This is to certify that the

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COST EFFECTIVENESS
OF USING FOAM CUSHIONING
FOR
ELECTRONIC PIECE PARTS

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COST EFFECTIVENESS
OF USING FOAM CUSHIONING
FOR
ELECTRONIC PIECE PARTS

BY

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ABSTRACT

COST EFFECTIVENESS OF USING FOAM
CUSHIONING FOR ELECTRONIC PIECE PARTS

BY

Jon Phillip Whitcomb

Growth of the electronics industry into multi-national producers has increased demand for cost effective packaging for piece parts which make up finished products. These packages must now be cost effective for distribution around the world.

Traditionally, the piece parts package is primitive. It is generally a polyethylene bag in a corrugated box, which is placed with many other boxes in a larger corrugated box.

The value of piece parts has increased, causing the cost effectiveness of traditional packages to decrease. The acceptable number of damaged parts resulting from the packaging is now lower.

This study was conducted to determine the cost effectiveness of several configurations of polyurethane foam cushioned packages. The first test shipment was from a Motorola plant in Arizona to one in South Korea, and back. A more extensive and conclusive second shipment was from Phoenix to South Korea. The results proved that foam cushioned packages were more cost effective than the traditional package.

DEDICATION

This work is dedicated to my wife, Nancy Carol Wrona, who enjoyed learning packaging terms and concepts in the course of my studies. Without her help, this task could not have been accomplished.

Acknowledgements

Several people made significant contributions which enabled me to complete this thesis. Russ Archer, my supervisor at Motorola, and Alice Lewis of our support staff aided and encouraged this effort. Dr. James Goff's guidance and advice were instrumental in the completion of this thesis. Connie Schweifler typed the rough drafts, an arduous task for which I am grateful.

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Introduction

Motorola Semiconductor Products Sector produces transistor piece parts for sale on the world market and for its own domestic and foreign assembly factories. Motorola assembly factories purchase up to 20% of identical piece parts from their numerous competitors. The foreign assembly factories perceive a difference in mechanical protection provided by the competition's packaging systems. The foreign assembly factories believe that the Motorola system is less effecient in protecting the piece parts from mechanical damage. The competitor's piece parts are composed of the same alloys, and have a similar distribution route. The most significant difference in the competitors' systems, which provides better mechanical protection, is the use of plastic foam cushioning, which Motorola does not use.

The question raised and answered in this paper is whether polyurethane foam cushioning in the primary package of the TO-39 transistor piece parts packaging system will be more cost effective than no foam cushioning. This possibility was investigated by conducting two test shipments containing thousands of piece parts in ten different packaging systems. The test shipments were conducted by the author, a member of Motorola's Packaging Engineering function, at the request of Electronic Materials Division, which produces the piece parts.

The specific problem to be investigated is the package system used for shipping transistor piece part TO-39 headers from Phoenix, Arizona, to Seoul, South Korea. The Motorola header experiences a 1.03% reject rate; the competitors have a .08% reject rate.

The competitors' parts are flown from Germany to the Seoul airport. Motorola's are trucked to Los Angeles, and flown approximately the same distance to Seoul. The distance the competitors' parts are trucked to the airport is not known.

Chapter 1

Multi-national Expansion of the Electronics Industry

The electronics industry is composed of national and multi-national companies competing in world wide markets. As this industry matured, and as electronic technology advanced from vacuum tubes to comparatively more complex discrete semiconductors and integrated circuits, cyclic price wars reduced the number of manufacturers. The surviving companies began fighting for larger shares of the market, and expanded to markets outside national borders.

As the competition increased, some of the companies discontinued manufacturing low or no profit finished goods, as well as piece parts which were assembled into finished goods. Other producers expanded into the resultant market space, and devised methods to increase profitability, including increased production scale. Some firms adopted a strategy of continued production of these items, in order to retain control of their product quality and distribution.

As the industry grew, companies had to re-invest in resource intensive new products and production technologies to remain competitive in an atmosphere of rapid change. Many producers became multi-national by acquiring production facilities in countries with lower labor costs. The strategy of mixing the low-cost, non-technological labor with higher cost domestic technological labor lowers the overall production cost of finished goods, and allows for a greater opportunity for profit than if produced entirely with domestic labor.

Typically, piece parts are produced in the high labor cost industrialized areas of Europe, Japan, and North America. They are then transported to low labor cost Third World countries for the labor intensive assembly. The unfinished goods are then redistributed to factories in the industrialized area. The unfinished goods are in a lower customs duty bracket than finished goods, encouraging final production in the industrial countries.

The finishing process involves little or no assembly. Often, the unfinished goods require only final electrical testing and unit code marking. It is standard operating procedure for a lead straightening operation to be included with the testing or marking functions to correct all but the most severe mechanical damage incurred in the long distribution route. The in-process and final inspection functions inspect the finished goods for all mechanical damage. Products are then packaged according to their mechanical and electrical sensitivities, and distributed to customers throughout the world.

Chapter 2

Motorola Semiconductor Products Sector

Motorola Semiconductor Products Sector has survived and prospered in the electronics industry, in part by investing in offshore assembly factories. The Sector has five groups, each made up of divisions, which in turn are comprised of business centers. The business centers are responsible for sales of their particular product line. The business centers are "in business" in the sense that they have their own profit and loss statements, and are Motorola's only source of revenue.

The groups are required to buy a large percentage of their piece parts, typically 80% to 90%, depending upon availability, from Motorola's Electronic Materials Division (EMD). The group purchasing department acquires the balance of the piece parts on the open market. Vendor prices are arrived at by arms-length bargaining by the purchasing department. The vendor price and the EMD price are compared, and if EMD's price is determined to be excessive, it is renegotiated. Both outside vendor piece parts and those produced by EMD must meet or exceed the appropriate Motorola specifications.

This policy of having EMD compete with outside vendors has benefits other than price. Piece part quality, on-time deliveries, problem response time, packaging, and other facets of the piece parts trade can readily be compared.

This competition theoretically forces EMD to be cost effective in both sales to Motorola, and on the world market.

