AN INVESTIGATION OF PACKAGING SYSTEMS FOR COMPUTER TERMINALS EXPORTED FROM TAIWAN

by

Ming-Ren Sun

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

SCHOOL OF PACKAGING

1985

ABSTRACT

AN INVESTIGATION OF PACKAGING SYSTEMS FOR COMPUTER TERMINALS EXPORTED FROM TAIWAN

By

Ming-Ren Sun

An investigation and assessment of current packaging used by Taiwan's computer terminal industry is reported in this thesis. Emphasis is on design processes.

Three cases studies of damage problems, how they arose, and how they were resolved are presented. Two major problems are indicated by the case studies and extensive interviews with terminal manufacturers, packaging suppliers, and supporting governmental agencies.

First, package design is not currently a controlled, planned, technically based part of a product's development plan. Secondly, there is a severe shortage of trained packaging engineers, with knowledge of distribution hazards, fragility testing, packaging materials, cushion design, and package verification testing.

A model for a sound package design program is presented, with the goal of improving the competitive position of Taiwan's computer terminal industry through reduced cost and improved product quality.

This thesis is dedicated to my parents,
Mr. and Mrs. Heh-Ling Sun, my wife and families
for their continual support and effective encouragement,
which has made this thesis possible.

ACKNOWLEDGEMENTS

The author would like to express his appreciation and gratitude to those who have contributed significantly to the development of this research. Through their efforts and patience the completion of this thesis has been possible. A most sincere thanks to my major professor, Dr. Julian Lee, Assistant Professor of the School of Packaging, for his advice and guidance.

The author also wishes to thank Dr. Richard Brandenburg, Assistant Professor of the School of Packaging, and Dr. David J. Closs, Associate Professor of the School of Business Administration, Mr. Stephen J. Henning, Package Engineer of the IBM-Boca Raton for their assistance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

AN INVESTIGATION OF PACKAGING SYSTEMS FOR COMPUTER TERMINALS EXPORTED FROM TAIWAN

CHAPTER 1

INTRODUCTION

To date, little emphasis has been placed on package design and testing for exports from Taiwan. This has not prevented high volume, low priced Taiwanese products such as textiles and consumer electronic products from enjoying success in the market place.

Market demand and governmental support have prompted a rapid transition into the computer industry, however, and the packaging materials, design methods, and test methods which were adequate for the textile and consumer electronics industries do not always meet export customers' requirements.

This thesis attempt to overcome this concern, first by assessing current package design strategies used in Taiwan's computer industry, and secondly by providing the most current information available on package design for fragile commodities, thereby providing a guide for improvement.

CHAPTER II

HISTORY

According to Yuan-Jing Cheng, Manager of the Product and Package Design Department of the China External Trade Development Council (CETDC), export customers for consumer electronics had been satisfied with the performance of protective packaging for the products.[1] Industry spokespersons have concurred with this assessment.[2]

In recent years, however, the television industry has seen a decline in Taiwan. Fortunately, during this same time, the computer industry has been rapidly developing world wide, and Taiwan has shared in this growth. The decline in television and increase in computer products exports is illustrated in Table 1.

The introduction of terminals, work stations, mini, micro, and personal computers has provided new products and markets for Taiwan's electronic engineering and manufacturing resources. Television and video game manufacturers such as Tatung, Sampo, Teco, and DEC have converted television and video game production capacity to computer terminal, peripheral, or component capacity for their very survival.[1,2]

Table 1 Taiwan Electronics Export Data[3,35]

	Millions U.S. Dollars		
Year	1981	1982	1983 Jan-Sept
Color Televisions	187.3	137.8	202.7
Black & White Sets	346.4	211.2	122.3
Computer Products	6.5	160.4	265.4

The Taiwanese government has established two new organizations to promote this development.

The Institute of Information Industry (III) was formed to support software development.[50] The Electronics Research and Service Organization of the Industrial Technology Research Institute (ITRI) was formed to support hardware technology development and product testing.[55]

The already existing China External Trade Development Council (CETDC) has been given the responsibility of providing package design and marketing support.[4,37]

Both the CETDC and the manufacturers agree, however, that existing package design and test techniques, which were adequate for the television industry, are not always capable of meeting the stringent package verification tests required by the new export customers. Meeting customer requirements for package performance is crucial if Taiwan's competitive position is to be maintained or improved.[1,2]

There are good reasons why the export customers for computer related products have more exacting requirements than prior consumer electronics export customers.

These products are more expensive, and are more likely to be business or educational tools. These users rely on such tools to conduct business, and so product quality and reliability become more important than low cost, which is a greater factor in consumer purchases.

Computer terminals, work stations, mini computers, and personal computers also are likely to be purchased in component form. This creates more shippable units, which increases the odds that some part of the system might be damaged during shipping and handling.

The major components of a computer system, whether it is a main frame or a personal computer, are all susceptible to shipping and handling damage, and the failure of any one component renders the entire system unusable until the component is repaired or replaced. Figures 1,2, and 3 show examples of computer terminals.

Main logic boards contain major logic and memory circuitry and components, any or all of which may be damaged by shock and vibration during shipping and handling.

Monitors, which display the user's typing and the computer's output or calculations on a cathode ray tube, are susceptible to shock and vibration during handling and shipping.

Keyboards, which are used by the operator to send messages to the computer, are susceptible to shock and vibration.

Disk drives, which store and retrieve data from floppy or hard disks, are particularly susceptible to shock and vibration. Mechanical deformation of the reading/writing heads and connecting arms is a serious defect which can be caused by shock and vibration during shipping and handling.

Power supplies, which control and distribute power for a system, may be susceptible to shock and vibration, depending on their design.[5]

Export customers recognize the potential for shipping and handling damage to computer terminals, systems, peripherals, and components. To meet quality requirements, these customers are insisting that protective packaging must be designed and tested in order to prevent such damage. Taiwan's computer industry must have the ability to design packaging which will meet export customer requirements if Taiwan is to maintain or improve its competitive position in the computer industry.

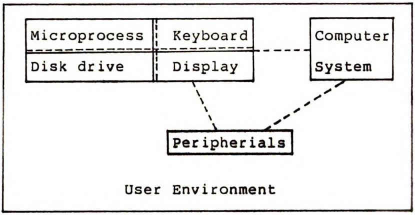


Figure 1. Terminal System Schematic[6]

Figure 2. Computer Terminal Example[53]

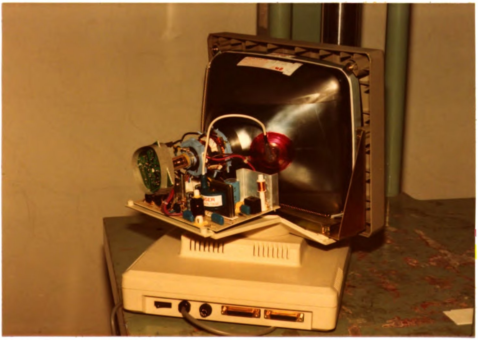


Figure 3. Inside Look at a Terminal.[7]

CHAPTER III

ASSESSMENT OF CURRENT PACKAGING SYSTEM

In my assessment of current packaging systems in Taiwan's computer terminal export industry, my primary investigation tools were interviews and site visits. The objective was to get information directly from the persons currently responsible for computer package design and testing. Due to the sensitive nature of corporate product/packaging volume, cost, and damage data, my data is necessarily descriptive and anecdotal in nature.

In this assessment, several key areas needed investigation.

The knowledge and experience of persons responsible for packaging terminals needed evaluation. Packaging responsibility falls into four areas: design and specification, testing, purchasing, and actual product packaging. Shortcomings in the performance of any of these functions can create packaging problems.

Design considerations and methods are crucial to packaging success; package testing methods and equipment are an essential element of design methodology.

The track record of package designs, from a protection and cost standpoint, also needed investigation.

Current Packaging Personnel

I interviewed in person the managers responsible for packaging at eight computer/terminal/peripheral/component manufacturers, and four more by phone. Of these twelve, only one currently has a packaging engineering department. At all others, package design, testing, and specification responsibility is a minor duty of mechanical design, distribution, marketing, manufacturing, and research and development departments.[13] None of the persons responsible is trained in packaging engineering, and none have a technical understanding of the distribution environment and its hazards.[8]

In most cases, packaging suppliers are relied upon for package design. In site visits and interviews with six of the suppliers most commonly used for design, I found that no supplier has a designer trained in packaging engineering.[9] Only one supplier has any test capability; this consists of a freefall drop tester with instrumentation for reading acceleration inside packages.[10] None of the suppliers demonstrated a technical understanding of the distribution environment and its hazards.

I also interviewed persons at the Electronics Research and Service Organization of the ITRI and the Packaging Research Laboratory of the CETDC. At the ITRI, package testing is a small portion of the testing services performed;[11] the manager and technicians have no training in package design and testing.[12] The CETDC's test engineer was trained in mechanical engineering, and has received training in the United States in package testing,[13] and has some knowledge of the technical aspects of distribution environment hazards.

At present, there are three persons in Taiwan who have degrees in packaging engineering. One presently is involved in injection molding in the rubber industry, a second works for a trading company, and the third for a package printing supplier.[14] None is involved in package design or testing for the computer industry.

For purchasing of packaging materials, the need for training in packaging is not critical, so long as good specifications are available. Due to the heavy reliance on vendors, however, specifications may not support competitive bidding to the greatest possible extent. In short, the lack of qualified personnel for the package design and specification functions has undoubtedly compromised the effectiveness of purchasing agents in keeping costs down and providing a properly fabricated packaging part that performs as required.

Like package design, specification, and testing, packaging lines have received little attention. Here the problem is not really a problem with training; the computer manufacturers have highly capable industrial and manufacturing engineers. Rather, the problem is one of emphasis.

I observed the packaging lines at five major computer terminal manufacturers, and only one performed any packaging operation in a nonmanual mode.[15] This one line used semi-automatic equipment to insert displays and cushions into shipping containers, and is shown in Figure 4.

In all cases, box erecting, closing, and sealing was done manually. In four of five casess, cushing and product insertion is entirely manual. All products were bagged manually.

The point here is not the lack of packaging equipment. Rather, it is that there are qualified personnel at these companies who are capable of being trained to make the packaging processes more efficient. These persons need only to observe other companies packaging lines to become aware of opportunities for using off-the-shelf packaging equipment to automate or semi-automate parts of the packaging process.

The computer export industry, therefore, already has the expertise to use equipment in place of labor for packaging operations, should this become cost effective.

Current Design Processes

Currently, package design responsibility in Taiwan's computer manufacturing companies resides in a variety of places on the organizational chart. The responsibility is held by package design, product design, research and development, manufacturing, distribution, and marketing departments.[8] The responsibility is fulfilled mostly by relying on packaging material suppliers for design services.

Figure 4. Semi-automatic Box Loading Equipment[16]

At six of eight manufacturers that I visited, packaging is designed after production begins. Since this creates a critical shortage of time, shipping container and cushion designs for similar products are adapted to the new product, and products begin shipping without package verification testing.[17]

Cushion design at all eight companies is based upon the goal of minimizing package size, in order to reduce packaging meterial costs and minimize handling and freight costs. The manufacturers test the performance of packages against shock and vibration hazards only if the customer's purchasing specifications require it.[8]

Available Materials

Most of the shipping containers used for exported terminals are constructed of corrugated fibreboard. Taiwan's corrugated industry relies heavily upon imported materials, so most corrugated medium is made from recycled pulp.[18]

There are about thirty corrugated fibreboard suppliers in Taiwan, and about 250 corrugated box manufacturers. Intense marketing and cost competition result in the frequent use of recycled pulp, in order to cut costs. Unfortunately, this results in wide variations in corrugated fibreboard box quality and strength.[18]

Most of the export terminal manufacturers are purchasing shipping containers from the handful of integrated box manufacturers which convert their own corrugated into boxes. By doing so, these suppliers can offer stable quality and better prices.[18]

There are two cushioning materials used today for terminal packaging, expanded polystyrene and polyurethane foam-in-place.

