) were identified, the design requirements were extrapolated.

The warehouse storage design requirements developed include the following:

- Two year storage.
- High humidity conditions (e.g. New Orleans, Miami, Taiwan).
- Temperature requirements of 40° to 120° F
- Minimum stack height of fifteen to eighteen feet.
- Minimum of sixteen clamp handlings.

The handling modes that the package design should ideally accommodate are these:

- Clamp truck.
- Hand truck.
- Man.

The shipping modes used include the following:

- FTL.
- LTL.
- United Parcel Service (UPS).
- Personal vehicles.

This information was compiled into a design standard and used for all new product and package development. See Appendix B.

The above specifications are the current specifications used for designing all new Whirlpool room air conditioner product. These requirements may seem elementary to those in the consumer products industry, but for the new visible role of RAC product packages, it was essential that these requirements be identified, understood, and agreed to by all parties.

Now that the design requirements are established a look at ECT can begin. The selection of a board grade for any corrugated box is dictated by the anticipated stacking load which this box may have to support during shipment and warehousing.³ The primary focus for Whirlpool Corporation is what type of container (Mullen or ECT) can satisfy the design requirements outlined above.

Knowing that this product package needs to be designed for two years of stacking under high temperature and humidity conditions, the use of an ECT specified container seems to be a logical choice. But what about the customers need for a container which is not tattered or torn? A Mullen specified container might better serve the purpose in for this requirement.

Per Alfred McKinlay's article sited below, he feels that much of the published literature to date discusses how the changes in

³Uldis I. Ievans, Container Corporation of America, The Effect of Warehouse Mishandling and Stacking Patterns on the Compression Strength of Corrugated Boxes, (photocopy of typescript), 1.

carrier rules (the addition of ECT performance specifications) effect the available options for specification of corrugated containers. Some of the available options today include "high performance" material, recycled material, materials manufactured to meet specific Mullen criteria, and material manufactured to meet specific edge crush criteria. A user of corrugated material must analyze his/her own distribution system and pick the material requirement(s) that best suit the needs of that distribution system. There is no correlation between ECT performance specifications and Mullen specifications as the former specifies the vertical compression strength of the box while the latter specifies the burst strength of the box. If a user of corrugated containers needs the strength of compression specified material but also needs the rough handling containment of a burst specified container, that user may want to specify both to his corrugated supplier.⁴

⁴ Alfred H. McKinlay, "How To Specify Corrugated," Packaging, October 1992,

CHAPTER 3

METHODOLOGY

The data required for calculating the ECT shipping containers in this thesis are the vertical compression strength of the product and its interior package, the box perimeter, the required compression strength of the box, the product weight, and the stack height.

The first step taken in formulating the vertical compression strength required of the ECT shipping container is to determine the strength of the interior packaging and product. In the case of Whirlpool room air conditioners, generally the product does support vertical compression load. Therefore, both the interior packaging and the product are tested together. For the test procedure used, see Appendix C. For vertical compression results see the data in Table I.

TABLE I. VERTICAL COMPRESSION STRENGTH OF PRODUCT
"M"

FORCE AT FAILURE (pounds)	DEFLECTION AT PRODUCT FAILURE (inches)
2804	1.07
2804	1.10
2801	1.02

After obtaining the product and package interior strength values, the safety factor (SF) of 4.5 (the proposed Whirlpool Corporation standard) needed to be verified with respect to the package design specifications that were outlined earlier. Remembering the requirement to design for long term storage, high humidity, LTL shipment, and many handlings, this safety factor appeared to be acceptable. See Table II.

TABLE II. SAFETY FACTOR⁵

BOX STRENGTH AFTER 90% RH [BS90RH] ⁶	45%
BOX STRENGTH AFTER 2 YRS [BS2YR] ⁷	48%
DESIGN SAFETY FACTOR ⁸ $DSF = \frac{1}{BS\ 90\ RH \times BS\ 2\ YR} *$ *Denominator rounded to the nearest hundredth.	4.5

Once the internal product strength and safety factors were confirmed, the calculations for shipping container ECT could begin. On all three products, the known quantities included the box perimeter, design environment (safety factor), the product weight, the stack height and the desired compression of the shipping container which was derived from the above knowns. The unknowns included the required ECT and ECT board grade of the shipping container.

⁵Whirlpool Corporation, (unpublished data, 1992).

⁶Arthur Catlin, Inland Container Corporation, (unpublished data, 1993).

⁷Ibid.

⁸Ibid.

In looking at the internal product/package strength of all the products in this study, failure of the product or package occurred well beyond 0.5 inch deflection. It is presently accepted that the failure of corrugated containers occurs at 0.5 inch deflection⁹, therefore, the product/package deflection from the recorded compression graph was derived at the 0.5 inch deflection point. Due to the reporting nature of this data, a plus or minus 10 pound error factor for human inaccuracy exists in reading this data from the graph.

Product "M" utilizes expanded polystyrene (EPS) as its only internal packaging material. Due to the physical properties and performance of the product "M" package when stacked in the warehouse, the use of EPS internally will negate any vertical compression loading that the product may be able to handle. If the support for the stack load is allowed to happen through the product and EPS interior package, then the design requirements for storage are not attainable. In short, for this study the shipping container will be required to support the entire stack of product. The required box strength will be simply the compression strength required of the bottom container.

⁹ George G. Maltenfort, Corrugated Shipping Containers: An Engineering Approach (New York: Jelmar Publishing Co., Inc., 1988), 79.

