PAPER TASK FORCE

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*Johnson & Johnson ** McDonald's*
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WHITE PAPER NO. 6A

FUNCTIONALITY ISSUES FOR CORRUGATED PACKAGING ASSOCIATED WITH RECYCLED CONTENT, SOURCE REDUCTION AND RECYCLABILITY

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I. INTRODUCTION

This white paper summarizes the results of the Paper Task Force's research and findings on functionality issues associated with corrugated packaging. This paper is one element of an extensive research process in support of the Paper Task Force's work to develop recommendations for purchasing "environmentally preferable paper" (paper that reduces environmental impacts and meets business needs).

This paper analyzes recycled content, source reduction and recyclability issues in corrugated boxes from the standpoint of the functionality of the box. The Paper Task Force's overall recommendations integrate findings on environmental, economic and functional aspects of paper use in a balanced manner that reflects the needs of users of paper in the private sector.

The findings in this paper are based on the Paper Task Force's own research and members' experience, a review of published articles, and interviews with representatives from the paper industry, academia, packaging design firms, freight carriers and companies that use corrugated boxes. On October 11, 1994, the Paper Task Force also assembled a panel of experts to address several issues in this area. The panel was preceded by a background "Issue Paper" prepared by the Paper Task Force. Both the Issue Paper and this White Paper have been reviewed by the panelists and additional expert reviewers (see Appendix A).

The Paper Task Force members endorse the broad principles set forth by the Task Force's final report. The findings and research in this White Paper reflects the contribution of Paper Task Force Working Groups and changes made in response to comments received from expert reviewers through the White Paper review process. The contents of this paper do not reflect the policy of individual Task Force member organizations.

Two caveats apply to the scope of this paper. First, this paper refers to 100% recycled containerboard in the findings and text. This is in part because statistics are reported by the American Forest & Paper Association in two categories, for example, kraft linerboard (which includes all linerboard that contains 100% virgin fiber or a mix of virgin and recovered fiber) and 100% recycled linerboard (as a separate category). Further, all of the major containerboard capacity additions in the U.S. from 1994 to 1997 are in the 100% recycled category.[1] However, readers should not infer from these discussions that the task force will make recommendations relating to a specific level of recycled content in containerboard.

Second, with respect to source reduction, this paper is primarily focused on reducing the weight of corrugated boxes by shifting to lighter containerboard or by redesigning the box. Other approaches to reduce the use of corrugated boxes include eliminating the box or substituting other materials, as with the use of shrink-wrapped trays and reusable shipping containers. Because the Paper Task Force's recommendations will focus on uses of paper, the task force is not conducting a full analysis of the implementation and environmental issues associated with source reduction techniques that extend beyond the corrugated box itself.

Corrugated boxes are made from corrugated board, a combination of linerboard and corrugating medium. In this paper, we use the term "containerboard" to refer to linerboard and corrugating medium.[2] If not otherwise stated in this paper, "recycled content" refers to both pre- and postconsumer materials. Definitions of industry terms are provided in Appendix B. Appendix C provides more information on the basics of box manufacturing and Appendix D describes developments in containerboard production technology. Appendix E shows typical box style categories.

The United States paper industry produced 26.4 million tons of containerboard for domestic use in 1993, including 18.2 million tons of linerboard and 8.2 million tons of corrugating medium.[3] Corrugated boxes are one of the major components of municipal solid waste. According to the consulting firm of Franklin Associates, old corrugated containers (OCC) made up 26.4 million tons or 12.7% of 206.9 million tons of municipal solid waste produced in the U.S. in 1993, the largest single category after yard waste. OCC accounted for 11.7 million tons or 7.2% of 162.0 million tons of municipal solid waste disposed in landfills and incinerators in 1993, the third largest category after yard and food waste. OCC was also the largest single category of materials recovered with 14.6 million tons or 32.5% of all municipal solid waste recovered.[4]

OCC has the highest recovery rate of all paper products. Franklin Associates calculates a "post-consumer" recovery rate as the amount of old corrugated removed from the waste stream for recycling relative to the total corrugated waste generated. The resulting recovery rate was 55.5% in 1993. The American Forest & Paper Association calculates a total recovery rate (including pre- and postconsumer material) as the amount of OCC and manufacturing scrap relative to the new corrugated containerboard supply. The resulting recovery rate was 62.0% in 1993 and 62.6% in 1994.[5]

II. FINDINGS

Following are the Paper Task Force's findings with regard to functional issues in adding recycled content, source reduction and increasing recyclability of corrugated packaging. The findings are based on research that is summarized in the body of this paper. The findings follow the organization of the paper, and include references to the corresponding sections within this white paper.

1. The ultimate performance of corrugated boxes, both recycled and virgin, depends less on the type of fiber used and more on individual mill and converting technology. Given the same technology, the type of fiber used makes a difference. [Section II and Appendix D]

a. Recycled fibers from OCC are shorter and present some disadvantages in manufacturing compared to virgin unbleached kraft fibers. However, with new production technologies, adjustments and the use of additives in the papermaking process, manufacturers can produce boxes with high levels of recycled content and no loss in major performance characteristics, such as box compression strength, compared to boxes produced from virgin fibers. Improvements in paper mill headbox and press section technology have made it possible to compensate in the manufacturing process for some of the properties of recovered fiber. Based on these new technologies, a few manufacturers produce corrugated boxes with 100% postconsumer recycled content with the same performance characteristics as virgin boxes.

b. Recycled content levels historically have been relatively high in the box industry and have been growing in recent years. There are several reasons for this trend. The above mentioned technologies have not only improved the quality of containerboard made from recovered fiber, but have also allowed mills that have exhausted their virgin pulping capacity to incrementally expand their paper production. For mills undergoing incremental expansions of capacity and for new mills, overall production costs are usually lower using recovered fiber rather than virgin fiber in times when prices for recovered paper are in their historical range (i.e., prior to 1994). Moreover, it may not be feasible for some mills to expand unbleached virgin kraft pulping capacity to meet the needs of incremental paper machine expansions. Also, improvements in OCC screening and cleaning technology have facilitated the utilization of more recovered fiber. Finally, some customers are requesting boxes that contain recycled content. (These topics are also covered in White Paper 9).

c. Between 1990 and 1993, the average recovered fiber utilization rate for all containerboard increased from 26 to 35%. Actual recycled content levels in corrugated boxes are about 10% less due to fiber loss in the recycling process. The recovered fibers used are mainly postconsumer materials. Precise data on postconsumer recycled content levels are not available. The generation of preconsumer scrap through the box converting process is estimated at 8 % of total containerboard production, or the equivalent of 2.0 million tons in 1993; this scrap is used in the manufacturing of containerboard and 100% recycled paperboard. The recovered fiber utilization rate is higher for corrugating medium (59% in 1993) than for linerboard (25% in 1993).

2. Three options are available for purchasers of corrugated boxes that potentially offer environmental benefits: source reduction, increasing the recycled content of boxes and improving the recyclability of coated boxes.

a. Changes in freight carrier standards, primarily of the trucking and railroad industry, and the acceptance of compression strength test standards, including the Edge Crush Test (ECT) option, allow for increased recycled content and source reduction through the usage of so-called "high performance linerboard" which has a lower basis weight. [Sections I. A, B, III. A]

Recovered fibers were at a relative disadvantage under the old basis weight/burst strength test standards. With ECT as an alternative testing measure, the recycled content in corrugated board can be increased and lighter weight board can be used by some manufacturers to make boxes with comparable compression performance to boxes made from linerboard with mostly virgin fibers. In some state-of-the-art mills, technology permits an increase in recycled content and a simultaneous reduction in basis weight. Thus, a few manufacturers offer 100% recycled lightweight containerboard. For some older mills, there is a trade-off between increasing recycled content and source reduction.

b. Source reduction in corrugated packaging can also be facilitated by box redesign, a responsibility and an opportunity shared by the box manufacturer and the box purchaser/user. For example, boxes can be redesigned to optimize box size and maximize truck utilization or the size of box flaps can be reduced. [Section III. B]

c. It may be possible to increase the recyclability of waxed boxes through the substitution of repulpable coatings [Section IV.A]

Waxed boxes are mainly used in the meat, poultry and produce industries for water resistance, and constitute about 3-6 % of all corrugated boxes produced, or 800,000 to 1.6 million tons of OCC. The wax is difficult to remove during repulping, causing problems in papermaking and affecting the quality of the new containerboard. With OCC recovery rates (including pre- and postconsumer material) already at 62.6% and mills seeking more and more recovered fiber, the development of water-resistant boxes that can be more readily recycled could provide an important new increment of usable fiber.

In order of their current availability, three alternatives to waxed boxes are possible: film laminates, the “bag-in-box” concept and repulpable water-resistant coatings. Old corrugated containers with laminated film linings are not accepted by some containerboard manufacturers as a furnish for recycled containerboard, and plastic bags inside of corrugated boxes must be removed prior to collection. The Fiber Box Association and the American Forest & Paper Association are working with containerboard manufacturers to set a voluntary industry standard for repulpable water-resistant coatings. These standards are scheduled to be published in mid-1995, and should speed the commercialization of coatings that are now in the development or early commercialization stages.

III. FUNCTIONAL REQUIREMENTS FOR CORRUGATED PACKAGING

This section analyzes functional requirements for corrugated boxes. Part A describes the different distribution environments that were considered for this analysis. Part B examines general trends that shape the box industry. Part C shows how these functional needs translate into specific performance characteristics.

A. Distribution Environment

This paper considers two types of distribution systems: shipments in corrugated boxes in bulk and single package shipments. In the first environment, a set of boxes typically is transported from a manufacturer to a warehouse or point-of-sale by truck or railroad. In this case, boxes may be stacked on pallets and handled by a forklift or similar equipment. Corrugated boxes must perform on packaging equipment, e.g. filling lines, and within the distance and conditions of transportation and warehousing. Most box specifications are developed by users, working with their suppliers, to meet true performance needs. Unless they use their own transportation fleets, manufacturers will determine box specifications based on the rules of the American Trucking Association (National Motor Freight Classifications) or the

National Freight Railroad Committee (Uniform Freight Classifications). These two organizations specify detailed box performance criteria that must be met in order for their members to accept the liability for the damage to any shipments. According to one expert, the top five trucking companies in the U.S. incur approximately $ 35 million in annual payments for damages.[6] The most important guidelines focus on box strength and are outlined in Item 222 and the new Item 180 of the National Motor Freight Classifications and Rule 41 of the Uniform Freight Classifications. Details are provided in Section I.B. Most large packaging users have their own defined specifications and requirements that are developed with the knowledge of these “rules.”

In the second environment, single boxes are transported from a manufacturer to individual destinations by a small parcel carrier, such as the United States Postal Service (U.S. Postal Service), United Parcel Service (UPS) or Federal Express Corporation (FedEx), all of whom were interviewed in the preparation of this paper.[7] Other carriers include Amtrak Express, Greyhound/ Trailways Package Express, air cargo provided by various airlines and other parcel services. In this distribution environment, corrugated boxes must endure handling by automated parcel processing systems and the varying conditions of transportation. For instance, at FedEx, each package is physically handled 10-18 times from pick-up to delivery. In this environment, boxes are more likely to be dropped and are in contact with other customers’ packages.

The small parcel carriers have developed basic packaging guidelines, but not at the level of detail provided in the National Motor Freight Classifications or the Uniform Freight Classifications. The guidelines limit maximum box weight and size.[8] The small parcel carriers allow their customers to choose the type of packaging and the packaging material. They agree that in many cases, the interior packaging or cushioning is more important than the outer packaging for drop and vibration resistance. For high volume customers, the three carriers we interviewed suggest package testing according to the International Safe Transit Association Preshipment Test Procedures.[9] In addition, the U.S. Postal Service has issued minimum box strength requirements dependent on various box characteristics. UPS has developed internal box strength specifications dependent on the gross weight of the box. It should be noted that in this environment many boxes are used without prior testing and the quality of the box only becomes an issue when it fails. More details are provided in sections I.B. and I.C.

