This is to certify that the

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Package Design For A Gas Range Product Line

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has been accepted towards fulfillment
of the requirements for

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Gary Burgess
Major professor

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PACKAGE DESIGN FOR A GAS RANGE PRODUCT LINE

By

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MASTER OF SCIENCE

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ABSTRACT

PACKAGE DESIGN FOR A GAS RANGE PRODUCT LINE

By

José Martínez Rivera

The purpose of this study was to test a proposed methodology for incorporating packaging concerns into the design process for a gas range product line. For this study several prototypes were tested to investigate the fragility of the products in order to decide the best packaging options and to improve the products design.

The conclusions were that this method has the advantage of taking into consideration several factors that help to improve the quality of the product and offers an adequate package for the product at a minimum cost. However, future work has to be done to evaluate in more detail the benefits of this methodology.

To my wife Pilar and my son Diego.

To my parents, Irma and José Maravasco

To my brothers, Lalo and Cuquín

To all my family and all my good friends

ACKNOWLEDGMENTS

I would like to thank my Director, Luis Hoyos, for giving me the opportunity to study at Michigan State University. I also want to thank all the people of Mabe for their help and support during my program, especially, Jorge Rodríguez Urtecho, Federico Flores, Carolina Beltrán, Rubén Tinoco, César Gutiérrez, Ricardo Ávila, Sergio Colín and Juan Carlos Ortega.

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Chapter 1

INTRODUCTION

The purpose of this study was to test a proposed methodology for incorporating packaging concerns into the design process for a product by designing a package for a gas range product line which was at this point, in a development stage. This methodology offers some advantages because the product can be improved to make it less fragile in order to reduce packaging costs. In the past, manufactured product was never modified to minimize damage during distribution, even after a high level of damage indicated that the product itself was too fragile for the distribution environment. The only alternative, then, was to accept the high costs of overpackaging the product. Now, however, we avoid heavy distribution damage by using the results of telltale fragility tests [1].

The gas range product line design development is a project of Mabe Technology and Development Center. Mabe is a major manufacturer of consumer appliances and all the product development is done in this center located in Queretaro, Mexico. In this center, highly qualified technicians and engineers work on the development of new ideas and technologies which allows for continuous improvement in performance and the introduction of new features to the marketplace. These engineers work very close with Mabe's marketing team.

Mabe is a Latin-American company that manufactures kitchen and laundry appliances. It was established in 1946 and by 1960 was the number one exporter of appliances in Mexico. Today Mabe is the largest manufacturer of appliances in the Mexican market and in the Spanish speaking countries of Latin America. During 1995, a total of 2.8 million units were manufactured and sold.

Currently, Mabe has thirteen manufacturing facilities located in Latin America in which they produce high quality appliances such as refrigerators, cooking and laundry products. These facilities are strategically located in different countries to satisfy the demand of a wide array of customers. The organization produces appliances for 14 brands including Mabe and General Electric. It exports its products to the US, Canada, the Caribbean, and most of Latin America, as well as some European countries. Mabe has a very high standard of quality and manufactures appliances that range from basic to high-end products.

In a highly competitive industry, Mabe is fully dedicated to the execution of a strategy designed to attain and maintain leadership in Latin America. This strategy is based on what they have called "The Four Basic Processes of the Organization". Technology, Manufacturing, Marketing and Service. These functions are the foundation of the culture and spirit of the organization and are supported by their infrastructure.

Mabe continuously pursues new opportunities in high-growth markets with the goal of expanding and strengthening their leadership in the Americas. Mabe has been exporting since 1978. They export refrigerators, ranges, cook tops and washing machines to the USA, Canada, Central America, South America and the Caribbean. One in every 3 gas ranges sold in the US is manufactured in the San Luis Potosi Factory.

In 1994 Mabe broke the million units mark for the first time by exporting 1,122,943 units to 33 countries. Taking into account units manufactured in all operations throughout Latin America, they sold 2.8 million units in 1995. Mabe manages several brands in the region. The main ones in Mexico are: "Mabe", "General Electric", "IEM" and "Easy". In addition, Mabe also commercializes the "Regina" brand in Venezuela, the "Centrales" and "Regia" brands in Colombia and the "Durex" brand in Ecuador and Peru.

The gas range product line now in development will substitute the actual product line manufactured in the Mexico City range facility. Table 1 shows that these ranges are for the Mexican market and the Central American market as well. At this point, Mabe has some information on the distribution environment for these places. This information will be helpful in defining some aspects of the packaging design. A selection of a design drop height and an acceleration-frequency profile is recommended as the first step in package design [2].

Prior to the packaging design, a series of tests should be performed on different prototypes. A package designer's goal is to be sure that the G level transmitted to the item by the cushion is less that the G level that will cause the item to fail [2]. One way is to strengthen the product in order reduce packaging costs and in general, the cost of the entire product/package system [1].

Table 1 - Mabe Facilities

Product	No. of Plants	Location	Markets
Ranges	4	San Luis Potosi (Mex) Mexico City (Mex) Maracaibo (Venezuela) Guayaquil (Ecuador)	U.S, Canada, Mexico Mexico, C. America Venezuela, Colombia Andean Pact.
Refrigerators	3	Queretaro (Mex) Mexico City (Mex) Manizales (Colombia)	U.S, Mexico, C.A. Mexico, C.A. & S.A. Andean Pact.
Washers	2	Monterrey (Mex) Saltillo (Mex)	Mexico, C.A. & S.A. Mexico, C.A., S.A. & U.S.
Compressors	1	San Luis Potosi (Mex)	Worldwide.
Motors	1	Monterrey (Mex)	Latin America
Transmissions	1	Saltillo (Mex)	Mexico, Venezuela
Plastic injection & Steel Stampings	1	Queretaro (Mex)	

Also in this study, consideration will be given to other factors such as packaging size. With a minimum product/package size, more products can be shipped and so transportation costs of the product can be reduced. Shipping costs and material costs increase as the size of the package increases, and even small reductions can effect significant savings [3].

This study is very important to Mabe because it is the first step toward changing the current methodology for product design. in Mabe. Figure 1 shows the proposed methodology for integrating packaging into the product design and development. One of the objectives of this study will be to determine if this methodology has benefits over the current process, which is to design the product first and then package it later. The investigation of the distribution environment will not be covered in this study because of equipment and time constraints and so some assumptions will be made to cover this aspect.

