

THE DETERMINATION OF A DIMENSIONAL SPARE OUT
AREA FOR PACKAGE CLOSURE PLACEMENT

by

Gregory J. Kuhn

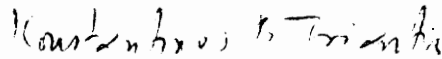
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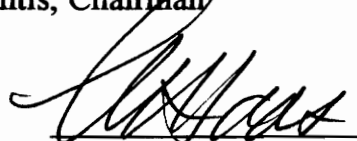
APPROVED:



Dr. K. P. Triantis, Chairman



B. S. Blanchard



Dr. T. W. Haas

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Dr. K. P. Triantis, Chairman
Department of Industrial and Systems Engineering

(ABSTRACT)

The purpose of this project and report is to determine a dimensional spare out area for the placement of the closure on packages. By investigating the variability in the closure placement on packages, a spare out area can be recommended so that the advertising design graphics are not covered during manufacturing. The closure is the strip of paper that holds together the top of the package. The spare out area is the length and width necessary for the placement of the closure on packages without covering the advertising design graphics.

Packages produced on three types of packaging equipment using two types of packaging labels from four manufacturing facilities are investigated. Labels are the paper into which the package is formed. When the labels are received from the suppliers, they may be either on a roll of 20,000, or individually cut.

Spreadsheets are developed to assess, evaluate, and determine the closure placement spare out area necessary to avoid covering the advertising design graphics. Statistical software is used in the analysis to determine if there are any differences in the closure placement. The recommended dimensions of the closure spare out area significantly reduce the probability of the closure touching or covering advertising design graphics during manufacturing.

The report also investigates the variability of the closure placement on a new product line extension that requires the closure to partially cover the advertising design graphics.

The spare out area proposed in this project and report has been recommended and was implemented on design graphics of new product lines. This spare out area is being changed on existing product lines as they are updated to meet domestic and international government regulations, cost reduction initiatives, and graphics changes recommended by marketing management.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

The initial presentation of a product to the customer is generally the product package. The quality and appeal of the packaging often influences the customer's decision concerning the purchase of a product. Therefore, extensive attention and expense are expended to ensure that the package is attractive and that the front, back, and side attributes and graphics are consistent with one another. The attributes of the package need to be symmetrical, with the same or similar qualities on the front and back and from side to side. These attributes include the colors advertising design graphics and their match where the package is folded and adhered along the side and top or bottom. Referring to Figures 1.1 and 1.2, one of the important attributes is the placement of the closure on the package. The closure is the strip of paper that holds together the package so that the top, bottom, or end attributes are visually apparent to the customer.

Objective

The objective of this project and report is to revise the current standard dimensional spare out area for the placement of the closure on packages to an area that takes into account all process variation. By determining only one closure spare out area and placing it on all new and revised graphics designs, the advertising design graphics will not be covered by the closure during manufacturing. The closure spare out area is the length and width dimensions

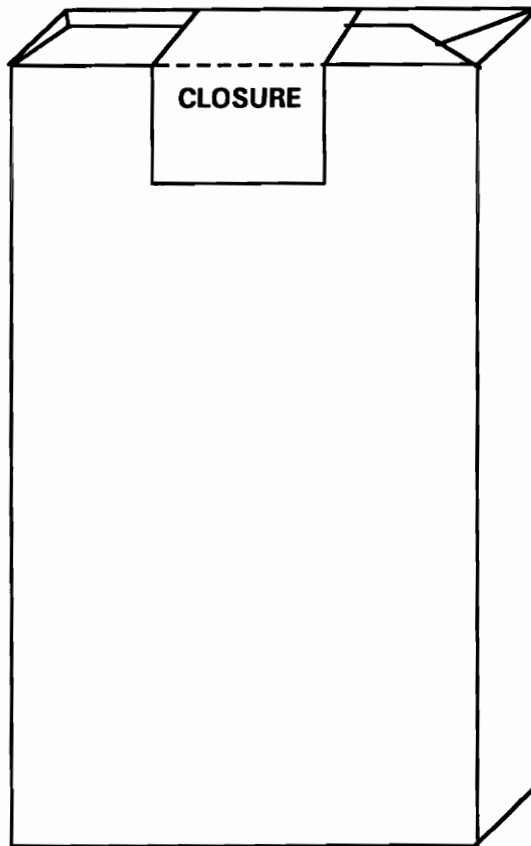
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Objective

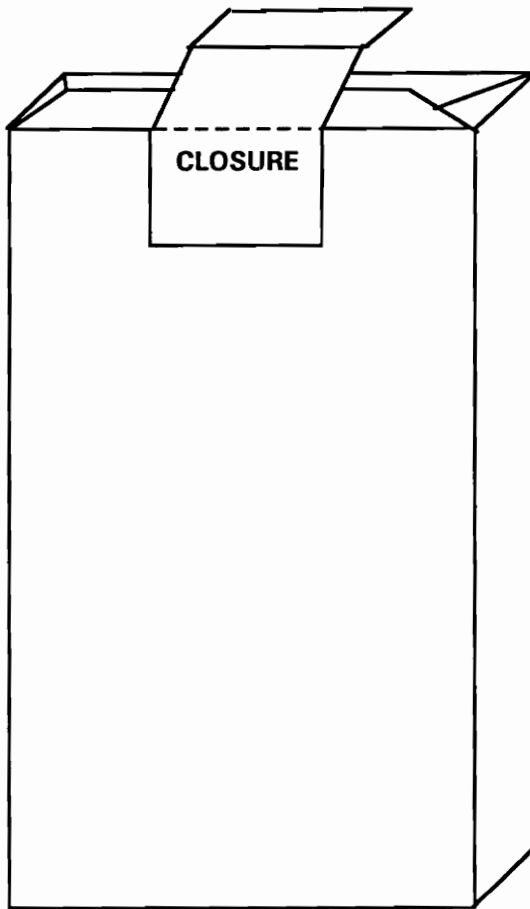
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FRONT OF PACKAGE

Closure Location and Position on Package

FIGURE 1.1



FRONT OF PACKAGE

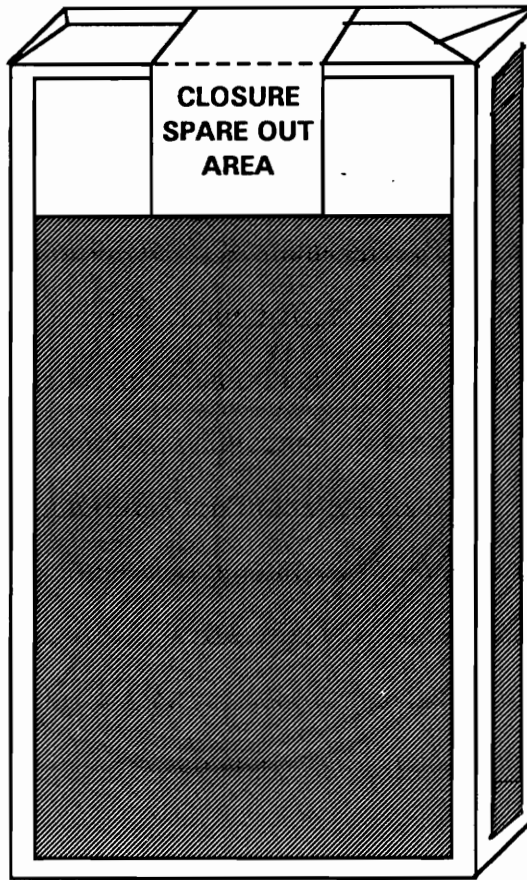
FIGURE 1.2

allotted for the closure to be placed on packages so that the advertising design graphics are not covered during manufacturing. The closure placement and orientation are dependent upon other variables, including the type of packaging equipment, the type of packaging label used, the thickness of the package, the length of the closure, and the speed of the packer.

Proper closure placement is critical because, if it is adhered to the package incorrectly, the advertising design graphics may not be visible to the customer as seen in Figure 1.3. Visual defects on packaging may inadvertently cause customers to assume that the product quality inside the package is poor also. Although the number of customer complaints is small due to the closure touching the advertising design graphics, the facilities' quality criteria states that this nonconformity is a critical defect and must be corrected. In order to adjust the packer to minimize the closure touching the advertising design graphics, the packer must be stopped and aligned leading to increased downtime. Depending upon the type of packer, type of label, and the product line being manufactured, this adjustment is difficult and time consuming. If there were a standard closure spare out area at a compromised length and width, both marketing and manufacturing would be satisfied.



ADVERTISING DESIGN GRAPHICS AREA



FRONT OF PACKAGE

**Package Closure Spare Out Area
Relative to Advertising Design Graphics**

FIGURE 1.3

History

The spare out dimension is the area on the package allotted to the placement of the closure as shown in Figure 1.3. This area was determined by stacking all worst possible tolerances from suppliers without considering the variation in the different capabilities of packaging equipment. As shown in Figure 1.2, since the closure is the last packaging material placed on the product prior to the final polypropylene film overwrap, the length and width dimensions of the closure present on the front and back of the finished product is determined by the overall variations in the production processes. The closure placement and location are dependent upon the variations in product size within the package and the supplier tolerances of print-to-print, print-to-cut, and cut-to-cut in the printing process. Also, the variations in the three different types of packers and packer speeds and the two types of labels are all accumulated in the finished product. Management requests the need for only one spare out length and width that encompasses all product lines, three types of packaging equipment, and two types of labels. This spare out area allows for the placement of the closure on packages without covering or touching the advertising design graphics.

In the past marketing has approved advertising design graphics much tighter than the previously agreed upon standard. Depending upon the product line, the packaging equipment could place the closure on packages without touching or covering the advertising design graphics. Over time marketing had moved the advertising design graphics farther up the label. As governmental regulations change concerning what information needs to be placed on the packages, the area for the advertising design graphics is reduced on the front

and back of the package. The dissonance between marketing and manufacturing concerning a more realistic spare out area for the placement of closures on packages is needed.

While manufacturing a package for a customer in the Asian-Pacific realm, the number of nonconforming packages became significantly higher than expected, causing increased amounts of downtime and rework costs. Upon investigation, the closure was touching the advertising design graphics. The distance from the top of the label to the highest graphic had been reduced for this product. After checking this dimension for other product lines, the standard spare out area had been violated. The spare out area is the length and width dimensions allotted for the closure to be placed on packages so that the advertising design graphics are not covered during manufacturing.

A study of this violation was initiated to satisfy this particular product. However, management decided to expand the investigation to include the manufacturing of all packaging product lines within the four manufacturing facilities produced on three types of packaging equipment using either roll or cut labels. Labels are the outside paper into which the package is formed; the advertising design graphics are printed on the label by suppliers. When they are received from the suppliers, the labels may be on a roll of 20,000 or individually cut so that they can be embossed to enhance a logo or trademark.

My part in this determination of one closure spare out area is to first interpret and assess the specific needs of both marketing and manufacturing. A compromise between eliminating the potential overlap of the advertising design graphics and increasing the advertising design graphics area beyond the manufacturing capabilities was decided. In this case, the manufacturing

capabilities are the actual dimensions needed for the placement of closures on packages. My investigation of the problem and input was a catalyst in the compromise to reduce the possible overlap from as high as 4.0% to approximately 0.006% nonconforming product. This compromise between marketing and manufacturing is the percent nonconforming beyond four standard deviations from the sample average.

My next logical step is to establish a plan to determine the number of sample packages and the sampling logistics necessary for this large reduction in percent nonconforming product. After completing the sampling plan and procedure, the sampling of packages was initiated and lasted for six months. The measurements of the product samples to determine the length and width necessary for one closure spare out area was done by a technician in the department. My responsibility is the analysis of the data which entailed determining the length and width dimensions and reentering the data into a spreadsheet software package. I compiled, evaluated, analyzed, and summarized the data to determine and recommend only one dimensional spare out area for the placement of closures on packages.

In summary, I assessed the current manufacturing capabilities of the products produced on the three types of packaging equipment which use the two types of labels that require closures on the packages. The length and width distributions of the closure placement are approximately normally distributed. However, the latest closure spare out length for the Asian-Pacific customer was beyond the capability of the particular type of packer. I determined the average length and width of the placement needed for the closure on the packages of consumer goods. The spare out area that I proposed is within the capabilities

of all three types of packers when using either roll or cut labels. My proposed spare out area for the placement of closures on packages was accepted and implemented by marketing.

I also analyzed the same data to determine a spare out area for a new product line which requires the closure to always touch the advertising design graphics. As above, my proposed spare out area for this particular product line also was acceptable to both marketing and manufacturing.

The System Engineering Process

The systems engineering process is a logical step-wise method of determining a solution to a problem. A systems engineering life cycle analysis of a subsystem of a process prescribes a number of steps, or stages, that are followed. These stages are the formulation and definition of the need, the planning of sampling procedures and collection, analysis of the collected data that quantify the need, and the interpretation of the results of the analysis. The objective must be explicit so that the outcome can be measured for effectiveness indicating how well the analysis is performed. [1] The systematic process followed in the pursuit of this objective enables management to make the best decision to successfully produce acceptable results that meet the customer's requirements.

This project and report represents the compilation of planning and organizing, sampling and analyzing, and presenting the results of an assessment of the closure placement variation. In determining this variation, the need for only one closure spare out area can be established so that the advertising design graphics are not covered during manufacturing. The advertising design graphics

are placed only up to but not within this closure spare out area. By not violating the prescribed spare out area, the number of nonconforming packages produced are reduced significantly. Also, the amount of rework associated with an inadequate spare out area which allows the advertising design graphics to be covered is reduced. The reduction in these costs enhances the profit margin of the company. This is the goal of system engineering: to create the requirement specification that enables the accomplishment of desired tasks that fulfill the needs of both the internal and external customers. [1]

The problem is the advertising design graphics being covered by the closure during manufacturing and the need is for only one closure spare out area at a realistic compromise between marketing and manufacturing. Next, the methodology of determining this spare out area is determined. Independent and random samples of packages are collected from the manufacturing process by following the procedures in the test plan. The packages are prepared for measurement on a coordinate measurement machine which is a manually operated precise measuring instrument.