In addition to the general distribution system, box specifications depend on the specific product to be packaged and on individual issues in the distribution environment. For example, the box for a personal computer sold in a retail store would have somewhat different functional requirements than a box of napkins shipped to a restaurant. The emphasis placed on box purchasing as part of the whole manufacturing operation varies. Large quantity box buyers use in-house packaging engineers, working closely with their corrugated suppliers in most instances. Smaller quantity buyers use the services provided by box manufacturers. In addition, box buyers also use independent consultants.

B. General Trends in Corrugated Packaging

Various trends are shaping the development of the containerboard industry. Customer requests to reduce costs and environmental impacts have motivated containerboard manufacturers to maintain or increase box performance while using less material and/or more recycled material. For the growing number of boxes that reach the end-consumer, box appearance is a more important functional requirement. On the supply side, environmental benefits and mill and converting economics have caused containerboard manufacturers to shift their investments in new capacity from virgin to recycled fiber and to develop high performance containerboard.

1. High Performance Containerboard and Performance-Oriented Testing Standards

Definitions for "high performance containerboard" vary. The common denominator is that high performance containerboard is manufactured to add compression strength to the containerboard, the corrugated board, and the finished box. The term "compression strength" is used both in a general sense and as an actual specification for the finished box. It is an indicator for the stacking strength of boxes. The specific measure of compression strength for the corrugated board is edge crush strength, and for linerboard and corrugating medium, it is ring crush strength or STFI. (See Appendix B for description of testing methods.) Various industry representatives confirm that a minimum of two pounds of ring crush strength per pound of fiber is a typical value for high performance containerboard; however higher levels are achieved by some containerboard producers as they strive for competitive advantage.[10]

In addition to compression strength, other more minor performance characteristics have been attributed to high performance containerboard, depending upon the mill, its fiber supply and its process. They include more uniform sheet formation, moisture absorption, caliper, and consistent water and ink absorption.[11] For most industry experts, the term "high performance containerboard" implies lightweighting of the board while maintaining stacking performance. Alternatively, it can imply increasing stacking performance while maintaining weight.

For bulk shipment of boxes, the acceptance of high performance containerboard was facilitated by alternative specifications added to Item 222 in the National Motor Freight Classifications and Rule 41 of the Uniform Freight Classifications. Traditionally, rules stipulated specifications for the strength performance of the corrugated board used to make the box rather than the box itself. They also mandated minimum facing (liner) weights. Within the last five years, the rules have been amended twice and more flexible performance requirements have been added.

Before 1991, under the prior transportation specifications, depending on the dimensions and the combined weight of the box and its contents, corrugated board was required to have a certain basis weight in combination with a certain level of burst strength. Burst strength measures the force that is required to burst through a piece of containerboard or corrugated board. Because burst strength is somewhat related to the basis weight (the average weight per 1000 square feet) of the corrugated board, the two measures are used in combination.

On March 31, 1991, edge crush strength was added to the above freight carrier rules as an alternative to the burst strength requirement. The Edge Crush Test (ECT) measures the force that is required to crush a small on-edge sample of corrugated board. The new crush strength parameter is a more performance-oriented parameter that in many instances is more directly related to content protection than is the burst strength/basis weight requirement. The crush strength parameter facilitated both source reduction and adding recycled content.

Source reduction can be achieved by lightweighting the board without compromising the compression performance of the box. More details on lightweighting are provided in Section III. A. Using the ECT as the strength performance measure, some manufacturers can also use more recovered fiber. Under the old basis weight/burst strength requirement, recovered fibers were disadvantaged because burst strength is related to fiber length and recovered fibers are relatively shorter than virgin fibers. Under the new ECT measure, this relative disadvantage is reduced for recovered fibers. The impact of increased recycled content levels are described in Section II.

At some mills, source reduction and adding recycled content can be achieved simultaneously. Recovered fiber from OCC has a relative advantage as the fiber source for lightweight containerboard compared to heavyweight containerboard. Recovered fiber has lower freeness than unbleached kraft pulp, that is, it drains water less readily on the paper machine. Because water can be pressed out of a thinner sheet more easily, recycled fiber is better suited for lightweight containerboard than it is for heavier board.[12]

High performance containerboard offers additional benefits. In the converting process, lightweight containerboard requires fewer roll changes and lowers roll stock storage costs, because more square feet of board are contained on the same size roll. In addition, corrugators benefit from improved runability and more consistent board quality. Box users benefit from increased stacking height, higher uniformity of performance and/or lower freight costs.[13] Due to fiber savings in manufacturing, per box prices do not necessarily increase when high performance containerboard is used. Box prices may decrease when heavier board is reduced in basis weight.

One industry expert currently attributes a 30-35% market share to high performance containerboard, using the broader definition of lightweighted containerboard and/or containerboard with other benefits. The same source estimates the size of the high performance lightweight linerboard segment to be 1.6 million tons in 1993, corresponding to 8% of all linerboard produced in the U.S., and projects this segment to grow to 2.5 million tons by 1998.[14]

While the adoption of the ECT standard promoted the success of high performance containerboard, the ECT is still a material-based rather than a packaging-based test method. For the box buyer, the most important criterion is most often the compression strength of the finished box, which determines stacking height. Naturally, the compression strength of the paper will largely determine the compression strength of the box, but the corrugating and converting processes are additional determining factors. Careless converting practices can reduce box stacking strength significantly.

To give box buyers and manufacturers even greater flexibility, another alternative packaging rule (Item 180) was added to Item 222 in the National Motor Freight Classifications on January 1, 1995. This rule includes a set of tests that measure the performance of the whole package rather than that of the corrugated board. The tests measure compression/vibration and impact/handling. Compression measures the resistance of a whole box to uniformly applied forces. It can be measured side-to-side or end-to-end, or, most importantly, top-to-bottom. Vibration tests can be performed on individual boxes or in combination with the compression test by vibrating boxes that are stacked on top of each other. Impact/handling tests include free fall drop tests, incline impact or pendulum impact tests and raised edge drop tests. The new rule is also more flexible in allowing palletized loads with plastic shrink wrap as an alternative packaging form.[15] While Item 180 offers more flexibility to some box users in designing their total package, other box users find it more time consuming and expensive to put a package through this procedure than to test for burst strength or ECT.[16]

Opinions vary on whether the move from measuring burst strength to compression strength is justified in the single package environment.[17] FedEx regards compression strength as the more important specification. The relevant measure in their distribution system is dynamic compression, which results when boxes are stacked on top of each other during transportation. UPS has developed alternative burst test and ECT requirements for its internal use based on the gross weight of the box. The requirements are similar to Item 222/Rule 41. According to UPS, box users should determine the appropriate box strength measure based on the nature of the product being shipped. For heavy and dense products, such as soup cans, UPS considers burst strength to be the crucial measure. For products that are less dense and less likely to puncture the box, such as fabric and books, edge crush strength would be more important. The U.S. Postal Service has not yet evaluated the relevance of burst strength versus compression strength. Their current packaging guidelines have not been revised for many years, and require minimum burst strength dependent on the type of load, the gross weight and dimensions of the box.[18]

The small parcel carriers agree with the move to measuring the performance of the whole box rather than that of the corrugated board, although the particular characteristics of their distribution environment have to be taken into account. FedEx and UPS were both involved in the development of Item 180 of the National Motor Freight Classifications. Vibration, drop and incline impact testing have long been encouraged by the small parcel carriers. These tests are part of the International Safe Transit Association (ISTA) Preshipment Test Procedures which essentially evaluate the performance of the whole package and are recommended by the small parcel carriers. UPS even goes further in suggesting drop tests from 10 orientations rather than 6 orientations as suggested in Item 180. On the other hand, UPS and FedEx agree that some of the test procedures such as forklift handling tests and static compression tests (i.e. when boxes are stacked on top of each other in a warehouse) do not reflect their distribution environment.

Overall, for both shipments of boxes in bulk and as individual packages, compression strength has gained importance relative to burst strength. However, box users will ultimately decide on burst versus compression strength based on the particular distribution circumstances and the products to be shipped. Box manufacturers, box buyers and freight carriers agree with the need to evaluate the performance of the whole package. For functional, environmental and economic reasons, testing of the whole package including its contents is superior to adhering to general specifications.

2. Graphic Appeal Packaging

In some industries, corrugated boxes are being promoted from pure transportation packaging to consumer packaging with added functions such as product information or advertising.[19] Recently, more products packaged in corrugated boxes have reached the end-consumer, such as unassembled furniture and appliances sold through mass merchandise outlets. In addition, corrugated boxes are replacing other packaging materials or entering new packaging segments, such as 24 beer can carriers made from containerboard, or point of sale displays.[20] These trends require enhanced box appearance, which can be achieved both by improving the look of the box surface, mainly by using "white" linerboard (mottled, white top, and solid bleached), by improving the quality of printing, or by laminating sheets of gravure- or litho-printed paper onto the board.

The use of white linerboard increased from less than 5% in 1980 to 8% of all linerboard in 1993. Of white linerboard, 90.5% is mottled white and white top. The latter grade is the newest and fastest growing.[21] As with unbleached linerboard, the top layer can be made from virgin or recovered fiber. Environmental concerns may arise if more bleached kraft pulp is used (see White Paper No. 5).

Linerboard can be printed before it is combined with corrugating medium (preprinting) or after (postprinting). Both applications have been growing. For instance, preprinting volume increased from 17,000 tons in 1984 to 214,000 tons in 1993.[22] One environmental concern is the potential increase in scrap waste from printing applications. Although most box plant clippings are recycled, the process does require energy and has other environmental impacts. On a positive note, improving print quality can be a substitute for the use of a white surface.

C. Specific Performance Characteristics for Corrugated Packaging

The major functional requirements for boxes are box strength, runability on automated packaging machines and/or automated parcel processing systems, consistency of performance and box appearance. For each of these characteristics, buyers use various specifications and tests to ensure the required performance level.

<u>1. Box strength:</u> Boxes must hold goods and bear up during transportation and under stacking during warehousing, so box strength is by far the most important performance characteristic. As outlined above, basis weight and burst strength were the traditional box strength specifications. The development of high performance containerboard and the adaptation of the guidelines of various freight carriers, for both shipments of boxes in bulk and of individual packages, have increased the relative importance of various measures of compression strength.

Another box strength characteristic is "wet strength". As corrugated board absorbs water, it loses strength characteristics. Wet strength means that the board is "strong when wet" and is different from being water-resistant or waterproof, which imply that the corrugated board itself holds out water and helps prevent water from penetrating through the box to the contents. Wet strength linerboards provide additional strength under conditions of high humidity.

2. Runability on automated packaging machines and automated parcel processing systems: For shipments of boxes in bulk, corrugated boxes are filled on automated packaging equipment. Two important performance characteristics of containerboard among the several that determine the runability of boxes on packaging machinery are internal plybond and air resistance, or porosity. Internal plybond measures the strength of the bond between the plies in multi-ply sheets. It is critical that the plies do not come apart when corrugated boxes are used on mechanical forming machines. Air resistance or porosity is important when automatic packaging equipment includes vacuum handling devices. Porosity is a measure of the amount of air that can be forced through containerboard in a given time. The more air can penetrate through the board, the higher the likelihood that boxes could fail on handling by vacuum cup opening or transfer devices in packaging equipment. However, properly designed and maintained vacuum systems, as outlined in the FBA/PMMI (Fibre Box Association/Packaging Machinery Manufacturers Institute) voluntary standard operational bulletin published in April 1968, can overcome many board porosity variations.[23]

For shipments of individual packages, corrugated boxes must endure the rigors of conveyor belts and slides of automated parcel processing systems. The three major performance characteristics are drop damage resistance (for boxes up to 100 lbs), incline impact damage resistance (for boxes weighing more than 100 lbs) and vibration damage resistance. Drop damage resistance is tested by free-fall drops, with varying heights based on the gross weight of the box. For heavier boxes, incline impact damage resistance is used as an alternative measure for drop damage resistance. It is tested by sliding a filled container down an incline, with various faces and edges striking a stop wall. Vibration damage resistance is tested by exposing a box to various types of motion. In all three cases, the box and its contents are inspected for damage after the execution of the various tests.[24]

3. Consistency of performance: While not a specification for an individual box per se, suppliers and purchasers of corrugated boxes consider consistency of performance, particularly in strength, as an important criterion. Low consistency means more package failures due to bulge, collapse, etc.