Expanded polystyrene (EPS) has been used for many years because of low cost, good supply, attractive appearance, and technical reasons. EPS is easy to mold in production quantities, with a relatively low level of technology. It is a good thermal insulator, is light weight, and is moisture resistant. The density of EPS can be varied; common densities are 0.015 g/cm^3, 0.020 g/cm^3, 0.025 g/cm^3, and 0.030 g/cm^3. Before it is molded, it occupies relatively little space.[19] A typical EPS cushion design is shown in Figure 5.

EPS has several technical difficulties. It is difficult to recycle, and is not biodegradeable. After it is molded, it takes up lots of space, like all cushioning materials. It generates static electricity. Worst of all from a cushioning standpoint, it is relatively low in resiliency; it deforms permanantly upon impact, lowering its protective value for multiple impacts. Only few Taiwan package engineers know well and consider thoroughly about this design constraint. There are two manufacturers of unexpanded polystyrene beads in Taiwan, and fifty EPS cushion molding suppliers.[38]

In 1981, polyurethane foam-in-place was introduced. This material has been marketed as a better cushioning material for fragile products. Its advantages include moderate cost, good supply, moldability in production quantities with a relatively low level of technology, and good thermal insulating properties. Its density can be varied from 0.01 g/cm^3 to 0.033 g/cm^3.[45]

Foam-in-place is higher cost than EPS. It also has a poorer appearance because it must be lined with plastic film. It is difficult to mold with consistent density and cell structure. Although more resilient than EPS, foam-in-place still experiences permanent deformation upon multiple or severe impact, limiting its multiple impact protection characteristics. The chemical ingredients must be imported from the United States.

There are currently two suppliers of premolded foam-in-place cushions in Taiwan.[45] Three manufacturers have developed inhouse foam-in-place molding capabilities.[20] An example of a polyurethane foam-in-place cushion design is shown in Figure 6.

Foam-in-place is often purchased in the lowest density for cost considerations, without considering its impact on cushion performance.[21] One company which molds its own foam-in-place cushions tears waste foam into pieces and places it into the shipping container before adding new foam in order to save material.[22] This probably reduces cost, but it also reduces the consistency of the cushioning

Figure 5. Example of EPS Cushion Design[23]

Figure 6. Example of Polyurethane Foam-in-Place Cushion Design[24]

material and influences its performance in unpredictable ways.

Current Testing Methods

Currently, package performance for protection against shock and vibration is tested in the laboratory only if buyer specifications require it.[8] Inadequate packaging is otherwise discovered only through shipping damage reports.[8]

There are four testing facilities in Taiwan that can do some sort of fragility or package testing:

CETDC Lab	Vibration Tester Shock Tester (Rubber Pad Type) Drop Tester
ITRI Lab	Vibration Tester Shock tester (Rubber Pad Type)
ADI Corp Lab	Vibration Tester
Instapak Lab	Drop Tester

Appendix A contains the technical specifications for the above equipment. Figures 7, 8, and 9, show the test equipment at the CETDC Packaging Research Laboratory.

The vibration testers all have serious shortcomings in their low frequency capabilities; the amplitudes at low frequencies are too small to meet the requirements of some purchasing specification.[25] Nonetheless, this equipment is still useful for resonant search and dwell testing.

The shock machines likewise have serious shortcomings. The shock programming capabilities are insufficient to perform fragility testing. No trapezoidal waves can be programmed. Limited control of the amplitude of half sine

Figure 7. Packaging Research Lab Shock Maching[26]

Figure 8. Packaging Research Lab Drop Tester[26]

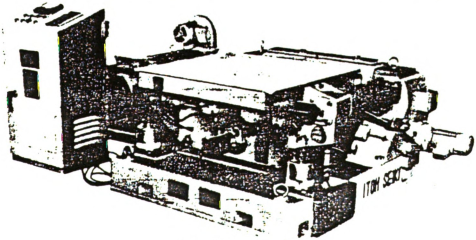


Figure 9. Packaging Research Lab Vibration Tester[39]

shock pulses is possible by changing rubber pads, allowing very limited fragility testing capability for shock fragility assessment.

Both shock machines, as well as the drop testers, are marginally adequate for performing package verification testing and comparing the performance of different package designs.

According to the CETDC, the electronic industries are the largest users of the CETDC Packaging Research Laboratory. Most computer terminal testing has been performed in this laboratory.[42]

The ITRI laboratory is used infrequently by terminal manufacturers. From June 1982 through July 1982, only four manufacturers used this test facility, for a total of 19 tests (18 vibration and one drop test).[27] The probable reason for the low useage rate of this facility is its distance (110 kilometers) from Taipei.

In short, the available test equipment is not fully utilized. Manufacturers are taking advantage of these test facilities only when required by buyer specifications.

CHAPTER IV

CASE STUDIES

Display #1

Display #1 was originally packaged in foam-in-place cushions. The cushion supplier provided the design.

This display failed package verification tests, which were requirements of the purchasing specifications. The specification required eight 36" drops: one edge, one corner, and all six faces.

Four of five units tested sustained serious damage. The cushion supplier was subsequently unable to provide a design which met the buyer's specifications.

Due to marketing demands, this display was shipped in volume. Significant shipping damage was reported by the customer corporation, the cost of which was borne by the manufacturer.

The display manufacturer sent two packaging engineers to the customer corporation to work with two trained packaging engineers in their laboratory. After testing a number of new design possiblities, all four returned to Taipei for final verification testing.

The end result was an expanded polystyrene design which successfully passed the required testing. The new design was approximately $1 cheaper per display, and allowed the use of many more suppliers than the original foam-in-place design.[28]

Display #2

This display was packaged in foam-in-place cushions designed by a foam-in-place supplier. The display suffered cover damage and transformer failure when dropped per the buyer specifications. The buyer specification required drops from 36". The packaging would not pass at 30".

Shipping damage required an immediate fix.

As a temporary fix, a packaging engineer at the customer company designed a larger box, with polyethylene foam blocks cushioning the inner box, which could be used to overpackage the already packed and shipped inventory. This resulted in temporary doubling of the display's packaging cost, material, labor cost, wasted shipping cost and impacted distribution of the display. But the display did pass 36" drop package verification testing when over packed in this manner.

The cover cracking problem was dealt with in part by modifying the mechanical design of the cover. The final solution was a new cushion design, which eliminated both cover and transformer failures. Again, the new design was an expanded polystyrene cushion, which was cheaper and had better availability.[29]

Micro Computer

The original package design for this micro computer consisted of expanded polystyrene cushions, designed by the manufacturer's mechanical design group. When dropped from 36", it sustained damage to its cover, card cage, and power supply mounts.

In an attempt to compensate for these failures, the micro computer was subsequently shipped in this packaging, with the addition of a wood crate.

A later model micro computer of similar dimensions was tested in the same package. When it failed, it too was placed in a wood crate.[30]

At the time this thesis was written, no known changes had been made.

CHAPTER V

AN OPTIMUM PRODUCT/PACKAGE SYSTEM DESIGN

Design Objectives

In the ideal product/package system, packaging must perform four major functions: containment, protection, communication and provide customer convenience. Clearly, the package/product system has commercial, psychological, distribution, and protection functions.

Design Criteria

Manufacturers and packaging engineers need design criteria if a successful product/package system is to be designed. According to Glenn R. Sontag, "Every package of a new product requires standards or criteria to make it an effective part of the overall packaging program. All the design research and testing cannot overcome any shortcomings in the total package design process caused by failure to analyze all of the design criteria that will be the basis for the complete package program."[52] In depth design criteria and analysis should be part of the design research, and are critical to the success of any package design program.

Ideally, a package should provide only enough protection to make up the difference between the severity of the distribution environment and the strength of the product.[36] Overpackaging creates unnecessary costs, and underpackaging results in product damage; either way, expenses are increased, profits are lowered, and the product/package system's marketing appeal is jeopardized.

Design Inputs

The achievement of an optimum package/product design requres many inputs. The following inputs, which are shown diagramatically in Figure 10, are:

- Marketing
- Distribution Environment
- Product and Material
- Technique
- Function
- Legal

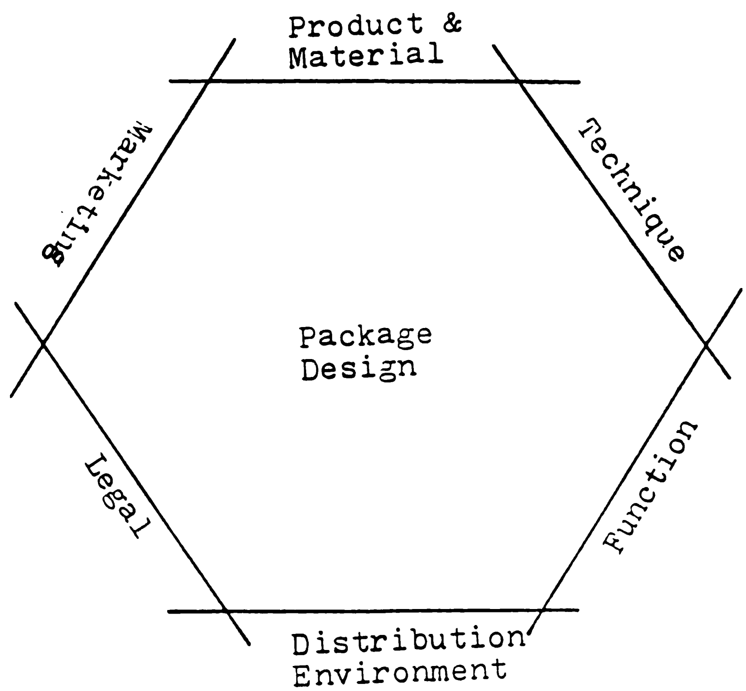


Figure 10. Design Inputs

Design Processes

The product and package have a dependent relationship. The package itself is a kind of product. Package design should receive as much attention as the product design. By using systematic concepts and design methods, a designer can solve and/or prevent many problems.

A good package design requires an in-depth understanding of technical, marketing and product demands. There are numerous design procedure models which can be used; the details of one design processes are shown in Appendix B.

In general, the design process stages are:

(1) Design planning

(2) Design approach

(3) Design development

(4) Design finalization

(5) Design control for production[31]

In package design, a systematic and total design is preferred to a linear design process which is used by most Taiwan terminal manufacturers.[8] Usually, the packaging for terminals in Taiwan is designed after the product is in production. It is then too late to conduct testing or to correct any defects the product design may have, prior to first shipment. Also, too little time is available for cost analysis of design alternatives. As a result, the package design may not result in an optimum product/package system.

Today's product/package designs can be very complex, and it is therefore difficult for a single person to complete the entire design process without help. It is seldom that a designer has sufficient knowledge of all technical, marketing, distribution, and commercial requirements; time is needed to obtain this information from the correct people.

In order to analyze all the appropriate inputs during the design process, team work is required. Packaging engineers must control the package design schedule so that the design project proceeds on a timely basis, but cooperation from many departments is an absolute necessity. The supporting groups include:

- Package Designers
- Product Designers
- Manufacturing Department
- Corporate Representatives
- Marketing Group
- Outside Research Consultants
- Suppliers
- Legal
- Purchasing
- Distribution
- Logistics Planning
- Research and Development

The packaging system is an integral part of th total system which includes the product design, package design, manufacturing and distribution systems. The package designers should complete package design and testing early, before the product is scheduled to ship.