The data are entered into a spreadsheet software package. The data is sorted by each of the three types of packaging equipment and two types of labels. The sorted data are imported into a statistical software package to determine averages and standard deviations per types of packer and label. The analysis also included plotting the frequency histograms and verifying their normalcy and testing the hypothesis that the closure placement lengths are equal. If they are not equal, the analysis will determine which packer and label combination has the largest spare out area for the placement of the closure on the packages so that the advertising design graphics are not covered during manufacturing.

The systems engineering process continued with the summarization and presentation of the results to various levels of both marketing and manufacturing management over a period of several months. The recommendation was accepted and the problem of the closure touching the advertising design graphics was resolved. After frequent follow ups, the initial problem was resolved and verified so that there is complete satisfaction between the marketing and manufacturing customers.

System Test and Evaluation [1]

Evaluation refers to the examination and judgment of an element of a system in terms of worth, quality of performance, degree of effectiveness, and the like. The purpose of evaluation is to determine the true characteristics of the elements of the system and to ensure successful fulfillment of the intended mission through a combination of measurement, analysis, and prediction.

When viewing test requirements, a true test is relevant from the stand point of assessing the element of the system performance and effectiveness. A true test constitutes the evaluation of the element deployed in an operational environment and subjected to actual use conditions. In such a situation, actual performance in a realistic environment can be recorded and subsequently evaluated to reflect a true representation of the system design.

Idealistically the desire is to wait until a system is fully operational before accomplishing an evaluation of an element of the system performance and effectiveness. However, this is not practical from the standpoint of allowing for possible corrective action. Accomplishing corrective action after the equipment is fully operational in the manufacturing environment can result

in costly and extensive modification programs. Although market-driven changes in any design after installation can not always be predicted, developing new equipment and new advertising design graphics for each product line developed also is costly. Thus a feasible overall test program allows for the evaluation of equipment, materials, software, and the support elements on an evolutionary basis. This enables changes in established and existing products and processes. [1]

In this project and report, the system is a subsystem of the packaging of consumer goods. The appropriate systems are existing and market-driven changes in the appearance of the advertising design graphics are needed. The problem is the changes in the advertising design graphics leads them to being touched or covered by the closure. The corrective action needed is the investigation of a new spare out area for the placement of closures on packages. The new closure spare out area will take into account all process variations that accumulate on the finished product.

An interdepartmental group must communicate a specific need to assure the proper integration with other elements in the system. For this project and report the closure is placed on the packages as in the past, but the amount of space allotted for the placement of the closure on packages will be improved.

Proceeding through the detailed test plan which included determining the appropriate sample size by assessing the current manufacturing process, I analyzed the collected data and determined a spare out area. This one and only spare out area encompasses current product lines, types of packers and types of labels. The recommended and accepted spare out area for the placement of closures on packages allows no more than .006% nonconforming product to

reach the customer. This percent nonconforming product is the accepted compromise between marketing and manufacturing that I recommended. The determination of the amount of this change is discussed in the analysis section of this report.

Statement of the Problem

As federal and foreign governments pass and implement packaging regulations concerning verbiage and placement of regulation warning notices on all packages, the marketing and manufacturing departments are seeking to find a compromise in the allowable area for the closure placement on packages. A dilemma arises from some international regulations which require these notices to be printed on the front or back of packages or both in the national language in addition to English. Currently, United States' regulations require that these notices be printed only on one of the sides of the package. If the regulation notice is placed on the front or back, the area available for advertising design graphics is reduced significantly. Also, as new products and product line extensions are introduced into the market, the packaging advertising graphics designers seek to maximize the front and back advertising areas.

As the advertising design graphics area is reduced in order to meet the regulations of foreign governments regarding warning notices, there is a propensity for the advertising graphics designers to move the design graphics upward on the package towards the closure. When this adjustment occurs, the advertising design graphics are moved into the established closure spare out area allotted only for the closure as seen in Figure 1.3. Often this action is approved by marketing management but is not always within the capabilities of the various

packaging equipment to place the closure on the package without interfering with the advertising design graphics.

Although having the closure touch or cover the advertising design graphics does not affect the quality of the product inside the package and is an infrequent customer complaint, the internal quality standards of manufacturing classify this issue as a critical defect. When this defect is observed during frequent audits, production is stopped until the overlap of the closure on the advertising design graphics is corrected. This dissonance between advertising graphics designers and production auditors creates problems for packer operators, mechanics, and first line supervisors. Although production personnel may realize that what they are asked to produce may not be within the capabilities of the equipment, production eventually continues even though there is a higher probability of this defective overlap. The packer downtime to correct the closure overlap of advertising design graphics is often in vain.

Typically, unless the potential for overlap is great, the probability of the auditor observing this type of nonconformity is relatively small. However, with the advent of on-line vision package inspection systems, the amount of nonconforming product audited definitely will increase. These systems will inspect 100% of finished products and, if programmed to the internal manufacturing auditing standards, will reject most of the packages that have the closure overlapping the advertising design graphics along with any other visual defects. The downtime and rework costs associated with this nonconformity could be eliminated by changing the dimensions of the spare out area so that the closure did not touch or interfere with the advertising design graphics.

Definition of the Need

A new dimensional specification for the closure spare out area on packages needs to be determined so that the placement of closures on packages does not touch or interfere with advertising design graphics, as seen in Figure 1.3. The purpose of this project and report is to determine the variability of the closure placement and set a better specification for the spare out area. I determine a new spare out area which takes into account all process variations. The spare out area is a length and width dimension into which the closure will be adhered during the manufacture of the packages. For example, the closure placement and location are dependent upon the print tolerances of the advertising design graphics on the package, the print-to-cut tolerances of the label manufacturer, the type of packaging equipment, the type of packaging label (roll or cut) used, the thickness of the package, and the speed of the packaging equipment.

There is a need to consolidate all of the variability of the three packaging equipment types and two kinds of labels in the placement of the closure on packages. The management objective is to have only one length and one width dimension. That is, I determined only one spare out area for the placement of closures on packages that will encompass all of the process variability. This consolidation of effort to determine only one spare out would facilitate the production of packages in a manufacturing environment of high speed packaging. This consolidation is necessary from both a marketing and purchasing perspective due to the printing logistics difficulties in keeping different spare out dimensions for each of the three packaging equipment and two label combinations for the hundreds of products and product line extensions currently being manufactured.

The spare out area is a length and width dimension into which the closure will be adhered during the manufacture of the package. The area needs to be large enough so the closure does not touch or interfere with the advertising design graphics and small enough so that the advertising designers have the most area available to place the advertising designs on the package. With respect to the mentioned various processes needed in order to create the package and product, an area allotted for the closure at the top of the package is determined by sampling product during manufacturing and measuring the area that the closure actually covers on either the front or back of the package.

Three different types of packaging equipment are used in the production of packages. To protect the confidentiality of the product, the packaging equipment types are described as packer types A, B, and C. The oldest packer is the type A packer. These have slower production speeds and through attrition are being replaced in production with type B and C packers. The design of both packer types has evolved over the years to be reliable and efficient at speeds of up to 500 packages per minute. Although there are a few type B packers in the newer manufacturing centers, the majority of the packages are produced on new and rebuilt high speed type C packers. The distribution of packers throughout the four manufacturing facilities is shown in Table 1.1.

Depending on the product line and the whether the label is embossed to enhance a logo or trademark, the packaging labels either can be cut individually at the suppliers or shipped in rolls of approximately 20,000 labels. The appearance of the labels are very similar. Each individual product line advertising design graphics of the label are identical whether the label is for type A, B, or C packers. The labels for type A packer can be cut or roll labels as shown in Figure 3.2. The

cut labels are rectangular in shape, and the roll label has the lower right hand corner removed during the packaging of the product. The type B packers can only package the roll type labels as shown in Figure 3.3. The cut and roll labels used on the type C packers are identical except for an eye-mark on the cut labels. The eye-mark is a small solid box which triggers a photocell on the packer to aid in the registration of the cut label at high speeds.

TABLE 1.1**Distribution of Packer Types in All Manufacturing Facilities**

Packer Type	Label Type	M/F 1	M/F 2	M/F 3	M/F 4	Total
A	Roll				4	4
A	Cut				2	2
B	Roll			15		15
C	Roll	13	15	9	5	42
C	Cut	10	7	6	4	27
Total		23	22	30	15	90

Costs Associated with the Incorrect Closure Spare Out Area

The costs due to the closure touching the advertising design graphics is two-fold. The downtime costs and the costs associated with rejecting, reclaiming, refeeding, and the salvage value of the product are delineated in Tables 1.2 and 1.3, respectively. The hours of downtime per year are determined by multiplying the percentage of downtime due to this particular nonconformity by the total scheduled runtime in a day, 22.5 hours. This product is multiplied by the appropriate number of packers as shown in Table 1.1. This total hours lost per day and the average packer speed, though it is conservative, is equal to the amount of production hours lost per day. Given the percent of scheduled utilization for these packers at the different manufacturing facilities (M/F), the total hours lost per year can be calculated. The percent scheduled utilization is the amount of runtime needed for production divided by the sum of this amount of runtime and downtime because of the closure touching the advertising design graphics.

The reject, reclaim, refeed, and salvage value costs are shown in Table 1.3. For accounting reasons the costs are based upon fifty packages. The sum of the losses of the consumable product, additives, direct materials, and the costs associated with converting the salvaged product into finished product may seem minimal. However, when these costs are made relative to the speeds of the packaging equipment and the net number of packages produced per day, the costs approach and exceed \$20,000 per year per facility.

An example from Table 1.3 may help in explaining these costs. From Table 1.4, the weighted percent defect rate from the closure touching or covering

advertising design graphics is 32/7295, or 0.0044. Packer speeds vary from 300 to 500 packages per minute (ppm). As shown in Table 1.2, for the first manufacturing facility (M/F 1):

- the packaging equipment has 73.6% utilization,
- production is for three shifts per day,
- packaging equipment speed of 340 ppm,
- there are 23 of the type C packers at M/F 1,
- the weighted defect rate is 0.44 percent,
- the price to reject, recycle, reclaim, refeed, and remake product is \$2.87 per 50 packages, as shown in Table 1.3,
- and on-line vision inspection systems are 77% efficient;

then the cost of this nonconformity would be approximately \$66 per day or approximately \$15,767 per year. The above utilization is a standard based upon BRAND 3 product. The efficiency is the runtime divided by the sum of the runtime plus downtime. Such costs could be avoided if this defect was eliminated by changing the dimensions of the spare out area so that the closure did not touch or interfere with the advertising design graphics.

As shown in Table 1.4, other products have defect rates of 4.00, 0.41, 0.27, and 0.19 percent. Table 1.4 shows the five highest rates of the closure position nonconformity during a three month period and compares these rates to the actual distance from the top of the label to the top of the highest advertising design graphic, logo, or trademark for that particular product. There is a correlation between this distance from the top of the label and the number of nonconforming packages. Therefore, by simply investigating the number of nonconformities to the distance between the highest advertising graphic and the

top of the label, the maximum closure spare out length would be no less than 0.506 inches. This minimum length of the closure spare out area would reduce the probability of the closure touching or covering advertising design graphics. At the present time there are no advertising graphic designs that extend up the left or right sides of the fronts or backs of the package. Since both the length and width of the closure placement were measured on the sample packages, a length and width of the closure spare out area is determined.

TABLE 1.2**Downtime Due to Closure Touching Advertising Design Graphics**

	M/F 1	M/F 2	M/F 3	M/F 4
Percent Downtime	1.4	1.1	1.3	1.5
Runtime/Day (Hr)	22.5	22.5	22.5	22.5
DT/Day/Packer	0.315	0.2475	0.2925	0.3375
Number of Packers	23	22	30	15
Hours Lost/Day	7.245	5.445	8.775	5.0625
Average Packer Speed	340	300	350	360
Production Lost/Day	2463.3	1633.5	3071.3	1822.5
Percent Utilization	73.6	75	48.3	72.7
Net Loss/Day	1813.0	1225.1	1483.4	1325.0
Days/Year	240	240	240	240
Net Loss/Year	435,117	294,030	356,019	317,990
Total Hours Loss/Year				1,403,156

- Downtime is based on I.E. studies during the six months of this evaluation.
- The number of packaging equipment is from Table 1.1.
- Utilization is based upon the standard for BRAND C product line
- Packer speeds are estimates and are considered conservative.

TABLE 1.3**Reject, Reclaim, Refeed, and Salvage Value Costs
of Packages per Manufacturing Facility**

	M/F 1	M/F 2	M/F3	M/F4
Consumable Goods:				
Loss	0.69	0.88	0.84	1.08
Salvage Value	-0.41	-0.13	-0.14	-0.16
Additives:				
C	0.12	0.02	0.13	0.04
T & A	0.55	0.66	0.67	0.59
Direct Materials Costs:				
Manufacturing	0.46	0.45	0.64	0.45
Packaging	0.2	0.22	0.6	0.16
Refeed (Conversion) Costs	1.26	1.07	2.73	1.58
Total Cost per Fifty Packs Rejected	\$2.87	\$3.17	\$5.47	\$3.74
Average Packer Speed/Min	340	300	350	360
Number of Packages Manufactured/Hr	20400	18000	21000	21600
Number of Packages Produced/Day	459,000	405,000	472,500	486,000
Percent Utilization (Table 1.2)	73.6	75	48.3	72.7
Net Number of Packages Produced/Day	337,824	303,750	228,218	353,322
Efficiency of Vision Systems	77	77	77	77
Net Number of Packages Produced/Day	260,124	233,888	175,727	272,058
Weighted Defect Rate (Table 1.4)	0.0044	0.0044	0.0044	0.0044
Net Number of Nonconforming Packages Produced/Day	1,145	1,029	773	1,197
Number of Fifty Packages/Day	22.9	20.6	15.5	23.9
Cost to Reject Fifty Packages/Day	\$66	\$65	\$85	\$90
Cost to Reject Fifty Packages/Year	\$15,767	\$15,659	\$20,301	\$21,490
Total Cost to Reject Fifty Packages/Year				\$73,217

TABLE 1.4

Comparing the Percent of Nonconforming Packages to
the Length to the Advertising Design Graphics

Brand	Defects per Number of Inspections	Percent of Nonconforming Packages	Distance from Top of Label to Advertising Graphics (Inches)
BRAND 1	4/100	4.00	0.488
BRAND 2	8/1518	0.53	0.445
BRAND 3	15/3688	0.41	0.453
BRAND 4	4/1457	0.27	0.440
BRAND 5	1/532	0.19	0.506

CHAPTER II

REVIEW OF THE LITERATURE

Marketing professionals, particularly those in areas of new products and product line development, emphasize the promotional and advertising aspects of a marketing plan and often overlook the remainder of the marketing plan such as packaging of the product. The manufacturing capabilities, with respect to the product, the package and packaging equipment, should be considered when developing the corporate management and marketing objectives. [4] Based upon the objectives of the management team, all components of the marketing plan should be developed to achieve a successful marketing program and maximization of profits. [4]

If products are marketed both domestically and internationally, packaging becomes a primary factor in the marketing plan. The package is the product-line advertising extension of the marketing plan to the point of sale of the product. The package should be attractive to the customer and designed to transport, protect, sell and resell the product. [5] The packaging promotes product identification and brand loyalty. In today's customer environment, if a minimal sales force is available to sell the products, the package should attract customers and communicate information about the product.