4. Box appearance: With the growth of the graphics appeal segment, this characteristic is gaining importance. The three main specifications manufacturers evaluate are shade, brightness and printability. Shade refers to the lightness of the color of the box. Lighter colors are preferred for boxes reaching the point of sale. Brightness, also referred to as whiteness or contrast, is measured as the reflectivity of the paper to a particular blue wavelength. Besides the appearance of the box itself, brightness also affects print quality and the scanability of bar coding.[25] Printability refers to the clarity and visibility of ink on containerboard and is measured by a density scan of the ink after printing. Even for boxes that do not reach the end-consumer, a minimum level of printability should guarantee the readability of the Universal Product Code (UPC). A minor consideration might be surface dirt, i.e. the number of particles on the surface of the containerboard.[26]

Other more specialized performance characteristics include water absorption and slide resistance. About 3-6 % of corrugated containers are wax coated to make them waterproof.[27]

Slide resistance, or the coefficient of friction, refers to the ability of a box to resist sliding during transportation or handling. A high coefficient denotes a low probability of sliding.[28] The industry uses a whole range of additional specifications such as fire resistance, oil resistance, etc., which are only required in particular circumstances.

IV. RECYCLED CONTENT

This section of the paper addresses the potential and limits of increasing the recycled content in corrugated boxes. Part A examines the history and current levels of recycled content in the containerboard industry. Part B considers the impact of adding recycled content on the performance of corrugated boxes. White Papers No. 2 and 9 address the concern of box manufacturers about the future availability of OCC, the current predominant recovered fiber source for containerboard, and thus, the potential of increasing the recycled content beyond current levels.

A. Current Levels of Recycled Content

The corrugated containerboard industry has a long tradition of recycling. As **Table 1** shows, containerboard is the paper application that consumed the largest quantity of recovered paper with over 9 million tons in 1992. As indicated in **Table 2**, the recovered fiber utilization rate for corrugated boxes was 35% in 1993, up from 26% in 1990. The recovered fiber utilization rate for linerboard increased from 15% to 25% and for corrugating medium from 53% to 59%. Actual recycled content levels are about 10% less due to fiber loss in recycling.[29] For industry-wide trends on the usage of recovered fiber for the production of new containerboard, recovered fiber utilization rates are often used. For products of individual manufacturers, box buyers can receive information on actual recycled content levels.

Initially, recovered paper was used primarily for the production of corrugating medium, but now is used increasingly as a fiber source for linerboard. More recovered fiber was used in corrugating medium than in linerboard because appearance is less critical compared to linerboard and compression strength is relatively more important in medium than burst strength. **Figure 1** shows that by the 1970's, about 20% of corrugating medium had 100% recycled content. The ratio has steadily increased since then to 32% in 1993. For linerboard, 100% recycled linerboard constitutes only a small percentage of linerboard production, 6% in 1993. It should be noted that the remaining corrugating medium and linerboard that are not 100% recycled also contain increasing amounts of recovered fiber, as shown in **Table 2.**

Jacobs-Sirrene Consultants report similar data on mill level. They show that of the 115 mills producing containerboard in the U.S., seven use 100% virgin fibers, 47 use 100% recovered fibers, and 61 use a mixture of recovered and virgin fibers. All of the 60 mills producing corrugating medium use recovered fibers in their furnish with 33 utilizing 100% recovered fibers. The remaining 27 mills utilize both virgin and recovered fibers (mostly 20-40% recovered fibers). Of the 55 mills producing linerboard, 14 utilize 100% recovered fibers as furnish, seven use 100% virgin fibers, while 34 mills (the majority) utilize both virgin and recovered fibers.[30] **Tables 3** and **4** show that most of the actual and planned capacity expansions at U.S. linerboard and corrugating medium mills are based on recovered fibers (not all projects may be built as announced).

Table 3. Major Announced Capacity Expansions at U.S. Linerboard Mills, 1994-1997

Company	City	State	Capacity (tons/year)	Start-up	Recycled Capacity (percent)	Recycled Capacity (tons/year)
Boise Cascade, Inc.	DeRidder	LA	45,000	1994	NA	
Gaylord Container	Bogalusa	LA	35,000	1994	100%	35,000
International Paper Co.	Oswego	NY	90,000	1994	R	
Longview Fibre Co.	Longview	WA	75,000	1994	40%	30,000
McKinley Paper Co. (Amcor)	Prewitt	NM	132,000	1994	100%	132,000
Menominee Co. (Bell Pkg.)	Menominee	MI	40,000	1994	100%	40,000
Riverwood International	Macon	GA	250,000	1994	100%	250,000
Solvay, Inc.	Camillus	NY	100,000	1994	100%	100,000
Southern Container Corp.	Camillus	NY	100,000	1994	100%	100,000
Union Camp Corp.	Savannah	GA	180,000	1994	K	
Virginia Fibre Corp.	Riverville	VA	118,000	1994	100%	118,000
Westfield Containerbd Inc.	Westfield	NY	250,000	1994	100%	250,000
Weyerhaeuser	Valliant	OK	100,000	1994	100%	100,000
Chesapeake Corp.	West Point	VA	70,000	1995	K	
International Paper Co.	Oswego	NY	90,000	1995	100%	90,000
International Paper Co.	Mansfield	LA	430,000	1995	K/R	
Liberty Paper	Becker	MN	90,000	1995	100%	90,000
Liberty Paper Inc.	Becker	MN	85,000	1995	100%	85,000
Packaging Corp. of America	Counce	TN	120,000	1995	100%	120,000
Pratt Industries	Conyers	GA	240,000	1995	100%	240,000
Rand-Whitney Corp.	Montville	CT	174,000	1995	100%	174,000
Stone Container Corp.	Jacksonville	FL		1995	K	18,000
Stone Container Corp.	Florence	SC		1995	K	12,000
Weyerhaeuser	Plymouth	NC	260,000	1995	100%	260,000
Willamette Industries, Inc.	Campti	LA		1995	K/R	275,000
Cedar River Paper Co.	Cedar Rapids	IA	324,000	1996	100%	324,000
Corrugated Services, Inc.	Forney	TX	166,000	1996	100%	166,000
Liberty Paperboard	Syracuse	NY	150,000	1996	100%	150,000
MacMillan Bloedel, Inc.	Henderson	KY	140,000	1996	100%	140,000
Minas Basin	Hantsport	NY	45,000	1996	100%	45,000
Stone Container Corp.	Port Wentworth	GA		1996	K	82,000
Stone Container Corp.	Hodge	LA		1996	K	
Stone Container Corp.	Missoula	MT		1996	K	43,000
Stone Container Corp.	Snowflake	AZ	165,000	1996	100%	165,000
Georgia-Pacific Corp.	Big Island	VA	215,000	1997	100%	215,000
Georgia-Pacific Corp.	Toledo	OR	115,000	1997	R	
McKinley Paper (Amcor)	Prewitt	NM	35,000	1997	100%	35,000
Pratt Ind.	New York	NY	240,000	1997	100%	240,000
Corrugated Supplies Corp.	Chicago	IL	160,000	prop.	100%	160,000

K = kraft, R = recycled
Sources: Pulp & Paper Project Report, Pulp & Paper Week, Paper Recycler, American Forest & Paper Association, RISI, Paper Task Force Interviews

Table 4. Major Announced Capacity Expansions at U.S. Corrugating Medium Mills, 1994 - 1997

Company	City	State	Capacity Expansion (tons/yr)	Year	Recycled Pulp Prdn.	Recycled Pulp Capacity (tons/yr)
Interstate Resources, Inc.	Reading	PA	71,000	1994	R	
Simpson Paper	Pomona	CA	70,000	1994	100%	
Solvay Paperboard	Syracuse	NY	115,000	1994	R	
Bay State Paper	Hyde Park	MA	85,000	1995	100%	85,000
Bay State Paper	Hyde Park	MA	100,000	1995	100%	100,000
Cascades	Niagara Falls	NY	50,000	1995	100%	50,000
Cedar River	Cedar Rapids	IA	300,000	1995	100%	300,000
Corrugated Supplies	Chicago	IL	80,000	1995	100%	80,000
Weyerhaeuser	North Bend	OR	213,000	1995	100%	213,000
Willamette	Oxnard	CA	23,000	1995	100%	23,000
Lafayette Paper	New Windsor	NY	45,000	1996	100%	45,000
Sonoco Products	Huntsville	SC	23,000	1996	100%	23,000
Stone Container	Snowflake	AZ	300,000	1996	100%	300,000
Stone Container Corp.	Ontonagon	MI		1996	S	25,000
Stone Container Corp.	Coshocton	OH		1996	S	25,000
Temple-Inland	Orange	TX	36,000	1996	100%	36,000
Mead	Stevenson	AL	230,000	1997	100%	230,000

S = semichemical
Sources: Pulp & Paper Project Report, Pulp & Paper Week, Paper Recycler, American Forest & Paper Association, RISI, Paper Task Force Interviews

No precise numbers for pre- and postconsumer material usage across the industry are publicly available. The majority of recovered fibers used for containerboard are OCC, i.e. postconsumer material. In 1990, 1.9 million tons of converting scrap were used for new containerboard.[31] This corresponds to 8 % of the 1990 containerboard production. Most of these "double lined kraft cuttings" (DLK) are recycled back into containerboard and boxboard.

Manufacturers can provide pre- and postconsumer content levels for their own products. As noted in the introduction, recycled content refers to both pre- and postconsumer materials in this paper, unless otherwise stated.

The increase in recycled content levels has been driven on the supply side by innovations in production technology, new product development, the flexibility of using recovered fiber for incremental mill capacity increases and the development of the mini-mill concept. More recently, on the demand side, the development has been driven by customer concerns about the environment as manifested by increased interest in recycled products. (The factors on the supply side are presented separately in White Paper No. 9.)

A number of companies that use boxes have set specific purchasing policies for corrugated containers that require a minimum recycled content. Among the Paper Task Force's members, Johnson & Johnson has set a 35% recycled content goal for 1995 and McDonald's has steadily increased recycled content requirements over the last few years. In 1990, after extensive discussions with industry on cost and availability issues, McDonald's asked its suppliers to use corrugated containers with 35% recycled content including at least 10% postconsumer material (PCM). In 1992, the requirements were increased to 40% recycled content including 25% PCM.

The recycled content targets adopted by these companies correspond to the U.S. EPA's current federal procurement guideline that requires 35% total recycled content.[32] Other companies have adopted similar targets:[33]

- The Clorox Company has achieved an average recycled content of 35%.
- IBM has started an initiative to implement a 30% target.
- Joseph E. Seagram & Sons, Inc., has achieved an average recycled content of 40-50% for corrugated packaging.
- Scott Paper Company increased its goal from 25% to 35% in 1992, and met this target.
- Shell Oil Company asks for 15-25% PCM for its oil products packaging.
- Veryfine Products, Inc., requires a minimum of 25% PCM for 90% of all its corrugated containers.
- S.C. Johnson asks for 100% recycled content for boxes used for its aerosol products and for 35% for all other products. The latter will be increased to 60% within one year.[34]
- Coors Brewing Company requires 100% PCM content for its corrugated packaging for beer. Since the beginning of 1994, 97% of all packages have achieved this level.

