CORRUGATED BOXES:

A SYSTEMS APPROACH

by

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ABSTRACT

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The widespread use of corrugated shipping containers is a questionable practice when a "Packaging Systems Approach" is applied to this packaging material. A systems approach necessitates the quantifiable identification of all aspects within a distribution system with which a packaging material interfaces. Such elements as transportation costs, labor, storage, protection, and material costs should all be examined when attempting to ascertain the true cost of using corrugated boxes. Also within the scope of a systems approach is to study the supply chain for a specific packaging material.

This thesis explores the intricacies of the corrugated industry which will eventually lead to severe price increases and supply bottlenecks. The technical aspects of using corrugated boxes are examined and shows the unreliability, and even dangers of employing this packaging material. A case study is presented to demonstrate the use of the systems approach, and the many benefits accrued, when one company switched from corrugated boxes to shrink wrap.

This thesis is dedicated to my parents, Norman and Terry Howard, without whose love, encouragement, and permissive attitude toward individual growth, this thesis would not have been possible. This work is also dedicated to the only Grandmother I ever knew, Ida Feldman, whose devoted love and all encompassing gentleness toward life has influenced her grandson for evermore.

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INTRODUCTION

Virtually every industry in America uses corrugated boxes to distribute its products. The Fibre Box Association reports that 85 to 90 percent of all shipping containers used are corrugated boxes.[11] Most companies that use corrugated paper containers do so out of traditionalism. Such companies assume there are no real alternatives to a corrugated distribution container. These companies feel a corrugated container performs reliably and inexpensively in protecting their product.

The purpose of this thesis is to explore these commonly held beliefs from a non-traditional point of view: the packaging systems approach. Only by combining all of the elements involved in using corrugated can one ascertain the true cost of its use. These elements include the costs of material, labor, freight, storage and protection, all of which are readily quantifiable. Also within the scope of a packaging systems approach is consideration of nontangible aspects of using a packaging material. Factors such as customer good will, ease of disposability, ease of handling (throughout the distribution system), and inventory control should all interface with the selection of a packaging material. Another major concern, particularly when considering the purchase of corrugated boxes, is the procurement of the materials from the viewpoint of examining the industry which supplies that material.

The first portion of this thesis is devoted to understanding the current status of the corrugated industry. It will put into perspective the present relationship of this industry to its own history, the economy, the forest products industry in general, and the availability of linerboard mill capacity. Second, the author will address the technical aspects of corrugated shipping containers. In general this will serve as a critical review of the reliability of corrugated boxes to adequately protect products. Finally, a case study will be presented to demonstrate the savings that are possible when approaching the subject of using corrugated shipping containers from a packaging systems viewpoint.

1. Limitations

While conducting the literature research needed for this study, it became painfully obvious that the validity of "facts" is nearly impossible to ascertain. Depending upon the affiliations of the author of an article, or even those of the publication itself, figures sometimes seem to reflect certain loyalties. Also, few--if any--forecasts of the various aspects of the corrugated industry written over the last several years accurately projected the future. In fact, the author found forecasting became much worse as the 1970's came to a close and people attempted to foretell the 80's. There are two general reasons for this difficulty. First, the "macro" aspect of an unprecedented uncertainty about world economics, particularly in the United States. Secondly, the "micro" aspect of customers' orders being placed when the material is wanted in an attempt to limit their inventories in times of tight money.[23] However, even with the aforementioned conflict of facts and figures, it will be demonstrated that certain inherent overviews and conclusions can be drawn.

2. Definitions

The primary raw materials for corrugated board, which has a sandwich construction, are unbleached kraft linerboard for the two outer plies, and a semichemical medium for the inner ply. The weights (per 1,000 square feet) of linerboard and medium can vary but the standard weights are 42 pounds and 26 pounds, respectively. Both the linerboard and medium industries are dominated by the major forest products companies.[L]

THE COMPLEX ASPECTS OF CORRUGATED

1. Background

In the 1950's and 60's the corrugated industry was rapidly growing in production volume. During the 1960's, corrugated consumption increased at an annual incremental rate of eight billion square feet per year. "By the end of 1969, cut up of corrugated paper was 184 billion square feet, having risen from 107 billion square feet in nine years."[24] Practically all of this growth was due to corrugated replacing more expensive wooden crates, but by 1970 this conversion was virtually complete. Due to corrugated's incredibly broad use, the fluctuations in its production volume then began to closely parallel this country's Gross National Product and overseas sales of liner and medium became the only new market growth potential. It is this readily available export trade which balances out capacity utilization for the corrugated industry.

This, then, was the advent of corrugated reaching the "maturity" stage of its product life cycle. Considered a commodity item, corrugated had penetrated virtually all markets. "Even though the profit rates in the paper industry have traditionally been lower than all manufacturing, a great number of traditionally non-paper firms entered the market between 1955 and 1965 due to the modest risk perceived in a 'stable' industry."[37] This invasion of suppliers caused for a highly competitive and price sensitive industry. Not having the foresight to anticipate a saturation point, management mistakenly equated profit to volume. This was a false premise, though not adequately proven true until 1972. In 1970-71, paper industry profits dropped 42%, although operating rates were between 90% to 92% of capacity.[48]

This volume orientation has never abated. In 1981, $10 billion of corrugated was shipped,[42] with 91% of this volume being conventional double-face.[39] Presently, the U.S. produces an average of 100 boxes each year for every man, woman, and child in this country. Many countries in Europe have per capita consumption figures which fall between 25 and 50 percent of this number, while on a world wide scale, per capita consumption is only one-tenth of the U.S. rate.[31] In 1979, Germany, France, and Denmark showed the highest consumption of corrugated in western Europe with about 30 kg per capita per year while the U.S. was at 68 kg per capita per year.[1]

2. Economic Considerations

There is a practical side to high levels of production for corrugated. Capital intensity and the nature of the production process require high levels of capacity utilization, 90 percent or greater for efficient operation. The President's Council on Price and Wage Controls[37] found that "... the paper industry invested a higher percentage of each sales dollar than any other industry after Petroleum and Chemicals between 1965 and 1975. The ratio of payroll to value added in 1972 was lower than the average for all manufacturing. This means that it [the paper industry] is particularly sensitive to increases in factors affecting capital costs, such as interest rates and construction costs, both of which have risen rapidly over the past few years."

A major part of the high capital and operating costs in the paper industry are devoted to pollution abatement equipment. According to the President's Council,[37] investment in such equipment by the paper industry's primary producing sector was between 25 and 35 percent of capital outlays from 1973 to 1976. However, the Council concluded that the added costs of pollution controls did not seem to affect the amount of investment needed to keep up with demand. Since 1976 though, this tremendous expenditure has taken on a new significance due to the staggering economic downturn. Raging inflation, causing a high cost of money, combined with the worst recession since the 1930's (resulting in a drastic cut in demand) has wreaked havoc on the forest products industry.