The package is not only an advertisement. [5] While the aesthetic appeal of a package is important, the package must protect the product during its distribution and product life at the lowest possible cost. To an extent, the package and the series of packaging containers, such as the carton, case, and

shipping container must be resistant to damage due to mishandling and extremes in environmental conditions. In addition, the package must communicate vital information to the customer, such as directions on how to use the product and ingredients, or warning of hazards as required by government agencies.

For the protection of consumers, most countries, including the United States, have regulations with which a manufacturer must comply before goods may be sold. [5] In the past, many foreign customers were eager to obtain goods produced in the U.S. regardless of the quality of the product or its packaging. Today, that attitude has changed. Foreign governments, especially Japan and others in the Pacific realm, have created specific laws and regulations to advise and protect their customers. Some governments require that product labeling information be printed on the package as well as on the containers in which the product is shipped. Therefore, in order to sell products in these countries, the manufacturers may have to redesign the package and its advertising design graphics to comply with these additional labeling requirements. For instance, the information must be printed in English and in the native language of the country in which it is being sold. Certain foreign countries require more printed information on the package than is required in the U.S. This creates an added burden on the marketing team in the design of the advertising graphics of the package and may significantly impact the final cost of the product to the customer. These factors must be taken into account during the development of the packaging concept, the pricing of the product, and the construction of the advertising campaign.

When increasing amounts of customer information are required on a package designed for sales in certain foreign countries, many companies use

labels or closures which can be moved or modified with some degree of flexibility while leaving the remainder of the package unchanged. Labels are made of sheet material, usually paper, printed and cut to a specified size. They can be die cut to any shape and embossed for special effects, and they may be applied to the package with hot melts or aqueous adhesives. [6] The closure is a sealing or covering device affixed to or on a container for the purpose of retaining the contents and preventing contamination of the contents within a package. [7] It may be part of a joint or seal formed in attaching two parts of the container or package. [7]

A closure is designed for its appearance and performance. Its appearance will depend upon its external shape, the material of which it is made, and the decoration required to achieve a particular effect or purpose. Its performance depends on how easily it can be applied and whether its usefulness extends through the entire product life. There are two primary types of closures utilized in the manufacturing of a paper material package. The "once only" closure has no re-closing capability. [8] It is inexpensive to produce and is designed for a single purpose package. The once only closure is used for non-durable goods which will be dispensed and used within a short period of time. It allows high speed packaging on conventional equipment. The second type of closure is adhesive sealing tape, which provides repeat closings, a speedy, clean, and efficient means of re-closing paper-wrapped merchandise. [8] This type is used for goods with longer shelf lives than goods with the once only closure.

Product packaging encompasses many activities within the marketing and manufacturing sectors of a company. Packaging designs are created by an agency or professional designer employed or contracted by the product manufacturer;

then the company usually moves the implementation of the design in-house. At this time proofs and transparent overlays of each design and color of the package are produced. These overlays are reviewed for detail and compliance to established manufacturing tolerances. It is at this point that the inter-relationship between the equipment and materials is recognized and adapted. The packaging machinists establish the tolerance ranges of their equipment, and the package material suppliers establish the tolerance ranges of the materials. The testing of these tolerances becomes a challenge because the packaging design often must be adapted to meet the external labeling requirements.

Overall, a package should protect the product, should meet informational requirements, and should attract existing and potential buyers. The packaging process must meet all regulations and also provide an attractive finished product to be used as a sales tool. The development, design and manufacture of a package requires well-trained professionals in marketing and manufacturing areas.

CHAPTER III

MEASUREMENT METHODOLOGY

This chapter describes the research method and experimental design, the population, sample, assumptions, instrument, procedure for data collection, and the sample size.

There are techniques to compare two or more populations in terms of their population means when the data scale is interval. Ironically, the statistical technique that tests and estimates the means analyzes the sample variances. For this reason the method is called the analysis of variance, often referred to as ANOVA testing. [3]

The experimental design is a determinant in identifying the appropriate statistical technique. When the samples are independently collected, an experiment has a completely randomized design. The problem addressed in this project and report is to determine a dimensional spare out area for the placement of closures on packages. The problem statement is to determine if there is a difference in the placement of closures on the packages due to type of packaging equipment or label type.

Population

The population of this study consists of all the packages produced in each of the four manufacturing facilities in three states as was shown in Table 1.1. Samples were produced on three different types of packaging equipment using either individually cut or roll labels. In order to reduce the logistics of sampling

each individual packer, final packaged samples were collected from the central auditing group. This group receives packages daily from each of the four manufacturing facilities. Inspectors on each shift in the four factories collect random samples from production throughout the shift. These samples then are sent to the central auditing group to compare products manufactured at the different facilities. This project and report examines all types of advertising product labels. The finished production package represents all possible supplier and packaging equipment variances.

Samples

Thirty packages [3] were randomly selected from the auditing group. When there is not any previous data concerning a process, thirty random and independent samples may be collected to estimate process parameters. The closure placement on these packages was measured to determine an estimate of the process average and standard deviation. Simple random sampling consists of selecting a group of packages in such a way that each of the packages has the same chance of being selected. From the average and standard deviation statistics, a sample size was determined to predict with 99% confidence that the tolerable error would be within 0.002 inches of all process variations. Since this project and report is concerned with the worst case of closure placement on or over advertising design graphics on either the front or back of the label, a one-tail normal distribution is used. The details of the sampling are explained in the following description of the procedure.

Assumptions

The assumptions for this project and report are:

- the population of closure placement is normal or approximately normally distributed [2]

- the samples from this population are independent and collected at random. (Independent means that the sampling of one sample does not affect the selection of another one. [3] Random sampling consists of selecting a group of packages in such a way that each sample has the same chance of being selected. [10])

- the packaging equipment is in control. In control refers to the fact that the special causes of variation have been removed from the process. [11] If the process is not in a state of statistical control, the future cannot be predicted from the past. [11]

Instrument

The Cambridge Opticheck 84Z [12] provides precise three-dimensional measurement which enables the Opticheck 84Z to accommodate a wide variety of components. (Appendix A) The 1X to 10X magnification lens of this instrument is an integral feature of the unit. The manually operated stage provides 8 inches of X axis and 4 inches of Y axis travel. The module includes a fiber optic ring illuminator to provide evenly reflected light, and Heidenhain encoders with direct inch or metric digital display for each axis. It provides simple yet precise operation. The ease of use, accuracy, and consistently reliable performance of the Opticheck 84Z makes it especially suited for the measurement of any material,

part, or component that might be distorted or damaged by conventional touch-probe metrology systems.

Procedure for Data Collection

The systematic procedure for the collection of packages and the determination of the closure spare out area are shown in Figure 3.1. After receiving packages as shown previously in Figure 1.1 from the central auditing group, the data about each of the sampled packages were transferred from the outside film to the individual label for traceability. These data consisted of the type of packaging equipment, the manufacturing facility, and the date and shift the package was produced. The closures of the samples were cut in half along the top of the package. Then the labels were opened and the product was removed without disrupting the closure placement, as shown in Figure 3.2. The labels were placed under a thin plate of glass and flattened to facilitate the taking of the measurements. The type of packaging equipment and label are determined from the individual packer identification number on the label and by the shape of the label as shown in Figures 3.3 through 3.5. The finished product with the label intact encompasses all the cumulative process variations and their effects on the front and back closure placement. Therefore, when the flattened label is measured using the Opticheck 84Z, the resulting measurements of the closure placement determine the length and width of the closure placement on each of the sampled packages. From these measurements, one length and one width are determined to define the recommended spare out area.

Using a LOTUS® spreadsheet, the four different dimensional lengths per label were segregated as front or back per packaging equipment type as seen in

Figure 3.6; measurements 5 through 8. These data were imported into a statistical software package and evaluated using box-and-whisker plots to determine if the closure was placed squarely on the package. The average length of closure per label was then determined. A length dimension for the closure spare out was calculated such that 99.994% or 4-sigma of closures are less than this length.

The measurement of the width dimension was determined from the packaging design specifications for each of the packaging equipment and label types. For example, the deviations from the theoretical center line of the closure position were added to or subtracted from the particular width dimension so that the side-to-side variation of the closure could be determined. (As seen in Figure 3.6; measurements 1, 2, 3 and 4) To calculate the dimensional closure width, this variation was added to the width of the closure.

Figure 3.6 shows the eight measurements that were made of each closure on the label in order to determine the closure placement on the packages. The left edge of the flattened label is the reference line for measurements 1 through 4; these measurements are from the left edge to each of the bottom four corners of the closure to determine the side-to-side variations and the recommended width of the closure spare out area. The top edge of the label is the reference line for measurements 5 through 8; these measurements from the top of the label to the bottom of each of the four closure corners are to determine the length of the closure spare out area on the labels. The measurements were made using a Cambridge Opticheck 84Z dimensional analysis instrument. As cited earlier, the Opticheck is a coordinate measuring machine (CMM) which is used for replication of precise measurements. [12] The measurements were initially made

in millimeters and the converted to inches after they were entered into the spreadsheet software.

These eight measurements of the initial thirty samples are shown in Table 3.2. Depending upon the packaging equipment type, the left half of the label could either be the front or back of the pack, as shown in Figures 3.3 through 3.5. Therefore, tracking and separating front and back closure measurements is possible.

Sample Size

To determine the number of observations to be included in the sample, the amount of information from the collected samples needs to be decided. If the sample size is too small, there will be an inadequate amount of information available to make a valid decision. However, if the sample is too large, time and talent are wasted. There are two considerations in choosing the appropriate sample size for estimating the process average using a confidence interval. The tolerable error, Δ , establishes the desired width of the confidence interval. The second consideration is the confidence level that should be selected. A confidence level of 99% is an extremely high level of certainty and equates to a constant value of 2.58 from the standard normal table. The tolerable error depends heavily on the context of the problem, and only the management team who is familiar with the situation can make a reasonable judgment about its magnitude. [3] The tolerable error in this project and report is .002 inches. (A worked out example is shown in Appendix D).

Table 3.3 summarizes the initial thirty sample lengths of the closure placement. The average and standard deviation from this table is used to

determine the total sample size for variable data. By using the desired tolerable error, confidence level and the inverse relationship between the sample size and the estimated standard deviation of the sampling distribution, the sample size can be determined. The sample size, n , was derived using Equation 1 [2,3]:

$$\Delta = (\text{constant}) * \left[\frac{(\hat{s})}{\sqrt{n}} \right] \quad \text{Equation 1}$$

where the constant for a 99% confidence level is 2.58 [3];

\hat{S} , the estimated standard deviation from Table 3.2, is 0.022 inches; and

Δ , DELTA, is the amount of tolerable error, which is decided to be

0.002 inches.

Solving for the sample size, n , yields:

$$n = \left[\frac{(\text{constant}) * (\hat{s})}{\Delta} \right]^2$$

The results after substituting the appropriate values and solving Equation 1 are:

$$n = \left[\frac{(2.58) * (0.022)}{0.002} \right]^2 = 805.42$$

From Equation 1, the resulting minimal sample size was determined to be 806 packages. The sample packages were collected over a six-month period.