Chapter 3

Offshore Factories and Distribution Problems

Motorola Semiconductor Products Sector has five offshore assembly factories, one each in Mexico, the Philippines, and South Korea, as well as two in Malaysia. The assembly function of each factory is generally geared to a small number of mechanically and physically similar transistors, which allows for assembly on a larger scale, and reduces production costs. Because the transistor chip is so small, many of the groups can use the same mechanical package to achieve their electronic objectives.

The Groups and the Sector share the responsibility of choosing, to a limited extent, where the production of a particular transistor product line occurs. The Group leaders, using good business judgment, desire their product to be built in the location they perceive to be most cost effective. The assembly factories recognize that they are in competition with each other, and therefore, make every attempt to be as cost effective as possible.

When the offshore factories perceive a problem, they are quick to respond. The problem may entail an action under their direct control, or it may be a problem not directly controllable, such as a piece part problem. If the piece part is produced by EMD, the response mode is consistent with the policy of having EMD compete with other vendors.

Since 1975, when the census of the Packaging Engineering function was reduced from four to one, the primary emphasis has been on cost effective finished goods packaging. The remaining engineer had to apply the majority of his time to finished goods packaging for several important reasons noted later. These considerations, combined with numerous other duties, and quick changes in the piece parts market did not allow for updating the piece parts packaging system.

The piece parts packaging system used by Motorola was developed during a period of low value piece parts production, short distribution routes, and less competitive markets. The packaging systems were primitive: a typical package system consisted of a polyethylene bag containing the parts, placed in a corrugated paper partition. The partition was located in a large corrugated shipping box with divider pads of corrugated paper and other partitions. When they were designed, the package systems did cost effectively fulfill the five basic requirements of a package: protection, containing, sanitation, communication, and utility.[1]

Piece parts are now of a higher value, are distributed around the world, and are the subject of stiff competition. The more aggressive of the numerous worldwide producers of piece parts during this time did review and redesign their packaging systems, to improve performance in mechanical protection. Some were also designed to present a more attractive appearance, on the theory that appearance can directly influence the consumer's perception of the quality of the packaged good.[2] Both practices, improving appearance and performance, were intended to maintain or increase that manufacturer's share of the market. Other piece parts producers did not change their package systems, possible because piece parts were a sideline, or due to a lack of awareness of changes in competitors' systems.

The Motorola Business Centers' purchase of both EMD and competing manufacturers' piece parts enlightened them to differences in appearance and perceived mechanical protection offered by the many packaging systems. The Motorola offshore assembly factories were particularly aware of the possible mechanical protection differences because their distribution lines were much longer than those to the Phoenix assembly factories. The offshore Business Centers, having their own profit and loss responsibility, were concerned about purchasing piece parts from the EMD which appeared to have a greater percentage of mechanically damaged parts than did those purchased from other manufacturers.

The largest and senior offshore assembly factory in Seoul, South Korea, had been aware of these packaging differences for several months. The South Korean factories had informed their Business Center headquarters in Phoenix, as well as EMD, that the competitors' packaging systems offered a better appearance, and possibly improved mechanical protection. The business center and the EMD agreed that the competitors' packaging systems offered a better appearance, but improved performance was not substantiated, and was also thought by the EMD not to be cost effective. However, the EMD packaging systems were obviously outdated and inadequate, and were, therefore, redesigned.

This redesign included double bagging piece parts which are sensitive to oxidation. The double bagging reduced the number of bags with puncture holes, thus reducing the quantity of oxidized piece parts. Some piece parts were put in corrugated boxes, rather than in partitions, to provide the customers with handling and storage characteristics which more closely matched the competitors' packaging.

The majority of the package systems were not redesigned, because of a lack of sufficient evidence on the performance of the competitors' packaging systems. Also, EMD, the Korean Business Center, and other areas most impacted by packaging held the opinion that piece parts most sensitive to mechanical damage were significantly damaged before packaging. This suspected damage was believed to occur in the plating process. During the plating process, tens of thousands of parts are tumbled in drums, and spin dried in a centrifuge. The piece parts were then poured by the thousands into a plastic bag supported in a metal bin, and were transported by truck six miles in the uncushioned metal bins to the packaging site at the International Warehouse.

EMD and the South Korean Business Center did eventually agree to determine the cost effectiveness of the current piece parts packaging systems. In 1980, EMD requested Packaging Engineering assistance in investigation of the packaging systems for piece parts. Meetings between the EMD representative and Packaging Engineering resulted in EMD supplying Packaging Engineering with samples of the competitors' packaging systems.

The competitions' systems chosen for comparison contained a piece part moderately sensitive to mechanical damage, of a high volume production, and of average cost. These stipulations were placed on the comparison process for several reasons. First, if the new package system protected a sensitive piece part from damage, then it would also protect less sensitive parts. Second, designing the packaging system around a high volume piece part would begin cutting cost at a faster rate when implemented, than if a lower volume piece part was used. Finally, the average cost of the piece part would better represent the trade-off between the increased cost of packaging material, and decreased in the dollar value of the mechanically damaged piece parts. The TO-39 header packaging system was chosen based on these criteria.

Chapter 4

Packaging Engineering at Motorola SPS

The Packaging Engineering function at Motorola Discrete Semiconductor Product Sector is essentially unique in the Motorola Semiconductor Product Sector. Only the Discrete Group and the Government Electronic Group have a Packaging Engineering activity, and the other groups do not include in their employment structure an engineer assigned full-time to these tasks. The Packaging Engineering function at the Discrete Group specifies incoming and interplant packaging, closure materials, labeling and printing, and performs its own drafting. This activity supports four factory locations in the Greater Phoenix area, and assist two others not in the Discrete Group. The engineer is also responsible for all world-wide Motorola packaging of finished goods, and piece parts which contain Discrete parts.

Packaging Engineering within the Sector has been in existence since 1961, and originally was a part of the Machine Engineering Department, with four people assigned to it. During the recession of 1974-1975, the staff was reduced to one person. In 1979, the activity was transferred to the Material Distribution Center, and assigned to the Manager of the warehouse and shipping functions. Packaging Engineering's cost is included in the warehouse and shipping cost, and is charged back annually to the nine business centers.