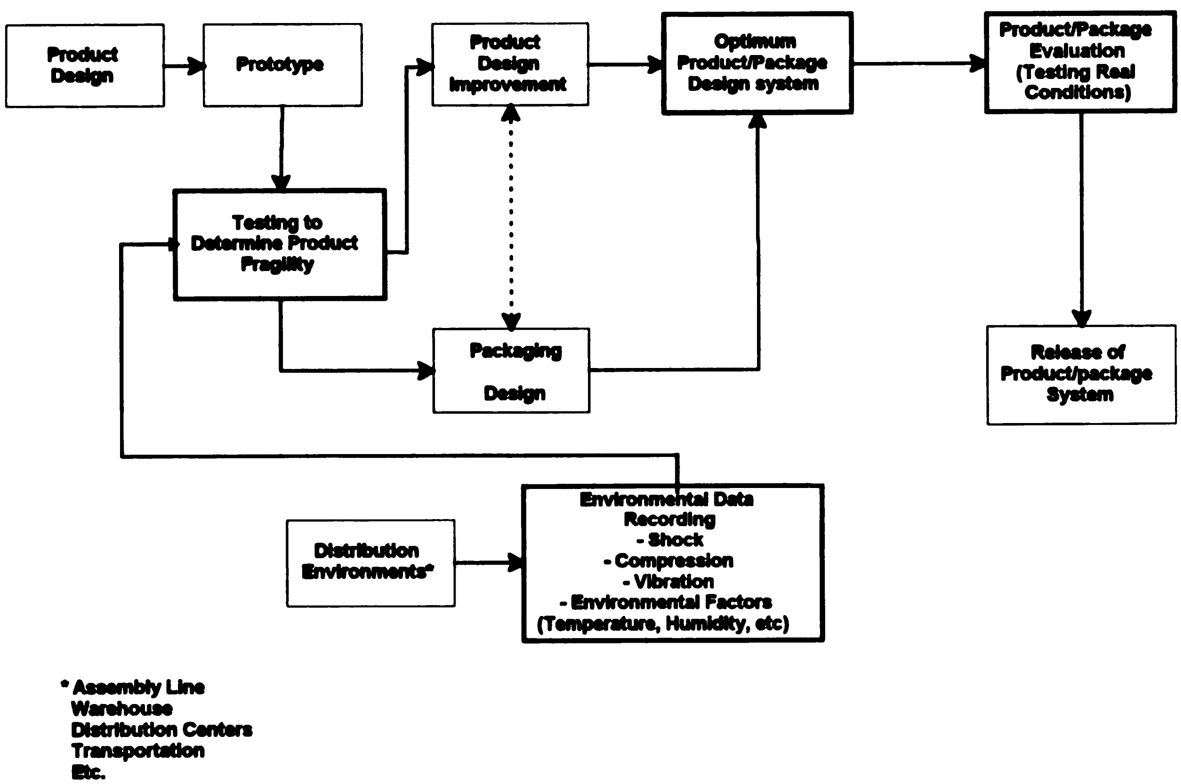


Figure 1 - Proposed methodology for product/package design in Mabe

Chapter 2

EXPERIMENTAL DESIGN, OBSERVATIONS AND RESULTS

In order to investigate the product characteristics related to fragility, Mabe had a total of six prototypes fabricated in the Mabe Technology and Development Center. Three of these prototypes were part of the first design stage. They were shipped in wood containers from Queretaro, Mexico to the School of Packaging at Michigan State University in East Lansing Michigan. All three prototypes were tested for vibration and two for shock. One of these three prototypes (sample P-203 in Table 3) was damaged during transportation before the tests. Therefore, the results of the vibration test were not included in this study because they were not representative.

The information obtained from these tests was reported to Mabe's product designers in order to correct those parts of the product which were subject to damage. In the second design stage, a series of new prototypes were built. The improved design of these ranges was based on the functionality tests and the shock and vibration tests results from stage one. Three of these prototypes were sent to the School of Packaging for vibration, compression and shock tests. Another four gas ranges from the actual production line of the Mexico City facility were sent for fragility testing in order to make a comparison between the actual product and the new design.

2.1 Gas range product line characteristics

The market for these ranges consists principally of Latin America countries including Mexico. In these countries, small ranges are very popular. Therefore, it is desirable to offer the customer a good quality product with different features and characteristics regardless of the appliance size. Some of these characteristics were good packaging challenges because these features often increase the number of critical elements of the product. The complete definition of the product line of these ranges is at this moment under development. For this study, the most representative models were chosen for testing. Table 2 shows a list of the principal characteristics of the prototypes used in this study.

Table 2 - Prototype-product general characteristics

CONCEPT	MODEL	P-203	E-204	P-242	1504L	42001	EV201	EM240	EMC203
TYPES	A, B		A						
	C, D	D		D	C	C	C	C	B
	E, F								
SIZE	20"	*	*		*	*	*		*
	24"			*				*	
BACK GUARD		*			*	*	*		
GLASS LID			*	*				*	
TOP BURNERS	CRI	2							2
	PE								
	QTS								
	QAS	2	3	3	4	4	4	4	2
	SQA								
OVEN BURNERS	CR-2	2		2					1
	QTT		1		1	1	1	1	
OVERALL DIMENSIONS (in)	DEPTH	23.3	23.3	23.3	27.9	27.3	23.6	23.25	23.6
	HEIGHT	45	28.65	37	34.8	34.8	35.8	37.5	27.5
	WIDTH	20	20	24	20	20	20	24	20
NET WEIGHT	(lb)	76.63	83.42	82.12	93.7	84.9	83.8	106.9	75.4
	(kg)	34.76	37.84	37.25	42.5	38.5	38.0	48.5	34.2
FINISH	FRONT	enamel	enamel	enamel	enamel	enamel	enamel	enamel	enamel
	BACK	Zn coated steel	Zn coated steel	Zn coated steel	Galv. steel	Zn coated steel	Zn coated steel	Zn coated steel	Zn coated steel
	SIDES	Pre-painted steel, enamel	Galv. steel	Pre-painted steel, enamel	Pre-painted steel, enamel	Pre-painted steel, enamel	Pre-painted steel, enamel	Pre-painted steel, enamel	Galv. steel

2.2 Fragility testing (phase one)

2.2.1 Vibration

The following tests were conducted according to ASTM D3580-90: Standard Test Method of Vibration Test of Products (Vertical Sinusoidal Motion). The products tested are listed in Table 3.