PROCEDURE FOR DATA COLLECTION

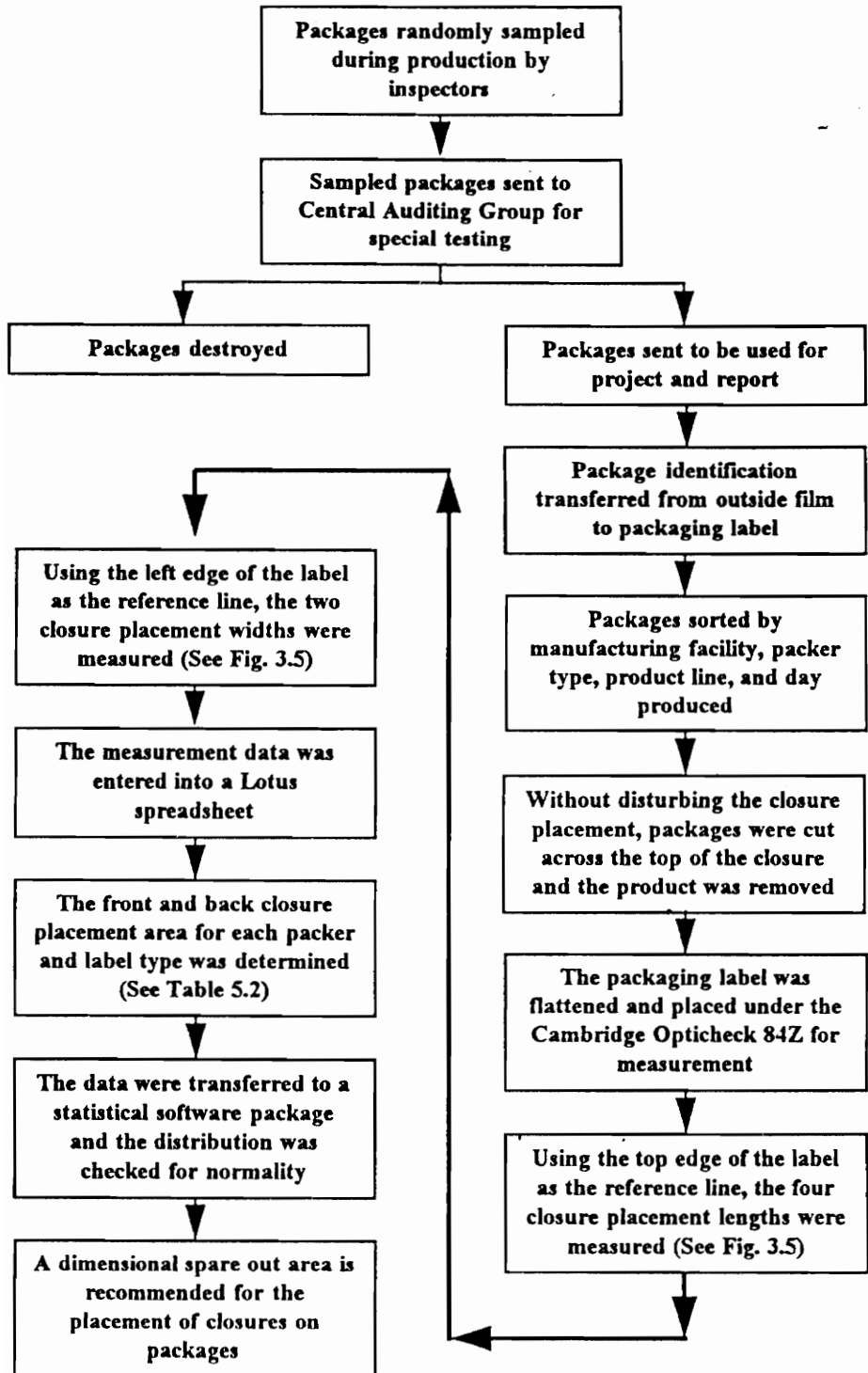
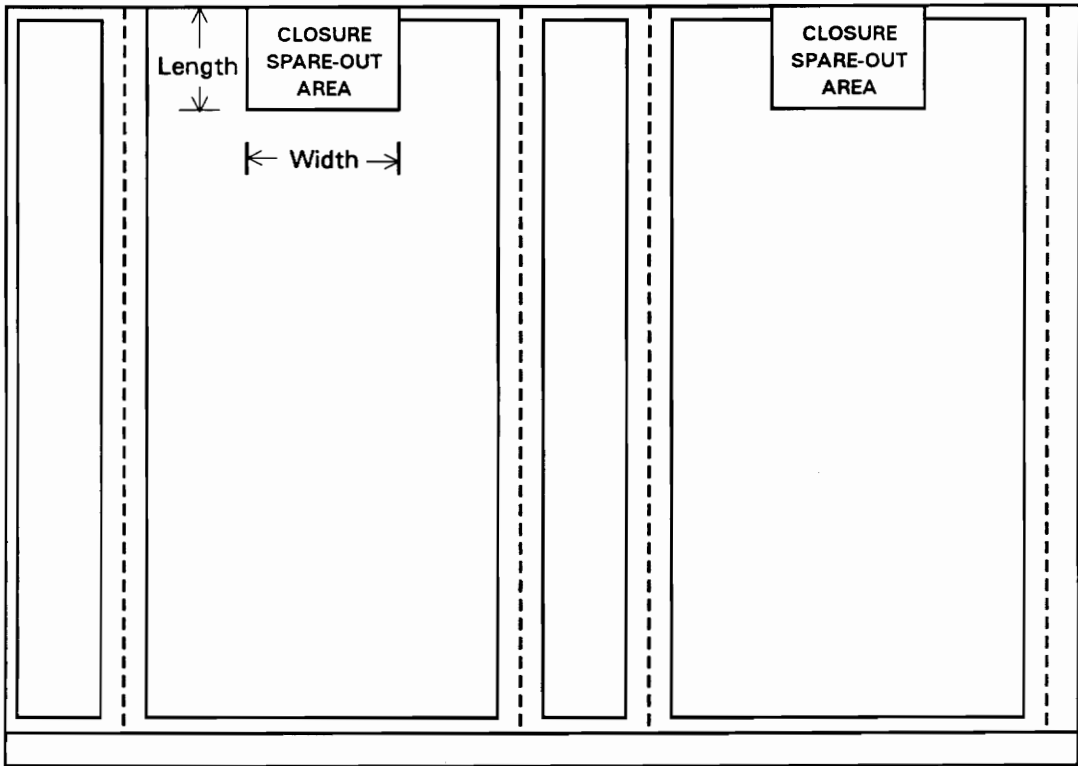