Since 1975, when the Packaging Engineering staff was reduced to one person, the primary emphasis has been on cost effective finished goods packaging. These products have greater sensitivity to mechanical damage; there is a higher customer awareness of packaging quality, and higher profitability per unit. The Motorola piece parts packaging systems were not annually reviewed or significantly changed for many years. The competing piece parts manufacturers began changing their packaging systems, as the value of the piece parts increased, and as part of an attempt to enlarge their market share by offering better service to the customer in regard to mechanical damage protection.

Chapter 5

Piece Parts Description and Distribution

Motorola Semiconductor Products Sector defines piece parts as components which are assembled into unfinished goods. The piece parts include electronic transistor chips, bonding wire, heat sinks, individual lead pins, and lead frames. Due to lengthy distribution routes for transport of parts and unfinished goods to offshore assembly factories, production scheduling offshore is more dependent on the the quality of the piece parts than is scheduling at domestic factories.

Motorola's EMD is located in Phoenix, Arizona, where the majority of the domestic production is done. If a problem arises, and the piece parts have to be repaired or replaced, the matter is quickly resolved. Shipping distances and customs procedures add significantly to the time delay in resolving problems at the offshore facilities.

The distribution of piece parts to the offshore factories is a Group function performed by the Material Distribution Center (MDC). MDC is also responsible for distribution of unfinished good world-wide, and for finished goods distribution in North America. All inventorying, shipping, and packaging engineering activities are under the control of the MDC. The MDC has no revenue base, and maintains its budget by charging back its costs to the business center being serviced. The charges are determined annually under a formula involving the dollar value of distributed piece parts, finished and unfinished goods.

Chapter 6

Comparison of Motorola's and Competitors' Packages

Motorola's South Korean Assembly factory purchases TO-39 headers from four vendors, including Motorola's EMD. The EMD inter-office memo of March 18, 1980, compared the four packaging systems in terms of mechanical protection in numbers of reject headers due to bent leads, as defined by Motorola's standard inspection specification. (Figure 1) Also compared were the general package systems specifications, material cost F.O.B. Phoenix, and the number of headers per package. (Table 1) This memo indicated that all of the competitors' packaging systems performed better in protecting the headers than did EMD's.[3] The reject headers are scrapped at a $.033 cost each, and an annual cost of $37,000 to Motorola. (Table 2)

The material cost effectiveness of the four packaging systems was compared. (Table 3) The material cost effectiveness was determined by comparing the additional packaging material cost over the EMD's standard cost, to the difference in the value of the TO-39 headers scrapped in each packaging system, relative to the standard packaging reject rate. If the additional packaging material cost above standard is less than the value of the headers prevented from being rejected, then the packaging system is cost effective,