3. The Forest Products Industry

Particularly important to depict is the relationship between suppliers of corrugated boxes, the forest products industry, and the ever changing economy. Companies produce corrugated boxes either at converting plants or at "sheet" facilities. The converting plants perform the corrugating operation (fluting the medium), make the corrugated board and fabricate containers and, according to an ARCO report,[41] comprise roughly 44% of the corrugated paper industry. Sheet plants purchase the corrugated board from the converter and produce containers. The converting mills are usually the downstream operations of integrated forest products companies. Sheet plants are independently operated. Note, however, that whether independent or not, the health of the forest products industry is an integral factor to all companies dependent on wood fibre products.

The "forest products industry" is comprised of a comglomeration of enormous, often vertically integrated firms. Economies of scale are an important aspect of being able to turn a profit and is reflected in the fact that almost half of the corrugating industry is owned by the firms that control the upstream timberlands, pulp mills, and paper mills. Though many of the firms comprising the industry are "giants" (e.g. Boise Cascade, Champion, Mead, etc.), no one company is considered "the leader" and monopolistic tendencies seem not to be a problem.

In 1979 the forest products industry as a whole made a grave error. At that point in time housing construction was booming, sales of paper products were expanding, and more corrugated board was sold during 1979 than at any previous time in history.[11] "The industry" decided to go heavily into debt to expand facilities for producing newsprint and magazine paper.[2] By the time these facilities came on line in 1981 and 1982, a recession had taken hold and a drastic decline in virtually all wood products sales occurred. Due to the slump in economic activity at all levels, advertising decreased greatly, resulting in less newsprint needs. Also, as the "computer age" becomes a reality, a shift in the types of paper needed is seen. The newsprint and magazine facilities just described are expected to have surplus capacity for years to come. The most dramatic occurence in the forest products industry after the huge 1979 capital outlays was the devastating decline in demand for housing and construction materials, the largest users of wood products.

Ill-conceived facility expansion wasn't the only debt concern. Prices for timber had been climbing steadily. With the optimism being shown in 1979 and 1980 for their industry, forest products companies decided that they needed to assure themselves of future timber supplies. The industry secured their grossly over-projected needs by signing long-term timber buying contracts. However, with the onset of the recession/depression, timber prices tumbled. Suddenly the forest products industry found itself locked into buying timber at four or more times above current market values. In 1980 the price of West Coast timber was $400 per 1,000 bd.ft. By September of 1982 that price had dropped to $65.[2] These timber prices are a poignant factor when related to corrugated. The March 1980 Wall Street Journal[8] reported that the sixth price increase since 1978 for 42-pound kraft linerboard had been announced, bringing the price to $300 a ton. The increase stemmed from "... a direct increase in material costs of

50% during those two years." Between being battered by high interest rates, facing heavy debts, contending with never-ending high production costs, and languishing in an industry of dramatic demand decline, combined with intensive competition for shares of a contracting market, the forest products industry found itself in dire straits by 1982.

The first quarter earnings of 1982 for the total paper/ forest products industry dropped 47.1 percent, with companies heavily involved in wood products seeing profits tumble up to 95 percent from a year earlier.[45] Between the peak, reached in 1979, and March 1982, earnings in the $40 billion forest products industry were down 60 percent.[46] To help reduce plunging corporate profits, most companies instituted large spending cuts, including slicing capital expenditures. The top 25 forest products companies in the U.S. cut capital spending by 24% below original estimates in 1982.[2] As for the paper industry per se, capital expenditures decreased from $6.7 billion in 1981 to $5.9 billion in 1982.[5] In the context of corrugated board, these capital spending cuts translate into "0.5% capacity growth for linerboard mills in 1983."[9] This low capacity growth coupled with a present 97% capacity utilization rate of linerboard mills,[24] plus seemingly unanimous projections of increases in linerboard production volumes for 1983 spells ominous tiding for users of corrugated in terms of supplies and prices.

4. Linerboard Mill Capacity

Virtually every sector of the economy has been affected, if not devastated, by the current recession. Industrial output in America has hovered around a 69% capacity utilization rate for the past nine months. Linerboard mills, however, haven't dipped below 94 percent capacity utilization since at least 1979.[44, 12] In fact, Irmen[24] states that between domestic and export uses, linerboard mill capacity was operating at a 97% utilization rate during the summer of 1982. Historically, the paper industry needs a 92% to 93% level of utilization to keep prices in line with costs.[44] To meet these utilization rates during the domestic decline in demand, export trade was increased and a short-sighted management decision to stockpile inventories was instituted.

In 1980, 18 percent of linerboard production was exported.[6] Of particular interest was a 40 percent increase, over 1979, in exports of linerboard to China.[12] Over the decade of the 80's, linerboard exports are forecasted to rise better than 6% annually.[6] The Chinese (PRC) are interested in buying linerboard from North America because the Japanese, their nearest supplier, charge nearly double the U.S. price (of $300/ton).[6] Between this export trade and domestic use, corrugated shipments are expected to rise 10.5 percent in 1983 vs. 2.5 percent in 1981 and 1982.[10] The real growth expected in the domestic market was projected by the Commerce Department[13] to be a 4.3 percent compound annual rate. This is based on the prospect of a stronger national economy. In short, demand and production volume will rise rapidly at a time when capacity additions, or even plans of additions, are quite limited. Operating rates for 1983 are expected to climb to 100.6%. The situation will intensify further through 1984 seeing that "... substantial increments in linerboard output cannot occur before 1985."[6] In terms of prices, it has been variously projected that by the end of 1983, linerboard costs could go as high as $475-525 per ton.[6] With a current selling price of $300/ton (and many companies are giving a $30 discount to bring that to $270/ton), even Irmen's[24] $420 per ton expectation is a hefty and sudden increase. In a historical context, Irmen points out that "... the base price of 42-pound kraft liner has increased more than $200 a ton in the last eight years..." In terms of cents per sq. ft. for 200-lb.-test board, the cost of a finished box went from 1.8 cents in 1973 to 3.7 cents in 1982.[28] Notice how costs outstripped prices--as costs tripled, prices doubled. In terms of profitability, this disproportionate ratio has been an ongoing problem for years.

It currently costs a U.S. mill $270/ton to produce unbleached kraft liner.[9] If mills can sell that product for $300/ton, an average gross margin of $30/ton is achieved. At the common $270/ton discount price, Morgan Stanley Investment Research estimates that 40% of the industry is not fully covering costs.[41] The situation is a result of recession-caused low demand for a product that must be constantly produced in high volumes, combined with the fact that the corrugated industry is extremely competitive due to the large number of suppliers involved. According to ARCO,[41] there are 887 corrugated plants, while the American Paper Institute reports 1,427 corrugated plants.[31] Though there is a wide disparity between these two figures, both sources report that 44 percent of these numbers are converting plants and the rest are sheet plants. Due to the interplay of low demand, high competition, and a need to produce at near capacity levels just to break even, "... prices crumpled in 1982 under the pressure of mounting inventories."[28] Bernie[3] describes the scenario of the paper industry's customers for more than a year before the demise of prices: "Due to depressed customer demand, all links in the manufacturing and distribution chain have suffered cash flow problems, leading to reduced stocks. This reduction of stock has been the most significant factor affecting sales." In January of 1982, the Paper Trade Journal[47] reported that the paper industry failed to adjust its production to match demand in want of staying at their efficiency point of 93 to 95 percent capacity utilization. This has caused an inventory accumulation at the mill site which will make it difficult to recover with the next economic upturn. The inventory reduction needed furthers major price competition and erosion of earnings. Official prices have yet to change, and stick, for linerboard since March 1980.