Table III illustrates the ECT calculations for Product "M". The ECT requirements at one-half inch product/package deflection are calculated to be 78.56 pounds per inch width for Product "M".

TABLE III. ECT CALCULATIONS FOR PRODUCT "M"

KNOWN:

- Box Perimeter (BP)
- Environmental Parameters
- Compression Strength Required (CSR)
- Packaged Product Weight (PPW)
- Stack Height (SH)

UNKNOWN:

- Required ECT
- ECT Board Grade (weight of material)

COMPRESSION STRENGTH REQUIRED:

PACKAGED PRODUCT WEIGHT [PPW]	55 lbs	
STACK HEIGHT [SH]	8	
SAFETY FACTOR [SF]	4.5	
COMPRESSION STRENGTH REQUIRED $CSR = PPW \times (SH - 1) \times SF$		1732.5 lbs

REQUIRED BOX STRENGTH:

COMPRESSION STRENGTH REQUIRED [CSR]	1732.5 lbs	
INTERNAL PRODUCT STRENGTH [IPS]*	0 lbs	
REQUIRED BOX STRENGTH $RBS = CSR - IPS$		1732.5 lbs

* Due to the interior packaging material (EPS) and acceptable amount of deflection (none), it will be assumed that the exterior container is to support the entire stack load and the product will not support any of this stack load.

EDGE CRUSH TEST:

REQUIRED BOX STRENGTH [RBS]	1732.5 lbs
THEORETICAL COMPRESSION STRENGTH [TCS] (for an unprinted RSC with a perimeter of 84 in) ¹⁰	838 lbs
FLUTE FACTOR [FF] (C-flute) ¹¹	1.0
CONSTANT MULTIPLIER [CM] (for a 200 lb ECT container) ¹²	38 lbs/in
EDGE CRUSH TEST $ECT = \frac{RBS \times CM}{TCS \times FF}$	78.56 lbs/in

Recalling that the required box strength of the bottom stacked container is 1732.5 pounds, what is the requirement for a Mullen specified container? Inland container's suggestion, and the one which will be used for this study, is a 275* "C" flute container.

¹⁰ Arthur Catlin, Inland Container Corporation, (unpublished data, 1993).

¹¹ Ibid.

¹² Ibid.

CHAPTER 4 CONCLUSION

The exterior containers used by Whirlpool Corporation for their room air conditioner product have many demands placed upon them. They not only have to stack in the warehouse for an extended period of time, they have to survive the unknowns of LTL shipment and mixed load shipment domestically as well as internationally.

Given the above conditions, the evaluation of ECT materials in this study resulted in the following material cost and weight comparisons.

TABLE IV. SUMMARY OF FINDINGS FOR PRODUCT "M"

	MULLEN (275 lbs/sq in "C" flute)	ECT (78.56 lbs/in)	PERCENT IMPROVEMENT
COST PER BOX	\$1.41	\$1.35	4.3%
WEIGHT PER BOX	4.18 lbs	3.45 lbs	17.5%

As shown in Table IV, ECT specified material is 4.3% more cost effective than Mullen specified material. Moreover, ECT specification results in 17.5% less material by weight than Mullen specification. Looking at the savings of \$0.06 and 0.73 lbs. per unit, this would equate to approximately \$15,000.00 and 182,500 lbs. savings on Product "M" using for this calculation a product volume of 250,000 units per year.

Currently there is no legislation requiring material source reduction in shipping containers. In this study, when comparing the final reduction in material for the ECT container versus the Mullen container, it could be concluded that the ECT container is more "environmentally friendly" than the Mullen container due to the use of less material in the container. Less use of material up-front is generally thought of at Whirlpool Corporation to be better than trying to recycle, reuse or incinerate materials used in products or packages.

FUTURE CONSIDERATIONS

Theoretically, this study has proven that an ECT specified container is more economical and uses less material by weight than a Mullen specified material. The logical next step in the study of this problem is to construct actual samples of this material for testing and evaluation. If the new material performs

as predicted by this study then it could be considered for possible production at a future date.

Other factors which may influence the performance of the materials selected in this study are the use of handholes in the shipping container, the effect of printing, and the use of other materials such as double-wall. The influence of these factors should be investigated before materials are chosen for final production.

APPENDIX A - TEST PLAN

TITLE: Test plan for determining the stacking strength required for exterior containers studied in this thesis.

1. SCOPE

- 1.1 This test plan covers the criteria and testing necessary for determining the vertical compression strength required on the room air conditioner identified as "M" chassis.

2. REFERENCED DOCUMENTS

- 2.1 ASTM D-642 Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads.
- 2.2 Whirlpool Corporation test method number LTP-2003 *Vertical Compression*.

3. TERMINOLOGY

- 3.1 For definitions of terms, see ASTM D-996 Terminology of Packaging and Distribution Environments.
- 3.2 ECT or edge crush test is the method of determining the edgewise compression strength of combined corrugated fibreboard.
- 3.3 Vertical Compression is an evaluation of top-to-bottom compression strength.

3.4 Floating platen compression test option is an option on a compression tester whereby one platen is rigidly restrained from tilting while the other platen is universally mounted and allowed to tilt freely.

3.5 Abbreviations used in Figure 1, Figure 2, and Figure 3:

3.5.1 Whse-IB is the abbreviation for warehouse inbound. This is the production that is received in at the warehouse.

3.5.2 Whse-OB is the abbreviation for warehouse outbound. This is the production that is shipped out at the warehouse.

3.5.3 RDC-IB is the abbreviation for regional distribution center, inbound. This is the product which is received inbound at the regional distribution center.