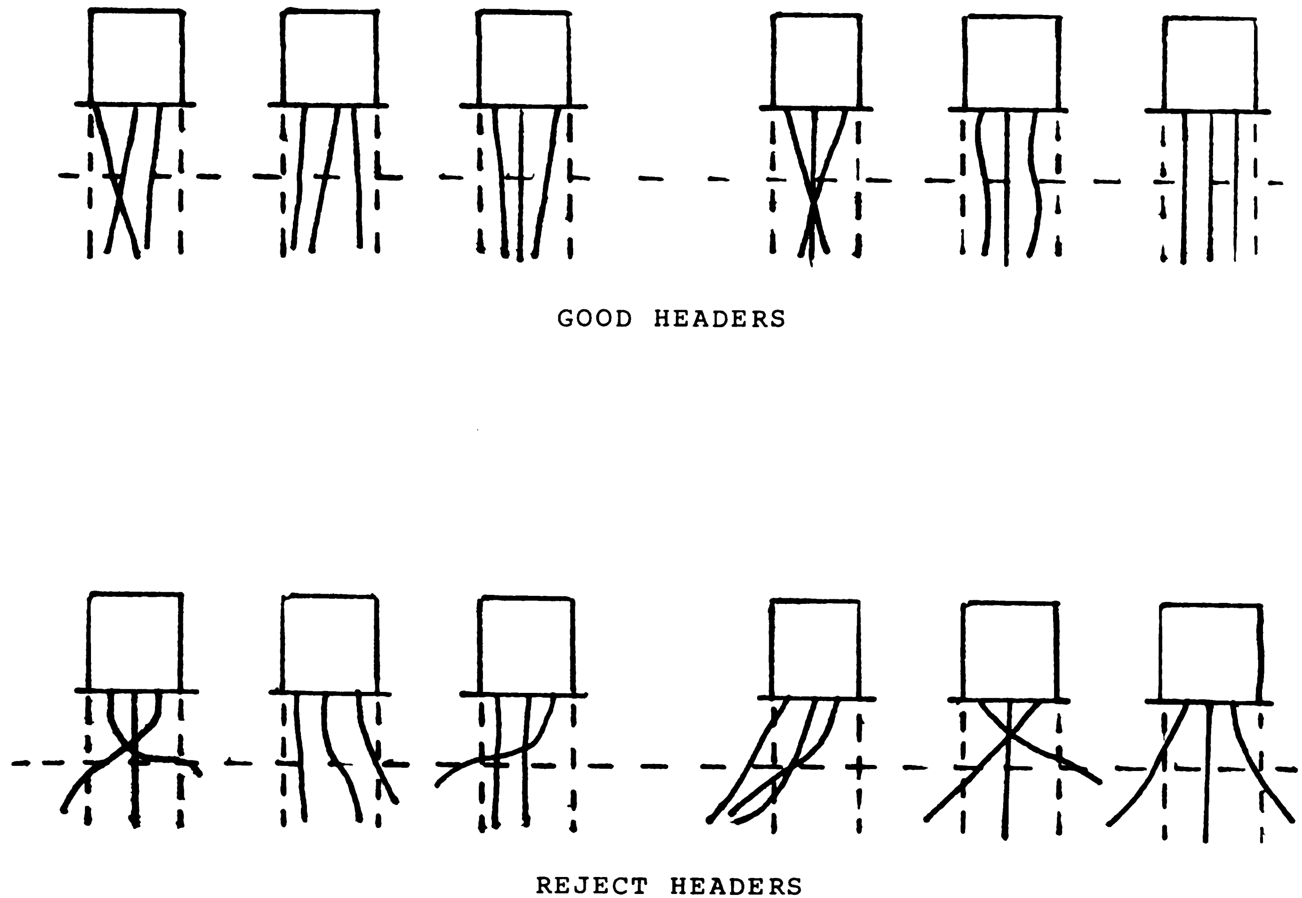

Figure 1

Motorola Standard Inspection
Specification for TO-39 Headers

Table 1

Motorola's and Competitors' Packaging Systems Specifications

	Motorola EMD	L.C.C.	Schott	Electrovac
Material Cost Per thousand Headers	\$.046	\$.25	\$.063	\$.070
Percent of Rejects	1.03	0.12	0.13	0.08
Quantity of Headers Contained	6,000	5,000	12,000	4,000
Packaging System Cost F.O.B. Phoenix	\$.28	\$1.25	\$.75	\$.28
Packaging System Specifications	13.50"X7.50"X4.19" 200lb C flute RSC Corrugated box, 4 mil low density polyethylene bag	14.00"X7.50"X 3.00", high density polyethylene thermoform box with lid	10.25"X8.25"X 8.25",2.01lb/ft^3 expanded polystyrene four cavity box with lid	7.50"X6.00"X4.50" C flute RSC corr. box with one 7.50"X 6.00"X.75" 1.2lb/ft polyurethane foam cushion in the bottom and a 4 mil low density polyethylene bag

Table 2

TO-39 Header Reject Cost
to South Korean Assembly Factory

1.	Air freight cost	$.00240
2.	Attempted lead straightening labor	.00111
3.	Associated product loss	.00250
4.	Header cost	.02600
5.	Return shipping to Phoenix	.00006
	Total Cost	$.03261

Annual reject header cost to Motorola:

1.03% X 2.2 million/week X 50 weeks X $.0261 each = $37,000

Table 3

Material Cost Effectiveness of TO-39 Header Packaging Systems
Preliminary Korean Inspection

Package System	Additional Packaging Material Cost Per Thousand	Value of Headers Saved from Reject Over Standard	Quantity of Headers not Rejected Over Standard Per Thousand		Value of Each Header
Electrovac	$.0240	$.313	9.5	X	$.0330
L.C.C.	$.204	$.300	9.1	X	$.0330
Schott	$.017	$.271	8.2	X	$.0330

that is, the larger the difference, the more cost effective the system is. In equation form:

$$\text{Value of additional packaging material} < \text{Value of headers rejected in standard package} - \text{Value of headers rejected in comparison package}$$

The Electrovac package system was determined to be the most materially cost effective by a wide margin. It had fewer parts per package, and included a .75 inch polyurethane foam cushioning on the bottom. These two factors were considered to be significant in reducing the mechanical damage to the TO-39 headers.

The Industrial Engineer from EMD who participated in the study calculated that any labor saving in the Schott and L.C.C. systems compared to the Electrovac system was offset by their higher material cost. From these findings, the EMD, the assembly business center, and Packaging Engineering decided to use the Electrovac system as a base to redesign EMD's TO-39 header packaging system. The Electrovac's packaging system was chosen because of its material cost effectiveness, and its similarity to the existing EMD packaging system.

An initial test shipment to South Korea was arranged. The test shipment consisted of the Motorola standard package as a control, two Electrovac packages, and seven other modified Motorola packages.

Chapter 7

Specific Problem

If the TO-39 header leads are bent beyond a Motorola specified tolerance (Figures 2, 3, 4) the header will not fit properly into the metal assembly belt (Figures 5, 6, 7) If the leads are not correctable within a two second time frame, they are rejected.

The reject headers are placed in a scrap drum designated for that specific alloy. The scrap headers and other scrap piece parts are then shipped back to Phoenix for reclaiming. The scrap value of the header is less than the freight charge, but the South Korean laws demand that all material brought into the country be exported, or a duty is imposed. As the export duty exceeds the shipping charges minus the scrap value, it is more cost effective to ship the scrap metal and reject parts to Phoenix.

The reject headers cost Motorola approximately $37,000 annually, based on a 1.03% reject rate. (Table 1)