5. Linerboard Mill Economics

Dell[12] reports that linerboard mills are run most efficiently at 95 percent capacity, the other 5 percent being needed for maintenance and repairs. Comparing these figures with the previously cited forecasts of capacity, usage rates exceeding 100 percent for at least the next two years (late 1983 through 1985) bodes ill tidings. Many of the linerboard mills are old and the long term effects of such continously high operating rates could be devastating. From over-use and lack of proper maintenance, what limited production capacity there is will deteriorate quickly. Obviously there must be some capacity expansion to meet demand. But as recently as September 1982, Paperboard Packaging[42] pointed out that "... modifications and extensions of existing facilities have been completed to the feasible maximum. Any significant further additions to capacity must come from new construction." This is easier said than done. There are several viable reasons as to why the industry hedges on new mill construction. The President's Council on Wage and Price Controls[37] point out such negative factors as insufficient price-cost margin, high investment costs, illiquidity, and uncertainty concerning future prices and raw materials.

Price-Cost Margin

When compared to the gross margin available on other paper products, the reluctance of companies to invest in linerboard mills becomes more apparent. As of January 1982 the gross margin for bleached kraft pulp was about $140/ton while for newsprint it was $100/ton.[44] As reported previously, few companies are making even $30/ton for linerboard. Certainly, as supplies tighten and prices rise in response to demand, the return on new linerboard investments should become more attractive.

Investment Costs

Dell[12] reports that between 1983 and 1985 the linerboard industry will have to add five large mills with supporting timberland if operating rates are to be kept at 95% level. To build that additional capacity with 1980 dollars would cost about $5.5 billion. However, inflation and the high cost of borrowing funds seems to have driven this figure even higher. Barely a year and a half after Dell's January 1981 writings, Irmen[24] conjectured the price of a new mill with supporting timberlands to be approximately $1.5 billion, bringing the requisite five mills to a cost of $7.5 billion. The difficulty of borrowing such funds are two-fold. First, when interest rates are high, external capital is expensive. These interest rates also have a secondary effect on "internal borrowing." Such diversion of funds is affected due to the high rates of return needed to compete with a company simply loaning its own cash flow out at high rates.

Significant investment costs can be directly related to the sudden increase of energy costs (e.g. the 1973 oil embargo) and newly instituted OSHA pollution control standards in the 70's. The long term expenses incurred for pollution abatement; to improve energy efficiency, and to improve mill productivity are all readily apparent when comparing historical start-up costs. Pöyry[43] points out that the investment cost of pulp mills that started up in the early 1970's was about $350/ton of annual capacity. By the late 1970's the unit investment cost had risen to $850/ton.

According to the American Paper Institute,[31] there are presently 88 containerboard mills in the United States. It has been estimated that a new mill's length of service is about 20 years.[37] Figures for construction time tables for building a new pulp or paper mill varies depending on the source of information. The ARCO report[41] states a minimum of two and one half years of lead time is needed from announcement to start up. In contrast, Gould[21] estimates a five to seven year lead time. Other than one mill in Lousiana, no new linerboard capacity is scheduled beyond 1983.[24, 43, 12 and 41] The fact of limited linerboard mill capacity coupled with expected increasing demand will be the major cause of supply bottlenecks and rapidly increasing prices.

Uncertainty of Raw Materials

There is one aspect of the corrugated industry which renders the concerns of mill capacity, the economy, investment costs, etc., moot: is there a sufficient supply of trees? There are some serious concerns as to whether the supply of wood fibre in America can keep up with growing demand. Sharing[40] reports that "... the U.S. Forest Service projects that demand for wood fiber in the U.S. will double at a steady rate in the next 50 years (1980 to 2030) to some

28 billion cubic feet annually, while supplies from our own timberlands will increase to only 21 billion cubic feet at present auspices." This equates to expanding wood demand by some two million annual tons, year after year for a half century. If true, the near inevitability of costs, and therefore prices, increasing is evident.

Of course, such long term projections can be faulty. The future of the construction industry, and even the economy in general, is not truly ascertainable. Also, there is a possibility that synthetic materials will be invented and used in place of products made from trees. Beyond this, alternative sources of wood fibre may yet be developed. Such an alternative exists in the form of a plant named Kenaf. The New York Times[38] reports that Kenaf, a plant which grows eight to twelve feet high, is being studied for its feasibility in producing pulp for newsprint. "Kenaf can be a supplement, extender, or alternative to wood in making newsprint." It has proven applications in other countries (e.g. cigarette paper in Sri Lanka), has a yield per acre nine times the pulp per acre of forest land, and grows in about 120 days. However, various drawbacks such as its density in terms of transporting it from harvest to mill, still makes its use questionable.

6. Discussion

The ensuing situation of tight supplies due to linerboard mill capacity is good news for the corrugated industry.

At long last corrugated manufacturers will be able to bring prices in line with costs. For several years the industry has borne the brunt of costs due to high operating rates; intensive capital outlays in terms of pollution control devices and energy efficiency improvements; an economic recession occurring once vast sums of capital had already been committed to expand facilities, and inflation making it unfeasible to borrow the funds needed to update and expand facilities whilst the industry suffers from lack of private funds due to the decline in earnings.

While the costs have escalated tremendously, prices have been kept artificially low for corrugated board. The corrugated industry has unwittingly subsidized the price of corrugated through volume orientation combined with fierce competition. With so many suppliers of corrugated vying for sales to a greatly reduced market demand (in direct proportion to the recession), most companies' revenues barely exceed costs. Price pressures were particularly pronounced when in 1981 and 1982 the users of corrugated not only cut back on the total amount of board being used, but because of their budget problems, decided to work down their inventory levels, too. Again, the corrugated industry's volume orientation didn't allow for production to meet demand, increasing inventories, and therefore competition, at the mill level. Only within the next few years (at least through 1985) will the true costs of corrugated be reflected in its price as a seller's market becomes evident. In fact, steep price increases can, under present conditions, be passed on quite readily due to the enormous dependence American firms now exhibit for this packaging material. However, if some recognition of the inadequacies and mis-use of corrugated is made by user industries, the demand should drop as corrugated is replaced by more appropriate methods of packaging.