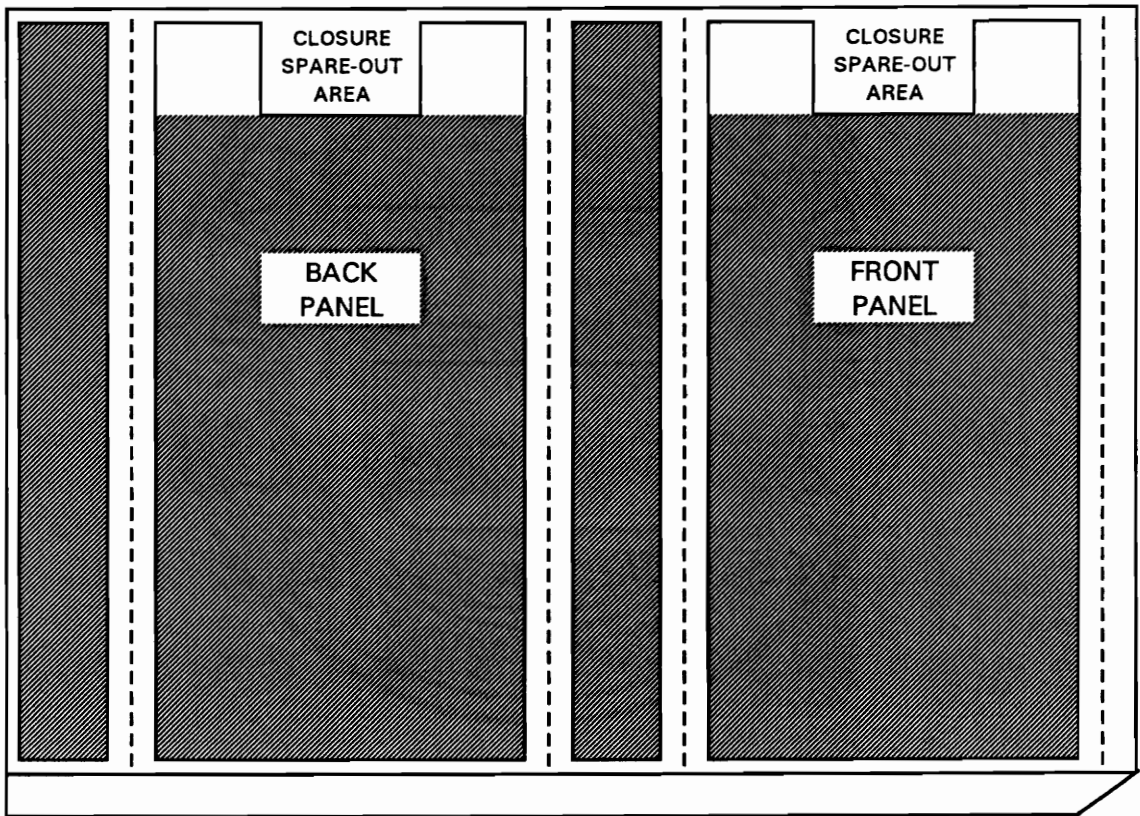
FIGURE 3.1



Typical Flattened Packaging Label

FIGURE 3.2

 ADVERTISING DESIGN GRAPHICS AREA
C CUT LABELS ARE SQUARE

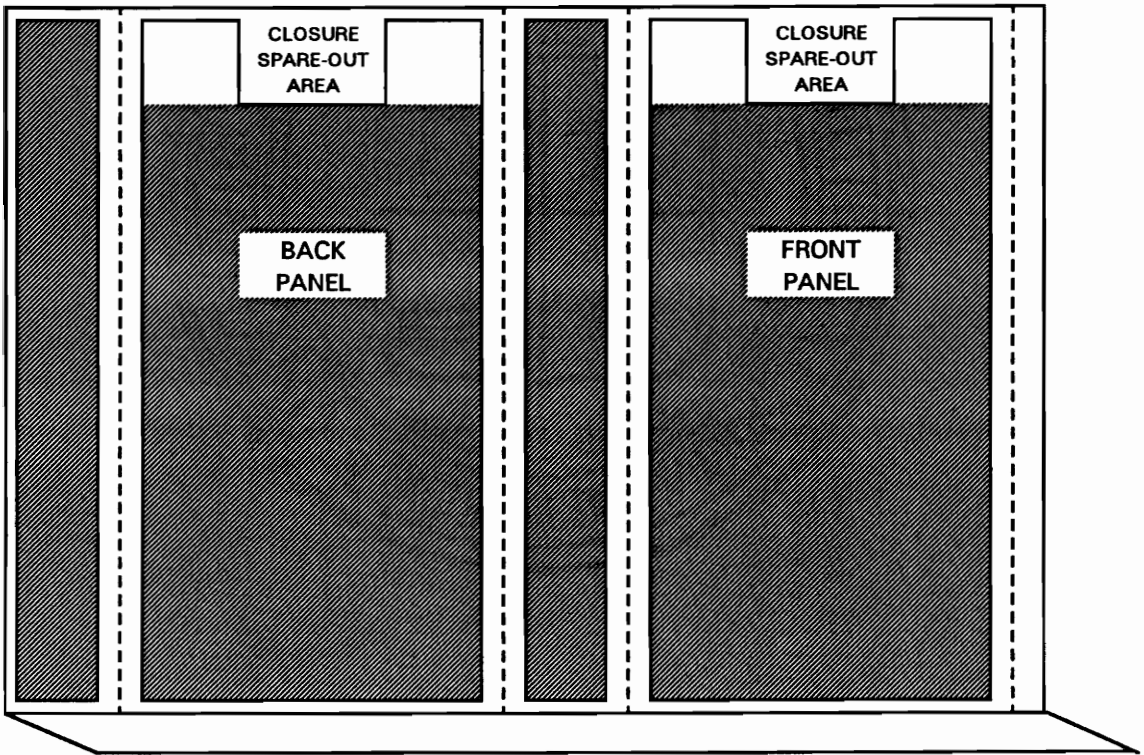


C

Type A Roll and Cut Label

FIGURE 3.3

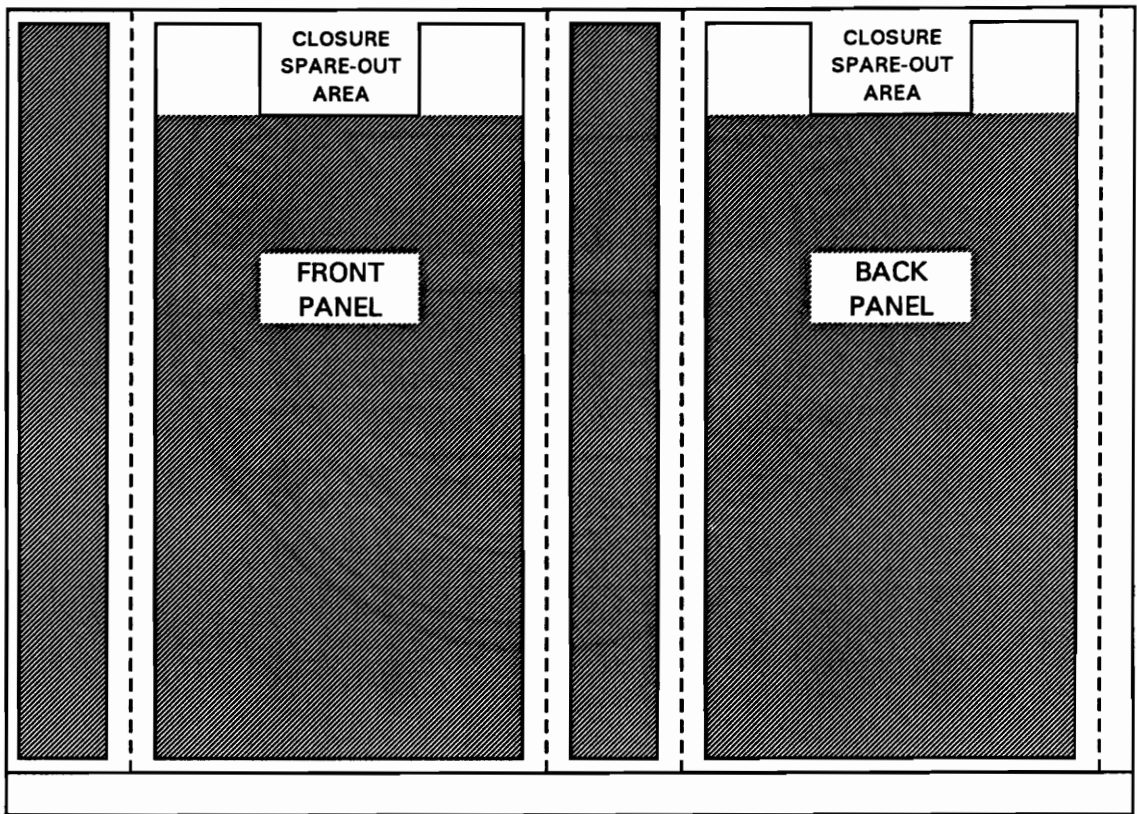
 ADVERTISING DESIGN GRAPHICS AREA



Type B Roll Label

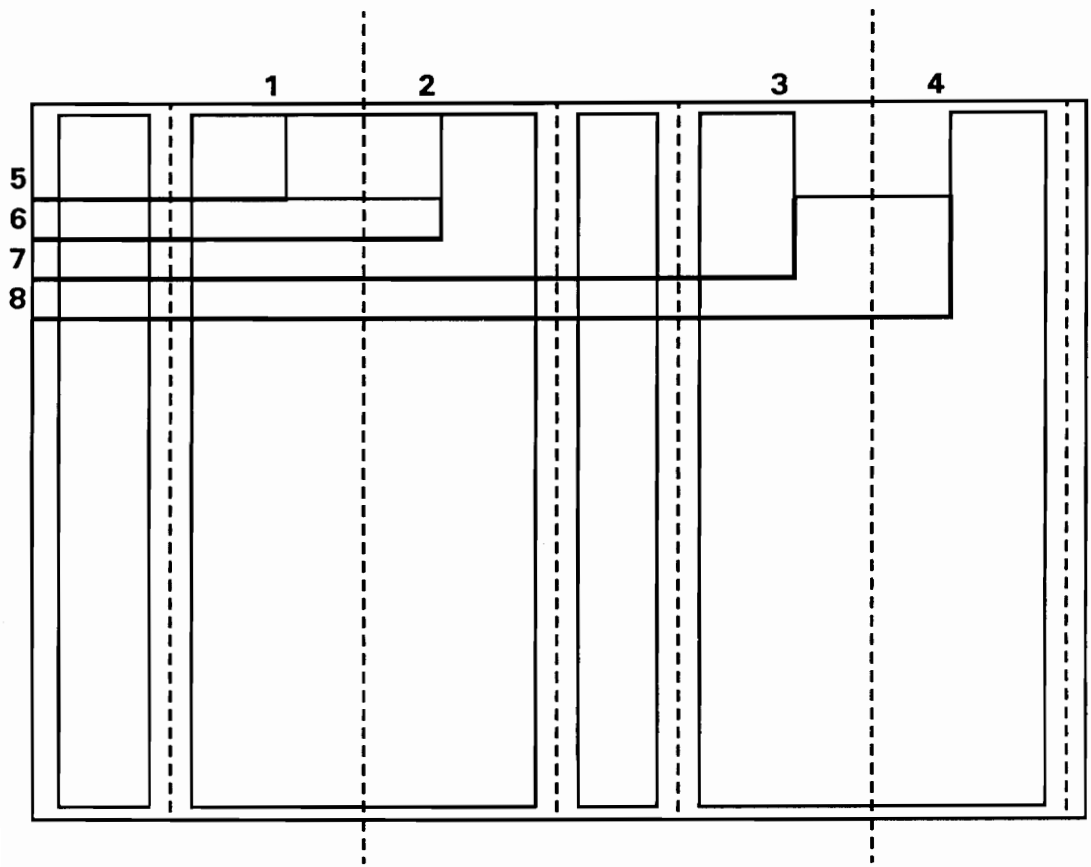
FIGURE 3.4

 ADVERTISING DESIGN GRAPHICS AREA



Type C Roll and Cut Label

FIGURE 3.5



1-4 Measured from left cut edge

5-8 Measured from top of label

----- THEORETICAL CENTERLINES OF THE CLOSURE PLACEMENT

Measurement Scheme

FIGURE 3.6

TABLE 3.1

Packer and
Label Type
Location

		Measurement Number							
		1	2	3	4	5	6	7	8
C TYPE ROLL M/C 1	1	36.061	55.169	109.359	128.459	10.197	10.320	10.216	11.231
	2	34.210	53.117	107.542	126.470	9.110	9.670	9.708	9.532
	3	34.680	53.579	107.847	126.827	9.915	10.519	9.458	9.693
	4	35.772	54.793	108.055	127.166	8.439	8.810	10.135	9.906
	5	36.195	55.275	108.378	127.508	8.848	8.964	10.013	10.372
	6	36.288	55.349	109.076	128.133	9.398	9.327	9.357	9.896
	7	36.221	55.414	107.992	127.057	10.409	10.332	9.365	9.560
	8	35.890	54.983	110.046	129.016	8.391	8.694	9.774	9.267
	9	36.308	55.428	110.080	129.005	9.396	9.560	9.093	10.204
	10	37.085	56.132	110.102	129.219	8.968	9.065	8.606	9.796
C TYPE ROLL M/C 2	11	37.093	56.149	109.946	129.097	9.098	9.052	9.735	9.288
	12	36.644	55.860	109.841	128.972	9.250	9.490	8.157	9.847
	13	37.127	56.130	109.012	128.050	9.324	8.888	9.842	9.070
	14	35.560	54.704	110.232	129.330	10.416	9.378	9.297	10.369
	15	35.721	54.809	109.554	128.646	9.724	9.074	9.366	9.191
	16	35.144	54.144	111.079	130.071	9.373	9.638	9.018	9.629
	17	35.544	54.657	111.770	130.827	8.899	8.210	10.625	9.844
	18	35.536	54.605	110.382	129.422	9.499	9.394	8.392	10.741
	19	34.790	53.885	110.072	129.017	10.541	10.149	9.764	9.324
	20	34.655	53.820	110.175	129.350	8.295	8.697	9.445	9.479
C TYPE ROLL M/C 3	21	36.445	55.604	110.377	129.591	9.867	9.396	9.165	10.076
	22	35.837	54.881	109.704	128.666	9.952	9.489	9.239	9.283
	23	36.891	55.969	108.374	127.494	9.952	8.940	9.941	9.511
	24	34.392	53.564	107.390	126.602	9.606	9.473	9.247	9.385
	25	35.561	54.609	109.686	128.685	8.978	8.539	9.037	9.464
	26	35.899	54.950	109.914	128.936	9.172	9.149	9.440	8.828
	27	34.927	53.947	110.306	129.361	8.574	8.813	9.408	9.257
	28	32.515	51.574	101.388	120.467	10.598	10.839	9.834	9.834
	29	33.227	52.207	100.609	119.676	11.891	12.189	10.845	10.053
	30	33.052	52.084	101.388	120.377	11.877	11.439	10.500	10.247

TABLE 3.2

Length Measurement of First Thirty Samples

Packer and Label Type Location	*	Measurement Number			
		5	6	7	8
C TYPE ROLL M/C 1	1	10.197	10.320	10.216	11.231
	2	9.110	9.670	9.708	9.532
	3	9.915	10.519	9.458	9.693
	4	8.439	8.810	10.135	9.906
	5	8.848	8.964	10.013	10.372
	6	9.398	9.327	9.357	9.896
	7	10.409	10.332	9.365	9.560
C TYPE ROLL M/C 2	8	8.391	8.694	9.774	9.267
	9	9.396	9.560	9.093	10.204
	10	8.968	9.065	8.606	9.796
	11	9.098	9.052	9.735	9.288
	12	9.250	9.490	8.157	9.847
	13	9.324	8.888	9.842	9.070
	14	10.416	9.378	9.297	10.369
	15	9.724	9.074	9.366	9.191
	16	9.373	9.638	9.018	9.629
	17	8.899	8.210	10.625	9.844
	18	9.499	9.394	8.392	10.741
	19	10.541	10.149	9.764	9.324
	20	8.295	8.697	9.445	9.479
C TYPE ROLL M/C 3	21	9.867	9.396	9.165	10.076
	22	9.952	9.489	9.239	9.283
	23	9.952	8.940	9.941	9.511
	24	9.606	9.473	9.247	9.385
	25	8.978	8.539	9.037	9.464
	26	9.172	9.149	9.440	8.828
	27	8.574	8.813	9.408	9.257
	28	10.598	10.839	9.834	9.834
	29	11.891	12.189	10.845	10.053
	30	11.877	11.439	10.500	10.247

average= 9.59711 MM 0.3794 INCH
 std. dev. 0.73317 MM 0.02224 INCH

CHAPTER IV

ANALYSIS OF THE DATA

The hypothesis for this project and report is that the placement of closures on packages from the three different packers is equal from package to package. To verify this research problem statement, the completely randomized experimental design was planned and executed as previously explained. The procedure is set up to ensure that the samples are random and independent. After the samples were collected and prepared for measurement, the closure placement was measured. The results were sorted by the type of packaging equipment and type of label. The average and standard deviation for the front and back measurements were determined.

The assumptions made for this analysis are that the sample was drawn from a population that was normally distributed. This will be checked later in this section. The second is that the samples are random and independent. This is verified in the detailed planned procedure that was followed during the collection of samples. The last assumption is that the process is in control. This was not validated because the control chart for each of the five sets of samples showed out of control points. This indicates that the past can not necessarily predict the future. However, by being conservative in allowing four standard deviations from the average instead of only three, the recommended spare out area for the closure is in line with the other continuous quality initiatives being implemented within the manufacturing facilities.

Hypothesis Testing

In almost all practical applications of statistics, decisions are made from inferences about populations based upon data from samples. In inferential statistics, a hypothesis must first be stated, and if it is rejected as stated, it is rejected with a level of significance or degree of confidence that represents the chance of its being correct or in error. [1] Any estimate that is based on a sample has some amount of sampling error. This is true even if the sample estimates are best estimates in the sense that they are unbiased of the population parameters.

A hypothesis is an assertion made about a population. Hypothesis testing is an area of statistical inference to validate this assertion and is carried out by the analysis of a sample of data. It is a procedure by which a hypothesis about some parameter of a population is either accepted or fails to be accepted. [2]

There are two reasons why sample results must be carefully evaluated. First, there are many other samples which, by chance alone, could be drawn from the population. Second, the numerical results in the sample actually selected can easily be compatible with several different hypotheses. These points are handled by recognizing the two types of sampling error. [3]

The two types of error associated with statistical inference are:

Type I error (α error): The maximum probability that a hypothesis that is actually true will fail to be accepted

Type II error (β error): The probability that a hypothesis that is actually false will be accepted.

These probabilities and their calculation as well as the development of operating characteristic curves are beyond the scope of this project and report. However, Juran [2] satisfactorily explains these topics.

Statistical inference generally involves four (4) essential steps:

1. Formulating a hypothesis about the population
2. Collecting a sample of observations from the population
3. Calculating statistics based on the sample
4. Either accepting or failing to accept the hypothesis based on the predetermined acceptance criteria.

In this project and report the hypothesis is the average lengths of the closure placement on three types of packaging equipment using two types of labels are equal. If they are equal, I will determine the one closure spare out length at the average plus four standard deviations of the average. This is the agreed upon compromise between marketing and manufacturing that allows no more than 0.006% nonconforming product. If they are not equal and the hypothesis fails to be accepted, then I will determine which packaging equipment and type of label results in the largest spare out area for the placement of closures on the packages. In this way, only one closure length that encompasses all process variation is determined. The corresponding closure placement width also can be determined so that only one closure spare out area is needed for any existing or new product line advertising design graphics. The objective of this project and report is to determine only one closure spare out area so that the advertising design graphics will not be covered by the closure during manufacturing.

Tests for Normality

Many statisticians' tests are based on the assumption that the population from which a sample is drawn is normally distributed. Therefore, it is wise to test this assumption of normality. In practice, a distribution is assumed by evaluating a sample of data. Goodness of fit tests evaluate any distribution assumption using quantitative criteria. [2] The test is applied to a sample of data to determine whether or not it is reasonable to assume that the sample was drawn from a normal population. Various procedures are available for making such a test.

If the sample is large enough to construct a histogram, a normal curve with the same mean and standard deviation as the given data can be plotted with the histogram to see how well the normal curve fits. This graphical method is a nonnumerical comparison and is probably not much good as a test of normality. A more commonly used method of testing normality is to employ a chi-square (χ^2) test of goodness of fit.

A χ^2 test compares a set of sample frequencies of a histogram with the theoretical frequencies that would be obtained by assuming that the population is normally distributed. If the two sets compare well, the hypothesis is accepted; if they do not compare well, the hypothesis is not accepted. This test is based upon the χ^2 distribution and can be used to test the fit of any frequency curve. The normal curve is 'fitted' by giving it the same mean and standard deviation as the sample histogram.

The χ^2 test of goodness of fit results are shown in Table 4.1. The critical value of χ^2 is 118.45 [3] for degrees of freedom greater than 100. The degrees of freedom is the sample size minus one. In this project and report the

sample size is 832 and the degrees of freedom is 831. The χ^2 test of goodness of fit for normality of the lengths is the top table and the bottom table is for the widths. In both cases the chi-square value is much less than the critical value. The chi-square value for the lengths is 8.84 and for the widths is 13.49. Both are less than the critical value of 118.45 and can be assumed to be approximately normally distributed.

Check for Equal Averages

To evaluate the hypothesis that the mean lengths are equal, the data was analyzed through a statistical software package. The sample size for the analysis of variance has to be equal for this particular software package. Comparing two or more means requires the F distribution. This comparison is accomplished through an analysis of variance (ANOVA) table. Therefore only the first eighty-three measurements of each type of package equipment and label type were evaluated. Eighty three is the number of samples collected for type A CUT labels. The ANOVA table is shown in Table 4.2. The F -ratio calculated is 7.914. The F critical or table value for $\alpha = 0.05$, with four and four hundred ten degrees of freedom is 2.37. [2] Since 7.914 is greater than 2.37, there is a difference in the measurement mean lengths, and thus they are not equal.

To know which of the means are different or if all of the means are different, the data is further analyzed using a multiple range test, a table of means, and a plot of the 95% confidence intervals of the factor means. The first two tables also are shown in Table 4.2. The latter plot is shown in Figure 4.1 From these series of analyses, type A CUT labels and B ROLL labels are

statistically different from the each other. The length averages of the other three are statistically the same; the hypothesis that A ROLL, C CUT, and C ROLL are equal is accepted.

The ANOVA table only analyzed the first eighty-three samples of each of the types of packaging equipment and labels. Individual *t* tests are necessary to verify the true means of all the data samples. The results of the analysis of variance and the *t* tests are compared in Table 4.3. The latter shows that type B ROLL is actually different from C CUT where this distinction is not available with only eighty-three measurements.