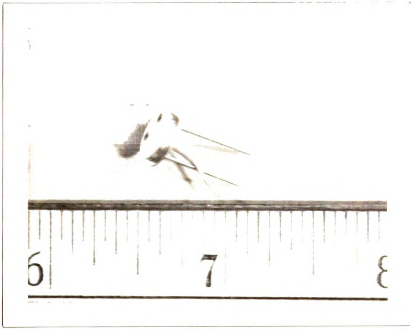

Figure 2

Reject Header

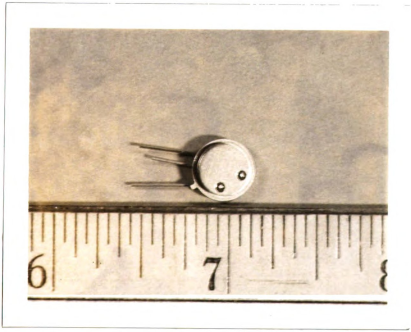

Figure 3

Reject Header

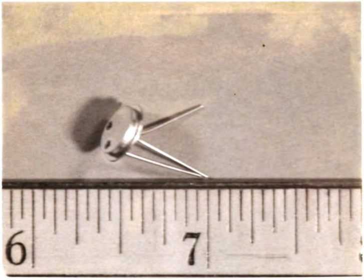

Figure 4

Reject Header

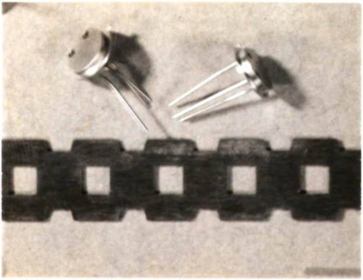

Figure 5

Reject Header   Good Header

Metal Belt

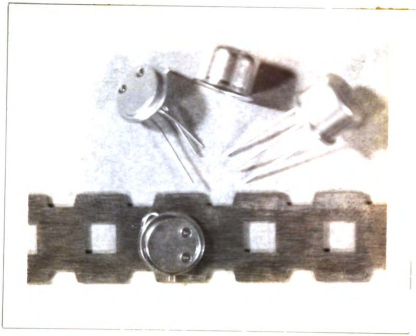

Figure 6

Reject Header Metal Top Unfinished Good

Header in Belt

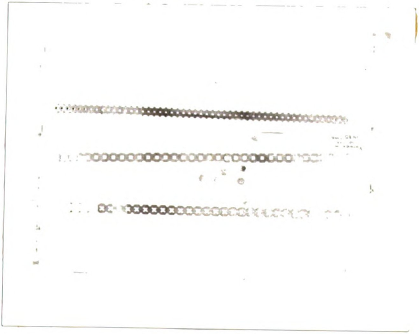

Figure 7

Three styles of metal belts

Chapter 8

TO-39 Header Description

The piece part used as the shipping test subject is the TO-39 header. (Figures 5, 6, 7, 8, and 9) The TO stands for transistor outline, and 39 is an identification number. TO-39 signifies a specific mechanical drawing used as a reference and controlled by the Electronic Industry Association. Header is a term used for a base on which a transistor chip is bonded.

The TO-39 header is a metal disc .360 inches in diameter, and .060 inches thick. Three wire leads are bonded perpendicularly to the plane of the disc on one side. The reverse side is the bonding site for the transistor chip. The wire leads are .016 to .019 inches in diameter, and .49 to .51 inches long.

The disc is made of 1010 cold rolled steel. The collector lead is made of an alloy called Kovar, which is 53% iron, 29% nickel, and 18% cobalt. The base and emitter leads are of 52 Alloy, which is composed of 52% nickle and 48% iron.

The competitors' headers purchased by Motorola are the same mechanical outline, and are allowed to vary in alloy makeup, if they meet Motorola specifications. The leads produced by Electrovac are identical to the headers produced by EMD; the other competitors use all Kovar leads.

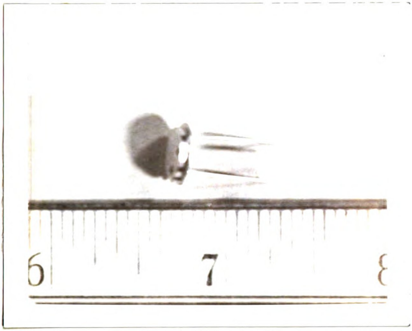

Figure 8

Good Header

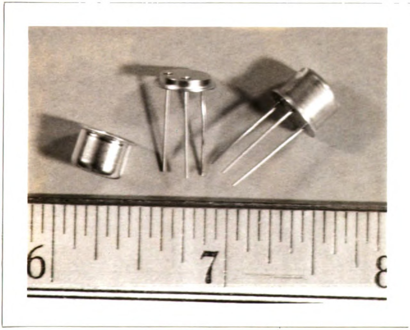

Figure 9

Metal Top   Good Header   Unfinished Good

The reason EMD does not use all Kovar leads is that the cobalt ingredient is more expensive, and comes from an unreliable source, Zaire. Electrically, at the power range of Motorola's applications, there is not a significant difference between Kovar and Alloy 52. Mechanically, the Kovar leads are much stiffer, and bend less than the Alloy 52 leads. The performance of the Electrovac packaging system containing all Alloy 52 leads is therefore more significant, as it protects a more easily damaged product better than the competitors' system protects a less easily damaged product.

The TO-39 header can be plated with a variety of materials, including gold, nickel, and tin. The headers used in the test shipment were nickel plated, as they are the highest volume part, and represent the overall average value header.

The TO-39 header is bonded with numerous electrically-different transistor chips. This versatility makes the TO-39 headers and finished goods very popular products world-wide. They are so popular that the EMD produces 2.2 million headers a week at the Phoenix facility. The EMD sells the headers to other Motorola Business Centers, and on the world market.

Chapter 9

TO-39 Header Distribution

The distribution of the Motorola TO-39 headers begins at the header assembly line on the second floor of Motorola's 52nd Street facility in Phoenix. The leads are hand loaded on to the assembly fixture, and are 100% inspected for straightness. The header disc is arranged on top of the leads and the fixture is conveyed through a furnace where the wire leads are bonded to the header disc. The headers are then poured into an empty metal bin. (Figure 11) The bins are loaded on a cart and taken out of the building to the plating shop located twenty-five feet away.

The headers are then poured in lots of twenty-four thousand into a plating drum. The drums are rotated in several tanks of liquid as they are plated. The plated heaters are next poured into a centrifuge drum, where they are spin-dried. The headers are finally poured in approximate groups of six thousand into a four-mil plastic bag, held in place in the metal bins. (Figure 10)

The bins are palletized and trucked six miles to the International Warehouse for shipping. There, the bagged headers are placed in the primary corrugated box. (Figures 12, 13)

The shipping box is trucked to Los Angeles International Airport, from where it is flown to Seoul, South Korea.

Figure 10

6,000 Headers in Bin

Figure 11

Empty Bin   Standard Package

Open   Closed

Figure 12

Standard Proposed

Modified Electrovac

Figure 13

Shipping Boxes REady for Shipment

In Korea the box is trucked twelve miles to the assembly factory.

At the factory, the boxed headers are stacked on top of each other on inventory shelves. When scheduled for production, the parts are carted to the assembly line where the assemblers remove the headers individually from the box, orient them and load them onto a metal belt. (See Figure 6)

The bonding material and the transistor chips are mounted on the bonding surface of the header as it is held in place by the metal belt. The belt carries the piece parts through a furnace which bonds the chip to the header. The header is then taken to the wire bonding assembly area, and is no longer affected by the packaging system.