3.5.4 RDC-OB is the abbreviation for regional distribution center, outbound. This is the product which is shipped out at the regional distribution center.

3.5.5 X-DOCK is the abbreviation for cross dock. This is an operation where typically product is received in on one side of the facility and directly shipped out on the opposite side of the facility.

3.5.6 DISTR-IB is the abbreviation for distributor inbound. This is the operation which distributes the

product. This abbreviation is used for the shipments into his facility.

3.5.7 DISTR-OB is the abbreviation for distributor inbound. This is the operation which distributes the product. This abbreviation is used for the shipments out of his facility.

3.5.8 LTL is the abbreviation for less than trailerload. This is used when less than a full trailer load of product is shipped.

3.5.9 TL is the abbreviation for trailerload. This is used when a full trailer load of product is shipped.

3.5.10 PU is the abbreviation for pick-up truck.

4. SIGNIFICANCE AND USE

4.1 See ASTM D-642.

4.2 See ASTM D-2808.

5. APPARATUS

5.1 Compression test machine:

5.1.1 Lansmont model 122-15K compression tester

5.1.2 Floating Platen fixture.

6. ACCEPTANCE CRITERIA

6.1 Testing completed shall be in accordance with Whirlpool Corporation test method T-135, LTP-2003 and ASTM D-642.

- 6.2 Data should be collected throughout the entire test until the product is damaged or its interior packaging has failed.
- 6.3 The ECT specified shipping container should be equal to or better in performance than the Mullen specified container through all of the Whirlpool Corporation packaging lab tests and distribution systems.

7. FAILURE CRITERIA

- 7.1 Vertical Compression
 - 7.1.1 Failure will be said to have occurred when any one or more of the packaging components has fractured, given-way, or broken.
 - 7.1.2 Failure will be said to have occurred when any one or more of the product components has fractured, given-way or bent.

8. SAMPLING AND TEST SPECIMENS

- 8.1 The product chassis size to be evaluated is identified as "M"
- 8.2 Three samples of the product identified will be tested.
- 8.3 Only production type packaging is to be used for all testing. Either production packaging or packaging which is representative of production is permissible.

- 8.4 Each test specimen shall be representative of a new, never-been-vertically-compressed product and package.

9. CONDITIONING

- 9.1 All test specimens shall be conditioned for at least 72 hours in standard lab conditions (70°, 30% RH).
- 9.2 Conditioning shall be done in accordance with ASTM D-4332.

10. PROCEDURE

- 10.1 Conduct vertical compression until failure.
- 10.2 Determine the ECT and Mullen material needed for required distribution conditions. See figure 1, figure 2, and figure 3 for distribution cycle types. If no distribution cycle is identified, then the Domestic Quality Express (Figure 1) distribution cycle shall be used.
- 10.3 Determine acceptable ECT material in single-wall.
- 10.4 Determine acceptable Mullen material in single-wall.
- 10.5 Determine costs of ECT material in single-wall
- 10.6 Determine costs of Mullen material in single-wall

11. INTERPRETATION OF RESULTS

- 11.1 Give performance data.
- 11.2 Give cost data.