TABLE 4.1
Chi-square Test Results

Chi-square Test

	Lower Limit	Upper Limit	Observed Frequency	Expected Frequency	Chisquare
at or below		.3225	23	17	1.729270
	.3225	.3433	49	56	.920040
	.3433	.3642	128	137	.584899
	.3642	.3850	210	214	.061153
	.3850	.4058	237	213	2.633642
	.4058	.4267	136	136	.000914
	.4267	.4475	44	56	2.488650
above	.4475		20	17	.417183

Chisquare = 8.83575 with 5 d.f. Sig. level = 0.115798

Chi-square Test

	Lower Limit	Upper Limit	Observed Frequency	Expected Frequency	Chisquare
at or below		.6833	15	20	1.339
	.6833	.7100	50	62	2.435
	.7100	.7367	153	146	.316
	.7367	.7633	236	219	1.362
	.7633	.7900	231	209	2.368
	.7900	.8167	108	127	2.871
	.8167	.8433	38	49	2.608
above	.8433		16	14	.194

Chisquare = 13.4939 with 5 d.f. Sig. level = 0.0191647

TABLE 4.2

One-Way Analysis of Variance

Data: ARL.AVG,ACL.AVG,BRL.AVG,CRL.AVG,CCL.AVG

Level codes: ACL.LVLCODE

Labels: 5 9 RESHAPE'A ROLL A CUT B ROLL C ROLL C CUT '

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	.0115628	4	.0028907	7.914	.0000
Within groups	.1497515	410	.0003652		
Total (corrected)	.1613144	414			

Multiple range analysis for ARL.AVG,ACL.AVG,BRL.AVG,CRL.AVG,CCL.AVG by ACL.LVLCO

Method: 95 Percent Confidence Intervals

Level	Count	Average	Homogeneous Groups
A CUT	83	.3751325	*
A ROLL	83	.3823092	**
C CUT	83	.3832910	***
C ROL	83	.3872640	**
B ROLL	83	.3908505	*

Table of means for ARL.AVG,ACL.AVG,BRL.AVG,CRL.AVG,CCL.AVG by ACL.LVLCODE

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
A ROLL	83	.3823092	.0022125	.0020978	.3781846	.3864338
A CUT	83	.3751325	.0023460	.0020978	.3710079	.3792571
B ROLL	83	.3908505	.0019394	.0020978	.3867259	.3949751
C ROL	83	.3872640	.0020945	.0020978	.3831394	.3913886
C CUT	83	.3832910	.0018591	.0020978	.3791664	.3874156
Total	415	.3837694	.0009381	.0009381	.3819249	.3856140

PACKER AND LABEL TYPES
95% Confidence for Factor Means

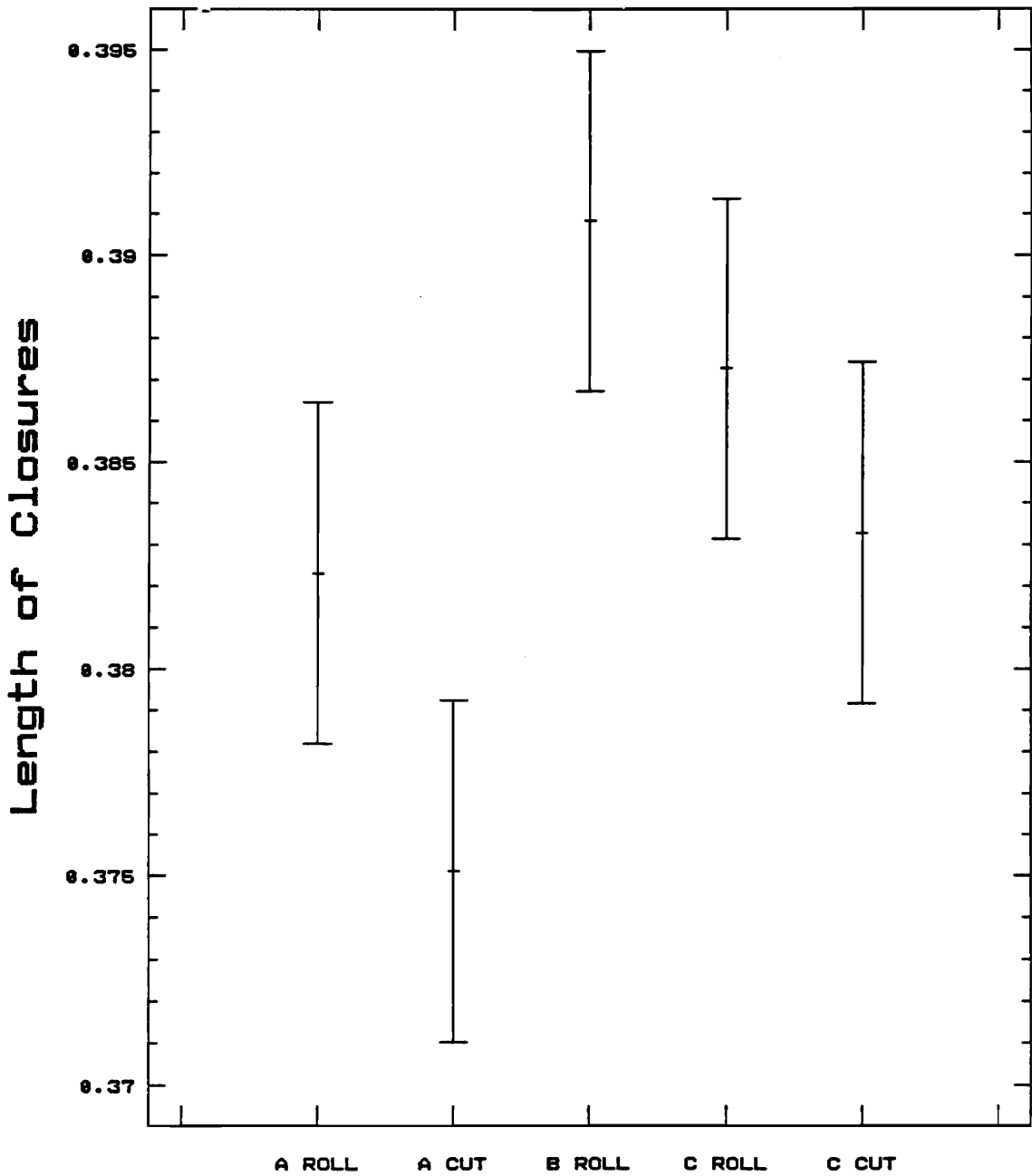


FIGURE 4.1

TABLE 4.3

**Analysis of Variance Table
Equivalent Sample Means**

	A ROLL	A CUT	B ROLL	C ROLL	C CUT
A ROLL		Yes	No	Yes	Yes
A CUT			No	No	Yes
B ROLL				Yes	Yes
C ROLL					Yes
C CUT					

**t Test Table
Equivalent Sample Means**

	A ROLL	A CUT	B ROLL	C ROLL	C CUT
A ROLL		Yes	No	Yes	Yes
A CUT			No	No	No
B ROLL				Yes	No
C ROLL					Yes
C CUT					

Variation is the difference among identically produced units of product. To determine the variation in this process, the concern is getting the measurement of the closure placement area. For this case only a lower specification limit is appropriate. The concern is the longest closure placement on either the front or back of the label. However, no matter how high an average is obtained, an excessive variation still can cause some closures to fall below the lower specification limit. Therefore, a compromise between manufacturing and marketing must be agreed upon as to how many possible defective packages per million (ppm) will be allowed to reach the customer. That compromise is to set the closure spare out length and width to the average value plus four times the standard deviation. As stated earlier, this reduces the possible percent nonconforming packages to approximately 0.006%. Since there are three packaging equipment types and two label types, the highest value of the five lengths and widths is the recommended closure spare out area because the objective is to achieve only one area dimension which encompasses all combinations.

Packaging the product with the established specification is necessary. Another requirement is customer satisfaction. In order to make sure these match, the data is analyzed to four standard deviations which encompasses 99.994% of the product. The specification limit set at a four sigma limit allows 63 packages per million unacceptable due to the closure touching the advertising design graphics.

CHAPTER V

RESULTS

This project and report focused on correcting the potential overlap of advertising design graphics by closures by evaluating the closure placement on packages. Figures 5.1 and 5.2 show the frequency histograms of the packaging process in the placement of the closure on packages. The closure placement lengths per front and back range from 0.350 to 0.490 inches. The range of the closure widths is 0.620 to over 0.900 inches.

The box-and-whisker plot in Figure 5.3 shows the spread of the data and that the closures are centered on the packages. The middle of the box, indicated by the horizontal line, is the median of the data; i.e., half of the measurements are above this line and half are below. The box contains the middle fifty percent of the data, and the whiskers go out to the last data point. Figure 5.3 shows that the type B packer roll labels have the highest median and type A packer roll labels have the greatest variability. This is shown by the box-and-whisker plot, labeled B ROLL, which is shifted up from the other four plots and whose median is highest compared to the other four plots. The variability in the box-and-whisker plots is shown by the amount of spread from the lowest data point to the highest data point; therefore type A packer with roll labels, labeled A ROLL, has the most variability.

The results of this project and report are summarized in Tables 5.1 and 5.2. The top half of Table 5.1 compares the combined total number of samples, n=832, widths and lengths measurements. The type A packer, as mentioned in

the procedure section, is being eliminated from production as newer or rebuilt versions of type B and C packers are brought into production. The bottom half of Table 5.1 compares the combined number of samples, n=615, front and back width measurements; and the front and back length measurements excluding both the type A packer roll and cut label samples. Information in Figure 5.3 compares the similar length data in Table 5.2; that is, for each packaging equipment and label type, the average and standard deviation of the width and length measurements are compared.

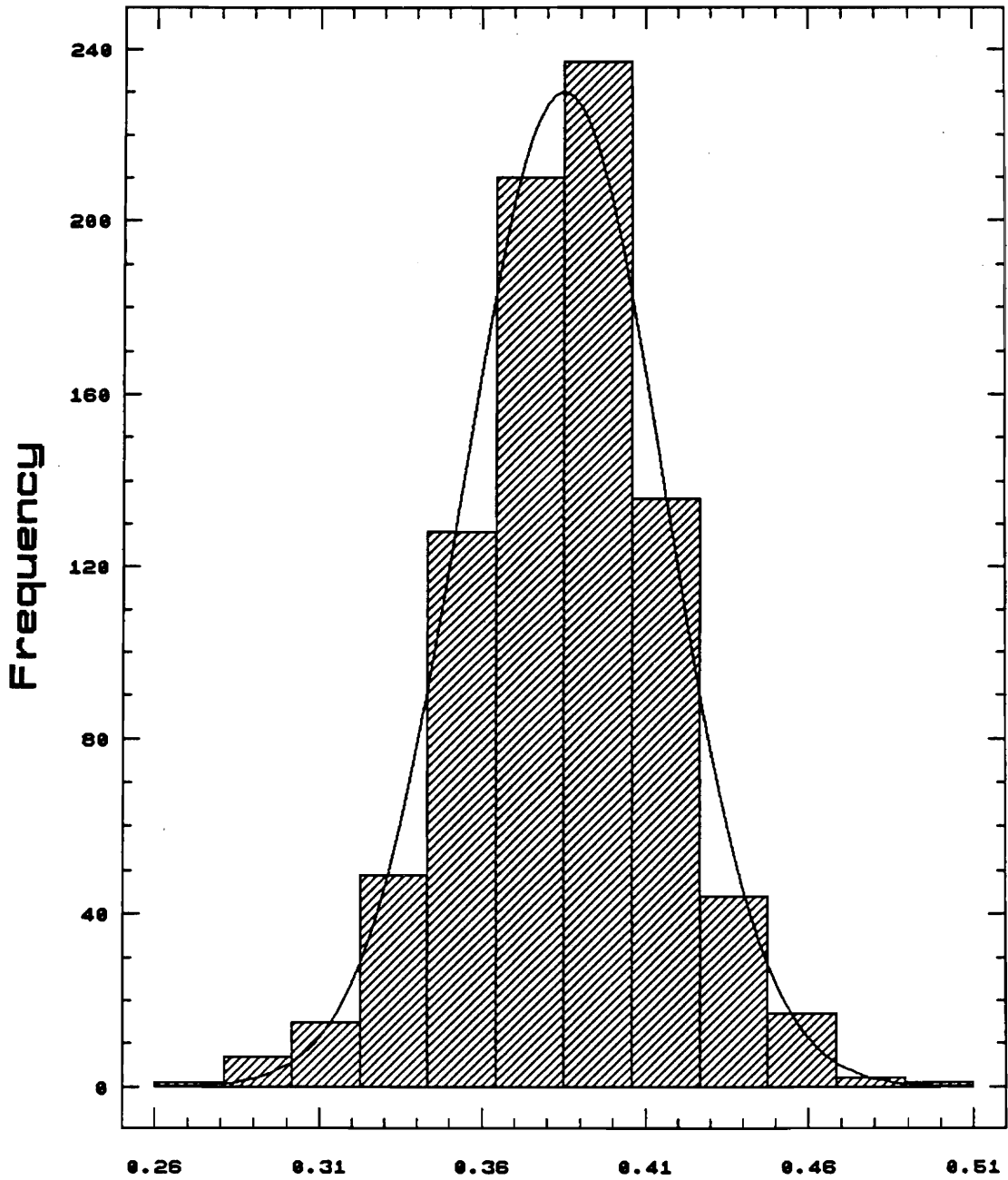
At the compromised distance of the average plus four standard deviations, type A packer roll labels have the widest and longest spare out dimensions necessary to encompass all three packer types and two label types. However, this packer type, due to its high processing variability, obsolescence of design and slower operating speeds, is gradually being phased out of the production environment. Therefore, these results are eliminated from the comparisons. The next combinations of averages plus four standard deviations to encompass the highest variability are types B and C packer roll labels. Type B packer has the highest variability in length, 0.5152 inches, and packer C roll labels have the most variability in width, 0.8770 inches. Again, in order not to have different closure spare out areas for each type of packaging equipment, label, or product line that are available, both marketing and manufacturing have agreed to have only one closure length and width that will encompass all combinations of packaging equipment, label or product lines.

As a comparison of results, the data in Appendix F are generated by sorting the widest and longest width and length closure placement dimensions of each of the 832 samples that were measured. The *average* and *standard deviation*

of these dimensions are evaluated at their 4-sigma limits. When comparing the actual average and standard deviation of the collected samples to the worst case ones, the type B packer roll labels have the highest variability in length on the front and back. Type C packer roll labels have the highest variability in width. In comparing Appendix F and Table 5.2, the resulting lengths are 0.513 inches for the former and 0.515 inches for the latter. The resulting widths are 0.888 and 0.877 inches, respectively. From the results of this project and report, all new and revised closure spare out areas are changed to 0.515 inches in length and .888 inches in width.