Chapter 10

TO-39 Header Standard Packaging System

The TO-39 header's standard packaging system for shipping was a four-mil thick low density polyethylene bag containing six thousand parts. The bag was placed in a 200 pound burst strength C flute RSC corrugated box. (Figures 11, 14) The primary box was slightly too large for six thousand headers, because it was designed for universal use. A larger order quantity discount resulted when using the universal box, which was traditionally thought to be more cost effective. Also, the universal box had the same inside dimensions as the metal bins, allowing for smoother transfer of the bagged headers from the bin into the box. The primary box was set up and closed by interfolding the flaps on the top and bottom. (Figures 11, 12) Not using tape or staples allowed lower material cost and more flexibility in packaging sites. The primary box was placed with forty-nine others in a large 600 pound burst strength, double wall, RSC corrugated box. This shipping box was assembled and sealed with three-inch reinforced paper tape, and was reinforced with two steel straps. Labels and markings were applied, and the packaging system was ready for shipment. (Figure 13)

Figure 14
Standard Package
Style C in Initial Test, Style D. in Final Test

Figure 15
Electrovac: Style A in both Tests

Figure 16

Modified Standard Foam in Bottom

Style F in Both Tests

Proposed Package

Chapter 11

Initial Test Package Systems

The test packages consist of eighteen packages of ten different systems containing a total shipping quantity of 104,000 TO-39 headers. Style A is an exact copy of the Electrovac (Figures 12 and 15), and B is modification. Style C is the EMD standard system (Figures 11, 12, 14). Styles D, E, F, (Figure 16), G, H, I, and J are modifications of EMD's standard. The corrugated paper boxes are all 200 lb C flute RSC style, and have one four-mil low density polyethylene bag in each. All bags contain 6,000 headers except A and B, which contain 4,000 headers. All systems but C and D have 1.2 lb/ft^3 open cell polyurethane foam cushioning. All boxes are taped closed with 3" reinforced paper tape.

A comparison of the components of the initial test shipment is noted below, by style letter:

A. One Electrovac style: 7.50" X 6.00" X 4.25" box with a .75" thick cushions in the bottom, containing 4,000 headers. (Figures 12, 15)

B. One modified Electrovac: The cushion is reduced to .50" thick, containing 4.000 headers.

C. Three EMD standards: 13.75" X 7.75" X 4.19" box with no cushion, containing 6,000 headers. (Figures 11, 12, 14)

D. Two modified standards: Box depth reduced to 2.75" with no cushion, containing 6,000 headers.

E. Two standard boxes with a .50" thick cushion in the top and bottom, containing 6,000 headers.

F. Two standard boxes with a .50" thick cushion in the bottom, containing 6,000 headers. (Figure 16)

G. Two standard boxes with a .25" thick full cushion sheet covering all inside surfaces of the box, containing 6,000 headers.

H. One modified standard: Box depth reduced to 2.75" with a .25" thick cushion sheet covering all inside surfaces, containing 6,000 headers.

I. One modified standard: Box depth reduced to 2.75" with a .50" thick cushion on the top and bottom of the box, containing 6,000 headers.

J. One modified standard: Box depth reduced to 2.75" with a .50" thick cushion in the bottom, containing 6,000 headers.

K. Standard box filled with scrap parts used to fill voids in large shipping box.

Chapter 12

Distribution of the Initial Test Shipment

All of the 104,000 TO-39 headers were inspected for straightness at the end of their assembly line by Packaging Engineering. The headers were then placed in their appropriate test package at the assembly line, to eliminate the influence of plating. The test packages were then trucked to the International Warehouse. The eighteen test packages were arranged in the shipping box to distribute the possible shock, vibration, and shipping damage to all packages. (Figure 17) Thirty-two boxes of scrap material were included in the shipping box to simulate a typical shipment. The test packages were routed to South Korea, then back to Phoenix, to provide a greater opportunity for mechanical damage to occur. This emphasized the differences in mechanical protection provided by each system. The headers were 100% inspected by Packaging Engineering, using the Motorola standard inspection specification.

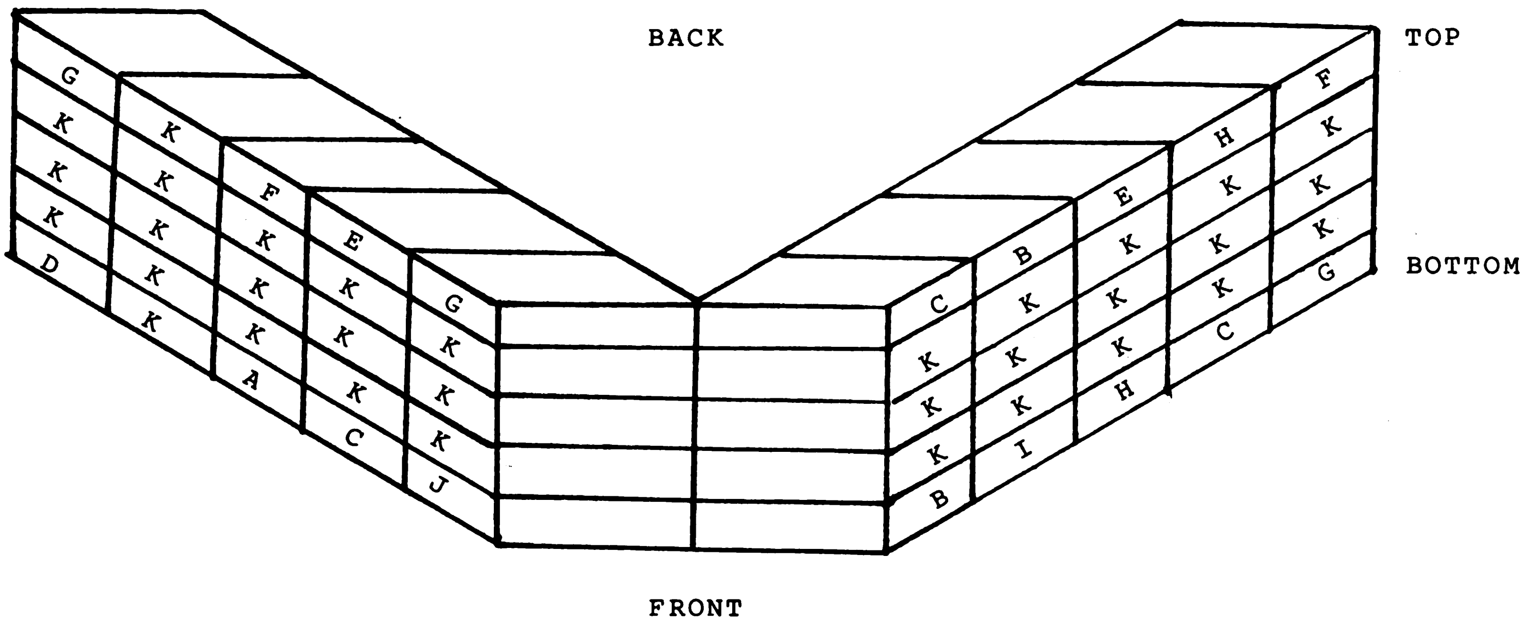

Figure 18

Arrangement of Test Packages
in the Initial Shipping Box

Chapter 13

Results of Initial Test Shipment

The results of the initial test shipment showed that the polyurethane foam cushioning did reduce the reject rate for the headers, and was cost effective. (Table 4)