B. Impact of Adding Recycled Content on Performance

This section evaluates the impact of adding recycled content on box performance based on the performance characteristics outlined in section I.C. The main focus of this section is on box strength as the most important box performance criteria. We are comparing box performance across mills. Within a certain mill type, the given technology will determine the capability to increase recycled content levels without affecting performance.

During the expert panel, various views about the impact of above-average levels of recycled content on the strength performance of corrugated boxes were presented to the Paper Task Force. One paper company's view is that corrugating medium can absorb up to 100% postconsumer recycled fiber whereas only a certain level is acceptable for linerboard without affecting box compression strength. Other industry representatives have stated that they can produce 100% recycled corrugated boxes with the same compression strength performance as virgin corrugated boxes. The latter statement was also extended to high performance containerboard.

Industry representatives that we have interviewed unanimously agree that differences in containerboard performance are more a matter of the technology installed at the individual mill than the fiber type. Various improvements in containerboard production technology, mainly the development of the extended nip press, facilitated adding recycled content and source reduction through lightweighting (See Appendix D). Experts also agree that containerboard quality cannot be attributed to one specific mill technology, but is rather a result of the overall process sequence in the mill and how it is managed.[35]

To illustrate the above point, **Table 5** summarizes the results of various containerboard manufacturers' performance testing. Again, the focus of the comparison is on box strength, primarily burst and compression strength, at various levels of the production sequence: linerboard and corrugating medium, corrugated board, and finished boxes. While these examples might not reflect the industry norm, they illustrate what containerboard manufacturers can do.

Example 1 in **Table 5** compares Company A's performance evaluation of its 100% recycled (75% PCM) corrugated boxes with that of a "typical" third-party "mostly virgin" box with 35% recycled content and a typical 100% recycled corrugated box. The typical 100% recycled corrugated board and finished box both have lower compression strength than the typical virgin board and box. However, Company A's own 100% recycled corrugated board and box outperform both of the typical virgin and 100% recycled counterparts.

In example 2, Company B compares the performance of its "mostly virgin" (28% recycled content) linerboard with that of two competitive 100% recycled linerboards (with 80 and 100% PCM). In terms of the burst strength and the compression strength of the linerboard, the virgin linerboard outperforms the recycled linerboard. However, in terms of the more critical compression strength criteria for the combined board and more importantly the finished box, the 100% recycled/80% PCM linerboard outperforms the virgin linerboard. The 100% recycled/100% PCM linerboard did slightly worse than the virgin linerboard.

Examples 3 and 4 show two series of tests done by Company C on containerboard which was sourced from mills owned by two other companies. The results illustrate how the performance of corrugated boxes produced by one company depends on the mills where the containerboard is produced rather than on the level of recycled content. Example 3 compares the burst and compression strength of corrugated board and finished corrugated boxes made from different combinations of virgin and recycled inner and outer linerboard and corrugating medium. The level of recycled content increases in the table from top to bottom. In this specific comparison, the board and boxes with the highest level of recycled content also have the poorest performance.

Example 4 compares 100% recycled containerboard, corrugated board and boxes to high performance lightweight and conventional virgin products. Company C sourced the recycled containerboard from a different mill than in Example 3. The source-reduced virgin corrugating medium outperforms the conventional virgin and the recycled mediums. However, in terms of overall box compression as the ultimately relevant criterion, the 100% recycled corrugated box outperforms both the conventional as well as the source reduced virgin box.

Table 5. Test Examples of Performance of Virgin versus Recycled Containerboard, Combined Board and Corrugated Boxes

				Burst Strength		Compression Strength					
Test Example	Type	Produced by	Recycled Content	Linerboarc	Combined Board	Linerboard			Corrugating Medium		
1. Company A	Virgin	Var. competitors	35%								
	Recycled	Var. competitors	100%								
	Recycled	Company A	100% (75 % PCM)								
				Burst Strength		*Ring Crush Cross Paper Machine 50% RH*	*90% RH*				
2. Company B	Virgin	Company B	28% (0% PCM)	100%		100%	100%				
(comparison	Recycled	Competitor X	100% (80% PCM)	94%		91%	97%				
of different	Recycled	Competitor Y	100% (100% PCM)	72%		93%	91%				
linerboards)											
					Burst Strength						
3. Company C	Virgin	Company C	0%		100%						
(with container-	Recycled	Company C	Only Medium Recycled								
board supplied	Recycled	Company C	Only 1 Liner								
from mill A)	Recycled	Company C	Medium and 1 Liner								
	Recycled	Company C	Both Liners								
	Recycled	Company C	100%		79%						
						Ring Crush Cross Paper Machine	*Machine Direction*	*45 Degree Bias*	*Ring Crush Cross Paper Machine*	*Machine Direction*	*45 Degree Bias*
4. Company C	Virgin	Company C	0%			100%	100%	100%	100%	100%	100%
(with container-	Virgin	Company C	0% (13% lightweight)			98%	87%	107%	100%	135%	162%
board supplied	Virgin	Company C	0% (18% lightweight)			98%	87%	107%	58%	100%	100%
from mill B)	Recycled	Company C	100% (83% PCM)			106%	92%	129%	132%	64%	90%

Table 5, continued.

Description of Test Examples:	*Description of Test Pr*
The following test examples show performance comparisons executed by various companies comparing virgin versus recycled containerboard, combined board and corrugated boxes. Performance differences between virgin and recycled should be considered within each test example, rather than across test examples, since the box configurations and the test procedures might vary slightly between the various examples. The virgin performance is always given as 100%.	Burst Strength
Higher percentages for the recycled performance denote better performance, lower values lower performance.	Compression Strengtl
1. Company A compares its 100% recycled (75% PCM) corrugated board to various competitors' boards. The competitors' boards were converted into boxes by Company A. The pre- versus post-consumer content of the competitors' boards could not be established.	
2. Company B compares its virgin (28% preconsumer recycled content) linerboard with two competitors' products. All linerboards have 42 lbs basis weight, the corrugated board was made at the same time, on the same corrugator, with the same 26 lbs corrugating medium (65% recycled content); the boxes were made on the same finishing equipment.	Ring Crush
3. Company C compares corrugated board made with different levels of recycled content. The various types of board are listed in the order of increasing recycled content (based on the logic that medium is lighter than linerboard and recycled linerboard and corrugating medium are 100% recycled). No exact recycled content levels could be established.	Edge Crush
4. The same company as in test example 3 did another series of tests comparing various virgin products (some lightweighted) with 100% recycled (83% PCM) products. The containerboard for these tests was sourced from a different mill than in example 3.	Predicted Box Strengt
PCM = Postconsumer Material	Tests can be done un RH stands for "Relativ

Source: Presentations during Panel Discussion on October 11, 1994, in Charlotte, NC, by Roger Hoffman, Hoffman Environmental Systems and David Etzel, Georgia-Pacifi
Weyerhaeuser Containerboard Packaging Division, "The Effects of Recycled Content on Corrugated Box Performance", presentation by James Brown at the Institute of Pac

Box purchasers report findings similar to those given by box manufacturers and the above study.[36] Some box purchasers have not experienced any performance loss when using boxes with higher recycled content. Others have perceived specific performance problems that are explored in more detail below. It should be noted that manufacturers can alleviate these problems with process adjustments and particular treatments. Manufacturers are confronted with similar problems in the production of virgin boxes where the same type of adjustments are used. For instance, sizing agents, which are typically made of a mixture of resin and aluminum sulfate, are used for both virgin and recycled containerboard production to improve the surface and physical characteristics of containerboard.[37]

1. Box strength: Recycled fibers are shorter than virgin fibers and lose strength with each reuse cycle. During the paper drying process, fiber cell walls collapse and fiber bonding is changed, reducing the swelling ability and thus the flexibility and strength of the fiber with each cycle of reuse.[38] Typical problems reported are scoreline cracking and tears in the containerboard, which are primarily caused by weak linerboard. New production technologies (see Appendix D) and special treatments can compensate for the decreased fiber strength. For example, starch can be added to increase strength properties.[39]

Recycled fibers absorb water more easily, which also can affect strength properties. Recycled fibers are shorter due to beating and refining and include a higher percentage of fines. This increases the surface area of the fibers and thus the ability of water to attach to the surface.[40] Manufacturers can use internal sizing to reduce water absorption.[41]

2. Runability on automated packaging machines and automated parcel processing systems: With increased recycled content, containerboard becomes more brittle and cracks more easily in packaging equipment. Also, it becomes more difficult to bend the containerboard at the score. Recycled containerboard bends more often before or after the score. Virgin containerboard can be equally affected by this problem. One manufacturer attributed the ability of paper to bend exactly at the score more to the technology in papermaking, e.g. fiber blending and sheet formation, rather than to the type of fiber used.[42]

Another problem attributed to containerboard with high recycled content is low internal plybond, i.e. multi-ply sheets fall apart more easily when used on mechanical forming machines.[43] Manufacturers use chemical bonding agents, mainly starch, in the pulping process to compensate for decreased plybond.[44]

3. Consistency of performance: Because it is harder to control the quality of the fiber supply of OCC and other recovered paper than it is for wood chips, it is argued that the performance of recycled containerboard may not be as uniform as that of virgin containerboard. One typical experience is that recycled containerboard not only absorbs water more easily, but that the water absorption across the containerboard varies more than with virgin fiber.

4. Box appearance: The shorter length of recovered fibers can lead to “fiber dusting” which can cause problems in printing.[45] Recycled containerboard can have more specks and spots. Manufacturers use surface agents and dyes to improve box appearance.[46] On the other

hand, using recycled fibers can also benefit box appearance: Recycled linerboard typically is lighter in color and has a smoother surface, which is beneficial for printing.

5. Other performance characteristics: Recycled corrugated boxes can be more slippery and can have reduced slide resistance performance levels, which affects their performance on forming and filling lines. Anti-skid materials such as silica sprays can be applied at the end of the paper machine, on the corrugator or the finished box to increase slide resistance.[47]

If there are problems with recycled corrugated boxes, they typically occur under high stress packaging uses, mainly under high humidity conditions and during long storage. For instance, some observers report that the edge crush strength of recycled corrugated board is not as resistant to cyclic humidity conditions as virgin containerboard.[48]

As noted above, the problems listed are a compilation of individual experiences. Other box users did not experience any performance loss at all. Furthermore, in the case of corrugated boxes, companies have accumulated experience on how to make adjustments in manufacturing.

V. SOURCE REDUCTION

This section of the paper shows how source reduction can be employed in corrugated packaging through lightweighting (Part A) and package redesign (Part B). This section also explores specific company examples that show how source reduction efforts can reduce fiber usage without loss in performance.

Other approaches to source reduction in transport packaging include corrugated trays or pallets with shrink wrap and reusable shipping containers, which are mainly made from plastic. Because the Paper Task Force's recommendations will focus on paper, a full analysis of the implementation and environmental issues associated with these approaches is beyond the scope of this study. For reusable containers, "Delivering the Goods - Benefits of Reusable Shipping Containers" published by INFORM, Inc., a non-profit environmental research organization, is a good source of examples.[49]

Source reduction is a proven approach to reducing the environmental impact of corrugated packaging. Although one would not expect much overpackaging in transport packaging because of box users' interest in minimizing its cost, box manufacturers agree that there are ample opportunities for source reduction.

The Paper Task Force has not found a systematic approach for source reduction in corrugated packaging. The CONEG Preferred Packaging Guidelines have been suggested as a good checklist. The hierarchy, given below, was developed as part of a program to reduce packaging waste initiated by the Coalition of Northeastern Governors.[50]

- Eliminate - Whenever possible, eliminate the package altogether.
- Minimize - Minimize the packaging.
- Refill/Reuse - Design packages that are either consumable, returnable, or refillable/reusable.
- Recyclable - Produce packages that are recyclable. Use recycled material to produce packages.