TECHNICAL ASPECTS OF CORRUGATED BOXES

1. Introduction

The leading proponent of the use of corrugated shipping containers is the Fibre Box Association (FBA). In their Fibre Box Handbook,[15] where regulations, styles and definitions concerning corrugated boxes are described, a multitude of accolades to the corrugated shipping container are paid. For example: "It the corrugated box is the least expensive container ever developed with such a wide range of protective abilities. The light weight also reduces handling problems and shipping costs." The purpose of this portion of the investigation is to demonstrate that such claims are not fully warranted.

Several of the following topics discussed are drawn from the text Notes On Package Design by Sergei Guins.[22] This book is perhaps the most comprehensive and adamantly positive writing dealing with corrugated box design. Guins wrote this book from the pragmatic point of view that since corrugated shipping containers are so widely used, and even required, someone should describe a set of principles in their design. However, it is Guins' pragmatism which ultimately colors the true utility of his work by not fully describing some of the various problems in using corrugated containers.

In Notes On Package Design, Guins purports that standard engineering principles, such as those used in the design of bridges and airplanes, can be applied to the design of a corrugated box. Guins points out that critics claim engineering practices and theories are not generally applied to the design of corrugated fibreboard due to the many variables that control the performance of the final container. Guins attempts to counter such critics, and thus the severe limitations of designing corrugated containers, with the following example.

> The reason for the above is that structural characteristics of the base product paper are affected by such factors as rate of loading and atmospheric conditions in the ranges of normal use, while more common, so called engineering materials are stable in the same range. One must remember that steel gets brittle under cold temperatures as evidenced by brittle cracks developing in some ships operating in cold climates, and develops creep characteristics at high temperatures, but as this happens in very special application the engineers learned how to correct for these phenomena either by design or by modification of materials with special characteristics ... modifying factors can be applied also for conditions under which the structure made from corrugated fibreboard will have to perform.

This author is readily confused by the logic of the above statement. Guins recognizes the fact that within the normal ranges of use, corrugated is not considered stable. Simply, this is the crux of the matter. His attempt to equate the predictability of steel with that of corrugated is fallacious. Within the normal ranges of use, steel is fairly predictable. Even when steel is used beyond its normal range of use, design changes or modification of materials with special characteristics can be employed, again with fairly high predictability. In designing with corrugated, predictability of strength characteristics will not be had either in its normal range of use, and certainly not beyond its normal range of use.

The one most basic fact that Guins does not address in his book is that all of his equations and various graphs relating to the stacking strength of a corrugated box are invalid when conditions of 85 percent or greater of relative humidity exists.[32] If one considers how wide spread such weather conditions are in the U.S., it becomes apparent how unpredictable the properties of a corrugated box really are.

There is one other basic flaw in Guins' attempt to characterize corrugated board as an engineering material. Guins defines an "engineering material" as one having consistent characteristics that do not vary to a great extent from batch to batch, so that in design calculation generalized constants can be used. In a study that was completed in 1976, Clifford[7] demonstrated that there is actually very little consistency between one batch of corrugated board and the next. This study will be described shortly. From that point, the author will describe other technical aspects to using corrugated boxes. However, the most important problem is that of the adverse effects of humidity and load variations that corrugated containers encounter during normal use.

2. Standards

The Fibre Box Handbook[15] points out that "... a box is usually constructed to fulfill the requirements of Rules 41 and 222--criteria established by rail and motor common carriers as minimum standards for protection in transit."

These two requirements, coupled with the aforementioned economic benefits of replacing wooden crates with corrugated boxes, are the two greatest reasons for the wide spread use of this packaging material. Within Rules 41 and 222 is the requirement that every box shipped by common carrier or rail be stamped with a "Box Certificate" (see figure 1). This certificate is supposed to be able to define a specific box's strength, with the major criteria being the Mullen Burst Test value. In fact, it is this Mullen test value that is used as the premier identifying factor when specifying a board's strength. The other information printed on the

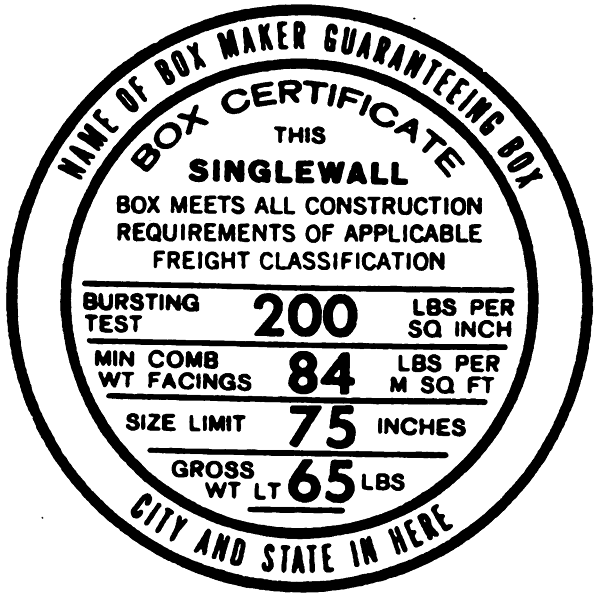

Figure 1

Replica of a Rule 41 Certificate
Source: Fibre Box Handbook, FBA 1977, p.56

certificate includes the "minimum combined weight of facings" (in pounds per 1,000 sq. ft., the added weights of the linerboards used), "size limit" (the maximum inside dimensions of length, width, and depth added together), and "gross weight limit" (the maximum weight of the box and contents measured in pounds).

Within Rules 41 and 222 are two assumptions which are the foundations of the Rules' existence. First, it is assumed that identical Box Certificates on different individual boxes assure those boxes to be identical in their strength characteristics. This belief is to hold true from one batch of corrugated to the next, whether it's from the same supplier of from competitors. Second, the Rules attempt to make a direct correlation between the Mullen Burst Test value and a box's strength. Both of these assumptions are patently wrong.

The Mullen Burst Test is a "... measurement of the resistance of a material to bursting expressed in pounds per square inch. The test is made on a motor-driven Mullen tester."[15] Attempting to relate the results of this test to a box's ability to withstand load or compression is difficult. As Guins[22] points out, "... if cloth was used for liners, the Mullen test results would be very high but the board's ability to support any load would be negligible." Along these same lines of reasoning, Mr. Dave Carlson lectured as a representative of the Fibre Box Association.[4] Mr. Carlson's presentation revolved around the FBA's joint effort with the American Paper Institute to develop an alternative to Rule 41. Their position is that the current Rule places too much emphasis on the bursting strength of corrugated board while not recognizing the fact that compression is one of the prime factors in the successful performance of these containers.

The other major point of contention as to the validity behind Rules 41 and 222 is the use of the box certificate's burst test value to identify consistency of strength attributes between one batch of corrugated board and the next. Clifford's[7] study on this matter is astounding. From January 1974 through December 1975, Clifford measured the properties of corrugated paperboard. Clifford explains his intentions thusly:

> Although a good deal of data of this type is held in the private sector (by board suppliers and large users), certain legalities allow the release of only "good" data. Results which are below the standards cannot be released. For suppliers, it would be an admission that they are selling something other than what they promised. For users, it would amount to an admission of violations of tariff regulations. As a result, this work is the first publicly available data on corrugated paperboard commercially produced by a variety of procedures.