12. REPORT

12.1 Either prove or disprove study objectives.

12.1.1 Material cost of an ECT specified shipping container is less than a Mullen specified shipping container.

12.1.2 Material weight is less using an ECT specified shipping container rather than a Mullen specified container.

FIGURE 1. DISTRIBUTION CYCLE - DOMESTIC QUALITY EXPRESS

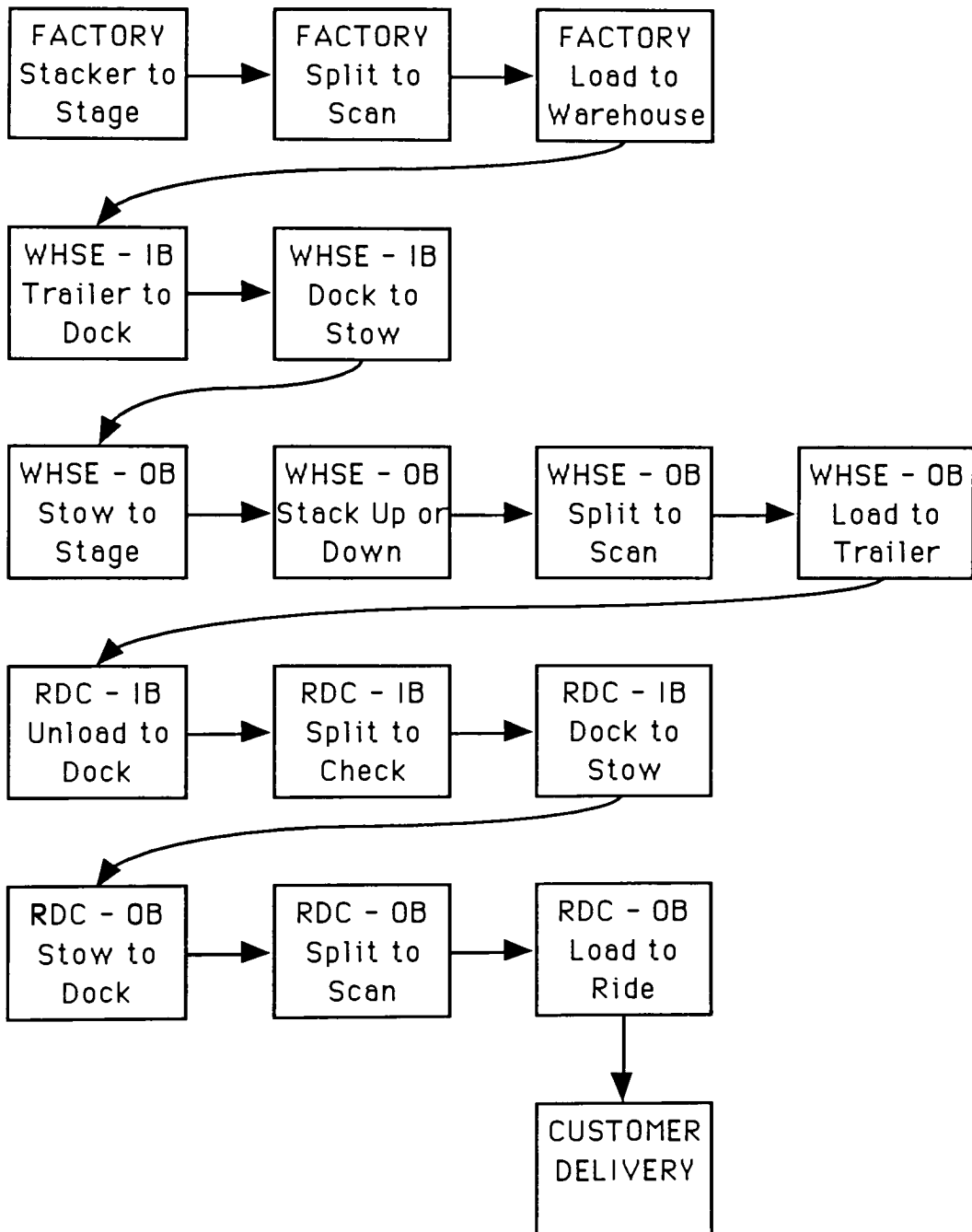


FIGURE 2. DISTRIBUTION CYCLE - DOMESTIC LTL

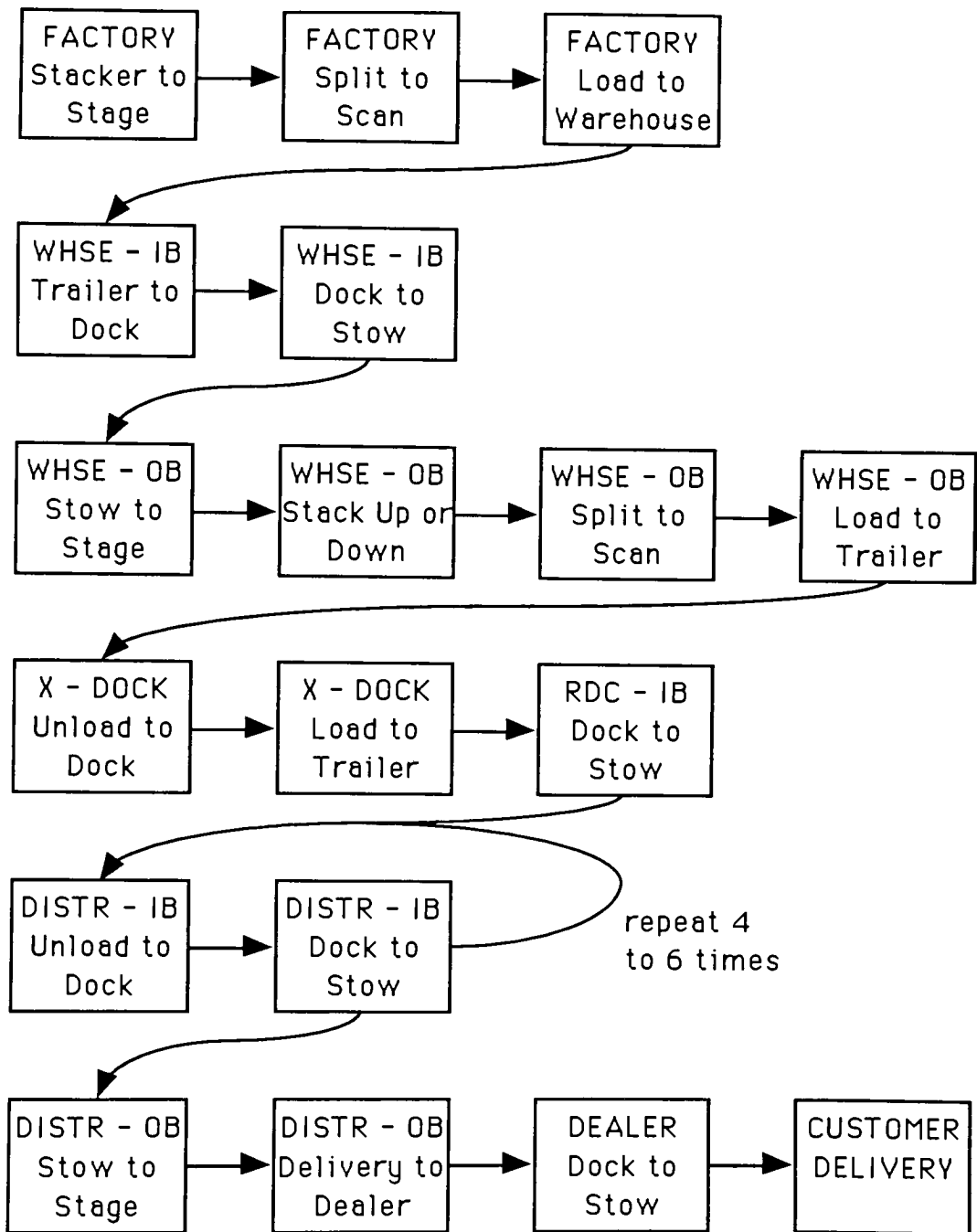
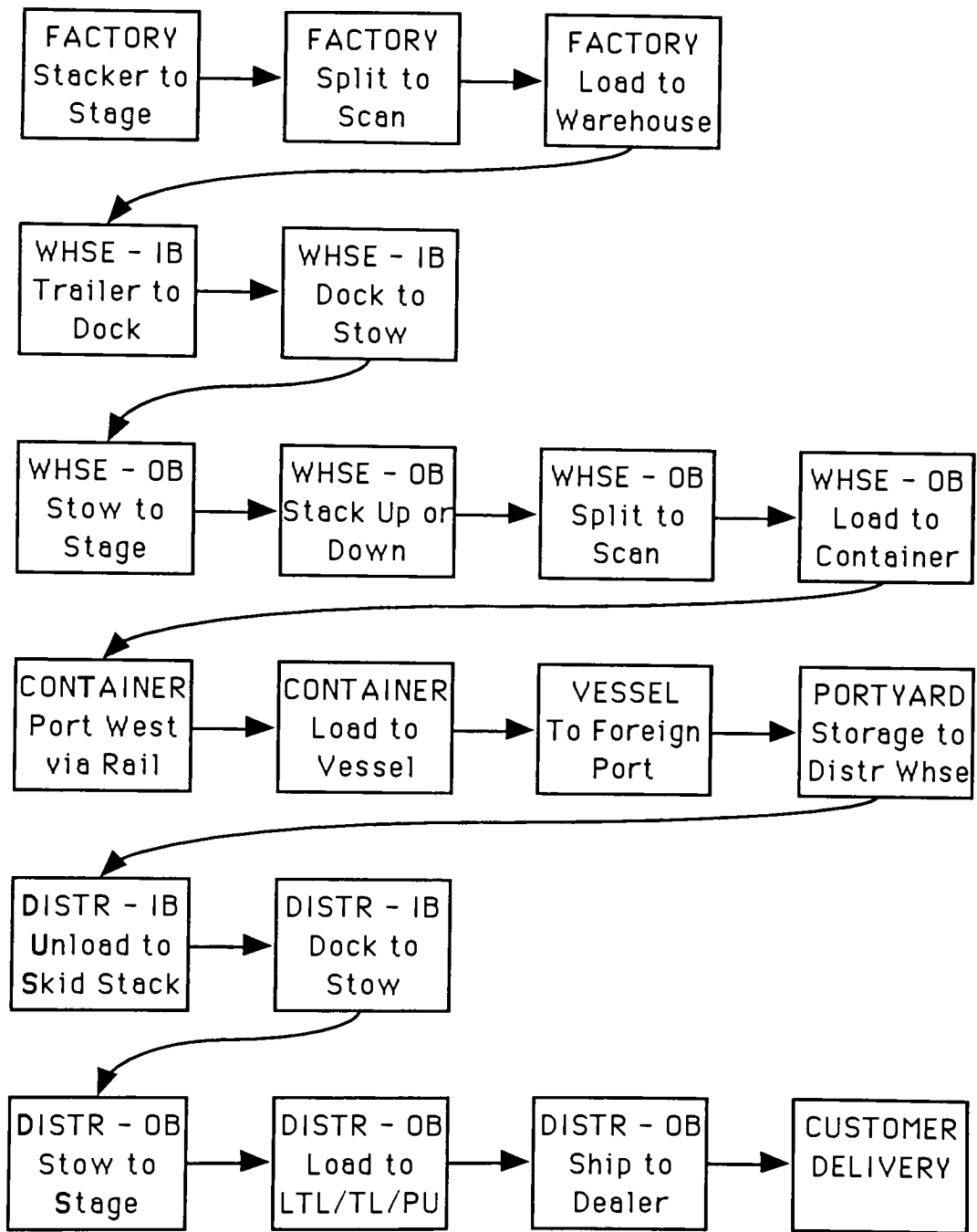


FIGURE 3. DISTRIBUTION CYCLE - INTERNATIONAL



APPENDIX B - DESIGN STANDARD

STANDARD FOR EVALUATING PRODUCT SYSTEMS AND THEIR PACKAGES IN THE WHIRLPOOL - LAVERGNE PRODUCT ENGINEERING PACKAGING LAB

1.0 PURPOSE

- 1.1. To provide a means of describing a laboratory test plan to uniformly evaluate the ability of product and packaging systems to withstand the Whirlpool, LaVergne division, distribution environment.

2.0 SCOPE

- 2.1. This document provides a method of evaluating, in the laboratory, the ability of products and packages to withstand the distribution environment to which they will be exposed. This document will specify the acceptance criteria, and provide a test plan for the evaluation of products and their packages in the product engineering packaging lab.

2.0 REFERENCED DOCUMENT

- 2.1. ASTM Standard:
 - D4169 Performance Testing of Shipping Containers and Systems.