A. Lightweighting

Lightweighting is a means to reduce fiber usage by making the containerboard lighter. The development of high performance containerboard, the change in freight carrier rules, and the increasing sensitivity of corrugated users to performance needs based upon compression strength have accelerated the evaluation and usage of lighter weight board. High performance linerboard was first developed in mills utilizing virgin fibers in their furnish. More recently, technology improvements have made it possible for state-of-the-art mills using 100% recycled fibers to also produce high performance linerboard. Some mills using a mixture of virgin and recycled fibers also have installed equipment to support the production of high performance containerboard.

Based on given mill technology, some manufacturers offer source reduction as an alternative strategy to adding recycled content. Example 4 in **Table 5** illustrates the trade-off of choosing between source reduction and recycled content. Both the 13% source reduced box and the 100% recycled corrugated box exhibit superior top-to-bottom compression strength compared to the conventional virgin box. **Table 6** compares four pairs of corrugated board manufactured by the same company with given strength characteristics for each pair and trade-offs between higher recycled content and source reduction.

Other manufacturers offer high performance lightweight containerboard with up to 100% recycled content.[51] For instance, Whirlpool switched from conventional virgin linerboard to 100% recycled lightweight linerboard for packaging its washing machines. Whirlpool registered a few minor problems, but felt that the problems were by far outweighed by the use of 100% recycled board that weighs less.

Eastman Kodak reduced the corrugated packaging for its chemical products by eliminating and modifying some packaging components as well as switching to high performance corrugated board.[52] Bristol-Myers Squibb Co. uses lightweight corrugated board and reduced the internal packaging for its Ready-to-Hang Tube Feeding product package. This reduced corrugated usage for this package by 19.5%.[53] General Motors North American Operations encourages its suppliers to re-evaluate corrugated packaging that far exceeds test strength requirements.[54]

As part of a lightweighting effort, box manufacturers and users also evaluate whether they are using the appropriate combination of linerboard and corrugating medium. They refer to new findings for optimal loadsharing in high performance containerboard, that indicate the medium should share a greater portion of the compression.[55] Because corrugating medium contains on average more recovered fiber than linerboard, this approach would increase average recycled content levels of corrugated boxes.

B. Package Redesign

Following are a few examples of design changes in corrugated boxes that demonstrate the range of available options. They have been provided by box manufacturers, packaging machinery producers and box users.

1. Optimize the box size: Corrugated boxes should match product size. First steps towards source reduction include the redesign of partially filled boxes or oversized support or cushioning material. Secondly, corrugated box size can be optimized to save truck space and increase transportation efficiency.

- James River Corporation has demonstrated how to take dead air out of its boxes when packaging disposable cutlery. In its DENSE PACK™ system, cutlery is nested together rather than thrown loosely into a box. This reduced the box size by 50% or since the same box size was maintained, the number of boxes required by 50%. In addition, damage to cutlery could be decreased and convenience for users increased.[56]

2. Reduce the size of flaps: This can be done in various ways.[57]

- Locate the opening of the box at the end with the smallest surface: Most manual box filling is done from the top. With new packaging equipment, e.g. with automated erector-packer-sealers, boxes can be filled from the side. For a box with length-to-width to depth dimensions of 2:1:2, switching the flaps from the top to the side saves 17% of corrugated board. As a minor benefit, using automated packaging lines can allow tighter packing of boxes and thus reduce box size and use of corrugated board.

- Use half-slotted containers (HSC): Half-slotted containers are regular slotted containers (RSC) without flaps on the top. They are often used in the beverage industry. They can be used on the same packaging equipment as RSCs and are used as an intermediary solution to tray packaging, which otherwise requires switching equipment.

- Use bliss boxes: Bliss boxes are made from three pieces. The two end panels are glued to a larger body panel, which forms the bottom, the other two sides and the top flaps. Compared to an RSC, a bliss box has no completely overlapping flaps and thus requires less corrugated board. However, the box is more difficult for the manufacturer to assemble for filling and for the retailer to break apart for disposal. Since the three pieces have to be assembled at the site where the boxes are filled, the box user becomes a box maker.

- Reduce the size of the flaps: Especially for larger products that cannot fall out, flaps can be made smaller. McDonald's reduced the top flaps on its shake box, leaving a gap of 2 inches at the top of the box. This reduced the use of corrugated board by 4% or 220 tons per year and saved 2% of packaging cost for this product.[58] The Clorox Company saved 4000 tons of fiber in four years by reducing the length of the flaps of its corrugated.[59]

3. Redesign the primary and/or inner packaging: In some cases, e.g. when products are sold in bulk in warehouse clubs, the primary packaging can be eliminated altogether. In other cases, the primary packaging and the inner packaging, mainly dividers and cushioning, can be redesigned for source reduction.

- Change primary packaging: Johnson & Johnson switched from cartons to bags as primary packaging for its "Carefree" and "Stayfree" sanitary napkins. Now, more products can be packaged in one corrugated box or the box can be reduced in size.[60]

- Reduce the number and use of dividers: Keebler Company eliminated the corrugated dividers in its Soft Batch Cookie shipping containers. General Motors' Packard Electric Division switched from double-walled to single-walled containerboard and eliminated cell liners for loads under 125 lbs.[61]

4. Redesign the product itself: Bulk packages, products sold in concentrated form (e.g. detergents), and products produced in larger sizes can reduce both primary as well as transport packaging.

- James River sells larger rolls of toilet paper without a cardboard roll in the center to commercial customers. James River developed a new cabinet for holding the rolls and also provides a special spindle to hold the toilet paper in conventional cabinets. The rolls are merely packaged with shrink wrap instead of in corrugated boxes. A net source reduction of 94.7% was achieved.[62]

- Working with Georgia-Pacific Corp., McDonald's reduced the background emboss of its napkins. This led to a source reduction in both the inner and transport packaging. The number of napkins per sleeve increased, resulting in fewer sleeves per case (25% source reduction). The size of the box decreased while still packing the same number of napkins in a case (23% source reduction).

- McDonald's also changed the case pack for one cup product from 500 to 800 cups per box which resulted in a source reduction of 70 tons of containerboard per year.[63]

VI. RECYCLABILITY

Box purchasers make it easier for producers to increase their use of recycled fiber by considering recyclability issues in their box purchasing decisions. Contaminants affect both the quantity and quality of the recovered fiber supply. Reductions in the supply of recovered paper increase prices. Quality problems increase the cost of sorting, screening and cleaning. Both of these effects can translate into higher recycled paper prices. Also, the quality of the recycled paper is affected. Waxed containers are the major contaminant in recycling corrugated boxes. Hot melt adhesives are considered another, but more minor, contaminant.

A. Wax Coatings

As noted earlier, about 3-6% of corrugated containers are wax coated for water resistance. They are used for packaging meat, poultry and produce and for international shipments in sea containers. Their impact on recovery might be proportionally greater than the above percentage suggests because waxed OCC are found primarily in supermarkets where OCC recovery rates are the highest. Waxed boxes account for one sixth of all grocery waste.[64] Packaging produce alone requires 100-200 million waxed boxes every year.[65]

The bulk of the coatings used are paraffin wax based and are applied with various techniques leading to different levels of wax concentration.[66] The wax provides good water resistance at low cost. Since some types of wax cannot be removed by many mills during repulping, if the waxed boxes are not removed from the feed stream, the wax ends up in the new containerboard affecting appearance, printability, and slide resistance. As noted earlier, recycled corrugated board already has a lower coefficient of friction than virgin board. With a high content of waxed containers, anti-skid materials have to be used. Wax also creates problems in the recycling process at the paper mill by plugging screens, wires, and felts, and affecting paper machine runability.[67]

Some containerboard manufacturers accept waxed corrugated boxes on a limited basis. These mills handle such boxes in the recovered fiber stock preparation process by blending with OCC and through extensive fiber screening and cleaning. Wegmans Food Markets, Inc., a supermarket chain based in Rochester, NY, is an example of a retailer that has found various paper mills that can use their waxed OCC.[68] While this might solve the recyclability issue for some end-users of waxed containers, e.g. retailers with access to such containerboard manufacturers, it does not provide a satisfactory solution for box buyers who sell to many different customers with different recycling opportunities.

Various repulpable coatings are under development or on the market.[69] There are two major types of recyclable coatings. Some coatings still include wax, but contain additives such as stearic acid, which break the waxes down during repulping. Other coatings do not contain any wax and typically are made of acrylic polymers that are alkaline soluble. Therefore, the coatings can be aggregated and separated from the pulp. A number of companies are working on the development of these coatings. Most wax-based coatings originate from paper companies, such as Packaging Corporation of America and Weyerhaeuser. Non-wax coatings are being developed by chemical companies such as Dussek Campbell, NuCoat and Spectra-kote, and by paper companies such as Stone Container. International Group, Inc. (IGI) is working on both wax-based and non-wax coatings.

Box purchasers will determine the type of coating to be used on their boxes based on the products to be packaged. For instance, fresh chickens that are packed in ice require "heavy-duty water resistance" whereas tissue products only require protection from "incidental water exposure." Produce, meat and frozen foods fall in between those two categories. Some companies offer coatings across this whole range of applications while others focus only on limited applications. Typically, the wax-based coatings are used for heavy-duty water resistance and the non-wax coatings for incidental water exposure to medium-duty water resistance. However, some companies such as NuCoat and Spectra-kote are also offering or developing non-wax coatings for heavy-duty water resistance.

Parallel to the development of new coatings, the corrugated box industry, led by the Fibre Box Association and the American Forest & Paper Association, is working on a voluntary standard for the recyclability of these coatings. The standard will include laboratory testing procedures for the repulpability of coated OCC and the quality of the recycled products made from a mixture of coated and uncoated OCC. The technical committee plans to have its draft ready for external review in mid-1995.[70]

Since most of the coatings are still in an early commercialization or late development stage and because some of the manufacturers are waiting with their product introductions for the final version of the recyclability standard, little information was available on the performance of these coatings. We received information on customer endorsement for the performance and recyclability for only one manufacturer's coating.

One example encountered by Weyerhaeuser illustrates the importance of a common industry standard and the marking of boxes. Weyerhaeuser developed RECYCLAWAX™, a wax-based repulpable coating. However, supermarkets could not easily distinguish boxes coated with traditional and the new waxes. Even color-coding of the flaps did not provide the reliability required for sorting out the boxes. In response, Weyerhaeuser offered its technology at no charge to the whole box industry through the Fibre Box Association. The offer will be under consideration after the recyclability standards have been set.[71]

Various other alternatives to wax coated boxes have been developed. Some box manufacturers offer corrugated board with film laminates. Although board and film laminate can be recycled, it takes extra effort to separate them. Board with film laminate cannot be handled by all containerboard manufacturers that use recovered fibers. For this reason, some OCC collectors are not willing to pick up these boxes. Other box users have switched to "bag-in-box" concepts or to reusable plastic containers. Compared to wax coated boxes, these options can be more expensive and more difficult to apply for some box buyers.[72]

B. Hot Melt Adhesives

Hot melt adhesives used in final sealing of the box after it has been filled are considered another, but more minor, contaminant in OCC. Hot melts are used to achieve high productivity on high-speed automated packaging machinery because of their low setting time, i.e. the time during which compression must be maintained to make the flaps stick to each other. Setting times for hot-melts are 2-4 seconds compared to 10-20 seconds for resin cold glues and 25-35 seconds for dextrin cold glues. This time-saving outweighs the higher cost of hot melts compared to cold glues.[73]

In repulping OCC, hot melt adhesives create "stickies," particles of adhesives that do not reemulsify, are not water-soluble and are difficult to remove. At water temperatures of 140 to 180 degrees Fahrenheit typical in the fiber cleaning process, stickies become pliable and squeeze through the mill's screens. At higher temperatures during the papermaking process, they become tacky and stick to the felts, wires and dryer cans, entailing downtime and replacement cost. Stickies can also tear holes into the sheet or show up as spots on the paper. They can affect print quality because the ink does not hold as well on the recycled containerboard. Compared to other recovered paper grades, stickies are a smaller issue for containerboard, particularly for corrugating medium. Containerboard is a thick and strong grade and for most applications, appearance is less critical.