Product Definition

As mentioned earlier, the terminal is a highly fragile and expensive product. The procedures for measuring and defining the fragility of a product are very important and useful for package and product designers. MTS Corporation states that "These theories and techniques can also be used by product designers to evaluate and possibly increase the ruggedness of the product. Sometimes it is more economical to modify the product than to provide more cushioning".[51]

Product fragility is typically determined through testing by a package designer or test technician in a package test laboratory. Ideally, it should be done by the product designers or by both the product and package designers. If the product fragility test can be performed by the product and package designers before the production begins, the optimum product/package system can be designed.

A product's fragility is the maximum shock the product can withstand without damage.[46] MTS Corporation defines shock damage and product fragility as "Shock damage to a product results from excessive internal stress which is induced by inertial forces. Since inertial forces are directly proportional to acceleration, shock fragility is characterized by the maximum tolerable acceleration level, i.e., how many g's the item can withstand."[51]

In the past, it was very difficult for companies to measure the fragility of a product. They could only perform field tests or trial and error drop tests, which wasted time and produced inaccurate results. Today, product designers and package engineers can use a shock machine to measure the critical velocity change and critical acceleration of a products. With this data, they can determine a product's shock fragility.[51] A damage boundary curve is shown in Figure 11.

Product Vibration Fragility

All materials and systems have one or more natural frequencies which respond to a vibrational energy input. They respond like a spring-mass system, because they are not totally rigid. Most of the products and packages contain different components, so the systems may have several critical natural frequencies. The natural frequencies (fn) of products are dependent on their spring constant (k) and mass ($M = w/g$, $g = 386.4$ inches/sec^2).

The MTS report states that "Damage is most likely to occur when some elements or components of the product have a natural frequency which is excited by the environment. If this tuned excitation is of sufficient duration, component accelerations and displacements can be amplified to the failure level".[51]

The transmissibility curve in Figure 12 have three sections. When input freguencies (f) less than the resonant frequency (f_R) of the system, the $A_R/A_I=1.A_t$ f is equal to or close to f_R, it is in amplified level. When $f=f_R$, the system is in resonant condition. Finally, at f is greater than f_R, the vibration is attenuated by the system.

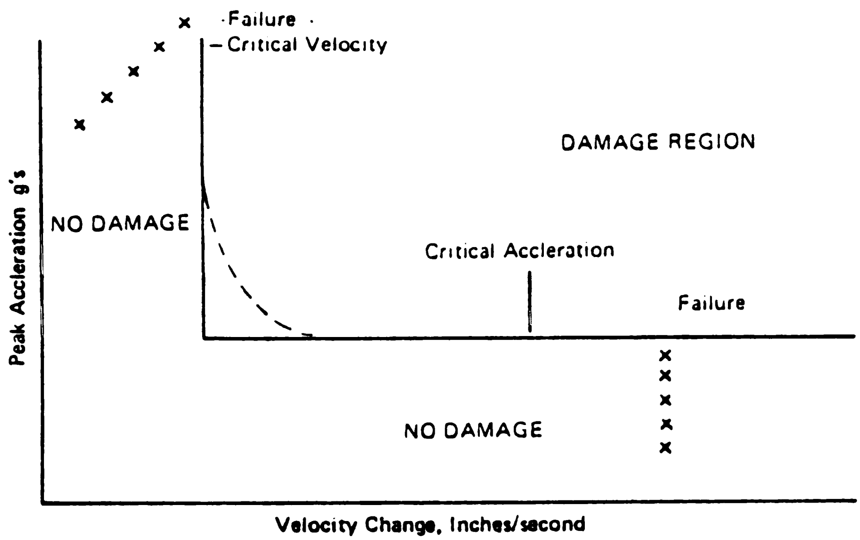


Figure 11. A Damage Boundary Curve.[46]

A product or component response to input vibration may be represented by a curve like that in Figure 12.

A_R = Response acceleration of the system

A_I = Input acceleration

f = Input frequency, Hz

f_R = Resonant frequency of the system

Product vibration fragility should be tested on an electrohydraulic vibration machine. The test method of resonance is commonly used to find the critical frequencies of the product, and dwell testing determines resistance to fatigue when the product is at resonance.

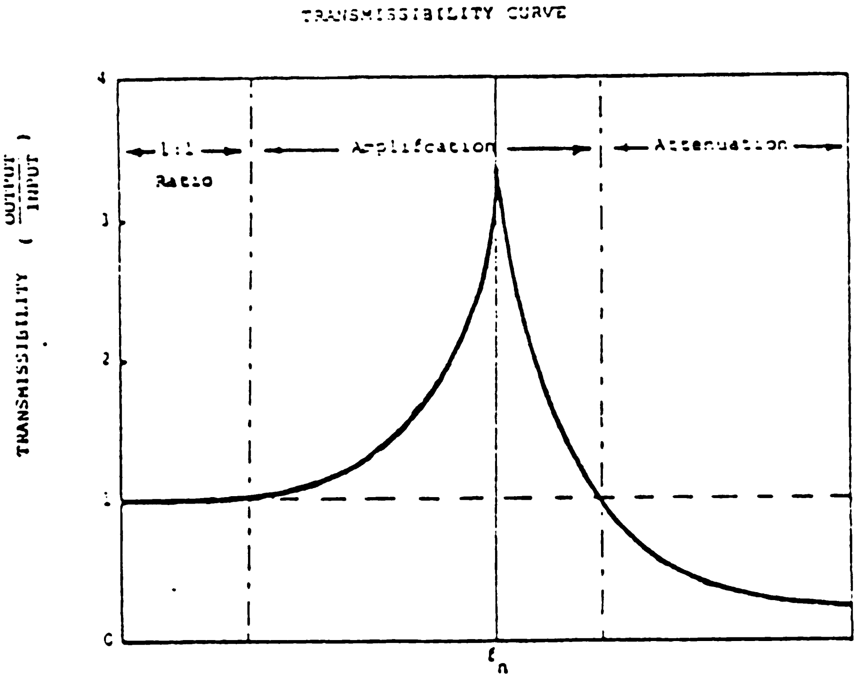


Figure 12. Vibration Response[51]

Product designers can change or reinforce the structure of a product, while the package designers can design packaging to prevent a product's critical components from damage or fatigue due to resonance during shipping.

Distribution Environment Definition

The most critical hazards for terminals exported from Taiwan to the United States in the transportation and handling environements are shock and vibration. Appendix C discusses these hazards and distribution environment in detail.

Based upon the distribution environment and the expected hazards, a package test standard should be chosen. A list of test standards which can be used appears as Appendix D. The package product system should then be designed to meet this test standard. Cost trade-offs between product improvements versus increased cushioning should be assessed as fragility testing proceeds.

Other Considerations and Analyses

Package design can be complicated by the requirements of international trade. More design factors and alternatives must be considered for international shipments than for domestic shipments. Examples of additional requirements may include buyer's quality requirements, testing methods and standards, more severe distribution modes, laws, regulations, carrier rules, maketing, logistics, etc.

For example, the modes of distribution (uncontrolled factors) are not decided by package designers or the manufacturer, but by buyers or customers. Different transportation modes may require different ways of packaging and handling.

Table 2, shows performance ratings based upon selection determinants. A subsystem has different solutions which will influence the ultimate design of the package.

For example, a designer may suggest a different transportation mode according to his/her own experience, judgement, or analysis, which could create a more cost effective product/package/distribution strategy.

Table 2. Performance Rating of Modes by Selection Determinants[41]

Selection Determinants	MODES Railroad	Motor	Water	Air	Pipeline
Cost	3	4	2	5	1
Transit Time	3	2	4	1	-
Reliability	2	1	4	3	-
Capability	1	2	4	3	5
Accessibility	2	1	4	3	-
Security	3	2	4	1	-

1=best, lowest., 5= worst, highest

The computer terminal package design process should suggest alternative solutions. A package designer is therefore advised to use morphological charts to develop ideas.[43]

Such a chart should:

1. Define the functions that any acceptable design must be able to perform.
2. List a wide range of sub-solutions i.e., alternative means of performing each function.
3. Select an acceptable set of solutions for each function.

An example of a morphological chart for terminal package design is shown in Table 3.[32]

Design Evaluation

In the final analysis, a product/package system can be divided into five main elements: product, shipping container, cushioning, inner package, and environment. The designer can use an interaction matrix which is directed towards permiting a systematic search for connections between elements within the system.[44] This matrix gives a ranking and weighting, helping the designers see easily the important relationship between elements. An interaction matrix is shown in Table 4.

Table 4 also shows that the distribution environment element has the highest score and greatly influences other elements. Product, shipping container, and cushion materials elements are of equal importance.
Secondary packaging such as taping, and printing, plastic bags are of little influence in the product/package system.

Usually, package designers cannot change the

Table 3. The Morphological Chart of Terminal Package Design

Sub-Systems	Sub-Solutions						
PRODUCT							
Structures	A:CRT B:CPU	C:Disk drive D:Keyboard	A+B+C+D	A+B+D	A+D	B+D	Others
Size							
Weight	1-10 lb	11-20 lbs	21-30 lbs	31-40 lbs	41-50lbs	over 50lbs	
Configuration				Other			
Fragility Shock Vibration	Fragile	Average	Ruggedness	Other			
Price	High value	Average	Low Value				
Probability drop height	Very high	High	Average	Lower	Very low		
Allowance damage rate	High	Average	Lower	Other			
Competitors' brand	IBM	Apple	Radio Shack	Epson	Fuji	Others	
PACKAGING							
Shipping container	Corrugated box (Single wall)	Double walls box	Triple walls	Wirebond	Plastic box	Wood box	Other
Container shape	Square	Rectangle	Round		Others		
Container size							
Container cost							
Competitors' package	Corrugated box						
Cushioning materials	Without Corrugated fiberboard	EPS Other	PU Foam-in-Place	PU flexible	Mold Polyethylene	Air	Polypropylene foam
Cushion property							
Cushioning Style	Total encapsulation	Face	Corner				
Cushioning Cost							
Competitors Cushioning	EPS	PU Foam-in-Place	Other				

Table 3 (Cont'd)

Sub-Systems	Sub-Solutions						
Testing Methods	Shock	Vibration	Compression	Others			
Testing requirement							
Supplier	One	Two	Three	Other			
Lead Time	10 days	20 days	30 days	40 days	Over than 40 days	Other	
Distribution Packaging							
Unit loads	Loose pack	Palletizing	Slipsheet	Skid	Skid box	Other	
Pallet size	40"x48"	40"x40"	36"x48"	36"x36"	32"x40"	36"x48"	Other
Pallet Style	Single face	Single face 4-way entry	Double face 4-way entry	Single Single Wing	Double Double Wing	Others	
Palletizing	A. Adhesives B. Strapping	C. Shrink Wrap	D. Stretch Wrap	A+B+C	A+B+D	B+D	Others
Pallet Pattern	Column	Interlocking	Tri-Lock	Spiral	Diagonal	Others	
Pallet box's layers & Ht	3 Layers	4 Layers	5 Layers	6 Layers	Other		
Material Handling	Forklift truck	Manual	Hand lift Truck	Others			
International Transportation Mode	A. Railroad	B. Motor	C. Water	D. Air	B+C	B+D	Others
Domestic Transit mode	A+B	A+C	B+C	B+D	A+B+C+D	B+C+D	Others
Container size	8'x8'x40'	8'x8'x30'	8'x8'x20'	8'x8'x10'	8'x8'x68"	Others	
Package in Container	A. Boxes Stacking	B. Pallet Stacking	A+B	Other			
Distribution hazards	Environmental Hazards	Physical Hazards	Miscellaneous Hazards	Other			
Physical Hazards	Shock	Vibration	Fatigue	Others			

Table 3 (Cont's)

Sub-Systems	Sub-Solutions						
Allowance Package Damage Rate	High	Averge	Low	Very Low	None	Others	
Storage Time	Less than	1 Month	2 Months	3 Months	4 Months	Longer than 4 Months	Others
Stacking Height	1 Pallet	2 Pallets	3 Pallets	Others			
Automation	Yes	No	Others				
Distribution Cost							
Others							

Table 4 Interaction Matrix for Product/Package System

	1	2	3	4	5	Score
1 Product		●	●	O	●	10
2 Shipping Container	●		O	O	●	10
3 Cushioning	●	●		O	●	10
4 Inmer Package (Secondary Package)	O	O	O		◐	5
5 Distribution	●	●	●	◐		11

● = 3 essential ◐ = 2 desirable
O = 1 little desirable X = 0 not needed

distribution environment or increase the durability of the products. However, the designer can develop proper cushioning and shipping containers to protect the product against hazards and fulfill the package's efficiency requirements.