Table 3 - Description of test products (phase 1)

Product	Model	Sample Code
20" Gas range	P-203	P-203
24" Gas range	P-242	P-242
20" Gas Range	E-204	E-204

The purpose of this test is to determine the resonant frequencies of these products in order to generate information that will help improve the product design as well as the package design. The procedure according to ASTM D3580-90 is to place the product on a vibration table and set the table to gradually sweep through a frequency range from 3 to 100 Hz and return. The acceleration level was 0.5 g's throughout the sweep. This procedure is supposed to replicate what goes on in most trucks and rail environments and so substitutes for the distribution analysis portion of Figure 1 for now. A Lansmont Vibration Test Machine (model 10,000-10 with 152 X 152 cm square table, 12,000 lb seismic base, one-G supports, 10 gallon/minute 3000 psi hydraulic power supply, and Touch Test control and instrumentation system) was used. Samples E-204 and P242 were tested with and without a corrugated protector (see Figure 2). The results and conditions for each product are described in Tables 4 to 7.

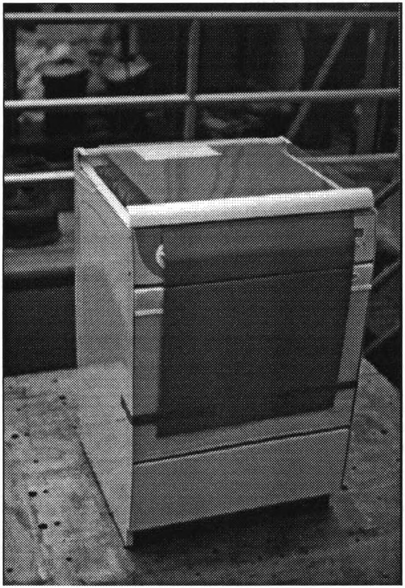


Figure 2 - Sample P-242 with corrugated board protector

Table 4 - Vibration test results for sample P-242 -test 1

Resonant frequencies (Hz)	Remarks
4-7	Banging from inside the oven (electric element of the oven)
8-10	Cabinet resonance (vibration causes range to move)
20-30	Glass lid resonance (glass lid banging)
Conditions: the range was tested as received, without packaging protectors and with the burners and glass lid in place. **Damage:** the control knob popped out at 23 Hz. Screw loose from the oven hinge.	

Table 5 - Vibration test results for sample P-242 -test 2

Resonant frequencies (Hz)	Remarks
21-30	Most critical frequencies. Glass lid resonance
Conditions: with burners and glass lid protector in place in order to see if the unit should be shipped whole, or in pieces. Electric burners were taped. **Damage:** no critical damage. Screw loose from the oven hinge.	

Table 6 - Vibration test results for sample E-204 -test 1

Resonant frequencies (Hz)	Remarks
7-12	Resonant vibration of glass lid
26	Noise coming from cabinet
30-40	Vibration causes the range to move
40-60	Burners banging
80	Noise from oven
Conditions: the range was tested as received, without packaging protectors and burners in place. **Damage:** no critical damage.	

Table 7 - Vibration test results for sample E-204 -test 2

Resonant frequencies (Hz)	Remarks
21-30 26-28	Continuous banging of the oven lid Resonant vibration of the cabinet and oven door Most critical frequencies at 20-21 Hz
Conditions: with burner protectors and glass lid protector taped to cabinet (see Figures 3 and 4). **Damage:** no critical damage.	

Improvements

Based on the results of these first vibration tests performed on the two samples ,P-242 and E-204, a protector element was designed to keep the glass lid from banging. This protector was made from corrugated board to prevent banging and to also keep the oven door closed and protect the control knobs from impact. Also, for sample P-242, the gas burners were attached to the range cover with tape using a single corrugated board protective element. For sample E-204, the protector element was improved by using one element for all gas burners (see Figure 3). The ranges were tested with these packaging elements and even though the natural frequencies of the critical elements were the same as in the previous tests, the protector elements maintained these parts free of damage. The vibration tests showed the need for a new hinge design because some loosening of the glass lid from the hinge and the screw from the cabinet hinge were observed. The protector for the glass lid did not help to prevent this problem (see Figure 4).

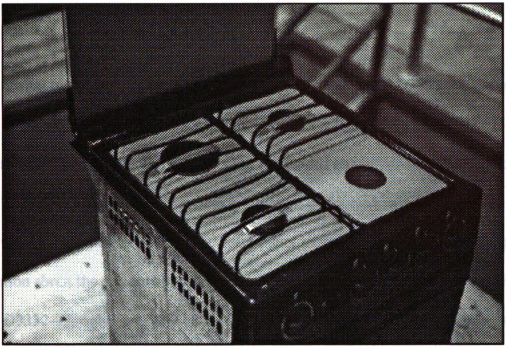


Figure 3 - Top view of sample E-204 with corrugated board protector

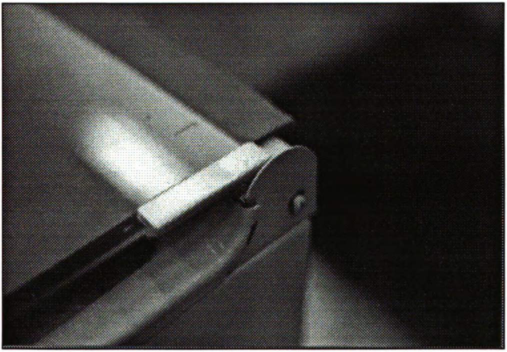
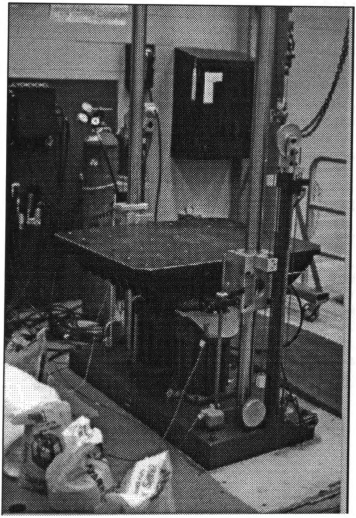