Major suppliers of adhesives for the box industry now offer new hot melt adhesives that are water-dispersible and thus easier to separate from the board.[74] Because these new technologies are proprietary and the volumes low, these adhesives are sold at a premium. Because box users often have no direct stake in the recyclability of their boxes and the effectiveness of these new adhesives still needs to be proven, the price multiple does not yet encourage a more widespread use. Other alternatives for box users include cold glues, stitching/stapling and strapping tape.

Handling contaminants is an issue of concentration and recycling technology. For instance, a batch of old magazines with a high and unpredictable concentration of adhesives poses more difficulties compared to OCC with a low and even concentration of adhesives. Box manufacturers stress that the technology of the individual mill will determine whether and which contaminants are a problem.[75]

Two examples from the CONEG Packaging Challenge demonstrate how box users can increase recyclability. Shell Oil Company switched to a new recyclable release coating for its corrugated boxes for plastic rubber products.[76] General Motors North American Operations requires its suppliers to make corrugated easily separable from other materials. For instance, wood cannot be stapled to corrugated boxes nor can foam be glued to corrugated board. Switching to mono-packaging also makes corrugated boxes easier to recycle. General Motors, for example, requires its suppliers to replace all polystyrene foam with material that is directly recyclable with the corrugated box such as die-cut corrugated or molded kraft paper pulp.[77]

APPENDIX A

Panelists and Reviewers

Members of the Task Force gratefully acknowledge the time, effort and expertise that the panelists and reviewers provided to its research. The work and final products of the Paper Task Force are the sole responsibility of its members. The panelists and reviewers listed below have not endorsed the contents of this paper.

Panelists (Panel held in Charlotte, NC, on October 11, 1994):

- David Etzel, National Manager, Graphics Sales, Georgia-Pacific Corp.
- Roger Hoffman, Chief Executive Officer, Hoffman Environmental Systems
- Ralph Locke, Quality & Product Development Manager, Containerboard Division, Inland Container Corp.
- John Schwann, Executive Vice President, Packaging Systems, Inc.
- Guyton Wilkinson, Director, Process and Product Technology, Containerboard and Paper Division, Stone Container Corp.

Reviewers (in addition to panelists above):

- Dan Goodwin, Chairman, Department of Packaging Science, Rochester Institute of Technology
- Alfred McKinlay, Consultant - Packaging, Handling, Warehousing, and Chairman of the Carrier Rules Subcommittee, Institute of Packaging Professionals
- Cliff Morgan, Senior Packaging Designer, Federal Express Company
- Mary Opfer, Manager Technical and Environmental Services, Fibre Box Association
- Paul Singh, Director, Center for Distribution Packaging Research, School of Packaging, Michigan State University
- Jerry Stone, Packaging Engineer, National Classification Committee, Motor Freight Traffic Association, Inc.
- Richard Storat, Vice President, Containerboard and Kraft Paper Group, American Forest & Paper Association
- Gregg Sutherland, National Director Solid Waste Management, R.W. Beck & Associates
- Hal Tanner, Manager, Containerboard Packaging Services, Containerboard Division, International Paper Company

Acknowledgement of these panelists and reviewers does not imply endorsement of this paper or the Paper Task Force's findings or recommendations.

APPENDIX B

Definition of Industry Terms

Basis weight, measures the mass (commonly called weight) per unit area of containerboard and corrugated or combined board, i.e. in lbs per 1,000 square feet. Typical basis weights for linerboard are 42 lbs per 1,000 square feet and for corrugating medium 26 lbs per 1,000 square feet.

Burst strength, measures the force required to rupture containerboard or combined board, using pressure applied with a round rubber diaphragm in a Mullen tester. It is therefore also referred to as mullen strength.

Combined Board, three or more layered board made from a combination of linerboard and corrugating medium. The former is used as inner and outer facing, the latter is used to form the middle fluting sheets. The two are combined on a "corrugator" into combined board (thus combined board is also referred to as corrugated board, compare below).

Compression Strength, can be used as a generic term for the force that is required to crush an upright standing piece of containerboard or corrugated board or to crush a complete box. It is an indicator of stacking strength, a crucial box performance parameter. As a specification, compression strength is mostly used to refer to the strength of the complete box. It can be measured side-to-side, end-to-end, or, most importantly for measuring stacking strength, top-to-bottom. Compare also ECT and ring crush.

Containerboard, comprises linerboard, corrugating medium, chip board and filler board which are mainly used as internal partitions and for other industrial uses. In this paper, we use the term collectively for linerboard and corrugating medium.

Corrugated Board, same as combined board, see above definition.

Edge Crush Test (ECT), measures the force required to crush a small on-edge sample of combined or corrugated board. Compare also compression strength and ring crush.

Extended Nip Press (ENP), paper machine press technology developed in the 1980s replacing roll presses on linerboard machines. In roll presses, the paper sheet passes between two rolls. The contact point between the two rolls is referred to as "nip". In extended nip presses, the sheet passes between a single press roll pushing against a pressurized belt that hugs the roll across a wider section of the press roll cylinder. Because of the enlarged contact point, the presses are referred to as "extended nip presses" which is the trade name used by the Beloit Corporation. The presses are also called shoe presses or long nip presses. Benefits of extended nip presses include increased productivity in papermaking and increased paper strength.

Half Slotted Container (HSC), regular slotted containers (RSC) without flaps on the top.

High Performance Containerboard, linerboard and corrugating medium with particular performance characteristics, mainly with increased compression strength (typically a minimum of two pounds of ring crush test per pound of fiber). High performance containerboard can be lightweight, i.e. exhibit a given strength at reduced weight, or it can exhibit improved strength at the same weight.

Lightweighting, means of source reduction; fiber usage is reduced by making the containerboard or corrugated board lighter.

Mottled White Linerboard, unbleached linerboard with a thin layer of bleached linerboard on top. In comparison to white-top linerboard (defined below), white coverage typically allows unbleached liner to show through which gives the linerboard a mottled effect.

(New) Double-Lined Kraft Clippings ((N)DLK), pre-consumer containerboard waste generated during box converting, mostly recycled back into new containerboard.

Old Corrugated Container (OCC), used corrugated containers, i.e. post-consumer waste.

Preprinting, printing on linerboard before it is combined with corrugating medium.

Postprinting, printing on combined board.

Ring Crush, measures the force required to crush a "specific" size piece of linerboard or corrugating medium between two platens. Compare also compression, edge crush strength and STFI.

Regular Slotted Container (RSC), most widely used corrugated box style. For overview of box styles see Appendix C.

Retripper, reusable corrugated box, often particularly designed for easy handling during reusage.

Solid Bleached Linerboard, white linerboard that consists of only bleached layers.

STFI, Short-Span Compression Strength, alternative measure to ring crush, measures compressive resistance of containerboard.

White Linerboard, linerboard with white appearance which is used for the production of "white" boxes in contrast to the usual "brown" boxes. The three types of white linerboard are mottled white, white top and solid bleached, each defined in this section.

White Top Linerboard, unbleached linerboard with a layer of bleached linerboard on top. In comparison to mottled white linerboard (defined above), the solid white top gives the linerboard a complete white appearance.

APPENDIX C

Basics of Box Manufacturing

The following information on the basics of box manufacturing and on major box styles is based for the most part on the "Fibre Box Handbook" by the Fibre Box Association,[78] a good reference for the interested reader.

Corrugated boxes are made from corrugated or combined board, a combination of linerboard and corrugating medium. The term "containerboard" includes the latter two as well as chip and filler boards, which are used as internal partitions and for other industrial uses.

Linerboard and corrugating medium are manufactured with various levels of recycled content and at various basis weights. As described in Section II.A., only 6% of linerboard is made from 100% recovered fiber; the remainder is made from either virgin kraft pulp or a mix of virgin and recovered fiber. Virgin unbleached kraft pulp is a very strong, dark brown pulp, primarily made by utilizing the long fibers found in southern and western softwoods in a chemical pulping process with a yield of 60-65%. Of corrugating medium, 32% is made from 100% recovered fiber; the remainder is made from either virgin semichemical pulp or a mix of virgin and recycled fiber. Semichemical pulp is made by pulping hardwood chips in a mild chemical process prior to mechanical defibrating, producing pulp with a high yield and an intermediate strength level.

Linerboard and corrugating medium, are produced in a variety of basis weights, with the linerboard typically being the heavier sheet. The standard basis weight for linerboard is 42 lbs/1,000 sq. ft., the standard basis weight for corrugating medium 26 lbs/1,000 sq.ft.

Singlewall corrugated board is made by combining on a corrugated machine a linerboard facing with a fluted medium and in turn combining a second linerboard facing completing the linerboard/medium/linerboard sandwich. Additional layers can be added to form doublewall or triplewall corrugated board as packaging demands.

The combined board is then converted into corrugated boxes in a multi-step process that includes printing, scoring, slotting or die-cutting and folding, gluing, taping or stapling. The boxes are shipped flat to the customers and then opened and filled. In some instances, printed and die-cut box components are shipped unassembled and then folded and glued together at the plant of the box user, as in the case of the bliss box.

Coatings and other treatments are applied at different stages in box manufacturing to enhance box quality. Coating corrugated board or boxes with wax to increase their water resistance is the most common treatment. Other treatments are applied for oil and grease resistance, abrasion resistance, better release of products packaged in a box, increased slide resistance of the box itself, flame retardation, corrosion inhibition, static control, gloss and color, etc.[79]

Linerboard and corrugating medium traditionally have been produced near the virgin fiber supply and then shipped in large rolls to converting plants, although the use of recycled fiber has shifted this pattern somewhat, especially for corrugating medium. Converters are typically located near urban areas and distribution and manufacturing centers where the boxes are used. The corrugated box industry is highly vertically integrated. Roughly 70% of linerboard production, for example, is converted into boxes by subsidiaries of paper manufacturers, 15% is exported and only 15% is sold to independent converters.[80]

APPENDIX D

Developments in Containerboard Production Technology

In the last 20 years, most of the increases in production capacity for linerboard and corrugating medium have come from increases in productivity at existing mills, rather than the construction of new mills. The technologies that enabled these capacity gains also have important implications for recycled content and source reduction in corrugated boxes.

One major productivity factor has been the increased usage of the extended nip press. During the 1980's, extended nip presses have largely replaced traditional roll presses. The term "Extended Nip Press" (ENP)[81] is the trade name used by the Beloit Corp., a major equipment manufacturer that developed the technology in a joint venture with Weyerhaeuser, which installed the first ENP at its Springfield, OR mill in 1980.[82] Presses are installed following the fourdrinier section of the paper machine and prior to the dryer section; the purpose of the press section is to squeeze water out of the newly formed fiber sheet before it is dried.

Traditional roll presses consist of two rolls between which the sheet passes with a typical loading of 2,000 to 2,500 PLI (pounds per lineal inch). The "nip" is the contact point between the two rolls. Due to geometry, the point where two cylinders are closest is very narrow.

By contrast, an ENP consists of a single press roll pushing against a pressurized belt that hugs the roll across a wider section of the press roll cylinder (hence the term "extended nip"). The sheet is passed through an extended nip press with higher loadings (up to 6,000 PLI or more) and for a longer period of time. More water can be thus removed from the sheet, which means that it can be run through the dryer section more quickly, increasing the running speed of the machine while requiring less energy to heat the dryers. Compared to roll presses, ENPs reduce peak pressure and increase overall compression.