- 2.2. Whirlpool Corporation - LaVergne Division - Standard:
- LTP - 2001 Test Method for Horizontal Compression Resistance of Loaded Boxes
 - LTP - 2002 Test Method for Drop Testing of Loaded Boxes.
 - LTP - 2003 Test Method for Compression Resistance of Shipping Containers.
 - LTP - 2004 Test Method for Vibration and Random Vibration of Products & Shipping Containers.

3.0 TERMINOLOGY

- 3.1. See ASTM D996 Standard Terminology of Packaging and Distribution Environments.

4.0 SIGNIFICANCE AND USE

- 4.1. This practice provides a guide for the evaluation of shipping units according to a uniform system, using established test methods at levels representative of those occurring in actual distribution. The recommended test levels are based on available information on the shipping and handling environment, and current industry practice and experience.
- 4.2. The tests should be performed sequentially on the same containers in the order given.

5.0 TEST SPECIMENS

- 5.1. The test specimens shall consist of the container as intended for shipment, loaded with the interior packaging and the actual contents for which it was designed. Blemished or rejected products may be used if the defect will not affect the test results and is recorded prior to the test. Dummy test items may be used for developmental testing when necessary, but may not be used for final acceptance testing. Sensors and transducers may be applied as appropriate to measure data points of interest with the minimum possible alteration of the test specimen. Parts and surfaces of the specimen may be marked for identification and reference. When necessary to observe the contents of the package during the test, holes may be cut in non-critical areas of the container.
- 5.2. Containers should be closed and secured in the same manner as will be used in preparing them for shipment.

6.0 EQUIPMENT AND CALIBRATION

- 6.1. The LaVergne division product engineering packaging lab test equipment shall be used for this testing.
- 6.2. The accuracy of instrumentation and test equipment used to control or monitor the test parameters should be verified prior to conducting each test to ensure

that desired test levels and tolerances are maintained.

- 6.3. All lab equipment shall be maintained as described by the manufacturer.
- 6.4. All lab equipment shall be calibrated annually.

7.0 CONDITIONING

7.1. If the distribution cycle contains climatic conditions that have an effect on the performance characteristics of the product, shipping container, or components such as cushioning , use one of the following procedures:

- 7.1.1. Conduct the test at standard conditions and compensate for the effects of any climatic condition. Condition the shipping units to a standard atmosphere of $73.4 \pm 1.8^{\circ}\text{F}$ and $50 \pm 2\%$ relative humidity. Condition fiberboard containers in accordance with ASTM D4332. If testing cannot be conducted at the standard condition, conduct the tests as soon after removal from the conditioning chamber as practicable. Recondition the shipping units to the standard atmosphere as necessary during the test plan.
- 7.1.2. Condition the shipping units to the climatic conditions (salt spray, water immersions,

humidity, or temperature) and conduct the tests as desired conditions as soon after removal from the conditioning chamber as practicable. Recondition the shipping units as necessary. If testing at desired conditions is impossible, conditions at time of test shall be recorded and reported.

8.0 ACCEPTANCE CRITERIA

- 8.1. Acceptance criteria must be established prior to testing and should consider the required condition of the product at receipt. The product engineering packaging lab may choose the acceptance criteria suitable for the specific purpose of the test. It is advisable to compare the type and quantity of damage that occurred to the test specimens with the damage that occurs during actual distribution and handling or with test results of similar container whose shipping history is known.
- 8.2. Typically, the acceptance criteria shall be that the product is damage-free and the package is intact and virtually damage-free. Often, this means that the shipping container and its contents are suitable for normal sale and use at the completion of the test cycle. Detailed acceptance criteria may allow for accepting specified damage to a product or its

package. The form and content of acceptance criteria may vary widely, according to the particular situation. Methods may range from simple pass-fail judgments to highly quantitative scoring or analysis systems.

9.0 PROCEDURE

- 9.1. Inspect - check the test unit(s) for visible defects that might affect the results of the test and record.
- 9.2. Define Shipping Unit - describe in terms of size, weight, and form of construction.
- 9.3. Establish Acceptance Criteria - acceptance criteria are related to the desired condition of the product and package at the end of the distribution cycle. See section 8.0 of this standard.
- 9.4. Select Distribution Cycle - select from the available standard distribution cycles. Use the distribution cycle that most closely correlates with the projected distribution of the product being tested. See appendix A, Figure 1, Figure 2, and Figure 3. When the distribution cycle is undefined, the Whirlpool Quality Express distribution cycle shall be used.
- 9.5. Write Test Plan - prepare by using the distribution sequence presented in Appendix A for the distribution cycle selected. Obtain the test intensities from the referenced test methods. Appendix A thus leads to a detailed test plan consisting of the exact sequence in

which the shipping unit will be subjected to the test inputs.

- 9.6. Select Samples - for test section 5.0 of this standard.
- 9.7. Condition Samples - see section 7.0 of this standard.
- 9.8. Perform Tests - as directed by the Whirlpool, LaVergne lab test procedures and ASTM standards.
- 9.9. Evaluate Results - to determine if the shipping units meet the acceptance criteria. See section 8.0 of this standard.
- 9.10. Document Test Results - see section 10.0 of this standard.
- 9.11. When possible, obtain feedback by monitoring shipments of the container that was tested to ensure that the type and quantity of damage obtained by the laboratory testing correlates with the damage that occurs in the distribution cycle. This information is very useful for the planning of subsequent tests of similar shipping containers.

10.0 REPORT

10.1 The report shall include the following:

- 10.1.1. Identification and description of the test specimen(s), including the container, the interior packaging, the product (give size, weight, and product modification, and any other

pertinent details, and photographs (before and after) of the test items, where possible.