Cushioning Design

After the packaging team developes and evaluates all necessary data such as the product fragility, distribution environment, and cushioning requirements, the designer can develop a design which provides adequate protection for both shock and vibration hazards.

The MTS report[51] mentions the fact that two types of curves are needed for each cushioning material and that they must be used simultaneously.

1. The Maximum Transmitted Shock Acceleration - Static Stress curve is shown in Figure 13.

2. The Vibration Natural Frequency - Static Stress Curve is shown in Figure 14.

The basic design process involves determining and analyzing the following elements:

. The fragility of the product: shock and vibration fragility.

. The product weight.

. The expected drop height during distribution and cushion curve such as in Figure 13.

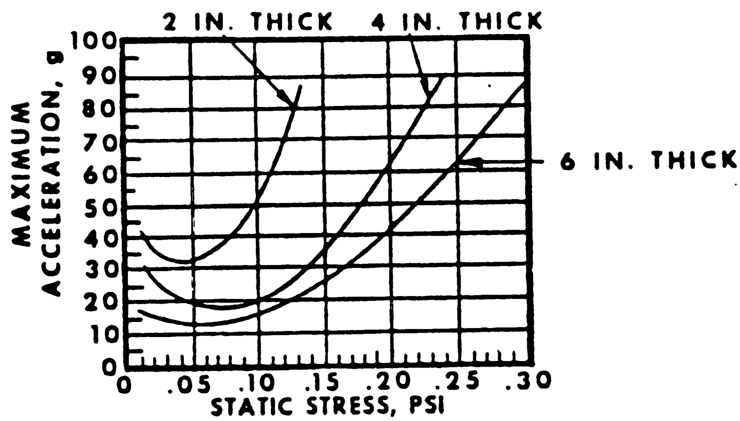


Figure 13. Cushion Curve for 24-inch Drop[55]

The process of cushion design ideally conforms to the above considerations. In reality, actual design is not so simple. Designers must consider more details and alternatives such drop configurations, cushion configuration (total encapsulation, face or corner pads), the area, style, and height of ribs, and the influence of deflection or compression.

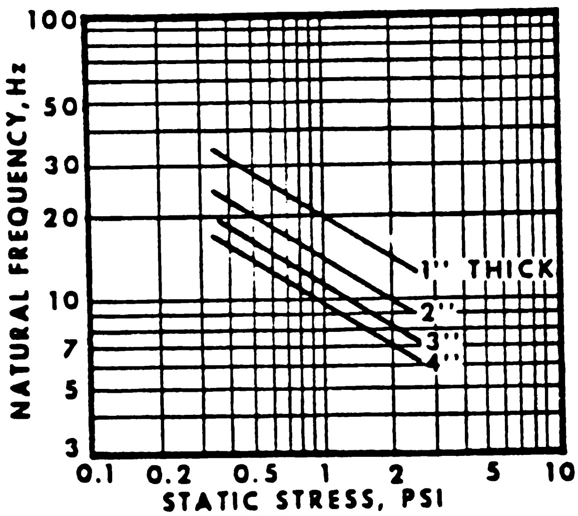


Figure 14. Natural Frequency - Static Stress Curve[51]

The designer should develop cushioning which will reach the highest efficiency rating, otherwise it is not economical in the overall system.

Package Design Finalization

In this step, the designer has already analyzed and evaluated many useful designs. Various considerations will influence the actual design and must be incorporated into the final choice.

The final decision making process of package design depends not only on the size of the product/cushion and the strength requirement of the package, but on the ability to reduce package material cost, reach an acceptable protection level, fit the distribution requirement, and have suitable marketability characteristics. A satisfactory package design is one which meets all of these requirements.

The ultimate objective of good packaging design is to find ways of lowering costs and increasing competitiveness.

Package Testing

Package testing is similar to product fragility testing. Here, the package engineer tests the completed product/package system to verify and evaluate its performance. By this method, the package performance can be assessed to determine whether it needs to be modified or retested.

The old methods of package testing, such as field shipping tests or stacking tests, take more time, have greater cost, result in less accurate conclusions than laboratory testing. In field testing, the designer can use only trial and error methods to do the job.

Now, the package/product system can be tested in the laboratory to simulate field shipping, handling and warehousing conditions by using new equipment and testing procedures. For instance, by shock and vibration testing, the package performance can be measured and analyzed for performance during distribution. Furthermore, according to the testing data, the designer can isolate the points of failure, analyze the cause of failure and look for ways to improve the package/product system.

Appendix D lists package tests for package testing consideration which are useful for judging package performance.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Taiwan's computer terminal industry has many opportunities for improving its competitive position in the world computer markets through improved package design methods. These opportunities are being missed for two fundamental reasons.

First, management has not made package design and testing a planned, controlled part of its product design and test process. The technical aspects of protecting a fragile, dynamic mechanical system from shock and vibration inputs during shipping and handling are ignored unless testing is required by buyer specifications.

As a result, when a product first ships, there is considerable risk of shipping damage, which is costly in terms of profits and reputation. Furthermore, there is no assurance that the product is being shipped in the best package from a cost, protection, and distribution standpoint.

Secondly, there are presently no trained packaging engineers working for the terminal industry. Extensive knowledge of distribution hazards, packaging materials, shock and vibratoin fragility testing, cushion design, and package verification testing are required to take full advantage of the cost reduction and product quality improvement opportunities.

Currently, terminal manufacturers rely heavily on packaging material suppliers to design protective packaging. As the first two case studies in chapter four show, this is no guarantee that serious problems will be avoided.

The third case study, in which a manufacturer's own mechanical design group designed packaging for a micro computer shows that bringing the design function in house will not, by itself, prevent problems, nor will it prevent a serious mistake from being repeated.

In all three cases, the damage problems were a result of inadequate knowledge of package design and testing methods and/or inadequate emphasis by management on early package design and verification testing.

Chapter five of this thesis outlines an approach to package design which will take the guess work out of this process, and provide a firm technical basis for making good packaging design decisions.

The cost and quality benefits of sound package design, in conclusion, will be realized only through a methodical, technically based package design process.

APPENDICES

APPENDIX A

THE SPECIFICATIONS OF THE CURRENT TESTING EQUIPMENT

Packaging Research Laboratory of the CETDC

The Packaging Research Laboratory package test equipment for pre-shipment consists of:

A. Vibration Tester

a. Specification

VBC-8A II Vibration Tester

Monufacturer: ITOH SEIKI Co., Ltd.

Maximum Testing Weight : 150 kg.

Vibration Directions: Vertical and horizontal

Maximum Acceleration : $\pm$ 10 G

Frequencies Range : 0.8 - 60 Hz

Amplitude : 0 - 40 mm

b. Applications

This testing machine cannot do a resonance search; up to 60 Hz, and can dwell at resonance for the product or package. However, when CNS-z6026 or CNS-z6027 are used, this resonance search feacture goes unused.

B. Rubber pad drop Table Type Shock Testing Machine

a. Specification

DST-800 B Shock Machine

Manufacturer: YOSHIDA SEIKI Co., Ltd.

Maximum measurement : 1000 x 800 x 1000 mm

Maximum drop height : 1200 mm

Shock acceleration : 10 - 100 G

b. Applications

This shock machine is used to measure the product or package's G-factor, but it cannot determine the product fragility.

C. Free Fall Drop Tester

a. Specification

SANGYO Drop Tester

Manufacturer: SANGYO Co., Ltd.

Maximum testing weight : 70 kg.

Drop height : 400 - 1500 mm

Maximum product size : 700 x 700 x 800 mm

b. Application

This tester with testing instruments is used very often by terminal manufacturers to measure the packaged product G-factor and the performance of the cushioning material.

Electronics Research & Service Organization of the ITRI

The Electronics Research & Service Organization offers many technical services for the electronic and terminal industries. Shock and vibration testing are only two of the many testing services available.

The specifications and application of the testing equipment are listed as follows:

A. Vibration Tester

a. Specification

UD TA 115 - 30/CSTA Vibration Test System

Manufacturer: EOD Co., Ltd.

Frequency Range	: 5Hz - 2000 Hz
Maximum Amplitude	: 1 inch
Maximum Acceleration	: 100 G
Maximum Output	: 3000 lbs
Wave Shape	: Sine wave

The test controls and instrumentation includes: charge amplifer, vibration monitor - limiter, resonant dwell counter, servo - programmer and sine sweep generator.

b. Vibration Testing

The Electronics Research & Service Organization was established in accordance with the U.S. Federal Test Method Standard 101, Method 5020 to test terminal products according to the following conditions:

(1) Terminals packed in a shipping container.

(2) The unpackaged terminal.

(3) Loose cargo bounce test.

The expenses of vibration testing are:

a. The basic price for testing is $ 25.00 for up to three hours and $5.00 per additional hour (for 20 cm x 20 cm x 20 cm or for a product weighing less than 10 kg).

b. The basic price for testing is $32.50, and the over charge is $6.25 per hour (for 20 cm x 20 cm x 20 cm or for a product weight higher than 10 kg).

B. Shock Machine

a. Specification

LAB SDH 36-1000 Mechnical Shock Tester.

Manufacturer: LAB Co., Ltd.

Table Size	: 36" x 36"
Maximum drop height	: 46"
Maximum acceleration	: 600 G (1000 lbs sample)
Maximum Testing Weight	: 1100 lbs.

Seven different rubber pads.

b. Applications

This machine is very seldom used by manufacturers. Measuring product fragility with it is very difficult. The cost for shock tests are between $12.00 and $14.00 per hour.

<u>ADI Corporation Laboratory</u>

ADI Corp. Laboratory owns a basic vibration table freefall drop tester, and other instruments purchased from Japan that performs the resonace search and G-factor measurements.

Specification

IMV-VE-3202 Vibration Tester

Frequencies Range: 5-500 Hz

Maximum Acceleration: ±20G

Amplitude: 0-30 mm

Instapak Laboratory

Instapak's Taiwan Branch has a precise freefall drop tester with the GHI instrumontation for reading in the package verification test.