Figure 4 - Hinge of glass lid

2.2.2 Shock

The following tests were conducted according to ASTM Standard D3332-93: Standard Test Method for Mechanical-Shock Fragility of Products Using Shock Machines [5]. The products tested are listed in Table 1. This test is intended to provide data on product shock fragility that can be used in choosing optimum-cushioning materials or packaging components for shipping containers and for product redesign. These tests can also provide information about the performance of the product at different drop heights. According to ASTM D3332-93, only Test Method A (Critical Velocity Shock Test) was performed because there was only one sample of each model. The Shock Machine is shown in Figure 5 (MTS 846 shock test system). Tables 8 and 9 show the results for results of the shock test.



hock Machine

Table 8 - Test results for sample P-242 (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	3	75.3	137.9	2.31	No damage
2	5	106.3	209	2.19	No damage
3	6 ¼	113.5	219.4	2.19	The support for the gas tube was loose. It was tight for the next drop (see Figure 6). Very slight damage to the cover
4	8	129.3	264.2	2.04	The main gas tube was out of place (see Figure 7). The steel support was bent (see Figure 8). Slight damage to the cabinet and oven door hinge. The cover was deformed (see Figure 8)
5	10 1/6	146.3	304.7	2.00	Front glass panel supports were bent (see Figure 9). The cabinet was severely damaged on the bottom and sides (see Figures 10 and 11)

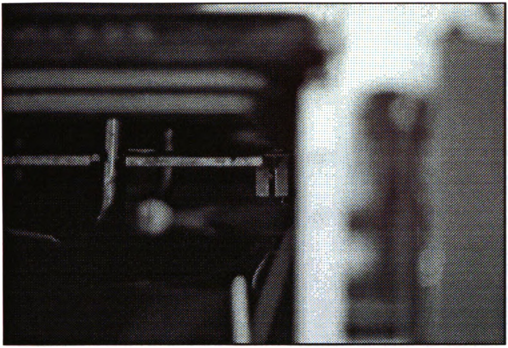


Figure 6 - Detail of the gas tube support

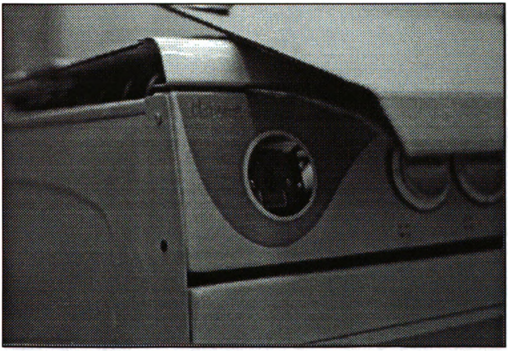


Figure 7 - Result of displacement of main gas tube

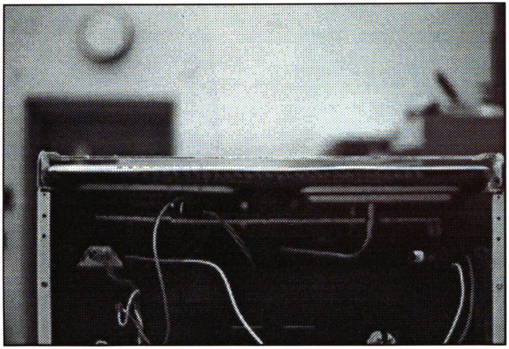


Figure 8 - Detail of rear view of sample P-242

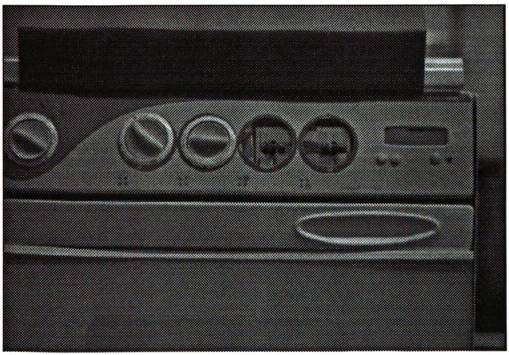


Figure 9 - Sample P-242 with glass support bent

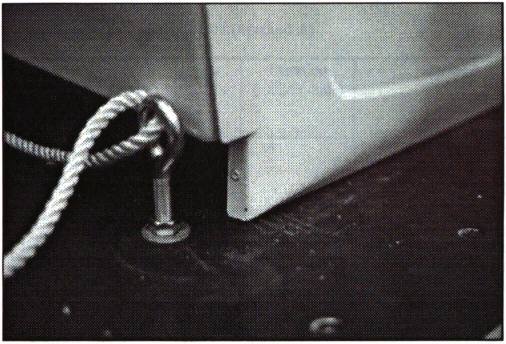


Figure 10 - Sample P-242 with damaged cabinet (rear right bottom corner)

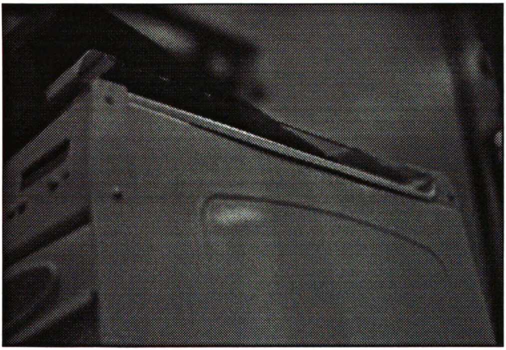


Figure 11 - Sample P-242 with damaged cabinet (right wall)

Table 9 - Test results for sample E-204 (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	3	77.2	141.1	2.35	Damage to the cabinet in rear upper and lower corners (see Figure 12) Note: these corners were damaged before, however; after this drop the damage was more evident. The lower front part of the glass panel was bent (see Figure 13)
2	4 1/16	93.4	179.6	2.23	Front glass panel fell down because the lower support was bent at impact (see Figures 14) The glass lid was out of place because the rear corners were bent (see Figure 15). Inner lower glass support was bent (see Figure 14). Enamel paint off the cover (see Figure 16)
3	5	103.3	200.1	2.19	Back panel was bent. Inner lower glass support was bent (see Figure 14). Enamel paint went off from the cover (see Figure 16). Loose controls (see Figure 17)
4	6	111.1	214.7	2.16	Increased level of same damages