10.1.2. Container structural and physical specifications shall include:

10.1.2.1. Inside dimensions for all shipping containers.

10.1.2.2. Description of the contents of the container and gross weight as tested.

10.1.2.3. Type of material, style of container, printing, access holes, and double scores.

10.1.2.4. Description and specifications for interior packaging and contents. Type of cushioning and blocking and bracing materials used.

10.1.2.5. Spacing, size, and type of fasteners, and method of attachment.

10.1.3. Detailed data documentation for each test specimen including:

10.1.3.1. Damage to the container and contents.

10.1.3.2. Any observations that may assist in correctly interpreting the results or aid in improving the design of the product and its container

10.1.3.3. Nature and cause of failure.

- 10.1.3.4. Any tests performed on the test specimen prior to drop testing.
- 10.1.3.5. Number of specimens tested.
- 10.1.4. Method, if any, of conditioning the container.
- 10.1.5. The results of any supplementary test of the materials from which the container is made.
- 10.1.6. Purpose of the test and the applicable changes to the product - including a through pre-inspection of the product with any existing damage or abnormalities.
- 10.1.7. Verification of compliance with the test methods or descriptions of any deviations from the specified test method.
- 10.1.8. A statement of the number of test replications, if any.
- 10.1.9. Atmospheric conditions to which the specimens were subjected, both prior to test and during test.
- 10.1.10. Any other test the specimens were subjected to prior to this test.
- 10.1.11. Description of the apparatus and instrumentation used.
- 10.1.12. Results of the tests, and a comparison between damage levels observed as a result of the test versus actual damage observed in transportation, if historical data exists.

- 10.1.13. Descriptions and photographs of any damage or deterioration to the containers or their contents as a result of the tests.
- 10.1.14. A statement of whether the test was for development purposes or new model approval purposes.
- 10.1.15. A statement of whether or not the specimens complied with the requirements of the applicable specification (Pass/Fail).

APPENDIX C - COMPRESSION TEST METHOD

TEST METHOD FOR COMPRESSION RESISTANCE OF SHIPPING CONTAINERS LTP - 2003

1.0 SCOPE

- 1.1. This test method covers compression tests on shipping containers, packaging components, products or all of the above. This procedure can be used for measuring the ability of the container and/or product to resist external compressive loads.
- 1.2. This test method is also designed to determine the resistance of a shipping container, and contents to a vertically applied constant load for either a specified time or until failure.

2.0 REFERENCED DOCUMENT

2.1. ASTM Standard:

- D642 Standard Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads.
- D4577 Standard Test Method for Compression Resistance of a Container Under Constant Load.

3.0 TERMINOLOGY

- 3.1. Floating platen test machine - a testing machine equipped with two platens, one rigidly restrained from tilting while the other platen is universally mounted and allowed to tilt freely.

4.0 APPARATUS

- 4.1. Whirlpool product engineering compression equipment (Lansmont model #122-15K or equivalent).
- 4.2. Compression tester with fixed and floating platen options.
- 4.3. X-Y plotter and chart recorder.

5.0 TEST SPECIMENS

- 5.1. The test specimens shall consist of the container as intended for shipment, loaded with the interior packaging and the actual contents for which it was designed. Blemished or rejected products may be used if the defect will not affect the test results and is recorded prior to the test. Dummy test items may be used for developmental testing when necessary, but may not be used for final acceptance testing. Sensors and transducers may be applied as appropriate to measure data points of interest with the minimum possible alteration of the test specimen. Parts and

surfaces of the specimen may be marked for identification and reference. When necessary to observe the contents of the package during the test, holes may be cut in non-critical areas of the container

- 5.2. When testing containers alone, a sample size of five containers shall be used.
- 5.3. Containers should be closed and secured in the same manner as will be used in preparing them for shipment.

6.0 CALIBRATION

- 6.1 The accuracy of instrumentation and test equipment used to control or monitor the test parameters should be verified prior to conducting each test to ensure that desired test levels and tolerances are maintained.
- 6.2. All electronic controls for the vibration equipment shall be calibrated annually.

7.0 CONDITIONING

- 7.1. Test specimens shall be conditioned for a minimum of 24 hours at $73^{\circ} \pm 4^{\circ}$ F and $50\% \pm 2\%$ relative humidity prior to performance of tests.

8.0 ACCEPTANCE CRITERIA

- 8.1. For constant load testing, the acceptance criteria shall be that the product is damage-free and the package is intact.

9.0 PROCEDURE

- 9.1. Inspect the test unit(s) for visible defects that might affect the results of the test and record.
- 9.2. Center the specimen on the lower platen of the testing machine in the desired orientation, so as not to incur eccentric loading. Bring the platens into contact with the specimen by applying an initial pressure or pre-load (see 9.2.1). Both platens must be fixed for tests where the compressive loads are applied on test specimen edges, or diagonal corners. Most face-to-face testing should be done using a floating platen, unless testing empty containers or unless otherwise specified.
 - 9.2.1. For single-wall corrugated containers, an initial pressure or preload, of 50 lbf on the specimen is recommended. For double-wall and triple-wall boxes, preloads of 100 lbf and 500 lbf respectively, are recommended. For other types of test specimens a suitable pre-load may or may not be selected.
- 9.3. Apply the load with a continuous motion of the moveable platen of the testing machine at a speed of

0.5 inches per minute until failure, maximum load or both have been reached.