While extended nip presses were first installed to increase productivity, manufacturers found that they also increase the strength of the paperboard mainly by improving the bonding between the fibers. Other related quality improvements are the increased dryness of the sheet and reduced sheet crushing in the press section.

The strength improvements that come from ENPs and other on-machine modifications can support increased use of recycled content as well as source reduction. Recovered fibers differ in properties from virgin fibers. Because they have been dried and pressed before, they are harder and stiffer and do not bond as well as virgin fibers. This impacts their strength characteristics. Using ENPs can compensate for losses in fiber strength and also allow the use of less fiber to achieve the same strength levels. Bond strength can also be enhanced with further refining and the use of chemicals.[83]

For some mills, the increased productivity in papermaking cannot be matched by capacity increases in pulping. Because capacity increases in bleached virgin pulping are only economical at large increments, these mills have another reason to use more recovered fiber.

Other factors contributing to increased productivity and mills' ability to adapt to higher levels of recycled content include new arrangements in the sequence of papermaking machinery, such as the use of size presses in the drying section.[84] Multi-ply linerboard, which is made with different headbox and former configurations, can accept recycled fiber in the middle of a three-ply sheet, for example. Fiber fractionation, which diverts long and short fiber pulps into different streams, can be used to distribute the shorter recycled fibers to the outer surface of the top linerboard (the outside layer of the box), to improve printing characteristics.[85] Paper manufacturers stress that it is often not one piece of equipment that makes the difference in allowing a mill to use more recovered fiber, but a rearrangement of the whole production flow of which adding an OCC recycling system is often one element.[86]

Another important technological evolution in linerboard manufacturing is the secondary headbox, which sits above the main fourdrinier section of the paper machine and adds another layer of fiber to the paper web as it is formed. A mill that uses a paper machine with two headboxes can use longer, stronger and coarser fibers for the base ply of the board, and smoother, shorter fibers for the top ply. This gives the linerboard both strength and a better printing surface. According to one estimate, by 1990, 20% of linerboard machines in the U.S. had installed on-top formers or secondary fourdrinier formers.[87] In addition to secondary headboxes, a number of mills have installed top wire formers over the main fourdrinier table which also provide improvements in strength and printing surface.

APPENDIX E

Box Styles

The following examples of major box styles are copied with the permission of the Fibre Box Association.

Slotted Box:
is made from one piece of container-board which is slotted to permit folding
Example: Regular Slotted Container (RSC)

Telescope Box:
is made from more than one piece, usually with separate top and bottom
Example: Full-Telescope-Design-Style Box (FTD)

Folder:
is made from one or more pieces of board providing an unbroken bottom surface; the containerboard is scored to fold around the product
Example: One-Piece Folder

Slide-Type Box:
two or more rectangular, scored pieces of board are folded so that each forms a tube or a shell
Example: Double-Slide Box (DS)

Rigid Box:
is made from three pieces (the body and two typically used end pieces) that are sealed together by six joints; the most common form is the bliss box
Example: No.2 Bliss Box

Self-Erecting Box:
is usually made from one piece, as time-saver for small-volume shippers
Example: Self-Erecting Box
International Box Code 0711

In addition to the above box styles, corrugated board can be converted into different types of displays and inner packaging forms. The most basic and most widely used box style is the Regular Slotted Container (RSC).[88]

APPENDIX F

List of Other White Papers

Paper Performance

Functionality Requirements for Uncoated Business Papers and Effects of Incorporating Postconsumer Recycled Content (White Paper 1)

Functionality Requirements for Coated and Uncoated Publication Papers and Effects of Incorporating Postconsumer Recycled Content (White Paper 8)

Functionality Issues for Corrugated Packaging Associated with Recycled Content, Source Reduction and Recyclability (White Paper 6A)

Functionality Issues for Folding Cartons Associated with Recycled Content, Source Reduction and Recyclability (White Paper 6B)

Recycling and Used Paper Management

Economics of Recycling as an Alternative to Traditional Means of Solid Waste Management (White Paper 2)

Lifecycle Environmental Comparison - Virgin Paper and Recycled Paper-Based Systems (White Paper 3)

Economics of Manufacturing Virgin and Recycled-Content Paper (White Paper 9)

Forest Management

Environmental Issues Associated with Forest Management(White Paper 4)

Economic Considerations in Forest Management (White Paper 11)

Pulp and Paper Manufacturing

Environmental Comparison of Bleached Kraft Pulp Manufacturing Technologies (White Paper 5)

Economics of Kraft Pulping and Bleaching (White Paper 7)

Environmental Comparison - Manufacturing Technologies for Virgin and Recycled-Content Printing and Writing Paper (White Paper 10A)

Environmental Comparison - Manufacturing Technologies for Virgin and Recycled Corrugated Boxes (White Paper 10B)

Environmental Comparison - Manufacturing Technologies for Virgin and Recycled Coated Paperboard for Folding Cartons (White Paper 10C)

Comparison of Kraft, Sulfite and BCTMP Pulp and Paper Manufacturing Technologies (White Paper 12)

Nonwood Plant Fibers as Alternative Fiber Sources for Papermaking (White Paper 13)

ENDNOTES

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[1]American Forest & Paper Association, 1993 Capacity Survey *Paper, Paperboard, Pulp,* Washington, DC: AF&PA, p. 7.

[2]"Containerboard" can also include chip and filler boards.

[3]American Forest & Paper Association, *Paper, Paperboard and Wood Pulp - 1994 Statistics,* Washington, DC, September 1994, p. 4.

[4]U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1994 Update,* EPA 530-S-94-042, November 1994, p. 67-72.

[5]Franklin Associates defines the OCC recovery rate as corrugated containers removed from the waste stream for recycling and/or composting relative to the corrugated containers generated from residential, commercial and institutional sources. In 1993, 14.6 Million tons of OCC were collected and 26.4 Million tons were generated resulting in a recovery rate of 55.5%. (U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1994 Update,* EPA 530-S-94-042, November 1994, p. 67, 69 and 70)

The American Forest & Paper Association defines the OCC recovery rate as old corrugated and solid fiber containers, container plant cuttings, kraft paper and bags, kraft bag clippings, carrier stock and carrier stock clippings relative to the new containerboard supply (domestic production minus exports plus imports). In 1993, 16.7 Million tons of "OCC" were generated and the new containerboard supply was 26.9 Million tons resulting in a recovery rate of 62.0%. (American Forest & Paper Association, *1993 Recovered Paper Statistical Highlights*, New York 1994, p. 16) The recovery rate calculated by the American Forest & Paper Association for 1994 is 62.6%. (Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995.)

[6]Phone interview with Jerry Stone, National Classification Committee at the American Trucking Association, October 25, 1994.

[7]The following information is based on the following phone interviews with the three mentioned small parcel carriers plus various publications:

- United States Postal Service: phone interviews with Bob Adams, Customer Service Support Analyst and Program Manager Hazardous Waste, Business Mail Acceptance Department, March 6, 1995, and Ed Wronsky, Manager, Rates and Classification Center New York, March 14, 1995; *Publication 2 - Packaging for Mailing,* Government Printing Office, Washington, DC, October 1989*; Publication 227 - How to Prepare and Wrap Packages,* Washington, DC, June 1992;

- United Parcel Services: Brad Cook, Packaging Systems Manager, Corporate Business Development, February 22 and March 6, 1995, and Bob Gordon, Corporate Packaging Manager, March 8, 1995;

- Federal Express Corporation: Larry Rutledge, Manager, Packaging Group, March 3, 1995, and Cliff Morgan, Senior Packaging Designer, March 3, 1995; *Test Procedure for the FedEx Air Express Distribution System; and Federal Express Guide to Proper Packaging,* March 1993.

[8]Domestic weight and size limitations for small parcel carriers:

- United States Postal Service: 70 lbs, length+ girth (width+depth) not more than 108 inches;

- Federal Express Corporation: 150 lbs for express shipments, not more than 119 inches in length and 165 inches in length+girth;

- United Parcel Services: 150 lbs, not more than 108 inches in length and 130 inches in length+width+girth.

[9]The International Safe Transit Association or ISTA (formerly National Safe Transit Association or NSTA) has developed four testing protocols dependent on the destination and weight of the package to be shipped:

- ISTA Preshipment Test Procedures 1A: vibration and drop tests for packages under 100 lbs;

- ISTA Preshipment Test Procedures 1: vibration and incline/impact tests for packages with 100 lbs and more;

- Overseas Preshipment Test Procedures 2A: vibration, drop and compression (static or dynamic) tests for packages under 100 lbs;

- Overseas Preshipment Test Procedures 2: vibration, drop and compression (static or dynamic) tests for packages with 100 lbs and more.

[10]Comment by David Etzel, National Manager, Graphics Sales, Georgia-Pacific Corp., during Paper Task Force panel discussion on October 11, 1994; phone interview with Ralph Young, Manager Product Development Printing Grade, International Paper Co, December 5, 1994.

[11]Ralph A. Young, “High Performance Containerboard - Will It Become the Standard?,” presentation at the 6th International Containerboard Conference, Boston, September 15-16, 1994.

[12] Phone interview with David Null, President Jacobs-Sirrene Consultants, September 22, 1994 and Roger Hoffman, Chief Executive Officer, Hoffman Environmental Systems, January 17, 1995.

[13]Ralph A. Young, "High Performance Containerboard - Will It Become the Standard?," presentation at the 6th International Containerboard Conference, Boston, September 15-16, 1994.

[14]Ralph A. Young, "High Performance Containerboard - Will It Become the Standard?," presentation at the Sixth International Containerboard Conference, Boston, September 15-16, 1994 and phone interview with Ralph Young, Manager Product Development Printing Grade, International Paper Co, December 5, 1994.

[15]National Classification Committee, Correction Notice - Disposition Bulletin 1207, November 18, 1994; phone interview with Jerry Stone, National Classification Committee at the American Trucking Association, October 25 and December 8, 1994; letters from Alfred McKinlay, Consultant - Packaging, Handling, Warehousing, October 12, 1994, Mary Opfer, Manager Technical and Environmental Services, Fiber Box Association, on October 18, 1994, Thomas Lowery, Director of Packaging Design, Ethan Allen Inc., November 4, 1994, and Dan Goodwin, Professor at the Rochester Institute of Technology, Department of Packaging Science , December 4, 1994.

[16]Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995.

[17]The information is based on the following phone interviews:

- United States Postal Service: phone interviews with Bob Adams, Customer Service Support Analyst and Program Manager Hazardous Waste, Business Mail Acceptance Department, March 6, 1995, and Ed Wronsky, Manager, Rates and Classification Center New York, March 14, 1995; *Publication 2 - Packaging for Mailing,* Government Printing Office, Washington, DC, October 1989; *Publication 227 - How to Prepare and Wrap Packages,* Washington, DC, June 1992;

- United Parcel Services: Brad Cook, Packaging Systems Manager, Corporate Business Development, February 22 and March 6, 1995, and Bob Gordon, Corporate Packaging Manager, March 8, 1995;

- Federal Express Corporation: Larry Rutledge, Manager, Packaging Group, March 3, 1995, and Cliff Morgan, Senior Packaging Designer, March 3, 1995; *Test Procedure for the FedEx Air Express Distribution System; and Federal Express Guide to Proper Packaging,* March 1993.

[18]The U.S. Postal Serivces requires minimum burst strength dependent on the following three parameters:

1. Type of load: Easy loads are items of moderate density that are not readily damaged, average loads are moderately concentrated items that provide partial support to all surfaces of the container, difficult loads are items that require a high degree of protection to prevent puncture, shock, or distortion.

2. Weight of box and its contents

3. Maximum dimensions of the box: sum of length and girth which equals the sum of length, width and depth.

For details, see *Publication 2 - Packaging for Mailing,* Government Printing Office, Washington, DC, , October 1989, p. 2.