Of 900 board samples tested, 90% were from five types of board: 200-and 275-pound single wall and 275-, 300-, and 500-pound double wall (these numbers representing the Mullen Burst values stamped on the samples). Clifford's results: "Less than 40 percent of the samples met the Mullen test specification stamped on them." This result was based on whether the sample had at least a 50 percent probability of passing a Rule 41 test. Since users of corrugated order their board by specifying a Mullen Test value, it becomes obvious that a designer can't possibly depend upon the corrugated to have identical strength characteristics from one order to the next. Clifford's results also point out the impossibility of viewing corrugated in terms of an engineering material: there simply is no dependable consistency between batches. The question of dependability will be broached again as the question of relative humidity in relation to corrugated box strength is explored.

3. Vibration

Corrugated fibreboard is considered to be a "springy" material. The distinctive structural feature of the board, the corrugated medium, lends itself to flexing, making for a structure resembling a miniature spring. As one layer of corrugated is placed onto another, such as in flaps overlaying each other, this "springiness" increases. In technical terms, the natural frequency is reduced as the spring is extended and the mass remains constant. This situation is further compounded as the boxes are stacked one on top of the other. Not only is each layer of corrugated acting as a spring, but the box walls are a spring, too. Due to the fact that boxes are made to specifications with tolerances of ± 1/8 inch, dead space (also know as "rattle space") in the top interior of the box can add significantly to the cumulative spring effect of a stack of boxes. The top boxes of a stack have lower natural frequencies than boxes progressively lower in the stack due to the longer spring (the other boxes) beneath them. (Note that it is not necessarily true the top box in a stack will exhibit the lowest natural frequency of any box in that stack. Due to the interplay between weight and spring constant, as exhibited in the equation $f_n = \frac{1}{2\pi}\sqrt{\frac{kg}{w}}$ [22], oftentimes it is the top two boxes in a stack that will couple-up and exhibit the lowest natural frequency.) At stack resonance, this top unit with the lowest natural frequency will exhibit the greatest displacement and acceleration levels. Guins[22] has observed acceleration levels that enter a stack of corrugated boxes with products to be amplified up to eight times. Two significant events can occur in this situation. First, because the top boxes are moving about so much, the top box has a chance of bouncing off the stack and falling to the floor of the truck or railcar. This could cause a shock great enough to damage the product and/or package. Second, it is possible that the bottom box would be crushed when receiving a dynamic compressive load many times the weight of the dead load it supports at rest. Once this bottom package is crushed (which is a distinct possibility due to the aforementioned loose tolerances, lack of consistency in quality, and the deleterious effects of high relative humidity), the stack of boxes have a good chance of falling over. In other words, the use of corrugated boxes may lead directly to vibration-related damage of products which, under a different packaging technique, might have been avoided.

In a recent Box Car Test, Goff and Twede[17] were able to directly compare the differences between a rail car full of corrugated boxes containing canned dog food to a car load of stretch-wrapped styrene trays of the same product. They began their testing with the conjecture that "bouncy" corrugated boxes may help cause damage to canned foods. Their results:

a. There was not much difference in "lading resonance" between the two package types. However, they had used pallets in this test. Prior to this test an electro-hydraulic shaker table was used to find the stack resonances of the two package types without a pallet. The corrugated boxes had a significantly lower stack frequency than the stretch wrapped stack. Upon returning from the Box Car Test, this same stack test was made again, but this time with a pallet added. It was found that the pallet is what made the two ladings' responses similar.

b. "Stretch bundles were a more cohesive and stable load since the internal out-of-phase behavior means that the load is compressed during each cycle of motion. The 'sticky' film snaps it back together. The corrugated boxes on the other hand, are always moving in the same direction, with the upper boxes experiencing higher acceleration than the bottom ones. This could contribute to the observed instability of the box lading."
This is a significant point due to their conclusion

that " ... vibration damage for can shippers occurs when a load becomes disorganized and the top boxes fall into a void."

c. The report also has a fleeting reference to the "rattle space" in the interior of a corrugated box due to the loose tolerance specifications mentioned earlier. They conjecture that if they'd had a higher frequency filtering system, "larger peak accelerations in the looser packed corrugated boxes where cans can rattle would have shown up."

d. The corrugated load was much more disorganized than the stretch bundled. The "phase" differences were significant between the two types of load. As the boxes escaped their palletloads throughout the car, "stretch bundles, tighter and stickier, formed more cohesive palletized units."

4. Creep and Misalignment

Guins[22] points out that corrugated boxes lose strength with time when submitted to a steady load. This is exactly the situation that is encountered in a warehouse. The previously mentioned "rattle space" becomes particularly important in this situation due to the fact that even a gradual sagging in a bottom container could cause stacks of products to fall over. In modern day, high rise warehouses, this can become a particularly perilous situation for warehouse workers, such as fork lift drivers.

Kellicutt[26] went beyond the problem of steady load and creep when studying the relationship of load to duration. He found that " ... when the load was a fairly large percentage of the compression test value of the box, slight changes in the amount of dead load applied to a box changed the duration considerably. It was found that loads of a magnitude of 80 to 90 percent of the static compressive strength of the box caused failures usually within minutes." Even loads of 65 percent of the static compressive strength of the box caused failure within a week. With "mixed loads" common in distribution systems, there is no surety that only certain weight loads will be placed on top of other loads. Again, confidence is compromised in a box's strength throughout a distribution system.

In a continuing investigation of the stacking strength of boxes, Kellicutt[27] makes the concerns of creep secondary due to handlings prior to storage. " ... It is difficult, if not impossible, to evaluate the reductions in strength that result from the several handlings a box receives before being placed in storage." In other words, the previously mentioned study on compressive strengths of boxes in storage is fairly worthless since there is no way to know the strength of the box at the beginning of storage. Yet Guins uses that moot information when describing how to design corrugated boxes. Kellicutt[27] summed up this report saying " ... there is no guide to follow in making a reduction in strength for the rough handling the box has encountered in handling prior to storage. Therefore, the magnitude of these reductions is dependent upon judgement, experience, and risk." This certainly isn't what could be termed a scientific approach to an "engineering material."

As for "misalignment," this term deals with the stacking configuration of boxes. Much of a box's strength comes from its corners.[27] Therefore, if boxes are stacked one directly on top of another, the maximum strength of the lower box is utilized. However, as Guins pointed out, " ... a misalignment of as much as half an inch in load application on the top of the box would reduce the load bearing ability of the case by as much as 55%."

Guins believes that a modification factor can be used to design around both creep and misalignment. Such modification factors, however, are seen as irrelevant since:

a. Consistency of board quality is in question, as shown by Clifford, leaving the designer in the dark as to what material he/she is designing;
b. As Kellicutt points out, it is probably impossible to know what strength is left in a corrugated box by the time it reaches storage, so how can one possibly know how long it will last, especially if subjected to heavier loads, and
c. None of the factors that Guins uses are valid when relative humidity climbs over 85%.