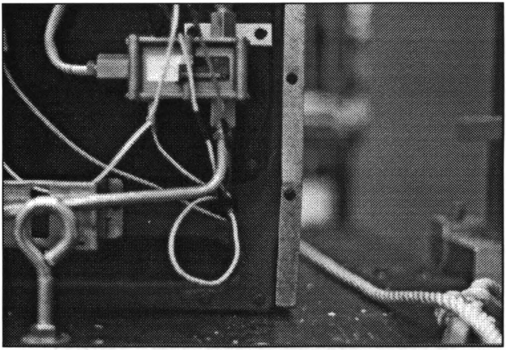


Figure 12 - Detail of rear view of sample E204

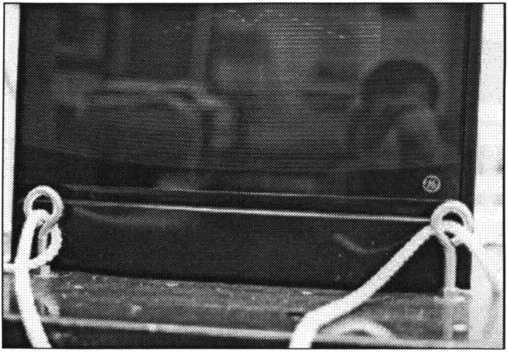


Figure 13 - Support of glass panel bent in E-204 sample

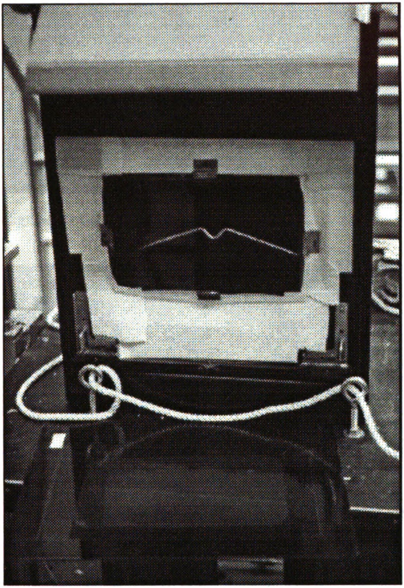


Figure 14 - Panel damaged of E-204 sample

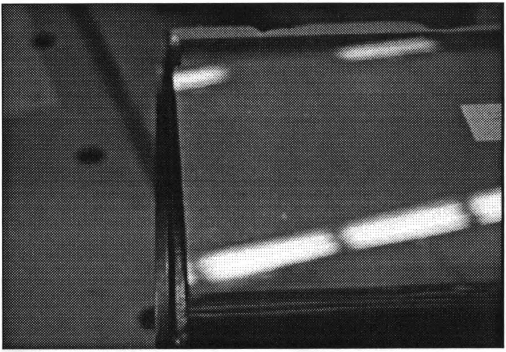


Figure 15 - Misalignment of glass lid of sample E-204

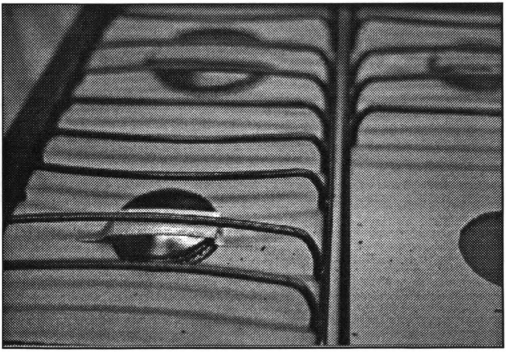


Figure 16 -Damage of cover finish of sample E-204

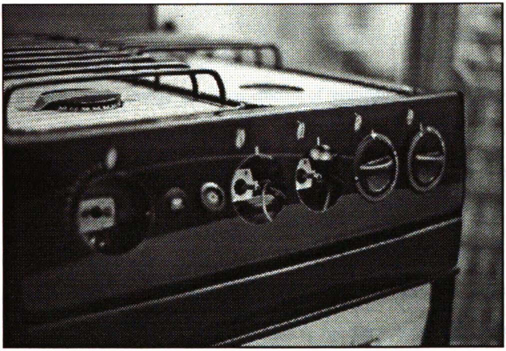


Figure 17 - Loose control knobs of sample E-204

Conclusions

Shocks can happen any time during the distribution cycle. These shocks are caused mainly by dropping the product/package. Since Mabe does not have data available on the average drop height, a 6 inch drop was used as the design drop height. This drop height is also used in the GE Appliance Test Method No. E50L008 "Free Fall Drop Test" [6].

For this test, it was important to know if the products needed a cushion for the design drop height. In order to say, the velocity change for a 6 inch drop can be calculated using the following equation:

$$\Delta V = (1+e)\sqrt{2gh} \qquad [1]$$

where ΔV is the velocity change , e is the coefficient of restitution, g is the acceleration due to gravity (386.4 in sec^2), and h is the drop height. The coefficient of restitution can vary depending on different factors. In the vast majority of packaging situations, the coefficient of restitution can be found to lie in the range .3 to .5 [7]. Using e=.5 as a worst case scenario, ΔV will be 102.2 in/sec. From the shock tests, sample P-242 would need a velocity change greater than 106 in/sec to damage the product. In this case then, it was possible to design a package with little or no cushion. Another way to view the results is to apply the following rule [7],

Equivalent Free Fall Impact Velocity = Shock Table Velocity Change [2]

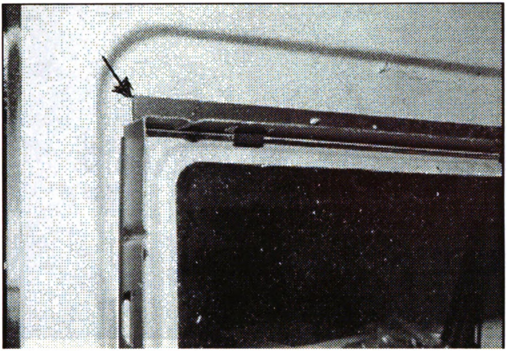
For sample P-242, the critical velocity change was 106.3 in/sec and therefore the equivalent free fall drop height would be $106.3^2/(2 \times 386.4) = 14.6$ inches, which is larger than the design drop height, and so a cushion is not needed. For the other product, however, the critical velocity change was found to be less than 77.2 in/sec. In this case this product is not strong enough to withstand a drop from 6 inches because 77.2 in/sec is less than 102.2 in/sec. Applying the rule to calculate an equivalent drop height for this test, a free fall drop height of $77.2^2/(2 \times 386.4) = 7.7$ inches would be required to damage it. This is only slightly higher than the design drop height, and so we have to consider that the product will probably be damaged in this drop.