[19]Elliot Rhode, “Making a Case for Corrugated”, *TAPPI Journal,* September 1994, p. 32-6.

[20]David Hopkins, “Trends in Improved Graphic Quality Linerboard,” presentation at Sixth International Containerboard Conference, Boston, September 15-16, 1994.

[21]*1994 North American Pulp & Paper Factbook,* San Francisco: Miller Freeman, Inc., 1993, p. 245 and 246.

[22]Tim Knapp, “Characteristics of Major Substrates for Preprinted Corrugated Boxes”, presentation at the Sixth International Containerboard Conference, Boston, September 15-16, 1994.

[23]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 61, letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific Corporation, October 31, 1994; letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995.

[24]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 59-60; phone interviews with Bob Gordon, Corporate Packaging Manager, UPS, March 8, 1995; Cliff Morgan, Senior Packaging Designer, Federal Express Corporation, March 3, 1995; and International Safe Transit Authority Preshipment Test Procedures.

[25]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 61.

[26]Weyerhaeuser Containerboard Packaging Division, “The Effects of Recycled Content on Corrugated Box Performance”, presentation at the Institute of Packaging Professionals Conference, Minneapolis, November 4, 1993.

[27]David Etzel, National Manager, Graphics Sales, Georgia-Pacific, presentation at panel discussion in Charlotte, NC, on October 1994; Richard Parke, “The Latent Demand for Repulpable Barriers in Fiber Based Packaging”, product material for NilWax Repulpable Coatings, Rock Hill, SC, 1994, p. 2 and phone interview with Terry Serie, Vice President, Containerboard and Kraft Paper Group, American Forest & Paper Association, September 30, 1994.

[28]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 60.

[29]Letter from Gregg Sutherland, National Director for Solid Waste Management, R.W. Beck & Associates, May 8, 1995.

[30]Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995, based on Jacobs-Sirrene Consultants multi-client studies "1994 Linerboard Annual Update of Competitive Costs" and "1994 Corrugating Medium Update of Competitive Costs."

[31]Franklin Associates Ltd., *Evaluation of Proposed New Recycled Paper Standards and Definitions,* November 25, 1991, Washington, DC: Recycling Advisory Council, Table A-1.

[32]Union Camp Corporation, Containerboard/Corrugated - Secondary Fiber Usage, presentation to McDonald's Corporation in 1990, based on data from EPA and Jaakko Poyry Consulting, September 1989.

[33]Most of the examples were taken from the CONEG Challenge on "Voluntary Packaging Reductions by Industry". This program was initiated by the Coalition of Northeastern Governors (CONEG) as a way for companies to inform public policy makers and the public on actions they have taken to voluntarily reduce packaging waste. Compare CONEG Source Reduction Task Force, *The CONEG Challenge - Voluntary Packaging Reductions by Industry,* Washington: CONEG Policy Research Center, Inc., 1993. The examples of Coors Brewing Company and Clorox were taken from Michele Raymond et al, *Transportation Packaging and the Environment - Regulation, Trends and Case Histories, Expanded & Updated July 1994,* Riverdale, MD: Raymond Communications, Inc., p.34ff.

[34]Phone interview with Carl Dirksy, Purchasing Manager at S.C. Johnson & Sons, August 26, 1994.

[35]Based on presentations at the Paper Task Force panel in Charlotte, NC, on October 11, 1994.

[36]Based on various phone interviews with Paper Task Force members (Peter Turso, Director, Corporate Purchasing, Johnson & Johnson, Linda Fransen, Environmental Project Manager, Perseco/McDonald's Corporation) and other box buyers (e.g. Carl Dirksy, Purchasing Manager, S.C. Johnson & Sons, Tom Lowery, Director of Packaging Design, Ethan Allen Inc., Bob Frailey, Manager of Packaging, Commercial Products Division, Shell Oil Company)

[37]Based on letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific, December 14, 1994 and phone interview with Jeff Long, American Forest & Paper Association, January 5, 1995.

[38] Susan Freeland and Bjorn Hrutfiord, "Caustic Treatment of OCC for Strength Improvement During Recycling," *TAPPI Journal*, April 1994, p.185.

[39]Based on letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific, December 14, 1994.

[40]Phone interview with Jeff Long, American Forest & Paper Association, January 5, 1995.

[41]Based on letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific, December 14, 1994.

[42]Phone interview with Richard Spangenberg, Research Development, Weyerhaeuser Company, March 31, 1995.

[43]Based on letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific, October 31, 1994.

[44]Phone interview with David Etzel, National Manager, Graphics Sales, Georgia-Pacific, and Richard Spangenberg, Research Development, Weyerhaeuser Company, March 31, 1995.

[45]Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995.

[46]Based on letter from David Etzel, National Manager, Graphics Sales, Georgia-Pacific, December 14, 1994.

[47]Phone interview with David Etzel, National Manager, Graphics Sales, Georgia-Pacific, and Richard Spangenberg, Research Development, Weyerhaeuser Company, March 31, 1995.

[48]Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995, based on Forest Products Laboratory, "Hydroexpansivitiy - Papermaking Variables and Corrugated Container Stacking Behavior," AF&PA/CKPG Project #3686-1, Phase 3; letter from Hal Tanner, Manager, Containerboard Packaging Services, Containerboard Division, International Paper Company, April 24, 1995.

[49]David Saphire, *Delivering the Goods - Benefits of Reusable Shipping Containers,* New York, 1994. Available from Inform, Inc., 120 Wall Street, New York, NY 10005, Phone (212) 361-2400.

[50]CONEG Source Reduction Task Force, *Preferred Packaging Manual,* Oxford, Ohio, 1991.

[51]Based on panel discussion in Charlotte, NC, on October 11, 1994.

[52]CONEG Source Reduction Task Force, *The CONEG Challenge - Voluntary Packaging Reductions by Industry,* Washington: CONEG Policy Research Center, Inc., 1993.

[53]Phone interview with Wayne Carlson, Manager of Issues Management, Bristol-Myers Squibb Co., December 15, 1994.

[54]General Motors North American Operations, Containerization Environmental Packaging Addendum, September 1, 1994.

[55]Based on report by National Starch presented by David Etzel, National Manager, Graphics Sales, Georgia-Pacific Corp., at the panel discussion in Charlotte, NC, on October 11, 1994, and

phone interview with Ralph Young, Manager Product Development Printing Grade, International Paper Co, December 5, 1994.

[56]Product brochures from James River Corp. and phone interview with Lyle McGlothlin, Manager External Affairs, James River Corp., December 14, 1994.

[57]The following examples were provided by ABC Packaging during phone interview, December 19, 1994.

[58]Information from Bob Langert, Director of Environmental Affairs, McDonald's Corporation.

[59]Michele Raymond et al, *Transportation Packaging and the Environment - Regulation, Trends and Case Histories, Expanded & Updated July 1994,* Riverdale, MD: Raymond Communications, Inc., p.35.

[60]Information from Elizabeth Richmond, Packaging Engineer, Johnson & Johnson Personal Products.

[61]CONEG Source Reduction Task Force, *The CONEG Challenge - Voluntary Packaging Reductions by Industry,* Washington: CONEG Policy Research Center, Inc., 1993.

[62]Product brochures from James River Corporation and phone interview with Lyle McGlothlin, Manager External Affairs, James River Corporation, December 14, 1994.

[63]Information from Linda Fransen, Environmental Project Manager, Perseco/McDonalds.

[64]Steve Apotheker, "OCC shines in its all-star recycling role", *Resource Recycling,*February 1994, p. 25.

[65]David Saphire, *Delivering the Goods - Benefits of Reusable Shipping Containers,* New York, 1994, p. 16.

[66]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 16 and phone interview with Rick Krause, Commercial Development Manager, SC Johnson, Polymer Group, December 13, 1994.

[67]Richard Parke, "The Latent Demand for Repulpable Barriers in Fiber Based Packaging", product material for NilWax Repulpable Coatings, Rock Hill, SC, 1994, p. 4; phone interview with Richard Parke, President, NilWax Repulpable Coatings, December 19, 1994.

[68]Michele Raymond et al, *Transportation Packaging and the Environment - Regulation, Trends and Case Histories, Expanded & Updated July 1994,* Riverdale, MD: Raymond Communications, Inc., p. 35; phone interview with Joe Maroon, Resource Recovery Manager, Wegmans Food Markets, Inc., March 3, 1995.

[69]Steve Apotheker, "OCC shines in its all-star recycling role", *Resource Recycling,* February 1994, p. 25-26; phone interviews with Kerry Kinst, Dussek Campbell, March 3, 1995; James Kalyta, Product Development Specialist, International Group, Inc., March 6, 1995; Jodi Dalvey, President/CEO, NuCoat, March 7, 1995; Jim Southward, Packaging Corporation of America, February 22, 1995; Charles Probst, General Manager, Spectra-kote, March 14, 1995; Glen Wickett, Director Technical Services, Weyerhaeuser, March 7, 1995.

[70]Phone interview with Mary Opfer, Manager Technical and Environmental Services, Fibre Box Association, March 8, 1995; and Fibre Box Association, *Draft for Voluntary Standard for Repulping and Recycling Treated Corrugated Fiberboard,* February 1, 1995.

[71]Phone interview with Glen Wickett, Director Technical Services, Weyerhaeuser, March 7, 1995.

[72]Letter from Hal Tanner, Manager, Containerboard Packaging Services, Containerboard Division, International Paper Company, April 24, 1995.

[73]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 50-51.

[74]Phone interview with Jeff Swaboda, HB Fuller Company, December 15, 1994, and Jim Owens, National Starch & Chemical Company, December 14, 1995.

[75]Phone interview with Ralph Locke, Quality & Product Development Manager, Containerboard Division, Inland Container Corp., December 5, 1994.

[76]Phone interview with Bob Frailey, Manager of Packaging, Commercial Products Division, Shell Oil Company, December 16, 1994.

[77]General Motors North American Operations, Containerization Environmental Packaging Addendum, September 1, 1994.

[78]Available from the Fibre Box Association, 2850 Golf Road, Rolling Meadows, IL 60008, Phone (708) 364-9600.

[79]*Fibre Box Handbook,* Rolling Meadows, IL: Fibre Box Association, 1992, p. 15.

[80]*1994 North American Pulp & Paper Factbook*, San Francisco: Miller Freeman, Inc., 1993, p. 247.

[81]Other manufacturers have developed presses based on the same principle and with similar effects. These presses are also referred to as shoe presses or long nip presses.

[82]The term "extended nip press" is used here in accordance with industry customs. The more generic term is shoe press and it is also referred to as high-impulse or wide-nip press.

[83]Letter from Richard Storat, Vice President, American Forest & Paper Association, April 25, 1995, based on D.A. Guest, "Recycle, Reuse and Disposal of Paper and Board," *Products of Papermaking, Volume 2,* Transactions of the Tenth Fundamental Research Symposium, Oxford, United Kingdom, September 1993, PIRA International, Leatherhead, United Kingdom.

[84]Phone interview with David Brandt, Product Line Manager, Press Section at Beloit Corporation.

[85]W. Musselmann, "Fraction of Fiberous Stocks: Fundamentals, Process Development, Practical Applications," *Secondary Fiber Recycling,* edited by Richard Spangenberg, TAPPI Press Atlanta, GA, 1993, p. 207-227.

[86] See for example, Jim Young, "MacMillan Bloedel Pine Hill Expansion is Quality Driven," *Pulp & Paper,* May 1991, pp. 85-87.

[87]Gary Smook, *Handbook for Pulp and Paper Technologists,* Vancouver, BC: Angus Wilde Publications, 1992, p. 313.

[88]*Fibre Box Handbook*, Rolling Meadows, IL: Fibre Box Association, 1992, p. 17ff.