5. Humidity

"It is well known that the adverse effect of moisture on the compressive strength of corrugated boxes has been the greatest single influence limiting their use."[25] This is Kellicutt's opening sentence in his February 1960 study on the compressive strength of boxes. This observation is equally true today.

All of Guins' calculations apply to corrugated at the standard conditions of 50% relative humidity and 73 °F. Under these circumstances, he states that the behavior of corrugated is fairly predictable. However, he also states " ... on either side of this point, change in moisture content is very rapid and strength of the board is seriously affected." Also, " ... the board has a tendency to lose more strength if the humidity environment is fluctuating than if it is exposed to a steady condition of high humidity.

In the real world of distribution systems, both of the above drawbacks will be encountered. Boxes are shipped and stored between varying altitudes, temperatures, and humidity conditions. In fact, temperature and humidity conditions can fluctuate greatly simply from night to day, let alone from one locale to another, thus reducing any strength which the box may have actually had.

Kellicutt[25] performed an investigation which dramatically and succinctly emphasizes the rapidity of the effects of moisture on a corrugated box's strength. He wanted to determine how rapidly the sudden exposure to a high humidity atmosphere affects the ability of the box to sustain a dead load. For the test, boxes were preconditioned in a standard atmosphere (73 °F, 50% R.H.) and then sealed in a flexible water vapor barrier under those conditions. Thus protected, the box was placed in an atmosphere of 80 °F, 90% R.H. and a load placed on it that was 50% of maximum machine test load. Ordinarily the box would be able to sustain this load for one year if the atmosphere did not change to one of higher moisture. After 48 hours had elapsed, the water vapor barrier was opened and the box became exposed to the 90% R.H. In one test, the box failed in 44 minutes; in a second test, failure occurred in one hour.

The importance of humidity in relation to corrugated box strength cannot be over-emphasized. Simply, there is no way to predict, design, or bolster a corrugated box's stacking strength when conditions of 85% relative humidity are exceeded (let alone all the other reasons thus mentioned).

6. Shock

In 1969, Goff applied shock analysis theory to study corrugated boxes in terms of fragility (as defined by a damage boundary curve). In that study the effects of damaging shocks applied to corrugated board were investigated. "The effects of these shocks on the item on the opposite side of the corrugated board were found to be greatly amplified in most cases." He goes on to report that the first drop of a package will most likely result in alteration of flute structure and that subsequent shocks will be amplified when experienced by the object on the opposite side of the corrugated board. A copy of one table of results from that report is reproduced in Table 1. Once again, an ominous situation seems to be awaiting those products which are encased in corrugated.

7. Discussion

Strength characteristics of corrugated boxes cannot be reliably predicted due to inconsistencies in its manufacturing process, the near impossibility of ascertaining structural compromise from rough handling, and the fact that corrugated is highly susceptible to humidity conditions that are within its normal range of use. There is also mounting evidence that the use of corrugated board as a packaging material in the form of a container might actually be promoting product damage due to its shock and vibration profile. From the technical aspects thus considered, one must seriously question the reliability of corrugated shipping containers as a protective and economical way of distributing products.

Flute Size	Static Stress (psi)	Drop Ht. (in.)	Input			Response Acceleration (g)				
			Programmer	Acc. (g)	Vel. Change (ips)	1	2	3	4	5
C	0.52	9		380	112	1000	-	-	-	-
C	0.52	6		250	91.8	140	1400	2200	2400	2400
C	0.52	3		130	64.9	80	140	400	800	900
C	0.38	12		500	130	1500	-	-	-	-
C	0.38	9		380	112	280	2700	-	-	-
C	0.38	6		250	91.8	260	900	1900	2100	2700
C	0.38	3		130	64.9	100	150	300	750	1000
C	0.28	12		500	130	400	3600	-	-	-
C	0.28	9		380	112	300	1800	-	-	-
C	0.28	6		250	91.8	200	500	1600	2800	2800
C	0.28	3		120	64.9	105	140	150	155	160
C	0.13	12		420	130	700	1600	4000	5000	3800
C	0.13	9		370	112	320	440	580	450	720
C	0.13	6		250	91.8	320	340	360	390	400
C	0.13	3		140	64.9	140	140	140	140	140

Table 1

Response On C-Flute Board to Large Magnitude Shocks
Source: Goff, Technical Report No. 16, M.S.U., 1969.

CASE STUDY

This case study serves as an example of a packaging systems-minded approach in discerning cost savings available in switching from corrugated boxes to shrink-wrap packaging. The study entailed in-depth interviewing, observation, and data gathering conducted on the property of the firm. This study was necessary because data form and content serves as the most succinct manner of demonstrating real-life advantages accruable from limiting the usage of corrugated boxes when applicable.

1. Background

The company observed is a maker of a finely finished building component. At present, the product is packaged in a telescoping corrugated box. To protect the edges, several pieces of folded corrugated strips are used around the perimeter as "dunnage." The boxes must be stapled at the corners and on ends during the packing operation. When the packaged product is completed, two operators manually place the package on a pallet for delivery to the warehouse.

Only within the past year did this company hire a Packaging Specialist. Until that time the responsibilities involved with any packaging concern fell upon any industrial or mechanical engineer who was available. As is typical with many companies, the design of most of the corrugated containers used came from the corrugated supplier.

The product weighs approximately 250 pounds and its shape is flat and rectangular. Each package contains one product and there are three metal straps tightly banding the carton closed. These three steel bands are placed approximately equidistant from each other about the width of the package. The packaged product is supposed to be shipped while standing on edge. There are several cautions printed on the box announcing the fact that the package should not be lain flat. However, the author observed that at the end of the packaging line, all of these packaged products were, in fact, piled on top of each other in a flat position. Whether the packaged products will actually go through an entire distribution system on their edges, as specified, is not known.

The frames of the product are finely finished and painted wood. Since this building component is commonly used in new housing, the product is highly visible and the cosmetic appearance is important. The frames are manufactured precisely with close tolerances for two reasons. First, it is important to have a tight fit to form an effective barrier between the inside and outside of a home. Secondly, this particular company prides itself on producing a top quality product and wishes to garner the reputation of making a product which is first class in all respects.

2. The Problem

For the past several years product damage has been viewed as inevitable. There are two major problems with the current package. First, the package rubs paint off of the units.

This type of damage was readily reproduced in vibration testing on an electro-hydraulic shaker table. The natural frequency of the packaged unit fell in the range commonly observed in transportation systems, 2-20 Hz. It seems that it is next to impossible to secure the package tightly enough around the product so as not to have any rattle space. In fact, it was found that most of the damage was found at the points where the steel strapping surrounded the package. It was a Catch 22: the straps had to be tight so as not to allow rattling, but the tighter they got, the worse the marring. The corrugated board was found to be both the spring and the abrasive causing this problem. The second concern is that there is inadequate protection to the interlocker, that area where two units interact. The interlocker is a protruding edge running the length of the product and is recognized to be the most fragile part of the frame. From historical data of damage claims, it was felt that there was inadequate cushioning for the shock levels found in the distribution system.