9.4. Prior to testing for each type of loading, critical points shall be established where applicable. Record the compressive load at these critical deformations, together with the maximum load and deformation.

9.5. Constant Load Testing (long-term stack)

9.5.1. The load to be placed on the test specimen shall be calculated as follows: $W * (H-1) * (4.5)$ = constant load weight of the test, where W is the packaged weight of the test specimen, H is the design stack height (this may or may not be the actual stack height) in the warehouse and 4.5 is the safety factor.

9.5.2. Force and deflection data shall be taken every minute for the first five minutes from the beginning of the test, then every five minutes until fifteen minutes into the test, then every thirty minutes until one hour into the test, then once per hour thereafter until the end of the test (i.e. - force and deflection data shall be gathered for minutes 1, 2, 3, 4, 5, 10, 15, 30, 60, 120, 180, 240,). Deflection angle, amount of bowing of the box and location shall also be recorded.

10.0 REPORT

10.1. The report shall include the following:

10.1.1 Identification and description of the test specimen(s), including the container, the interior packaging, the product (size, weight, and product modifications, and any other pertinent details, and photographs, before and after, of the test items, where possible).

10.1.2. Container structural and physical specifications shall include:

10.1.2.1. Inside dimensions for all corrugated containers.

10.1.2.2. Description of the contents of the container and gross weight as tested.

10.1.2.3. Type of material, style of container, printing, access holes, and double scores.

10.1.2.4. Description and specifications for interior packaging and contents.

10.1.2.5. Spacing, size, and type of fasteners, and method of attachment.

10.1.3. Detailed data documentation for each test specimen including:

10.1.3.1. Damage to the container and contents.

- 10.1.3.2. Any observations that may assist in correctly interpreting the results or aid in improving the design of the container.
 - 10.1.3.3. Nature and cause of failure.
 - 10.1.3.4. Any tests performed on the test specimen prior to compression testing.
 - 10.1.3.5. Printing amount and location on the container.
 - 10.1.3.6. A tabulation of individual maximum load and deformation results.
 - 10.1.3.7. Graph or table showing the load-deformation relationship for each test.
 - 10.1.3.8. Graph or table showing the deflection angle, bowing of the box and location.
 - 10.1.3.9. Number of specimens tested.
-
- 10.1.4. The weight of the product and stack height used for the test shall be specified.
 - 10.1.5. For long-term stack testing a graph or table showing the deflection verses time for each test.
 - 10.1.6. Use of fixed or floating platen for the test.
 - 10.1.7. Preload used for the test.
 - 10.1.8. Method, if any, of conditioning the container.

- 10.1.9. The results of any supplementary test of the materials from which the container is made.
- 10.1.10. Purpose of the test and the applicable changes to the product - including a through pre-inspection of the product with any existing damage or abnormalities.
- 10.1.11. Verification of compliance with the test method or descriptions of any deviations from the specified test method.
- 10.1.12. A statement of the number of test replications, if any.
- 10.1.13. Atmospheric conditions to which the specimens were subjected, both prior to test and during test.
- 10.1.14. Any other test the specimens were subjected to prior to this test.
- 10.1.15. Description of the apparatus and instrumentation used.
- 10.1.16. Results of the tests, and a comparison between damage levels observed as a result of the test versus actual damage observed in transportation, if historical data exists.
- 10.1.17. Descriptions and photographs of any damage or deterioration to the containers or their contents as a result of the tests.

10.1.18. A statement of whether the test was for development purposes or new model approval purposes.

10.1.19. A statement of whether or not the specimens complied with the requirements of the applicable specification (Pass/Fail).

GLOSSARY

Edge Crush Test. Also referred to as a short column test, this test is executed on a sample of a corrugated or solid fibre sheet to correlate the compression strength of a container made from that sheet.¹³

Flute Factor. This is a constant used to denote the strength that a certain flute size used in corrugated contributes to the container.¹⁴

Full trailer load. This refers to the freight rates or classes published in the truck and rail tariffs for which a truckload minimum weight is provided, and charges are assessed at this truckload minimum weight.¹⁵

¹³ The Packaging Institute International, Glossary of Packaging Terms

(Connecticut: The Packaging Institute International, 1988), 74.

¹⁴ Arthur Catlin, Inland Container Corporation, (unpublished data, 1993).

¹⁵ American Trucking Associations, Inc., National Motor Freight Classification

(Virginia: American Trucking Associations, Inc., 1992), 201.

Just in time. Also known as Kanban, involves a program of greatly reducing the quantity of inventory that is stocked at places like an assembly plant, warehouse, or retail outlet.¹⁶

Less than trailer load. This refers to the freight rates or classes which are applicable to a quantity of freight shipped that is less than the total volume of the trailer used for shipping.¹⁷

Mullen test for burst strength. This is a test made to determine the bursting strength of a flat specimen of paper, paperboard, film, foil, plywood, corrugated fibreboard, solid fibreboard or other material.¹⁸

Safety Factor The term safety factor refers to the ratio of the box compression strength at standard conditions to the maximum stacking load which will be applied to the box in service.¹⁹

¹⁶ James C. Johnson and Donald F. Wood, Contemporary Logistics (New York: Macmillan Publishing Company, 1990), 16.

¹⁷ American Trucking Associations, Inc., 201.

¹⁸ The Packaging Institute International, 151.

¹⁹ George G. Maltenfort, 125.

Vertical Compression. This term refers to the top-to-bottom static compression testing of a shipping container.

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