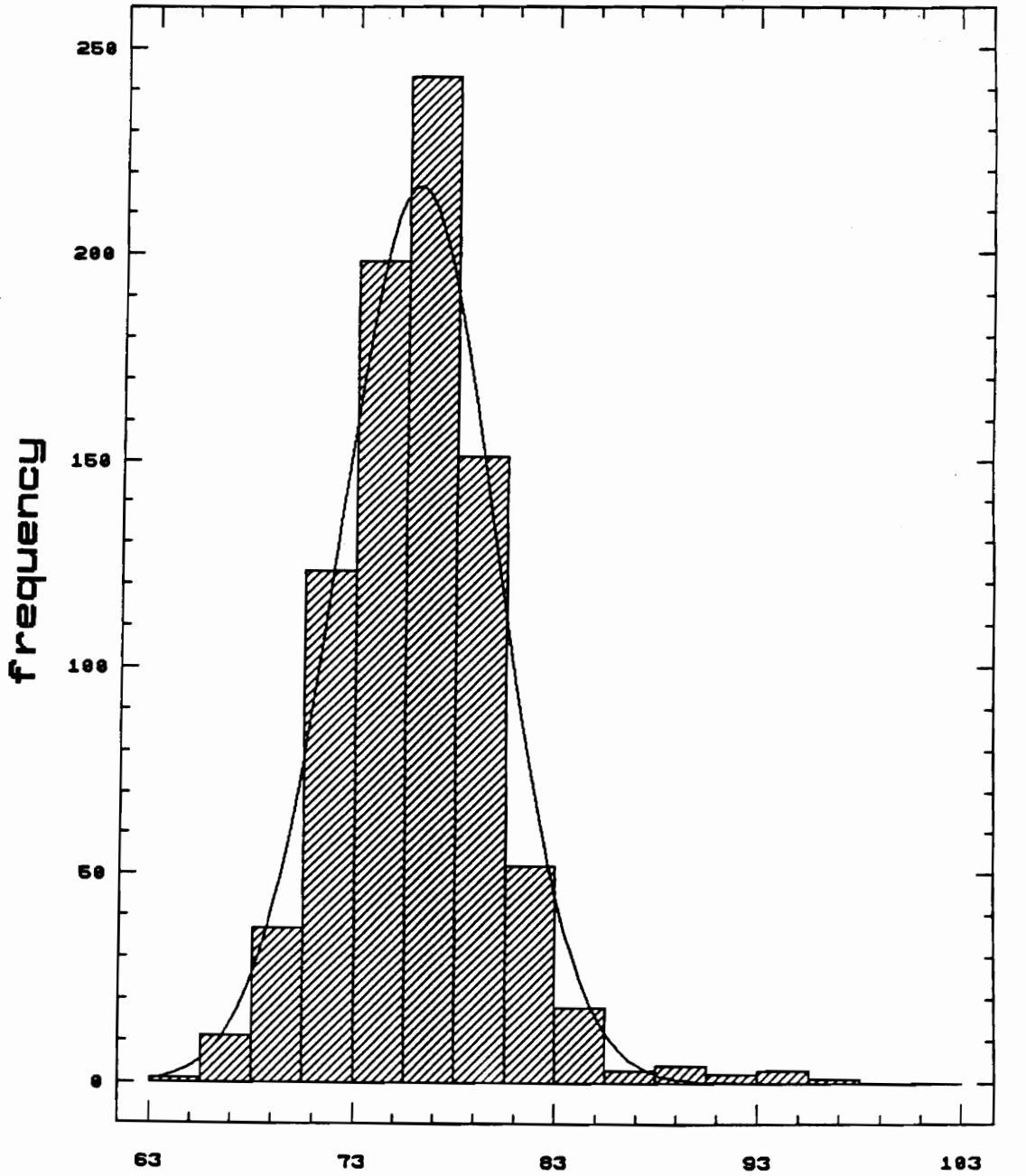
After collecting and analyzing these data, marketing decided that the resulting closure length limited their 'creative license'. (The term 'creative license' refers to the attitude of some marketing management that misrepresents the facts with experience.) Since a new product line extension was currently in development, the advertising design graphics team decided the new graphic would *always* touch the critical design graphics as shown in Figure 5.4. The data were analyzed to give the results of the highest and widest dimensions that the advertising design graphics could be moved up on the package without moving the graphics all the way up to the cut edge of the label, as this is where the original product line advertising design graphics is located. The results of this exercise are given in Appendix C. In this case, the closure always touches the artwork but the artwork does not go all the way to the cut edge of the label. From these results, a closure placement spare out area was implemented on the new advertising design graphics.

CLOSURE PLACEMENT LENGTHS Frequency Histogram



Lengths of Closures
FIGURE 5.1

CLOSURE PLACEMENT WIDTHS Frequency Histogram



Widths of Closures
FIGURE 5.2

(X 0.01)

PACKER AND LABEL TYPES

Multiple Box and Whisker Plots

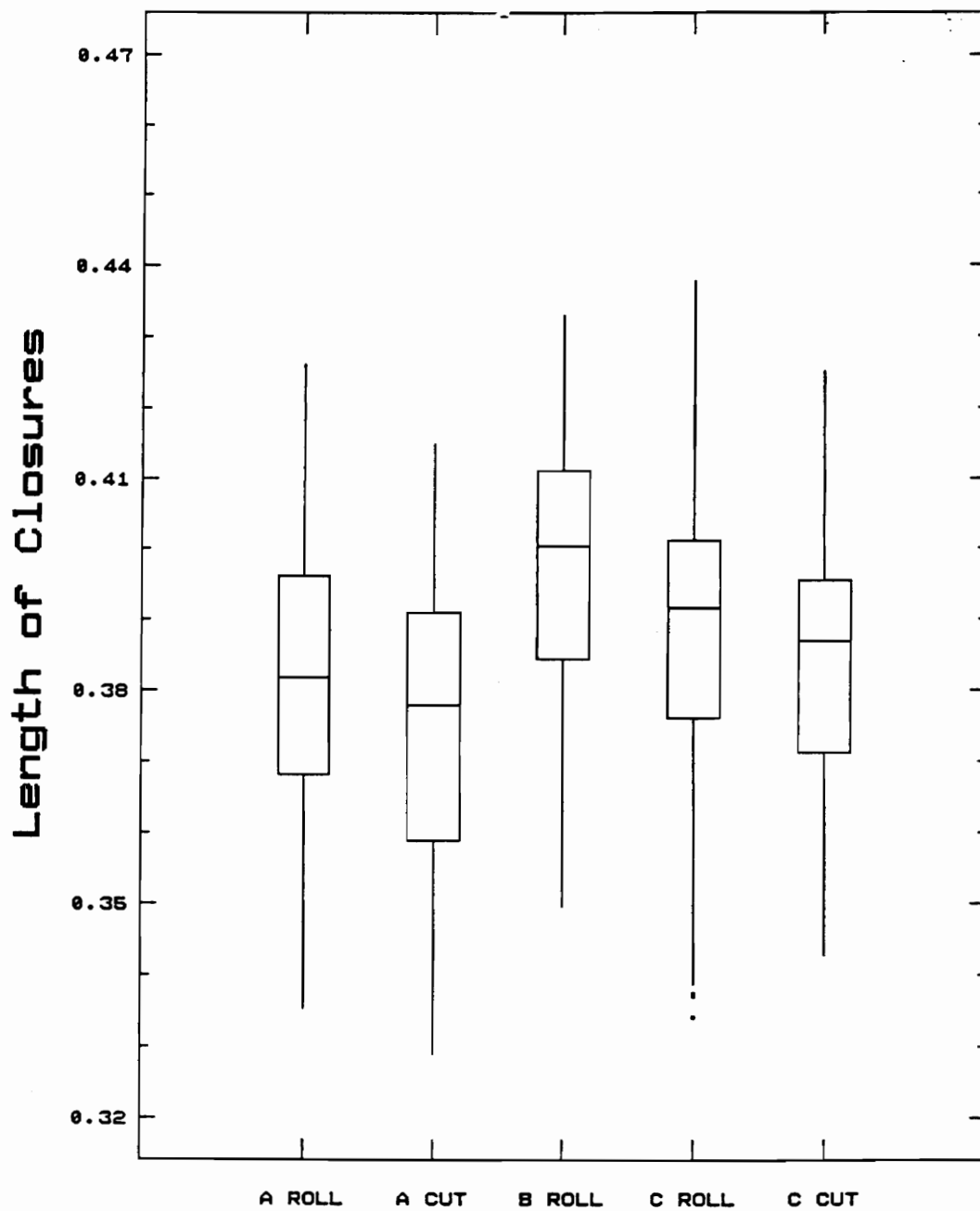


FIGURE 5.3

TABLE 5.1**Closure Placement Dimensions (in Inches)****Total Summary Data Summary**

	WIDTH (Side to Side)			LENGTH (Top to Bottom)		
	Back	Total	Front	Back	Total	Front
n=832						
Average =	0.7809	0.7797	0.7786	0.3920	0.3874	0.3829
Standard Deviation =	0.0228	0.0222	0.0215	0.0299	0.0303	0.0301
AVG. + 4(S.D.) =	0.8721	0.8685	0.8001	0.5116	0.5086	0.5033

Total Label Data Summary (Without Type A Packers)

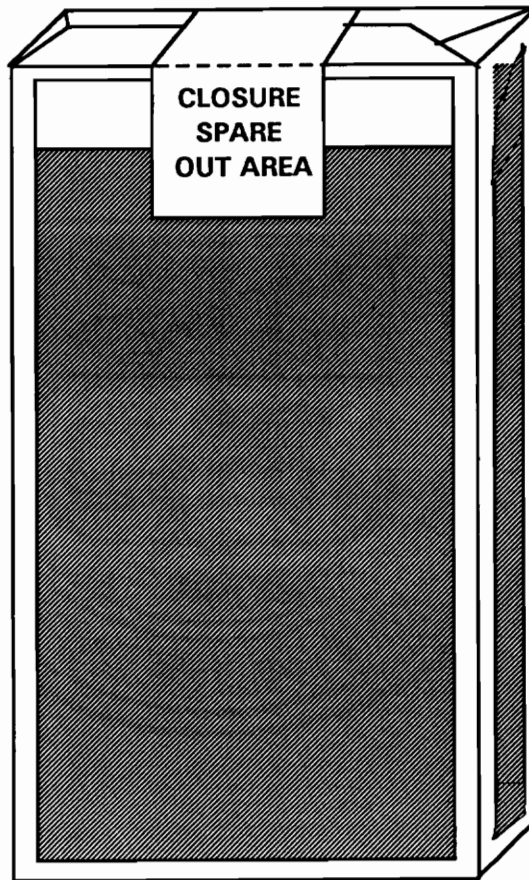
	Back	Total	Front	Back	Total	Front
n=615						
Average =	0.7787	0.7776	0.7766	0.3949	0.3902	0.3855
Standard Deviation =	0.0214	0.0210	0.0205	0.0278	0.0274	0.0263
AVG. + 4(S.D.) =	0.8643	0.8616	0.8586	0.5061	0.4998	0.4907

TABLE 5.2
Closure Placement Dimensions (in Inches)

	WIDTH (Side to Side)			LENGTH (Top to Bottom)		
	Type A Packer Roll Labels					
n=134	Back	Total	Front	Back	Total	Front
Average =	0.7840	0.7824	0.7809	0.3857	0.3823	0.3790
Standard Dev =	0.0264	0.0246	0.0225	0.0349	0.0374	0.0395
AVG + 4(S.D.)=	0.8896	0.8808	0.8709	0.5253	0.5319	0.5370
	Type A Packer Cut Labels					
n=83	Back	Total	Front	Back	Total	Front
Average =	0.7920	0.7906	0.7893	0.3800	0.3751	0.3703
Standard Dev =	0.0234	0.0236	0.0237	0.0313	0.0336	0.0352
AVG + 4(S.D.)=	0.8856	0.8850	0.8841	0.5052	0.5095	0.5111
	Type B Packer Roll Labels					
n=175	Back	Total	Front	Back	Total	Front
Average =	0.7746	0.7756	0.7767	0.3930	0.3984	0.3872
Standard Dev =	0.0179	0.0189	0.0198	0.0258	0.0289	0.0269
AVG + 4(S.D.)=	0.8462	0.8512	0.8563	0.4962	0.5140	0.4948
	Type C Packer Roll Labels					
n=321	Back	Total	Front	Back	Total	Front
Average =	0.7822	0.7802	0.7781	0.3896	0.3880	0.3864
Standard Dev =	0.0237	0.0228	0.0217	0.0266	0.0265	0.0264
AVG + 4(S.D.)=	0.8770	0.8714	0.8649	0.4960	0.4940	0.4920
	Type C Packer Cut Labels					
n=119	Back		Front	Back	Total	Front
Average =	0.7749	0.7736	0.7722	0.3876	0.3840	0.3804
Standard Dev =	0.0169	0.0170	0.0170	0.0247	0.0246	0.0239
AVG + 4(S.D.)=	0.8425	0.8416	0.8402	0.4864	0.4824	0.4760



ADVERTISING DESIGN GRAPHICS AREA



FRONT OF PACKAGE

**NEW PRODUCT LINE ADVERTISING
DESIGN GRAPHICS LABEL**

FIGURE 5.4

CHAPTER VI

CONCLUSION

As stated throughout this project and report, the objectives are to determine: (a) a dimensional area for the placement of the closure on packages so that the advertising design graphics are not covered during manufacturing and (b) a distance for a new product line graphics so that the closure always touches the advertising design graphics. Based upon this project and report, the closure spare out length and width dimensions have been changed to 0.515 and 0.888 inches, respectively. This revised closure spare out area is placed on all new advertising design graphics and grandfathered graphics as they are updated because of graphics changes, new product line introductions or cost savings initiatives. This new spare out area prevents the closures from interfering with packaging advertising design graphics when placed on packages during manufacturing. The recommended distance so that the closure always is touching the advertising design graphics is 0.272 inches in length.

These objectives have been met, and both marketing and manufacturing are pleased with the modifications, which entailed moving the advertising design graphics by 0.027 of an inch in length. Since the change, there have been no internal complaints of closures interfering on advertising design graphics. On the new product line where the distance between the top of the label and the graphics also was modified, there have been no complaints. The results have met the objectives and eliminated the dissonance between marketing and manufacturing.

CHAPTER VII

RECOMMENDATIONS

This project and report focused on correcting the potential overlap of advertising design graphics by closures by evaluating the closure placement on packages. Future consideration to correct this potential problem include: (a) designing a packer that adheres the closure on the inside instead of the outside of the label, (b) developing clear or transparent closures, or (c) developing shorter closures that still could hold the packaging label together but would not interfere with advertising design graphics. An easy and quick alternative to this dilemma is to change the internal quality criteria since very few, if any, customers have complained about this nonconformity. The logic of the vision systems could be changed or modified so that only extreme occurrences of this overlap are rejected from production. A final suggestion of future work to solve the problem of the closures touching or interfering with advertising design graphics on packages is to design an all-in-one label that does not need a closure to hold the package together, and therefore, eliminate the potential of this nonconformity altogether.