At present, and for the past several years, it was common to have 20 percent of each shipment of this product physically marred by the time they were to be used. Many times this figure grew to 50 percent. Very often the damage was hidden by the corrugated box and would travel the length of the distribution system before being discovered at the job site. This situation proved to be both a financial drain and caused ill-will in customer relations.

3. The Proposed, Tested, and Accepted Solution

The most obvious aspect of the above situation is that much money and reputation could be saved as the result of a correct change in packaging. However, it was the more subtle aspects of the true costs incurred in using the current package that only the Packaging Specialist recognized.

It is proposed that the product be packaged in 3 mil shrink film using edge protectors to prevent damage to critical points on the product. The protectors are made of triple wall corrugated with the outer wall made of double A-flute medium. The double medium makes for an extremely stiff cushion, especially compared to the folded corrugated presently used. The shrink film will be applied by use of an automated film bundler system. The metal bands will no longer be needed. The shrink film causes an extremely tight package with a constant pressure around the perimeter of the product. There will be no more pressure points and rattle space will be eliminated. This is a result of the combination of a stiff cushion in conjunction with a very tight package of shrink-wrap. Through testing it was also found that the new edge protector gives an increased amount of shock prctection.

Over the past several months of test shipments, dramatic results were recorded. In terms of product damage, the 20 to 50 percent figure previously cited dropped to zero. At the same time, the material cost of the actual package dropped 66%. On top of this, the intangible yet extremely important fact that customer service will be greatly improved is a large plus. With the see-through shrink package, damage will be noticeable instantly. Distributors won't be storing and shipping damaged units, retailers won't be selling damaged products, and end consumers won't find hidden "surprises." But these are only some of the more obvious, and dramatic benefits of changing over to shrink film. There are a multitude of other benefits as well.

The proposed system change includes the purchase of a conveyor system on which the product is built by hand, inspected, and pre-packaged; an automated bundling system which will index finished panels through shrink film applicator, secondary seal bars, and shrink tunnel, and an automatic panel stacker and skid dispenser which will place the packaged panel on a flat skid for pick up by a warehouse fork truck. Besides the average material savings per unit of 66%, 3,000 manhours per year will be saved by not having to make cartons, wrap open stops, and manually place packages on flats. The investment required for the machines, equipment, facilities, and maintenance labor needed are expected to be fully offset by savings in materials and labor in less than one and a half years. Note, however, that this estimate was based upon current corrugated prices. As the author has pointed out, these prices are expected to increase greatly in the future. This would cause the payback period to decrease. The firm's expected and optimistic forecasts for internal rate of return is anywhere from 52 percent to 70 percent, depending upon the actual material and labor savings and the number of units packaged. A detailed account of the projected savings is given in Appendix A.

4. Other Improvements

There are a host of improvements that are noted, but considered "intangible." Although these might not be directly quantifiable, it is undeniable that efficiency and productivity will increase from the change. They include:

a. Reduction of support service labor. Presently material control labor is used for delivery of various cartons to the line on a sporadic basis. Though there are only two sized of this product, there are several variations, necessitating a unique carton for each (i.e. individual markings). With the advent of film packaging, delivery of material to the line for eight foot units will be once/month and 6'8" unit film once/ week. This also alludes to the fact that one roll of film takes up a fraction of the space needed for the same number of packages that pallet loads of corrugated necessitate. In fact, it is due to limited storage space at the production line that much support service is presently used.

b. The company's Packaging Specialist also considered warehouse and freight costs of bringing in the corrugated board. This consideration is within the true scope of a systems approach to using a packaging material. As stated above, rolls of film have two important space-saving advantages over corrugated. First, they represent vastly more packages to the foot of storage or transportation space (also, film will be lighter per package when shipped from the supplier, greatly reducing transportation charges). Secondly, the film is "generic;" it will cover all products of the same size. Film will let labels and the actual product describe what's in the package.

In this particular situation though, such savings could not be specifically calculated (the corrugated supplier included, in the price of the corrugated, shipping and storage costs, also). At present, all corrugated is stored in a warehouse across the street from this company. Therefore, the cost decrease for transportation and storage is included in the material costs of the corrugated.

c. The see-through aspect of film package will help prevent damage because people will be able to see where there is and isn't edge protection.

d. Less damage will result from the psychological aspect that workers will see they are handling a fragile product and treat it accordingly. When completely encased in corrugated, the product is thought of as being adequately protected and handling is not particularly important.

e. Attention will be called to the fact that primed metal surfaces need to be painted.

f. Inventory procedures at the distributor will be improved due to ability to see if a panel has muntins, what color it is, if it has a screen, if it is a joining panel, etc.

g. Help in alleviating mismarking of cartons on the line and its detection by the shipping department.

h. Reduction in packaging material waste disposal in both volume and trouble.

i. Elimination of staples reduces safety hazards when opening packages.

j. The product is kept much cleaner than when packaged in corrugated.

k. Film wrap is not affected by humidity.

l. Simplified inventory. It currently costs about $800/year to keep a part number on the computer. Several of these numbers which identify the boxes presently used will be eliminated for the two sizes of film needed.

If non-traditional accounting methods could be somehow employed to quantify the money saved from not having damaged products; from not sending mis-marked packages to customers;

for assuring the distributor that his/her inventories are correct for size, color, product, fittings, and etc. through visual check, and by identifying those sales not lost due to improved customer service, then surely the payback period would be greatly decreased and the Internal Rate of Return increased. In other words, the figures cited previously for these two criteria represent only the most easily identifiable savings.

5. Supporting Comments

The use of shrink film for packaging is not a new concept. In 1969, Goff[20] expounded upon the possible uses of shrink wrap packaging. "Products in containers of a regular form (folding cartons, paperboard or metal cans, etc.) would be particularly suitable for shrink wrapping. Products by themselves which are not extremely sensitive to surface damage or denting, and of regular shape, may also be candidates for shrink film and tray packaging." It is within that report that Goff demonstrated that shrink wrapping can eliminate at least part of the traditional corrugated box shipping container. He cites the example of using shrink wrap in conjunction with a corrugated tray to contain 12 cans of vegetables. The protective function was not decreased and the canned goods showed no significant increase in damage.

In a seperate study, the benefits of product visibility through shrink wrap are pointed out. A 1967 study on furniture, also done by Goff,[19] reports that "packages which allow a piece of furniture to be seen have been cited as reducing damage because the handler is psychologically more careful with something he can see is fragile. Many handlers feel that if a product is in a package, it is protected and can be thrown around or rough handled." However, he does go on to say that though major damage is reduced through this type of packaging, the occurrence of minor damage may be increased. This doesn't seem to apply to the author's case study, though.