These tests gave some input about the performance of some parts during impact. Some of the damage observed was reported to the Mabe product design department and some changes were made based on the results, some of which are discussed in the following section.

2.3 Product improvement from fragility tests results.

According to the damage reported from the vibration and shock tests, the following parts were improved:

- The inner glass oven support now has a more rigid design and holds the glass oven door much better(see Figures 18 and 19).
- The oven door support is also stronger than the previous design (see Figure 20).
- The glass lid hinge has a more integrated design. The glass is attached to the hinge with two screws instead of an adhesive. The hinge has a better system that makes it more rigid and more functional (see Figure 21).
- The lower cabinet support was reinforced to make it more rigid (see Figures 22)
- The gas system supports were redesigned to improve strength and rigidity. (see Figure 23).



18 - Front view of inner glass oven support

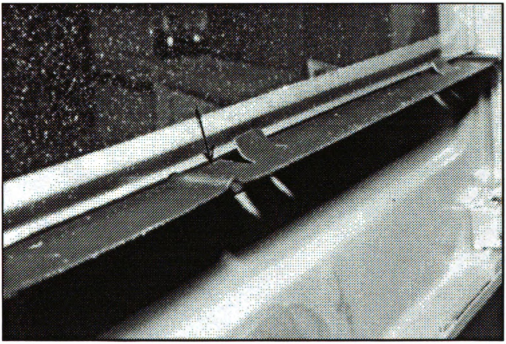


Figure 19 - Rear view of inner glass oven support

Figure 20 - Oven door support

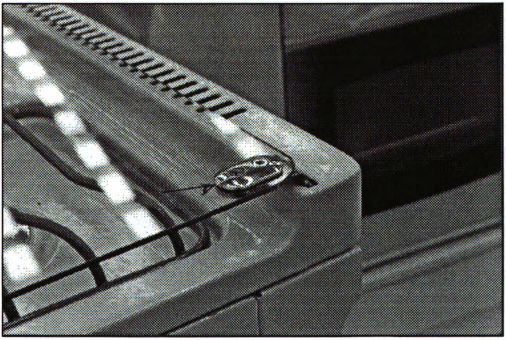
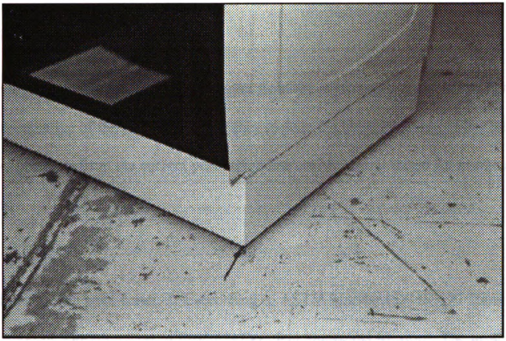


Figure 21 - Glass lid hinge



22 - Lower cabinet support

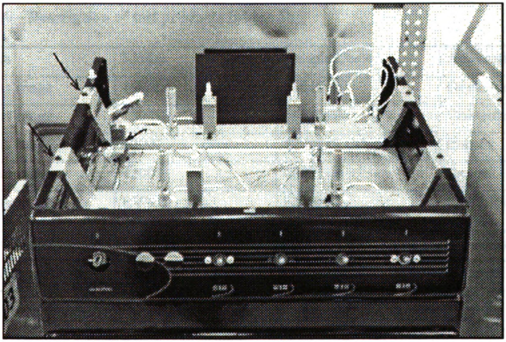


Figure 23 - Gas system support

2.4 Fragility testing (phase two)

The products tested in this phase are different from the previous tests. These products are also representative of the product line and they include the changes reviewed in section 2.3. Two products from the current production line are also being tested for comparison purposes.

2.4.1 Vibration

The following tests were conducted according to ASTM Standard D3580-90 Standard Test Method of Vibration Test of Products (Vertical Sinusoidal Motion). The products tested are listed in Table 10.

Table 10 - Description of test products (phase 2)

Product	Model	Sample Code	Application
20" Gas range	1504L	1504L-A	Domestic
20" Gas range	1504L	1504L-B	Domestic
20" Gas range	42001	42001-A	Export
20" Gas range	42001	42001-B	Export
20" Gas range	EV201	EV201	Economic Model
24" Gas range	EM240	EM240	With glass lid
20" Dual Fuel Range	EMC203	EMC203	Built-in

The purpose of this test is to determine the resonant frequencies of these products in order to generate information that will help improve the product design as well as the package design. The procedure according to ASTM D3580-90 is to place the product on a vibration table and set the table to gradually sweep through a frequency range from 3 to 100 Hz and return. The acceleration level was 0.5 g's throughout the sweep. A Lansmont Vibration Test Machine (model 10,000-10) was used. The conditions and results for each product are described in Tables 11 to 32.

Table 11 - Vibration test results for sample 1504L-A - test 1

Resonant frequencies (Hz)	Remarks
8 9.8 15-48	Resonant vibration of rear post Banging noise from the back The parts inside the oven hit the oven walls.
Conditions: corrugated protectors, with back-guard and burners placed inside the oven. These parts are packaged with a shrink film. The oven rack is over the oven floor and it also attaches the lid of the oven floor. The handle of the oven was bent. See Figure 24. **Damage:** the oven wall had small scratches.	