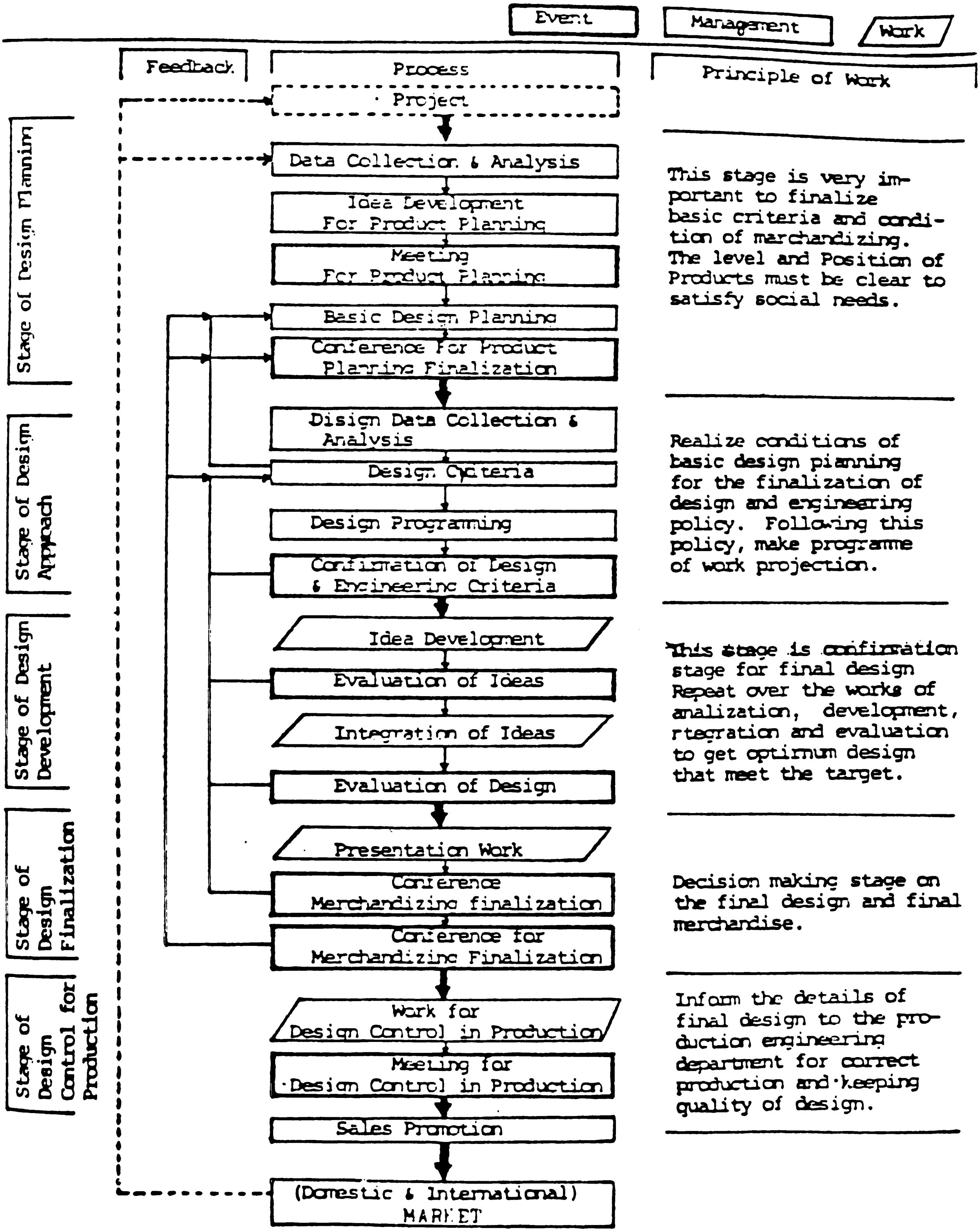
Specification

Lansmont Precise Freefall Drop Tester

CHI TRIAD-II Computing Transient Record System

APPENDIX B

THE DESIGN PROCESS CHART



APPENDIX C

DISTRIBUTION ENVIRONMENT

Many products such as tires, cloth products and canned food are strong enough to withstand the hazards of distribution and need only be unitized or protected for easy handling and transportation. Conversely, there are many highly fragile products that need proper packaging to pervent damage caused from environmental hazards, and to facilitate safe and economical distribution.

Manufacturing Distribution Environment

Terminals and other computer peripherials are fragile and technical products. These products need protection and need to be fixed in the package in order to prevent damage due to the hazards of transportation and handling.

The operation of most packaging terminal lines depends on manpower. The current manual systems need at least three or more operators to enclose a terminal in a cushioning material and place it into a shipping container. The boxes are then taped and manually moved to a pallet to complete a pallet pattern. A hand lift or forklift truck moves the unit load to a warehouse for storage where it awaits shipping.

Usually, the weight range of a packaged terminal is within 20-40 pounds. The relationship between package weight and the form of handling is shown in Table 5.

Table 5. Handling Environments[46]

Handling environments				
		Most severe probable environment		
Package weight, pounds	Greatest dimension, Inches	Drop Height Inches	Type of drop	Form of handling
20	48	42	Any side or corner	One man throw
20-50	36	36	Any side or corner	One man carry
50-100	48	24	Any side or corner	Two men carry
100-150	60	21	Any side or corner	Two men carry
150-200	60	18	Any side or corner	Two men carry
200-600	72	24	Rotating, either end-roll or tip	Mechanical
600-3,000	Unlimited	18	Rotating, either end-roll or tip	Mechanical
3,000	Unlimited	12	Rotating, either end-roll or tip	Mechanical

Unit Loads

A. Pallet

Most of the terminal importers in the U.S. requires that the product/package be palletized. These importers widely use mechanical handling equipment for distribution to increase efficiency and decrease labor cost.

The current unit loads used are 4 boxes per layer, stacked 3 layers in height, 6 boxes x 5 layers, 4 x 5 or 4 x

2 etc, depending on the size of containers and the requirements of the buyer.

After completing the pallet pattern, the pallet is strapped by polyethylene belts or steel belts. Either PVC or EVA films can be used for stretch or shrink wrap pallet packaging.

The packaging material costs are as follows:

1. Pallet cost : $10 - $13.
2. Stretch - wrap cost per pallet : $2 or higher. (Approximate size 1.2 x 1.2 x 1.2 m)
3. Shrink - wrap cost per pallet : $4 or more.
4. Pallet & Stretch wrap cost per unit: $1.1 or higher.
5. Cushioning material per unit : $0.85 - $1.85.
6. Carton, PE bag, tape per unit: around $1.25.
7. Total cost of terminal package material: $2.5-$3.5.

The most frequently used pallet sizes in Taiwan are 1000 x 1000 mm, 1200 x 1000 mm, 1140 x 1000 mm, etc.

B. Containerization

Containerization uses the container to distribute the goods in a compact, safe and versatile way which offers door to door service directly from the shippers to the consignees.

The characteristics of contemporary industry are mass production, mass distrbution, and mass sales. Unit loads and containerization can provide greater efficiency in the primary distribution channel.

Terminal Distribution in Taiwan

Based on cost considerations, most of the terminals have been shipped in dry cargo containers (40' x 8' x 8' or 20' x 8' x 8'). They are shipped from Kellung Harbor which is in north Taiwan or from the Port of Kaohsiung to the west or the east coasts of the United States.

Most of the terminal manufacturers are located in north or central Taiwan, so it is advantageous to use the port of Kellung to export terminals. Sometimes, because of higher marketing demands, buyers may require that the products be shipped by air. The flow chart of terminal exports are as follows:

Manufacturer Level

Terminal —Pallet→ Unit loads —Forklifts→ container

Trailers / Trucks → Container Freight Station —Exported Documents→

By Sea or By Air Distribution Environment → U.S. Seaports or Airports.

To increase the space- effectiveness of exporting computer terminals, package engineers have to consider the dimension of shipping container, unit loads, and pallet patterns. Also, the size and capacity of container has to be considered in order to reach cost - effectiveness.

The dimensions and freight costs of common use container are listed in Table 6.

Table 6. The Dimensions and Freight Costs of Container[33]

Catagory	Loading dimension (m/m) L	W	H	Capacity (cube feet)	* Freight Cost West Coast	East Coast
20'	5920	2340	2410	1186	\$1550-\$1650	\$2300-\$2450
40'	12040	2340	2360	2359	\$2350-\$2450	\$3640-\$3710
40'	12040	2340	2540	2550	\$2775	\$4175

* The freigh rate based on July 1983 freight level.

Some distribution pictures are shown in Figure 15 and Figure[34]16.

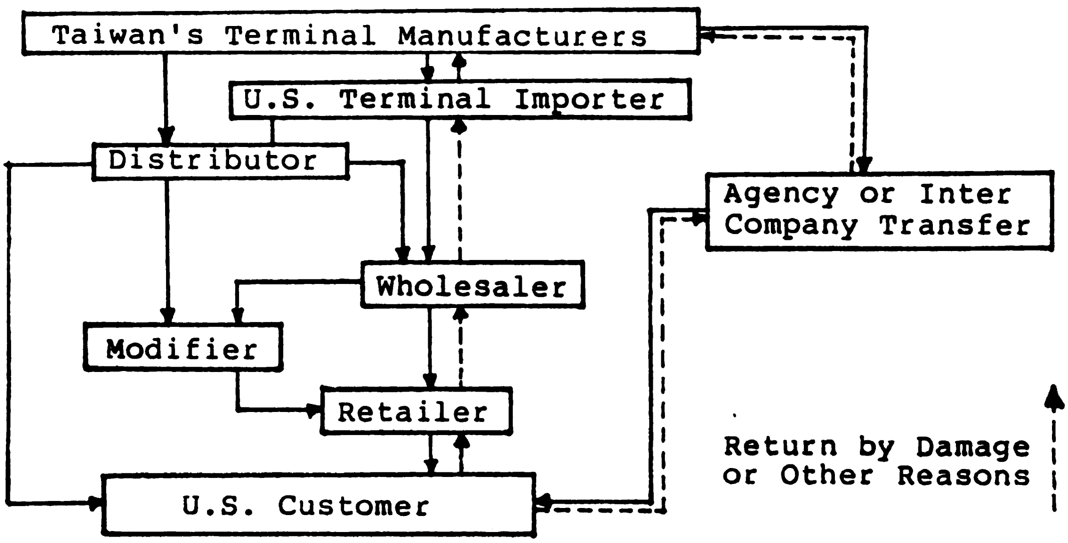
Distribution in the U.S.A.

The United States uses convenient transportation networks such as railroad, highway, and air or water transportation systems.

Containerization is a multi-mode or a combined transportation system. The terminal products arriving at the American sea ports or airports (west coast or east coast), then most of them are carried by truck to the customers. The probable distribution chain is listed in Table 7.

The distribution time of computer terminal from Taiwan to the west coast of U.S. is approximate 30 to 35 days (to East Coast around 35 to 40 days). Most of the computer terminals are imported from Taiwan to the West Coast of the U.S. such as the seaport of San Francisco or Los Angeles.

Table 7. The Distribution Flow Chart



In general, the distribution chain is from the distribution center to computer retail stores or to other regional distribution centers and then customers transport the products from stores by automobile. There is also a trend mail order sales and delvery by United Parcel Service. The per unit freight rate for terminals shipped from Taiwan to the West Coast of the U.S. is approximately \$4.5-\$8.0. Cost is approximately \$6.5-\$11.5 for East Coast shipments.

Usually light weight and high value products, such as terminals, are shipped by truck. The reason is that highway transportation is more economical than air transportation, and it is faster and safer than railroad. From the Table[49] 8, we can see the important role of using highway transportation.

Figure 15. The Dry Cargo Containers Shipped at Harbor[34]

Figure 16. The Container Freight Station and a Container Ship[34]

Table 8. Expenditures for the Movement of Property in the United States, 1978.[49]

Mode of Transportation	Amount Spent (000,000)	Percent
Railroad	$ 21,896	11.5
Highway	147,404	76.7
Water (including international)	12,379	6.5
Oil Pipeline	5,452	2.3
Air (including international)	2,654	1.5
Freight Forwarders and REA Express	583	.3
Other Shipper Costs	2,185	1.2
Total	$192,553	100.0
Gross National Productt	$2,127,600,000,000	
Freight Bill as a Percentage of Gross National Product	9.1	

* Includes mail and express; includes payments made to for-hire carriers and <u>expenditures</u> on private transportation.