Most surprising to this author is the amount of time that has passed since Goff's studies in the 1960's and the present with still little usage of shrink wrapping in America. Some light is cast on this question by a study completed by Business Communications Company.[35] "So far, corrugated boxes have lost only about two percent of their volume to shrink handling, despite materials cost savings of at least 40 percent. This is because the packaging, transportation, warehousing and retailing infrastructure hasn't been ready for a major shift. But, with corrugated prices rising and film prices declining, the BCC concludes that savings are greater than before and opportunities abound. It is projected that if stretch bundling proves itself in forthcoming testing--and the equipment and film are available--then corrugated-replacement bundling film could reach a 10 percent penetration level of corrugated shipping container volume by 1986."

6. Discussion

The case study presented demonstrates the all encompassing benefits of replacing corrugated with shrink film for a specific instance. The most important aspect of this case is the superior protection achieved with markedly reduced material costs. Until now, the level of product damage was outrageous. What's worse is that much of this damage was hidden--there was no apparent physical damage to the package. What must be realized when speaking of this type of damage is that it is not simply the cost of the product that is lost, but also the handling, storage, and distribution costs plus the cost of the lost sale. Along the same line of thought, LaLonde[29] tells of one company that discovered "a returned shipment for any reason cost eight times as much as the cost of shipping it to the customer." This is because distribution systems are designed for one-way travel. Obviously, if the products aren't damaged they won't have to be shipped back. Not only will shrink wrap decrease package costs and product damage, but it will also allow for viewing of the product at all stages of distribution. This is a great aide in identifying product damage soon after it occurs, wiping out additional costs incurred in owning and moving that product. It is this line of thinking that represents the essence of a systems approach to packaging.

CONCLUSIONS

The use of any packaging material should be viewed in the context of all aspects affecting its use. The author demonstrated that from a systems point of view (which includes procurement, materials, labor, freight, protection, and storage aspects), corrugated is an expensive and unreliable packaging material. Due to limited linerboard mill capacity lagging behind tremendous demand growth, supplies of corrugated will tighten and prices will rise dramatically. By the end of 1983, a seller's market will emerge for corrugated fibreboard.

Technical studies of corrugated fibreboard containers are conclusive: within the normal ranges of use, one cannot predict strength characteristics. The major negative factor in technical aspects of using corrugated boxes is humidity. Also, it has been shown that there is little consistency in quality of corrugated from one batch to the next.

The case study described depicts a systems approach in cost analyzing the changeover from using corrugated boxes to shrink wrap. In this situation, superior protection was obtained at a 66% reduction of material cost. Also, labor was greatly reduced. Several other factors also point to the superiority of see-through film as opposed to the traditional corrugated box for the product studied.

The author would advise that companies across America start considering alternatives to using corrugated boxes. Sheer economics in the ensuing months will persuade many to switch to the more economical shrink and stretch wrap technologies.

APPENDICES

APPENDIX A

INTERNAL RATE OF RETURN AND PAYBACK PERIOD CALCULATIONS

APPENDIX A

INTERNAL RATE OF RETURN AND PAYBACK PERIOD CALCULATIONS

Due to the wishes of the company under study, the company's name and product has been omitted. In the same vein, the following figures have been disguised in terms of values, but all ratios are true to those supplied by the firm. The payback period and the internal rate of return figures are exactly those which the company used in their changeover from corrugated to shrink wrap.

EXPECTED SAVINGS DATA

Assumptions:

A.) Corrugated prices for present box will remain at current levels.

B.) Film costs will be $.57 per pound for 3 mil film.

C.) Labor savings will be 3,000 hrs./yr/ for 1984 production levels.

D.) Average material savings per package is $1.72.

E.) Ratio of packages per unit is 1.92 due to a certain percentage of units being packaged together.

F.) 1983 forecast is for last 5 months after the system is installed.

	1983	1984	1985
# units	15,400	38,900	44,400
# packages	29,568	74,688	85,248
material savings	$ 50,866	$128,515	$146,679
labor hrs. saved	1,187	3,000	3,425
labor savings	$ 14,956	$ 37,800	$ 44,402

Continued

	1986	1987	1988
# units	47,000	44,200	41,500
# packages	90,240	84,864	79,680
material savings	$155,268	$146,022	$137,109
labor hrs. saved	3,625	3,410	3,200
labor savings	$ 45,676	$ 42,966	$ 40,320

ECONOMIC JUSTIFICATIONS FOR EXPECTED COST SAVINGS

	1983	1984	1985	1986	1987	1988
CASH OUTFLOWS						
Capitalized @ 100%						
Equipment	166.0					
Maintenance Installation	3.5					
TOTAL OUTFLOWS	169.5					
CASH INFLOWS						
Operating Labor Saving @ 54%		20.5	24.0	24.7	23.2	21.8
Material Savings @ 54%		69.4	79.2	83.8	78.8	74.0
Depreciation Tax Shield @ 46%		11.7	17.1	16.4	16.4	16.3
Investment Tax Credit		17.0				
TOTAL INFLOWS		118.6	120.3	124.9	118.4	112.1
NET CASH FLOW	(169.5)	118.6	120.3	124.9	118.4	112.1

INTERNAL RATE OF RETURN 52.1%   PAYBACK PERIOD 1.42 YEARS

OPTIMISTIC SAVINGS DATA

Assumptions:

Same as expected savings data with following exceptions:

A.) Film costs will be $.54 per pound for 3 mil film.

B.) Labor savings will be 4,000hrs./yr. for 1984 production levels.

C.) Average material savings will be $1.76 per package.

	1983	1984	1985
# units	15,400	38,900	44,400
# packages	29,568	74,688	85,248
material savings	$ 52,040	$131,450	$150,036
labor hrs. saved	1,583	4,000	4,565
labor savings	$ 19,945	$ 50,400	$ 57,519

Continued

	1986	1987	1988
# units	47,000	44,200	41,500
# packages	90,240	84,864	79,680
material savings	$158,822	$149,360	$140,237
labor hrs. saved	4,832	4,545	4,267
labor savings	$ 60,883	$ 57,267	$ 53,764

ECONOMIC JUSTIFICATIONS FOR PESSIMISTIC COST SAVINGS

	1983	1984	1985	1986	1987	1988
CASH OUTFLOWS						
Capitalized @ 100%						
Equipment	166.0					
Maintenance Installation	3.5					
TOTAL OUTFLOWS	169.5					
CASH INFLOWS						
Operating Labor Saving @ 54%		13.6	13.6	13.6	13.6	13.6
Material Savings @ 54%		57.3	57.3	57.3	57.3	57.3
Depreciation Tax Shield @ 46%		11.7	17.1	16.4	16.4	16.3
Investment Tax Credit		17.0				
TOTAL INFLOWS						
NET CASH FLOW	(169.5)	99.6	88.0	87.3	87.3	87.2

INTERNAL RATE OF RETURN 46.16%   PAYBACK PERIOD 1.8 YEARS

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