Table 12 - Vibration test results for sample 1504L-A - test 2

Resonant frequencies (Hz)	Remarks
3-36 21.6-28	Continuous banging of the oven lid Resonant vibration of the cabinet and oven door. Most critical at 20-21 Hz.
Conditions: without the cover and accessories placed inside the oven. Here the oven rack was not over the oven floor. See Figure 25 **Damage:** screws missing of the right lower oven wall	

Table 13 - Vibration test results for sample 1504L-A-test 3

Resonant frequencies (Hz)	Remarks
8-9 22-24	Resonant vibration of rear post Resonant vibration of the cabinet and oven door (most critical frequencies)
Conditions: without the lower oven floor lid and side walls. Without the accessories inside the oven. Without the cover **Damage:** no damage	

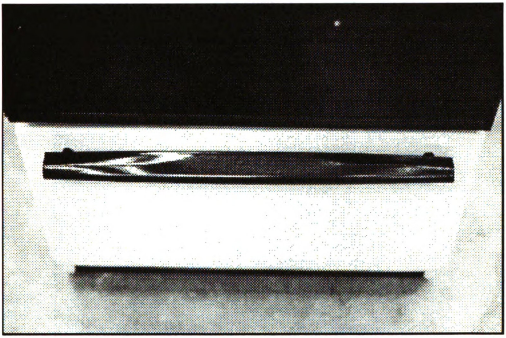


Figure 24 -Sample 1504L-A with damaged handle

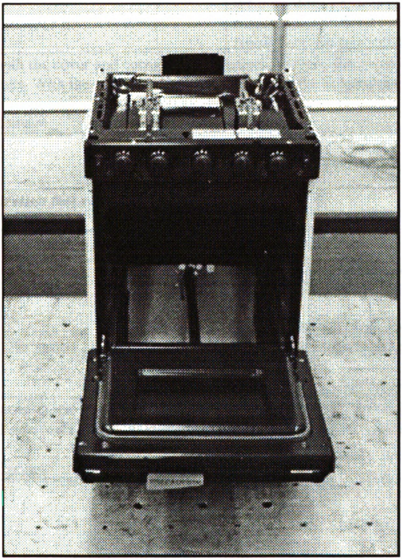


Figure 25 - Sample 1504L-A without cover and accessories (test 1)

Table 14 - Vibration test results for sample 1504L-A - test 4

Resonant frequencies (Hz)	Remarks
8-9	Resonant vibration of rear post
13-16	The parts inside the oven hit the oven walls
22-25	Resonant vibration of the cabinet and the oven door (most critical frequencies)
37-42	Noise from top (not critical).
Conditions: with the cover and corrugated protectors. Without the lower oven floor lid and the side walls. With the rack over the oven floor. With the accessories inside the oven **Damage:** no damage	

Table 15 - Vibration test results for sample 1504L-A - test 5

Resonant frequencies (Hz)	Remarks
8	Resonant vibration of rear post
11-17	The parts inside the oven hit the oven walls
19-27	Resonant vibration of cabinet and oven door (most critical frequencies at 20-21 Hz)
34-40	Noise from top (not critical)
Conditions: same as test 4 but with Polystyrene foam base and PS protection for handle. With floor and side walls of the lower oven. The missing screws were replaced. See Figure 26 **Damage:** no damage	

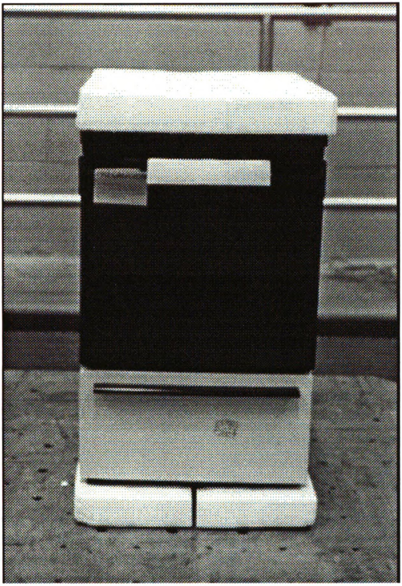


Figure 26 - Sample 1504L-A with PS base and PS protectors

Table 16 - Vibration test results for sample 1504L-B -test 1

Resonant frequencies (Hz)	Remarks
19.5-23	Resonant vibration of the cabinet and oven door
Conditions: without oven floors, accessories and cover. **Damage:** no damage	

Table 17 - Vibration test results for sample 1504L-B -test 2

Resonant frequencies (Hz)	Remarks
8-10 16 15-20 48	The oven floor lid was banging Banging sound from inside. Resonant vibration of the cabinet and oven door Resonant vibration of the oven floor (slight resonance)
Conditions: with the cover and oven floor lids. Without the accessories inside the oven floors. The rack was inside the oven **Damage:** no damage	

Table 18 - Vibration test results for sample 1504L-B -test 3

Resonant frequencies (Hz)	Remarks
9-16 18-24	Banging sounds from inside the oven. Resonant vibration of the cabinet and oven door (most critical frequencies from 18-22 Hz)
Conditions: with cover and corrugated protections. With the lower oven floor lid and side walls. With the rack over the oven floor. With the accessories inside the oven. With Polystyrene foam base and PS protection for handle **Damage:** screw loose from lower oven wall. Scratches on oven walls	

Table 19 - Vibration test results for sample 42001-A -test 1

Resonant frequencies (Hz)	Remarks
17-29 40	Resonant vibration of the cabinet and oven door Resonant vibration probably from the gas pipes.
Conditions: without the oven floor lid, without the cover and without the accessories inside the oven. See Figure 27 **Damage:** no damage	

Table 20 - Vibration test results for sample 42001-A - test 2

Resonant frequencies (Hz)	Remarks
6 17-30 13	Slight banging of accessories Resonant vibration of the cabinet and oven door (more critical between 19-20 Hz) Slight banging of the cabinet
Conditions: with cover and oven floor lids. With accessories inside the oven. Note: The plastic layer of the cabinet peals off with the yellow tape **Damage:** no damage	

Table 21 - Vibration test results for sample 42001-B- test 1

Resonant frequencies (Hz)	Remarks
18-28 35-40	Resonant vibration of the cabinet and the oven door Noisy. No critical.
Conditions: without the oven floor lid, without the cover and without accessories inside the oven **Damage:** no damage	

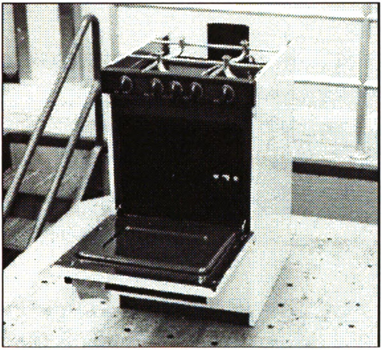


Figure 27 - Sample 42001-A without cover and accessories (Test 1)