Table 4

Initial Test Shipment in Cost Per Thousand Headers

Packaging System	Labor Cost	Material Cost	Total Cost	Cost Above Standard	Rejects	Reject Reduction	Prevented Reject Value	Cost Effectiveness
Electrovac	.0195	.1063	.1298	.0331	4.3	52.2	1.723	1.689
Mod Electr	.0195	.1034	.1229	.0302	8.3	48.2	1.591	1.561
Standard	.0120	.0807	.0927	--	56.5	--	--	--
Mod Stand. No cushion	.0120	.0780	.0900	(.0027)	32.3	24.2	.799	.802
Standard Bottom cush.	.0124	.0923	.1047	.0120	41.3	15.2	.502	.514
Standard top/bottom cushion	.0130	.1040	.1170	.0243	27.7	28.8	.931	1.048
Standard full cush.	.0149	.1180	.1329	.0402	17.5	39.0	1.287	1.247
Mod Stand. Full cush	.0128	.1080	.0281	.0281	9.7	46.8	1.544	1.516
Mod Stand. Top/bot cush	.0130	.1013	.1143	.0261	11.3	45.2	1.492	1.466
Mod Stand Bottom cush	.0124	.0896	.1020	.0093	25.0	31.5	1.040	1.031

Chapter 14

Final Test Shipment

Meetings between the EMD, Korean Assembly Business Center, and Packaging Engineering on the initial test shipment resulted in a more extensive, and final test shipment.

The distribution of the headers was the same as the initial test, with the exception that the headers were not routed back to Phoenix. Instead, they were inspected and used for assembly by the South Korean factory. The test packages were arranged in the shipping containers to distribute the possible shock, vibration, and shipping damage to all packages. (Figure 18).

The final test packaging systems components were identical to the initial test shipment. All boxes were 200 lb. C flute RSC style, with the same dimensions as the initial shipment. Open cell, 1.2 lb/ft^3 polyurethane foam cushioning was used in all packages, except D and G. Low density polyethylene bags were used to contain the headers, and the boxes were all closed with 3" reinforced paper tape. System components, denoted by Style letter, were as noted below:

A. Four Electrovac boxes with a .75" bottom cushion, containing 4,000 headers. (Figures 12, 15)

B. Four standard boxes with.25" full wrap cushion, containing 6,000 headers.

C. Four standard boxes with .50" bottom cushion containing 6,000 headers.

D. Four standard boxes with no cushion, containing 6,000 headers. (Figures 11, 12, 14)

E. Eight modified standard shallow boxes, with .25" full wrap cushion, containing 6,000 headers.

F. Eight modified standard shallow boxes, with .50" bottom cushion, containing 6,000 headers (Figures 12, 16)

G. Eight modified standard shallow boxes with no cushioning, containing 6,000 headers.

H. Five standard boxes with a .375" full cushion, containing 8,000 headers.

I. Four standard boxes with a .50" bottom cushion, containing 8,000 headers.

J. Four standard boxes with no cushioning, containing 8,000 headers.

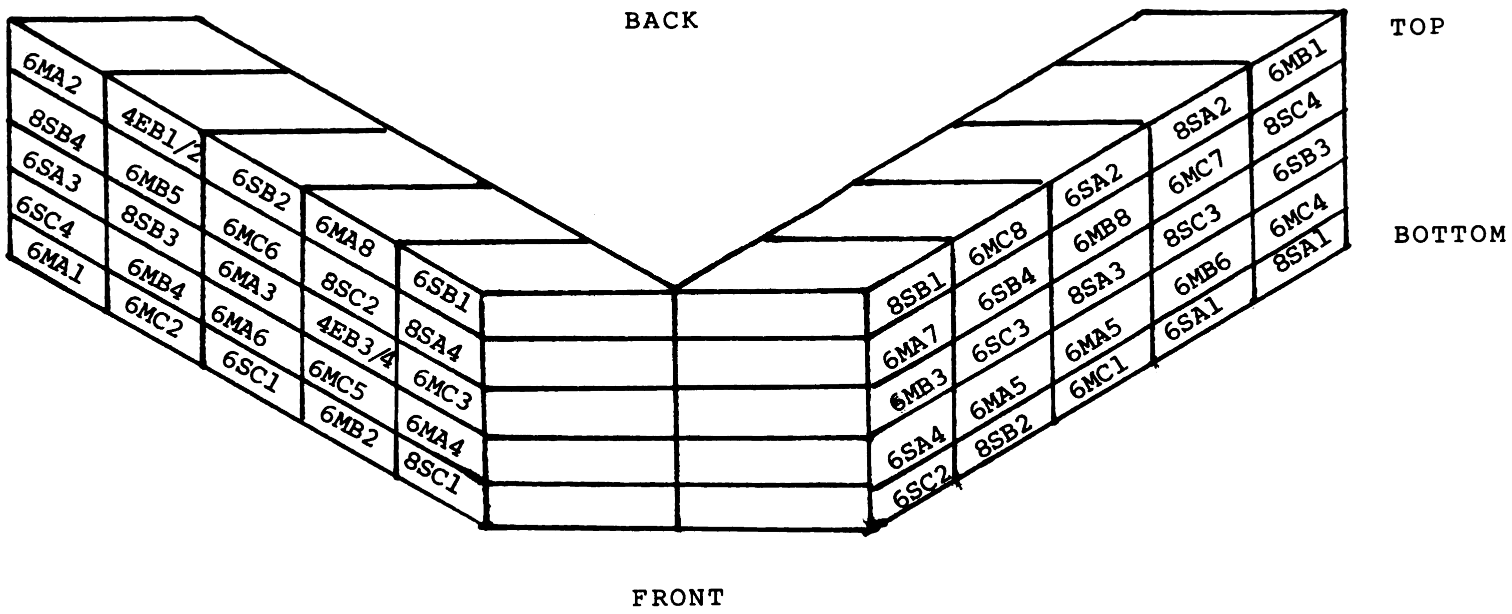

Figure 19

Arrangement of Test Packages in the Final Shipping Box

TEST PACKAGE LABELING CODE

4	4,000 UNITS	E	ELECTROVAC	A	.25" FOAM WRAP	4TH CHARACTER IS
6	6,000 UNITS	M	MODIFIED	B	.50" FOAM BOTTOM	TEST PACKAGE NUMBER
8	8,000 UNITS	S	STANDARD	C	NO CUSHIONING	

6MB1 IS A 6,000 UNIT MODIFIED BOX WITH BOTTOM CUSHION PLACED IN THE TOP RIGHT BACK OF THE SHIPPING BOX.

Chapter 15

Test Results Discussion

In the initial test shipments, the two packaging systems with no foam cushioning, the EMD standard, and the EMD shallow, were least cost effective. The systems containing foam cushioning were the most cost effective.

In the final test shipment, the same two packaging systems were the lease cost effective of those containing the standard quantity of headers. The systems which were the least cost effective contained foam cushioning, but were overloaded with 8,000 headers, rather than the standard load of 6,000 headers. The most cost effective systems were those containing foam cushioning, and the standard quantity of headers. (Table 5)

The test results reinforced the conclusion drawn from the initial test shipment that the polyurethane foam cushioning reduced the reject rate of the headers, and was cost effective.

Table 5

Final Test Shipment Results in Cost per Thousand Headers
Note: parentheses mean a negative number

Packaging System	Labor Cost	Material Cost	Total Cost	Cost Above Standard	Rejects	Reject Reduced Value	Prevented Reject	Cost Effect-iveness
A. Electro-vac	.0195	.1063	.1258	.0331	15.6	7.2	.238	.2049
B. Standard Full Cush	.0149	.1180	.1329	.0402	15.4	7.4	.244	.2038
C. Standard Bot Cush	.0124	.0923	.1047	.0120	19.4	3.4	.112	.1000
D. Standard	.0120	.0807	.0927	--	22.8	--		
E. Mod Stand Full Cush	.0128	.1080	.1208	.0281	17.7	5.1	.168	.1399
F. Mod Stand Bot Cush	.0124	.0896	.1020	.0093	17.5	5.3	.174	.1647
G. Mod Stand No Cush	.0120	.0780	.0900	(.0027)	26.2	(3.4)	(.112)	(.1147)
H. Standard Full Cush 8K units	.0110	.0932	.1042	.0115	28.6	(5.8)	(.191)	(.2025)
I. Standard Bot Cush 8k units	.0102	.0820	.0922	.0005	21.5	1.3	.056	(0.555)
J. Standard no Cush 8K units	.0091	.0697	.0788	(.0135)	21.1	1.7	.056	(.0695)

Chapter 16

Summary and Conclusions

Both test shipments showed that polyurethane foam cushioning is more effective than the Motorola standard packaging system with no cushioning, when both packages contain the standard 6,000 headers. The most logical and apparent reason for the higher efficiencies of the cushioned package is that the shock and vibration which cause damage are reduced. If the proper testing machinery and personnel were available, the test shipments would not have been necessary and the most cost effective package could have been developed in a shorter time span.

APPENDIX

Footnotes

1. Jack Melgrom and Aaron Brody, Executive Summary, Packaging in Perspective: A Report to the Ad Hoc Committee on Packaging (Cambridge, Massachusets: Arthur D. Little, Inc., 1974) pp. 5-3, 5-4.

2. Robert J. Kelsey, Packaging in Today's Society (Edgewood, New Jersey: St. Regis Paper Company, 1978), p. 31.

3. Interoffice Memorandum to Tom Hunt from B.H. Lee and J.S. Han, 18 March, 1980.

4. Interoffice Memorandum to Steve Lehward from D.H. Kwon, 4 March 1981.

Glossary

Alloy 52: An alloy composed of 52% nickel and 48% iron.

Can: A metal cylinder with one closed end used to seal to a header to protect the transistor chip.

Discrete: A separately packaged single circuit element supplying one fundamental property as a lumped characteristic in a given application. Examples: resistors, transistors, and diodes.

Distribution: The movement of the header from its initial construction at the assembly line through all its handling and shipping routes to the assembly line in Korea where it is die bonded.

EMD: Electronic Materials Division of Motorola's Discrete Semiconductor Products Sector, which builds and markets electronic piece parts.

Finished Goods: A discrete semiconductor device which is unit marked, tested, and ready for shipment to the customer.

Header: The part of a sealed component or assembly which provides support and insulation for the leads passing through the walls.

Kovar: An alloy composed of 53% iron, 29% nickel, and 18% cobalt.

Lead: A wire to or from a circuit element.

Mechanical Damage: Damage sustained by a discrete semiconductor device or piece part which is derogatory to its mechanical function, but not necessarily its electrical function.

Offshore Factory: A Motorola factory located other than in the United States of America.

Piece Part: The components which are assembled into a semiconductor device.

Plating: The process of depositing a metallic coating on a piece part.

Polyurethane Foam Cushioning: A low cost open cell ester foam used as a packaging material.

Semiconductor: A solid electronic conductor with resistivity between that of metals and that of insulators.

Transistor: An active semiconductor device, usually of silicon, and having three or more electrodes. Conduction is by means of electrons and holes (mobile electrion vacancies equivalent to a positive charge).

Unfinished Goods: Semiconductor units which are assembeled, but not unit marked.

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Fibre Box Handbook. Chicago: Fibre Box Association, 1976.

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