\+ Total output of goods and services in 1978 dollars.

<u>The Potential Hazards Experienced by a Product/package</u> in the Distribution Environment.

Terminals need to be contained and protected in packages because of hazards in the distribution environment.

According to Walter and Jerome[47], the hazards inherent in the distribution system are (1) environmental hazards,

(2) physical hazards and (3) miscellaneous hazards.

Environmental Hazards.

Temperature and humidity are two of the many environmental hazards experienced by terminals in distribution. Terminals which are exported to the United State may need protection from the influences of heat, cold, humidity, etc.

These hazards are not too serious in the distribution of terminals. In a package design, one only needs to use the correct package or make minor changes so that terminals can be protected against these hazards.

Physical Hazards.

Terminals must be protected against one or more of the following physical hazards[47]:

(1) Vibration & Shock Hazards.

Walter mentions the fact that vibration-induced shock can be encountered both during inplant handling and in shipment, but the majority of vibration damage is caused by transit. Packaging can offer protection against scuffing, marring, abrasion, loosening, fracturing, and misalignment[47].

S.G. Guins[48] recommends that the frequency and magnitude ranges of vibration shown in Table 9 should be considered.

(2) Impact Shock

Impact shocks are caused both during handling and in transit. According to Walter[47], handling impacts result from manual handling and potential abuses such as throwing, dropping, and tumbling. Also, the sudden accelerations and

Table 9. Forcing Frequencies of Major U.S. Transportation Modes[48]

Railroads		
Suspension frequency vertical	2 - 7 Hz, peak acceleration .5g.	
Suspension frequency lateral	.75 - 2 Hz, peak acceleration .75g.	
Suspension frequency	50 - 60 Hz, peak acceleration .25g.	
Highway		
Suspension frequency	2 - 7 Hz, peak acceleration .5g.	
Tire frequency	15 - 20 Hz, peak acceleration .25g.	
Structure frequency	15 - 20 Hz, peak acceleration .25g.	
Ship		
Frequency	Average Acceleration	Peak Acceleration
3 - 10	.25g	.5g
10 - 30	.25g	1.0g
30 - 70	.25g	.5g
Airplane		
Usually higher frequencies with low g values.		

decelerations of carriers can cause transit impact shock.

Vibration and impact shock are the most serious hazards which cause terminal damage. Package engineers have to consider these hazards in detail. They can then design a "damage free" package for these products. For example, S.G. Guins[48] states, "In highway vehicles, longitudinal forces can be produced either by acceleration or brake application and are of limited severity. Vertical impact is caused by chuck holes, rail crossings, and other irregularities and can be quite severe".

The impact shock values for forklift trucks, trains, and higway trucks are listed in Appendix E.

(3) Compression.

According to Walter[47], compression stresses may be caused by (1) static conditions due to the superimposition of weight onto merchandise or by (2) dynamic stresses of impact shocks. In this type of hazard, the strength of the shipping container and cushion material and the structure of the terminal must be strong enough to resist compressive stresses. Otherwise, it will cause crushing, buckling, bending, deflection, and damage the products.

(4) Puncture and Other.

Puncture hazard and other physical conditions of tension (shear, torsion, and tear) have little influence on the terminal distribution environment.

Miscellaneous Hazards.

Some products have to be protected against microorganisms, insects, pilferage or shelf life problems, but these are not important in terminal distribution. These hazards can be prevented easily in terminal packaging design.

According to the IBM technical report "The Distribution Environment", a product and its industrial package is subjected to a varity of stress during the distribution process[54]. The distribution stress and mechnical stress are showed in Figure[54] 17 and Figure[54] 18.

Before designing a package, the fragility of the product and the hazards of the distribution environment must be known. Many design alternatives can then be rationally compared and evaluated.

Marketing Research.

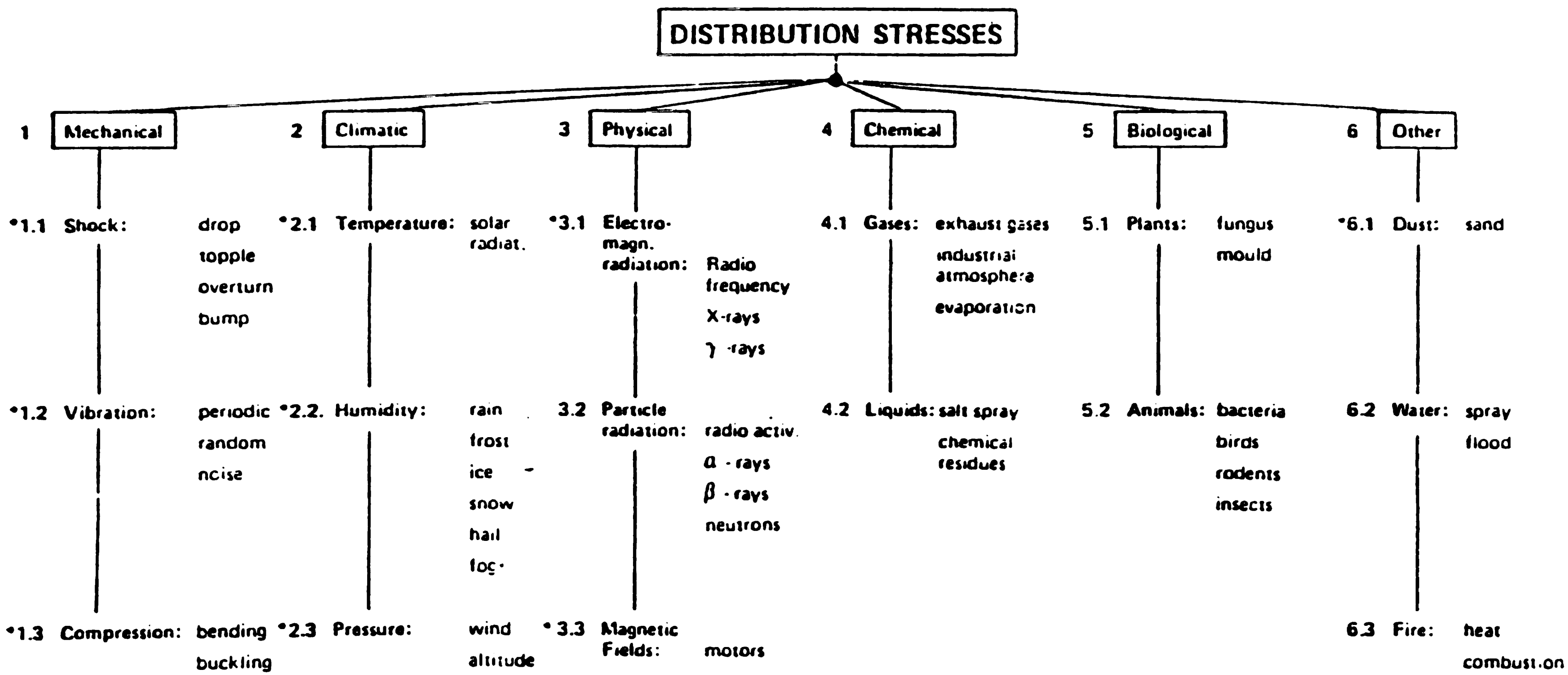
Marketing research is a very important part of the product/packaging design. It can determine whether a package is strong enough to protect the product and if the product/package will sell. In October, 1983 to Dec. 1983, I mailed questionnaires to about 20 terminal importers. The contents of the questionnaire are listed in Appendix F.

The few questionnaires returned may not be enough to develop a statistical analysis that is reliable. But we can still look for trends and make an evaluation of overall package performance.

According to the above investigation, the terminals exported from Taiwan have good quality and are reasonably priced from a hardware standpoint.

Famous multi-national terminal manufacturers, such as Wang Labs, (Taiwan) LTD are also usually statisfied with their package designs. Some of the bigger buyers, such as IBM, emphasize package testing and require higher package performance. Adequate package design and proper testing standards result in better terminal protection.

However, for most members of the terminal industry the package design and performance is not adequate or economical. One of the questionnaires showed the damage rate of packages exceeded 30%, resulting in a loss of profit, product, and market advantage.



* Description relevant for computer terminal

Figure 17. Distribution Stresses Summary Chart[54]

MECHANICAL STRESSES

- **A. Shock** (direct to the product or package)
  - topple
  - drop
  - overturn
  - bump
- **B. Shock** (indirect, via the transport vehicle)
  - rail/trailer coupling
  - railcar shunting
  - road conditions
  - landing
  - container/module handling
- **B. Vibration** (indirect, via the transport vehicle)
  - drive, power systems
  - suspension
  - road conditions
  - conveyors
  - rolling on casters
- **A. Compression** (direct to the product or package)
  - stacking
  - strapping
  - load shift

  (improper storage)

* A. Stresses which can be influenced by means of equipment, instruction, routing, etc.

B. Stresses which cannot be influenced and are inherent to the environment.

Figure 18. Mechanical Stresses Summary Chart[54]

APPENDIX D.

TESTING CONSIDERATIONS AND TEST STANDARDS

I. PRODUCT

1. Product: Terminal

2. Product Weight: 20-40 lbs (This terminal is a desktop product, and the trend is toward minimizing it's components. Its weight is no too heavy).

3. Product Price: Higher than average (over $700.00)

4. Product Fragility: Fragile.

5. Possible Hazards: Shock & Vibration.

6. Product Shipability Requirement: At least withstand 30 G's (such as NCR's standard)

7. Probable drop height: 36" (considered for international shipping)

8. The possibility of damaged parts:
   . The cover of disk drive may be damaged
   . The heavy structures such as: disk drive and transformer parts may become loose, crack or break.
   . CRT broke
   . The fixed parts of the CRT crack or break
   . Outside plastic corners break or crack
   . The keys of keyboard become loose
   . PC board become loose or breaks
   . Others

9. Product fragility test:
   A. ASTM D-3332-77 Mechanical - Shock Fragility of Products using Shock Machine. It can be used to develop the product damage curve.
   B. Vibration test:
      . ASTM D3580-80 Vibration (Vertical Sinusoidal Motion) Test of Product
   C. Compression test
   D. The other tests
      Such as: temperatur test; humidity test; special environment test; and Electromagnetic Interference (EMI) test. (These are required for product design or quailty assurance).

10. Natural frequency of the product:
    Natural frequency or frequencies and other factors can be measured by vibration fragility tests.

II. Package

11. Cushioning Materials:
    - Expanded polystyrene (EPS) specification Density: 0.02 kg/m (most of the terminal manufacturers use this density).
    - Polyurethane, Foam-in-place Density: 0.6 lbs/ft (some of the terminal manufacturers use this density).
    - Other

12. Testing Methods:
    - ASTM D-2221-68 Standard Test Method for Creep Properties of Package Cushioning Materials.
    - ASTM D-1596-78a Shock Absorbing Characteristics of Package Cushioning Materials.
    - ASTM D-1372-64 Standard Methods of Testing Package Cushioning Materials.

13. Cushioning Design Procedures:
    - First, the product fragility, shipping environment, and cushioning properties of cushion materials are known. Then, it can be decided that the product need a cushion design to protect or not.
    - Using the cushion curves to determine the foam thickness and the optimum cushioning area by means of the formula:

$$\text{Area} = \frac{\text{Weight}}{\text{PSI}}$$

    - Using the formula: A minimum area - $(1.33\ T)^2$
      T= the thickness of cushioning material to check if it will buckle.

    - Design criteria: to provide adequate protection for both shock and vibration.

14. Cushioning Style:
    - Total encapsulation
    - Face
    - corner

III. Shipping Container

15. Shipping Container Specification
    Corrugated fiberboard container, double-wall

16. Testing Methods:
    - ASTM D-775-61 Drop Test for Shipping Containers.
    - ASTM D-642 Compression Test for Shipping Containers.