While this project has focused exclusively on package closures, there are other industries and products that could benefit from this study and information. For instance, using a similar methodology, a plan of study could be implemented by clearing houses and periodical publishers to prevent the name and address labels on the covers of magazines or the pricing labels on books from covering or interfering with the 'tease' on the covers intended to attract customers. Any product with external closure or labeling requirements may utilize this type of information to improve the packaging of their product.

APPENDICES

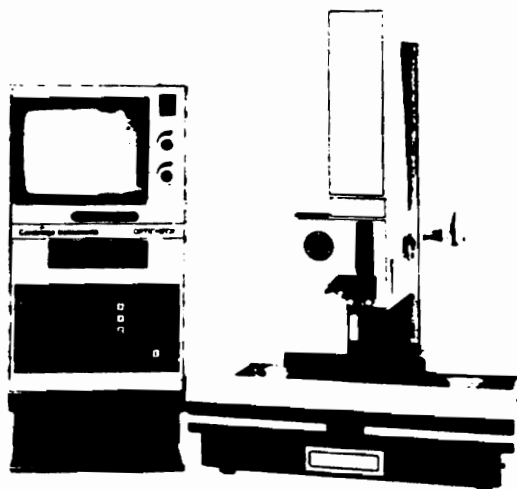
APPENDIX A

**Cambridge
Instruments**

New System Bulletin!

OPTICHECK 84Z

Non-Contact Optical 3 Axis Measuring System



The Opticheck 84Z provides precise 3-dimensional measurement of a wide variety of components. For maximum stability, the bench-top Opticheck 84Z is engineered with a solid cast base and a polished Granite work table.

A manually operated stage provides users with 8" of X axis and 4" of Y axis travel. Optics are mounted on a precision engineered Z column with 8" of travel for Z axis measurement. A 1X to 10X zoom enables the Opticheck 84Z to easily accommodate a wide range of part or component sizes. A fiber optic ring illuminator provides evenly reflected light; an attachable transmitted light illuminator is available as an option.

The image is clearly displayed on a 9" Black-and-White monitor mounted in the master electronics module. The module also incorporates a programmable elec-

tronic line generator with push-button controls. Heidenhain encoders with direct inch/metric digital display for each axis, an incremental/absolute counter, and an RS232 computer interface port. The Opticheck 84Z provides simple yet precise operation. Minimal operator training is needed.

When interfaced with an IBM/PC XT (or compatible) computer, the Opticheck 84Z provides full geometric measurement capability. Statistical Process Control software is available as an option.

The Opticheck 84Z's unmatched accuracy and consistently reliable performance makes it especially suited for the measurement of any material, part, or component that might be distorted or damaged by conventional probe-contact metrology systems. The system is particularly suited for small or intricate components.

Work Table: 5" x 9" granite surface

Measuring Capacity: X axis 8" (200mm)

Y axis 4" (100mm)

Z axis 8" (200mm)

Illumination: Fiber optic cold light illumination for reflected light. Transmitted light illumination attachment with rotatable top plate.

Focus & Movement: Manual control. Rack and pinion counter balanced Z Axis.

Magnification System: 10X - 100X (200X with auxiliary 2X objective)

Resolution: 0.000050" (001mm)

Repeatability: 0.0002" (004mm)

Accuracy: ± 0.0002" (004mm full travel per axis).

**A CAMBRIDGE INSTRUMENTS
COMPANY**

APPENDIX B

Closure Placement Dimensions (in Inches)

WIDTH
(Side to Side)

LENGTH
(Top to Bottom)

Type A Packer Roll Labels

	Back	Total	Front	Back	Total	Front
n=134						
Average =	0.7857	0.7970	0.7828	0.3868	0.4133	0.3906
Standard Dev =	0.0264	0.0252	0.0225	0.0379	0.0270	0.0343
AVG + 4(S.D.)=	0.8913	0.8978	0.8728	0.5384	0.5213	0.5278

Type A Packer Cut Labels

	Back	Total	Front	Back	Total	Front
n=83						
Average =	0.7937	0.8065	0.7911	0.3790	0.4023	0.3859
Standard Dev =	0.0232	0.0215	0.0238	0.0341	0.0281	0.0301
AVG + 4(S.D.)=	0.8865	0.8925	0.8863	0.5154	0.5147	0.5063

Type B Packer Roll Labels

	Back	Total	Front	Back	Total	Front
n=175						
Average =	0.7762	0.7879	0.7785	0.4096	0.4205	0.4150
Standard Dev =	0.0178	0.0187	0.0198	0.0264	0.0208	0.0246
AVG + 4(S.D.)=	0.8474	0.8627	0.8577	0.5152	0.5037	0.5134

Type C Packer Roll Labels

	Back	Total	Front	Back	Total	Front
n=321						
Average =	0.7840	0.7936	0.7800	0.3970	0.4087	0.3934
Standard Dev =	0.0242	0.0236	0.0225	0.0257	0.0221	0.0262
AVG + 4(S.D.)=	0.8808	0.8880	0.8700	0.4998	0.4971	0.4982

Type C Packer Cut Labels

	Back	Total	Front	Back	Total	Front
n=119						
Average =	0.7772	0.7851	0.7742	0.3947	0.4032	0.3849
Standard Dev =	0.0185	0.0184	0.0179	0.0237	0.0192	0.0233
AVG + 4(S.D.)=	0.8512	0.8587	0.8458	0.4895	0.4800	0.4781

APPENDIX C

Closure Placement Dimensions (in Inches)

WIDTH
(Side to Side)

LENGTH
(Top to Bottom)

Type A Packer Roll Labels

	Back	Total	Front		Back	Total	Front
n=134							
Average =	0.7822	0.7679	0.7789		0.3711	0.4019	0.3809
Standard Dev =	0.0263	0.0156	0.0222		0.0395	0.0277	0.0349
AVG - 4(S.D.) =	0.6770	0.7055	0.6901		0.2131	0.2911	0.2413

Type A Packer Cut Labels

	Back	Total	Front		Back	Total	Front
n=83							
Average =	0.7903	0.7748	0.7877		0.3616	0.3868	0.3741
Standard Dev =	0.0236	0.0156	0.0234		0.0341	0.0293	0.0314
AVG - 4(S.D.) =	0.6959	0.7124	0.6941		0.2252	0.2696	0.2485

Type B Packer Roll Labels

	Back	Total	Front		Back	Total	Front
n=175							
Average =	0.7730	0.7634	0.7748		0.3815	0.4102	0.4041
Standard Dev =	0.0178	0.0115	0.0197		0.0268	0.0199	0.0270
AVG - 4(S.D.) =	0.7018	0.7174	0.6960		0.2743	0.3306	0.2961

Type C Packer Roll Labels

	Back	Total	Front		Back	Total	Front
n=321							
Average =	0.7805	0.7671	0.7764		0.3841	0.3969	0.3822
Standard Dev =	0.0232	0.016	0.0208		0.0262	0.0230	0.0275
AVG - 4(S.D.) =	0.6877	0.7027	0.6932		0.2793	0.3049	0.2722

Type C Packer Cut Labels

	Back	Total	Front		Back	Total	Front
n=119							
Average =	0.7728	0.7630	0.7702		0.3806	0.3912	0.3759
Standard Dev =	0.0150	0.0109	0.0160		0.0238	0.0186	0.0238
AVG - 4(S.D.) =	0.7128	0.7194	0.7062		0.2854	0.3168	0.2807

APPENDIX D

CHOOSING THE SAMPLE SIZE FOR ESTIMATING A PROCESS AVERAGE EXAMPLE [8]

A federal agency has decided to investigate the advertising weight printed on cartons of a certain brand of cereal. The company in question periodically samples cartons of cereal coming off the production line to check their weight. A summary of 1500 of the weights made available to the agency indicates an average weight of 11.80 ounces and a standard deviation of .75 ounce. Use the information to determine the number of cereals the federal agency must examine to estimate the average weight of cartons being produced now, using a 99% confidence interval of width .50.

Solution The federal agency has specified that the width of the confidence interval is to be .50, so $\Delta = .25$. Assuming that the weights made available to the agency by the company are accurate, we can take the standard deviation to be = .75. The required sample size with 99% confidence the z-score is 2.58 is:

$$n = \left[\frac{(\text{constant}) * (\hat{s})}{\Delta} \right]^2$$

$$n = \left[\frac{(2.58) * (.75)}{.25} \right]^2 = 59.91$$

That is, the federal agency must obtain a random sample of 60 cereal cartons to estimate the mean weight to within + or - .25 ounce.

Glossary

Accuracy: The deviation of an estimate from the true value

Advertising design graphics: The printed information on the label.

Bias: The difference between mean value of a sample statistic and the universe parameter it is used to estimate.

Box Plot: A chart of the median, upper, and lower quartiles is represented by a box, the width of which is arbitrary and has no significance. By extending lines from the quartiles to the extremes, a box and whiskers plot is obtained.

Closure: The strip of paper that holds together the package so that the top, bottom, or end attributes are visually apparent to the customer.

Completely Randomized Experiment: An experiment in which other factors than that being studied are assigned in a random manner.

Confidence Coefficient: The chance that a confidence interval has of including the universe value.

Confidence Interval: An interval that has a designated chance (the confidence coefficient) of including the universe value.

Confidence Limits: The end points of a confidence interval.

Controlled Process: A process in the control chart which shows no points outside the limits and no non-random variation within the limits.

Cut Label: A sheet of paper printed with the advertising design graphics. This particular label is individually cut at the supplier and is embossed to emphasize a trade mark or logo.

Cut-to-cut tolerances: The allowable variability in the supplier's slitting of the labels from the larger base roll. A printed base roll of advertising design graphics is slit into six smaller rolls. This allowable variability is between the six slit rolls.

Degrees of Freedom: The number of "free" elements associated with a sum or some other function.

Efficiency of a Statistic: A statistic which is approximately normally distributed in large samples with a mean equal approximately to the parameter being estimated and a sampling variance equal to the square of the standard deviation

Eye mark: A small solid box printed on the label. This box triggers a photocell on the packer to aid in the registration of the cut label.

F Distribution: A particular type of sampling distribution.

Histogram: A bar diagram representing a frequency distribution.

Homoscedastic: Having uniform scatter or having equal variances.

Hypothesis: An assertion made about a population.

Hypothesis testing: An area of statistical inference to validate an assertion; it is carried out by the analysis of a sample of data.

Independence: The sampling of one sample does not affect the selection of another sample.

Labels: The outside paper into which the package is formed; When received from the suppliers, the labels may be on a roll of 20,000 or individually cut so that they can be embossed to enhance a logo or trademark.

Normal: Term refers to the property of being distributed in the form of a normal frequency distribution. A curve or distribution showing a central peak and tapering off smoothly and symmetrically to 'tails' on either side.

One-Tail Test: A test of a hypothesis that has only one critical value, either an upper or lower acceptance limit.

Outlier: An extreme individual or extreme mean.

Parameter: A constant or coefficient of a universe that describes some characteristic of its distribution.

Population: The totality of items or units of material under consideration.

Print-to-cut tolerance: The allowable variability in label supplier's process of printing the advertising design graphics and the slitting of the rolls of labels and the individual cut labels.

Print-to-print tolerance: The allowable variability in label supplier's process of printing colors on the advertising design graphics labels.

Process Average: The mean value of a quality characteristic or of the output of a process.

Process Capability: The limits within which a tool or process operates based upon minimum variability as governed by the prevailing circumstances.

Random Factors: Factors in an analysis of variance, the values of which are randomly selected in each sample from a universe of such values.

Randomized Block Experiment: An experiment in which the treatments to be compared are assigned at random to positions in each of several blocks of replications. In a complete block experiment, each block contains all treatments.

Randomness: An intuitive concept referring to a condition of disorder and unpredictability of individual results.

Roll Label: A sheet of paper printed with the advertising design graphics. This particular label is supplied in a roll of about 20,000.

Sample: A set of objects or things from a larger set called a universe. Unless otherwise stated, all samples are assumed to be random samples.

Sample Space: The totality of all possible results; term is used in discussions of probability.

Sampling Distribution: Distribution of a given statistic in the set of all possible sample from a given universe.

Sampling Plan: A plan that designates sample size(s) and acceptance criteria.

Sampling Scheme: A coordinated set of sampling plans that may be applied to attain a given objective.

Significant: Term that indicates that a result deviates from some hypothetical value by more than an amount that can reasonable be attributed to the chance of errors of sampling.

Spare out area: The length and width dimensions allotted for the closure to be placed on packages so that the advertising design graphics are not covered during manufacturing. It is a length and width dimension into which the closure will be adhered during the manufacture of the package

Standard Error: The standard deviation of a sampling distribution.

Statistic: A function of sample observations used to estimate a universe parameter.

Stem and Leaf Display: Used in exploratory data analysis to show the distribution of an ordered set of data.

t Distribution: A particular type of sampling distribution.

Unbiased estimator: A statistic the mean of which in a universe of samples is equal to the corresponding parameter of the universe of individual values.

Universe: The larger set of objects or things from which samples are drawn. It is usually assumed to be infinitely large or at least very large relative to the sample.

Variance: The square of the standard deviation.

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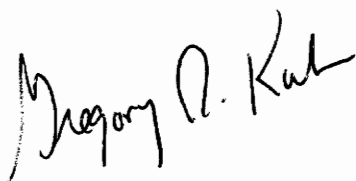
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Vita

Gregory J. Kuhn, the youngest son of William F. and Norma J. Kuhn, was born on August 29, 1961 in Richmond, Virginia. After graduating *cum laude* from Benedictine Military Institute in Richmond, he attended Old Dominion University. He transferred to Virginia State University and earned a Bachelor of Science degree in Mechanical Engineering Technology in December, 1987. He also earned a Bachelor of Science degree in Industrial Engineering Technology *cum laude* in May, 1988.

Greg is an Associate Quality Engineer in a large packaging manufacturing firm in Virginia. Prior to his current position in the New Products and Processes Group, he held various positions throughout the manufacturing facilities. He is a Certified Quality Engineer. He is an active member of the American Society of Quality Control (ASQC) Chapter number 1104 and is currently Treasurer of Chapter 116 of the Institute of Industrial Engineers (IIE). For six years, he has been married to Andrea G. Hoffman.

He began graduate studies in Systems Engineering at Virginia Polytechnic Institute and State University in August, 1989.



Gregory J. Kuhn

Richmond, Virginia

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