- ASTM D-880 Incline Impact Test for Shipping Containers.
- ASTM D-999 Vibration Testing of Shipping Containers
- ASTM D-996 Definition of Terms Relating to Packaging and Distribution Environments.
- ASTM D-4169-82 Performance Testing of Shipping Containers and Systems.
- ASTM D-2956-71 Controlled Shock Input Tests for Shipping Containers.
- ASTM D-782-68 Shipping Containers in Revolving Hexagonal Drum.
- ASTM D-685 Conditioning Paper and Paper Product for Testing.
- Others:
  Such as NSTA Pre-Shipment Test procedures, PI, TAPPI, Federal Standard and Military Standards.
- MIL-STD-810B (World wide most sever test)
- IBM-CH 1-9711-005 Packaged Product Tests
- MIL-P-7936 (Worldwide)
- MIL-STD-810B (Domestic)
- Federal Test STD 101B (worldwide)
- Federal Test STD 101B (Domestic)
- NSTA Project 1A "Transit Tested"
- IBM Corp. STD C-H 1-9711-001, Product Fragility -Vibration
- IBM Corp. C-H1-9711-004, Product Fragility- - Shock.

CNS Standard:

CNS 2543-26006 Method of Compression Test for Packaging and Shipping Container.

CNS 2544-z6007 Method of Incline Impact Test for Packaging and Shipping Container.

CNS 2999-z6012 Method of Drop Test for Packaging and Shipping Container.

CNS 3511-z6016 Method of Test for Compression Strength of Corrugated Fiberboard Container.

CNS 5637-z6026 Shipping Test for Consumer Electronic products.

17. Stacking Height:
    a. At transportation: Maximum height 7'4" (the max. door height of the 40' dry cargo container).
    b. At warehouse: Most of the time the terminal stack is one pallet heighth or may use frame or rack to store it. It is very seldom stacked over two pallets in heighth. The stacking height range: 3'8" - 7'4" height (based on-one-half of the maximum door heighth of the 40' long dry cargo container).

18. Shipping Container design procedures:
    A. Decide the container size.
       It is decided according to the size of

cushioning, the efficiency of distribution and the cost of the packaging materials.

B. Calculate the stacking height and required compressive strength of the container. According to the required stacking layers and safety factors of the corrugated box or using K. Q. Kellicutt formula, the required compressive strength can be calculated, and these equations, are listed as follows:

a. $$N = \frac{P}{G.W \times SF} + 1$$

N= Stacking layers
P= required compressive strength of the container.
G.W= gross weight of the container
S.F= Safety factor (depends on different considerations, and usually uses 3-5).

b. Safety factor (S.F)

$$S.F = \frac{1}{\text{safety rate}}$$

Safety rate= (1-a) (1-b) (1-c) (1-d) (1-e) ..
a-e= the decade rate of the container

C. According to the required compressive strength, protection, and cost-efficiency a flute size is chosen
D. To design an optimum package to meet the cost and distribution efficiency requirements.
E. Package testing and evaluation.
F. Packaging design feedback or continuing next design.
G. The shipping container has to meet the Railroad Classification Rule 41 "Corrugated or Solid Fibreboard Boxes." and Truck Classification Rule 222" Corrugated or Solid Fibreboard Box".

IV. Distribution Packaging

19. Unit loads:
    a. pallet: Using a 40"x48" 4-way pallet in order to get the higher unit load efficiency and satisfy the U.S. distribution system.
    b. Using stretch films, PVC or steel belt with corner pad or with the mixed pack style.

20. Packaging efficiencies
    Make sure to get the maximum distribution efficiency. The designers can use the

following equations to evaluate the packaging efficiencies:

a. Case efficiency

$$\text{Case efficiency} = \frac{\text{Product cube per case}}{\text{Case cube}}$$

b. Pallet load efficiency

$$= \frac{\text{Case cube per pallet load}}{\text{Maximum pallet load cube}}$$

c. Trailer load efficiency

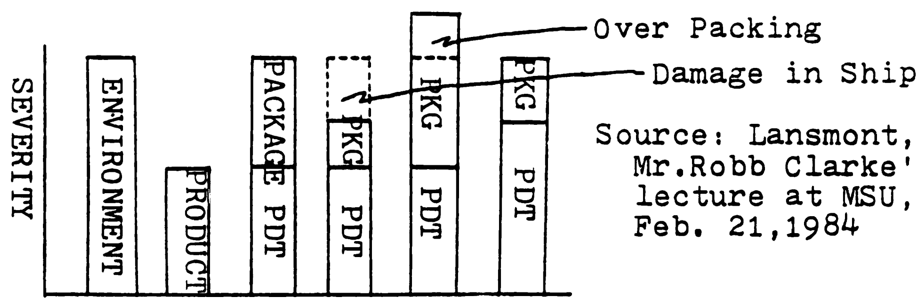
$$= \frac{\text{Pallet load cube per trailer}}{\text{Maximum trailer cube}}$$

d. Warehouse storage efficiency

$$= \frac{\text{Maximum pallet load cube}}{\text{Warehouse cube to store one pallet}}$$

21. Computer-aided package design
Designers can use the computer to outline and evaluate the cushioning design and distribution efficiencies. It can save design time and distribution costs.

22. Other considerations and evaluations
The following figure shows the relation within the product/package system in the distribution environment.



Source: Lansmont, Mr.Robb Clarke's lecture at MSU, Feb. 21,1984

APPENDIX E

THE TYPICAL SHOCK VALUE OF SOME VEHICLES

Table 10. The Fork lift truck's Shock Value[40]

		Vertical	The Side of Right - Left	The Side of Front - Rear
Vibration Value in motion 6-7 km/hr	Smooth road	0.2-1.36	0.2-0.3	0.1-0.2
	Rough road	0.6-1.6	0.3-0.4	-
Fork-lift motion	Begin lift	1.7	-	-
	Begin down	0.2	-	0.3
	Down stop	0.4-1.0	0.1-0.2	0.4-0.8
	30 cm drop to ground	3-4	-	0.6-1.1
Incline motion (Front & Rear)		1.2-1.9	-	-

Table 11. The Shock Value of Truck & Train[40]

			Vertical G	The Side of Right - Left G	The Side of Front - Rear G
Truck	Vibration Value in motion 20-40 km/hr	Smooth Road	0.2-0.9	0.1-0.2	0.1-0.2
		Rough Road	1-3	0.4-1.0	0.5-1.5
	35 km/hr speed brake		0.2-0.7	-	0.6-0.7
Train	Vibration Value in motion 30-60 km/hr	Track	0.1-0.4	0.1-0.2	0.1-0.2
		Pass joint	0.2-0.6		
	Start & Stop	Common	-	-	0.1-0.5
		Sudden	0.6-0.9	0.1-0.8	1.5-1.6

Appendix E (Cont'd)

Table 12. The Shock Value of Goods in Train[40]

	Train's bed	Pallet Surface	The Highest layer
Right- Left	0.9 G	1.5 G	-
Vertical	1.5	1.5	9.0
Front-Rear	1.3	9.5	6.0

APPENDIX F. QUESTIONNAIRE

1. Kinds of products imported from Taiwan?
   ( )Microcomputer ( )Color display or monitor ( )Monmonitor
   ( )Terminal ( )Other.

2. The range of sale price?
   ( )Microcomputer: $__________ ( )Terminal: $__________
   ( )Monitor: $__________

3. Amount of order on the above produets?
   ( )Initial_________ ( )Annual___________ ( )Potential________

4. Trading system with the manufacturers?
   ( )F.O.B. ( )C.I.F ( )Other

5. Reasons buy product(s) from Taiwan?
   ( )Reasonable price ( )Good quality ( )Function consideration
   ( )Other(s)____________

6. Brand used on products?
   ( )Manufacturer's brand:____________
   ( )Your company's brand:____________
   Name the manufacturers:______________

7. Modes of transportation?
   ( )By sea, if using container____________ What size____________
   ( )By air, does it shipping by container what size____________

8. Kind(s) of inland transportation?
   ( )Truck or____________
   ( )Railroad ( )Ship ( )Mixed ( )Other____________

9. Your marketing area(s)?
   ( )West ( )East ( )Centeral ( )North east ( )South
   ( )Other____________

10. Is pallet load, unitized load or containerization desired
    ____________ type size____________ (such as 48"X40" or
    48"X40" ----etc) ( )Other___________

11. Shipping package would be?.
    ( )Corrugated box -- ( )Single wall
    ( )Double wall
    ( )Other__________
    ( )Solid fibre ( )Wood ( )Other__________
    ( )Corrugated bulk container

12. Kinds of cushional material(s) used?
    ( )Expend polystyrene ( )From-in-place (PU)
    ( )Polyethylene foam ( )Aircap ( )Other___________

13. Is the design appropriate to the product?___________

14. Is the product (or package) of?
    ( )Reliability ( )Availability
    ( )Serviceability ( )Usability
    ( )Installability ( )Other___________

15. Is package strong enough to protect the product from manufacturer to customer? ( )Yes ( )No

16. What is/ are the damage situation(s) of external package?
    ( )Serious domage ( )Slightly deformation
    ( )Puncture ( )Shape defect ( )Other__________

17. What is/ are the damage situation(s) of cushional material(s)?
    ( )Serious damage ( )Buckle
    ( )Slight deformation ( )Unchange ( )Other___________

18. What are the usual damages of the product?
    ( )Exterior eage of product ( )Keyboard loose
    ( )PC board loose or damage ( )Out of function
    ( )CTR damage ( )Other____________

19. What is the product damage rate?
    ____

20. What is the package damage rate?
    ____

21. What hazards may be involved?

____

22. What package modification is necessary for distribution or storage?
    ( )Extremes of storage ( )Extremes of temperature
    ( )Extremes of transportation ( )Other__________

23. When goods stacked on pallet are these boxes overheaded or fallen? ( )NO ( )Yes__________

24. What inconvenientes or influences do you have caused by unreasonable packaging or damaged products?

    ____

25. How long are the products stored in warehouse?
    ( )1 month ( )2 months ( )3 months ( )4 months
    ( )Longer__________months

26. How high and how many layers do you stack these products?
    ( )Height__________ ( )layers__________
    Do you use the frame or rack to store pallets or produets?
    ( )NO ( )Yes, What size__________,structure__________

27. Do you use pallet(s), slipsheet(s) or other unit loads to handle and store your products?
    ( )Pallet(s) Size__________,__________
    ( )Slipsheet(s) Size__________,__________
    ( )Other__________

28. What are the advantayes and disadvantages of the packaging of these products?
    ( )Advantages:______________________________
    ____
    ( )Disadvantage:______________________________
    ____
    ____

29. What immeadiate corrections and improvement should be made on the packaging of these products?

____

30. What information you think is very important but not listed above? Would you kindly offer to me?

31. Would you please offer me the photographs of package or product damage situations?
( )Yes ( )NO ( )Other____________

Thank you very much!

Name:____________________________
Title:____________________________
Company:____________________________
Address:____________________________
TEL: ____________________________

Please Mail To:
Sunny Sun
1536 H Spartan Village, MSU
E.Lansing, MI.48823
TEL: (517)355-2951

FOOTNOTES

1. Yuan-Jing Cheng, Manager of the Product and Package Design Department of the China External Trade Development Council; July 11, 1983 conversation with Ming-Ren Sun, at CETDC, Taipei.

2. Mu-Wang Lee, Manager of Packaging, Tatung Corporation, Taipei; July 14 and 27, 1983 conversations with Ming-Ren Sun, at Tatung.

Fu-Nan Cheng, Manager of Packaging, Teco Corporation, Taipei; August 18, 1983 conversation with Ming-Ren Sun, at Teco.

Chu-Chie Din, Manager of Packaging, Cal-Comp Corporation, Taipei; August 23, 1983 conversation with Ming-Ren Sun, at Cal-Comp.

Tatung, Teco, and Cal-Comp are all television manufacturers. Lee, Cheng, and Din stated that export customers for television sets have been satisfied with the quality of the products they have received. Present packaging materials, designs, and testing have been adequate for meeting customer requirements.

3. Mu-Wang Lee, Manager of Packaging, Tatung Corporation, Taipei; July 14 and 27, 1983 conversations with Ming-Ren Sun, at Tatung.

Fu-Nan Cheng, Manager of Packaging, Teco Corporation, Taipei; August 18, 1984 conversation with Ming-Ren Sun, at Teco.

Chu-Chie Din, Manager of Packaging, Cal-Comp Corporation, Taipei; August 23, 1983 conversation with Ming-Ren Sun, at Cal-Comp.

Shu-Shon Kao, General Manager, Kao Computer Corporation, Taipei; July 26, 1983 conversation with Ming-Ren Sun, at Kao Computer Corporation.

Bin-Chan Lai, Manager of Packaging and Quality, ADI Corporation, Taichang; August 1, 1983 conversation with Ming-Ren Sun, at ADI Corporation.

Mu-Tor Wang, General Manager, China Data Processing Corporation, Taipei; August 4, 1983 conversation with Ming-Ren Sun, at China Data Processing Corporation.

Win-Wus Wu, Manager of Packaging, Hongi Computer Corporation, Taipei; August 4, 1983 conversation with Ming-Ren Sun, at Hongi Computer Corporation.

Tatung, Teco, Kao Computer, ADI, China Computer, Hongi Computer, and Cal-Comp are all computer and/or peripheral manufacturers. In the referenced converations, all industry spokespersones stated that there is a shortage of information on protective package design and testing in Taiwan. Currently, most information available is from Japan. Since the largest export customers for Taiwan are in the United States, current information on materials, design processes, test methods, and packaging line processes in the United States are needed, particularly since package performance requirements from the American customers are incresasingly technical and rigorous.

4. Min-Chan Chen, Manager of Packaging Research Laboratory, Kao-Chun Shie, Packaging Engineer of the CETDC; July 15, August 1, 18, 19 and August 25, 1983 conversation with Ming-Ren Sun, at Packaging Research Laboratory, CETDC, Taipei.

5. Stephen J. Henning and Daniel H. Hudson, Packaging Engineers, IBM, Boca Raton, FL, USA April 2 and April 3, 1984 conversation and product tests with Ming-Ren Sun, at Entry System Division of IBM-Boca Raton, Florida.

6. Ming-Ren Sun, ed. Terminal System Schematic, School of Packaging, Michigan State University, Lansing, Michigan; January, 1984.

7. Photograph taken by Ming-Ren Sun at Packaging Research Laboratory, August 19, 1983, Taipie.

8. The author visited the following corporations: Tatung Co., Teco Co., Cal-Comp Co., ADI Co., Hongi Co., Pan Asia Co., China Data Processing Co., and Kao's Computer Co., from July 1983 to September, 1983.

The Sampo Co., Sony Co., Wang Co., and Hellet-pakard were interviewed by telephone on august 1983.

9. Chi-Chan Cheng, Manager of Mechnical Engineering of Cheng Loong Co., (corrugated board & container supplier) July 13, 1983 conversation with Ming-Ren Sun, at Cheng Loong Co..

Mr. Wang, Manager of Marketing of Fong Loong Co., (corrugated container converter) August 12, 1983 conversation with the author at Fong Loong.

Mr. Kao, Manager of Manufacting of Hu Dar Co., (EPS manufacture) July 30, 1983 conversation with Ming-Ren Sun at Hu Dar Co., Tao Yuan.

Mr. Chang, Manager of Marketing of Hu Chin Co., (EPS manufacturer) conversation with Ming-Ren Sun, at Hu Chin Co., Taipei.

Yan-Ming Yong, General Manager of Fu Young Co., (The Taiwan Agency of IPS, Foam-in-place supplier), August 26, 1983 conversation with Ming-Ren Sun at Fu Young Co., Taipei.

Kai-Luan Chen, Manager of Packaging, Instapak Taiwan Branch (Foam-in-place supplier) August 25, 1983 conversation with Ming-Ren Sun at Instapak, Taipei.

10. The author surveyed the package test equipment at the office of Instapak's Taiwan Branch, August 25, 1983.

11. The author visited the RESO Laboratory with Chin-Hea Cheng, Manager of Product Service RESO of the ITRI, August 22, 1983, at Tao-Yuan.

12. Chin-Hea Cheng, August 22, 1983 conversation with Ming-Ren Sun at the ITRI Laboratory.

13. Kou-Chan Shie, Packaging Engineer of Packaging Research Laboratory of the CETDC, mentioned to Ming-Ren Sun on July 12, 1983 at CETDC Laboratory.

14. Min-Chan Chen, Manager of Packaging Research Laboratory of the CETDC, mentioned about this fact on July 12, 1983.

15. Teco is the only one of the five major computer terminal manufacturers that has a semi-automatic box loading machine.

16. Photograph by Daniel H. Hudson, Packaging Engineer at IBM, Boca Raton, Florida, May, 1983 at Teco's packaging line, Taipei.

17. Mu-Yuan Lee and Yuan-Yu Shei stated the problem on July 12, and August 16, 1983.

18. The author visited the Cheng Loong Co., and these problems were mentioned by Mr. Chi-Chan Cheng on July 13, 1983.

19. The author visited Hu Dar Co., and discussed the manufacture and design procedure of EPS with Mr. Kao on July 30, 1983.

20. In early 1983, the three main color display export manufactures, Tatung, Teco and Cal-Comp, were required to use foam-in-place as the cushion of color display by IBM.

21. Mu-Wan Lee, July 27, 1983 conversation with the author at Tatung, Taipei.

22. The author visited the Teco plant on August 18, 1983 and found the mold operators to recycle the waste foam-in-place.

23. Photograph by Ming-Ren Sun, taken at Hu Dar Co., Taipei, on July 30, 1983.

24. Photograph by Ming-Ren Sun, August 12, 1983 at Packaging Research Laboratory of CETDC.

25. The testing frequency of vibration testers of CETDC are not high enough to run the resonance search. And the vibration testers amplitude of ITRI Laboratory is not large enough for testing.

26. Photograph by Ming-Ren Sun, August 12, 1983 at the Packaging Research Laboratory of CETDC.

27. According to the testing records of ITRI Laboratory and Chin-Hea Cheng August 22, 1983 conversation with Ming-Ren Sun at ITRI Laboratory.

28. Mu-Wan Lee and Geroge Chen, July 14 and July 27, 1983 conversation with Ming-Ren Sun at Tatung. Also Daniel H. Hudson, Packaging Engineer at IBM, Boca Raton, mentioned it to Ming-Ren Sun June 15, 1984 at Packaging Engineering Department at IBM in Boca Raton. The model number of display is CM-13B.

29. Fu-Nan Cheng mentioned the problem to the author August 18, 1983 and gave the author a copy of the testing report. The model number of display is CM-13A.

30. The author visited Pan Asia Co., at August 2, 1983 and attend the PA-5000 micro computer package verification testing with Bing-Jone Hwang, Manger of Quality Control Pan Asia Co., on August 24, 1983 at Packaging Research Laboratory of CETDC.

31. The design processes are cited from the author's report, "A Project on Sporting Shoes Product Design", Which wrote at Taipei in 1981.

32. This morphological chart was developed by the author at Lansing, Michigan in 1983.

33. The data was survey by the author at Taiwan in 1983.

34. Photograph by Ming-Ren Sun, taken at Kau-Shun Harbor, Kau-Shun, on July 15, 1983.

REFERENCES

35. "0 & 1 Technology", October 1983, p. 112.

36. Baird, Terrence W. "The Significance of Product and Material Performance Data." Lansmont Corporation, 1978, pp. 1-2.

37. CETDC. The Introduction of Packaging Research Laboratory. Taipei, 1983.

38. CETDC. Directory of Packaging Materials Suppliers. Taipei, 1982.

39. CETDC. The Introduction of Packaging Research Laboratory. Taipei, 1983. p. 14.

40. CETDC. "Cushion Design for Electronic Exports", Design and Packaging, Volume 3, 1980.

41. "Chapter7. The Network System", MGT 800 Textbook, Michigan State University, Lansing, Michigan. p. 215.

42. Cheng, Yuan-jing. "Basic Packaging Testing", Special Issue of Taipei Pack's 1983. Taipei, 1983, p. 109.

43. Christopher, Jones, J. Design Methods. New York: John Wiley & Sons, 1973. pp. 273-295

44. Christopher, Jones, J. Design Methods. New York: John Wiley & Sons, 1973. pp. 300-303.

45. Chu Chen, Trin-Tan. "Polyurethane Foam-in-Place Packaging Methods". Special Issue of Taipei Pack's 1983. Taipei, 1983. pp. 130-137.

46. Dylite Expanded Polystyrene Package Design. Philadelphia: Arco Chemical Company.

47. Friedman, Walter F. and Kipness, Jerome J. Distribution Packaging. New York: Krieger Publishing Co. Inc., 1977. pp. 37-50.

48. Guins, S.G. Notes on Package Design. 1981. pp. 1-35.

49. Harper, Dorald V. Transportation in American Users, Carriers, Government. New Jersey: Prentice-Hill, Inc., 1982, p. 10.

50. Institute of Information Industry. A Prospectives of R.O.C.'s Information Industry 1980. Taipei, 1983.

51. Montery, 5 Step Packaging Development, MTS, April 1971.

52. Sontag, Glenn R. and Walter, Stern. Handbook of Package Design Research. New York; John Wiley & Sons, 1981, p. 88.

53. Tatung Catalog. The Computer Terminal Product Catalog of Tatung Corporation. Taipei, August, 1983.

54. The Distribution Environment. IBM Report, March 1983, p. II-1 & P. III-1.

55. The ERSO of the ITRI. The Introduction of the Electronics Research and Service Organization of the ITRI. Taipei, 1983.

GENERAL REFERENCE

Roebuck, J.A. and Kroemer, K.H.E. Engineering Anthropometry Methods. New York: John Wiler & Sons, 1975.

Department of Statistics, Ministry of Economic Affairs, R.O.C. Taiwan Industrial Production Statistics Monthly Republic of China. Taipei, July 1983.

Packaging Engineering. The Packaging Encyclopedia 1983. Denver: Cahners Publishing Company, March, 1983.

Cahners Publishing Company. Packaging Engineering. Denver. January, 1983 - February, 1984.

Kulwiec, Raymond A. Basic of Material Handling. Pittsburgh: The Material Handling Institute, Inc., 1981.

Industrial Design Promotion Center. Product Design and Packaging. Taipei: Industrial Design Promotion Center CETDC, Volume 1-14.

Economics Daily. Taipei Pack 81'. Taipei: Economics Daily, 1981.

Economics Daily. Taipei Pack 83'. Taipei: Economics Daily, 1983.

Chen, Shin-Lan. New Product Planning, Taipei: Chang-Cheng Management Company, October, 1975.

Woodson, Wesley E. and Conover, Donald W. Human Engineering Guide for Equipment Designers. Taipei: Central Book Company, 1964.

Hanes, Richard S. "Recording and Analysis of Truck Vibration." Boulder: IBM Company, August, 1983.

Fibre Box Association. Fibre Box Handbook. Chicago.

Hanlon, Joseph F. Handbook of Packaging Engineering. New York: McGraw-Hill Book Company, 1971.