Table 22 - Vibration test results for sample 42001-B- test 2

Resonant frequencies (Hz)	Remarks
9	Slight banging noise from accessories inside the oven
10-20	Banging noise from accessories inside the oven
12-27	Resonant vibration of a cabinet (most critical at 20 Hz)
30	Resonant vibration of gas pipes, Noise from cover
Conditions: with the cover and oven floor lids. With the accessories inside the oven **Damage:** no damage	

Table 23 - Vibration test results for sample EV201 -test 1

Resonant frequencies (Hz)	Remarks
9	Resonant vibration of the oven
17-24	Resonant vibration of the cabinet
25-34	Very noisy. Oven floor lid banging.
81	Resonant vibration of gas pipes.
Conditions: without back-guard, oven rack, burners. With oven floor lid. See Figure 28 **Damage:** no damage	

Table 24 - Vibration test results for sample EV201 - test 2

Resonant frequencies (Hz)	Remarks
6	Noise from top. No resonance.
10-11	Noise from the oven. No resonance.
20-24	Resonant vibration of the cabinet (most critical frequencies)
25-35	Critical noise coming from cabinet and oven
33-35	Product moved over the vibration table
80	Resonant vibration of gas pipes.
Conditions: same as test 1 but without the oven floor lid. **Damage:** no damage	

Figure 28 - Sample EV201 on the vibration table

Table 25 - Vibration test results for sample EV201 - test 3

Resonant frequencies (Hz)	Remarks
10 15 20-24 41	Parts banging inside the oven. No critical. Oven door lid banging inside the oven. Resonant vibration of the cabinet Oven door lid banging inside the oven
Conditions: accessories inside the oven, with the oven rack, and cover floor lid. See Figure 29 **Damage:** no damage	

Table 26 - Vibration test results for sample EV201 - test 4

Resonant frequencies (Hz)	Remarks
3-15 17-30 20-30 15-30	Continuous banging from back-guard and oven floor lid (slight) Resonant vibration of the cabinet Resonant vibration of the cabinet (most critical frequencies) Resonant vibration of the cabinet
Conditions: with corrugated base (double wall), with back-guard inside the oven, with rack and oven floor lid, without burners and supports **Damage:** no damage	

Table 27 - Vibration test results for sample EM240 - test 1

Resonant frequencies (Hz)	Remarks
23-27 44	Resonant vibration of cover and glass lid Noise from top, probably from the cover
Note: the oven floor lid does not fit well to the oven floor because it is bent. Also, the lid is twisted. See Figure 30 **Conditions:** without the oven floor lid and rack. The glass lid is taped to the cabinet. With burners and supports. See Figure 31 **Damage:** no damage	

Figure 29 - Sample EV201 with accessories inside the oven

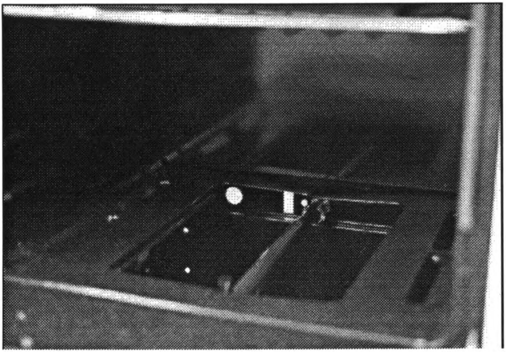


Figure 30 - Oven floor of sample EM240 bent

Figure 31 - Sample EM240 on the vibration table

Table 28 - Vibration test results for sample EM240 - test 2

Resonant frequencies (Hz)	Remarks
13-14 20-25 30	Range moving (no critical) Resonant vibration of cabinet and cover Resonant vibration of the glass lid
Conditions: same as test 1. **Damage:** no damage Note: during the tests I detected that the rear left corner of cover is not well attached to the cabinet. There is a problem of the cover banging continuously to the cabinet during vibration	

Table 29 - Vibration test results for sample EM240 -test 3

Resonant frequencies (Hz)	Remarks
14-22 33 12-26	Resonant vibration of the glass lid Resonant vibration from inside Resonant vibration of the glass lid
Conditions: with double wall corrugated base. See figure 32. With glass lid protection (early design), without the oven floor lid. I attached the rear cover corner to the cabinet with duct tape **Damage:** no damage Note: The tab of the protection glass lid was torn during the resonant vibration of the glass lid. I will add a radius to the tab to prevent the tear	

Table 30 - Vibration test results for sample EM240 - test 4

Resonant frequencies (Hz)	Remarks
13.8-22 20-13	Resonant vibration of the glass lid Most critical resonant vibration of the glass lid at these frequencies.
Conditions: with corrugated base (double wall), with glass lid protection (early design) and with a modified tab, without an oven floor lid. I attached the rear cover corner to the cabinet with duct tape. **Damage:** one of the screws of the glass lid went loose during the test	

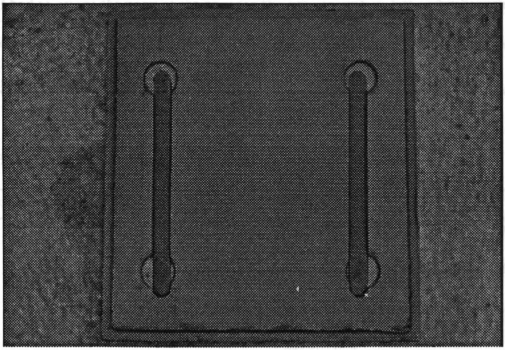


Figure 32 - Corrugated base

Table 31 - Vibration test results for sample EMC203 -test 1

Resonant frequencies (Hz)	Remarks
4	Slight banging from inside the oven
12	Banging noise of the oven floor lid.
22-23	Resonant vibration of the cabinet (critical)
25	Banging of the rear electric burner cover
30-31	Resonant vibration of cover
36-47	Resonant vibration of electric burners. Most critical from 20-30 (Resonant vibration of the cabinet)

Note: I had to attach the back of the cover to the cabinet with duct tape because the clips used for that loosen easily. See figure 33
Conditions: with the oven components, without gas burners and supports. With electric burner. See Figure 34
Damage: no damage

Table 32 - Vibration test results for sample EMC203 - test 2

Resonant frequencies (Hz)	Remarks
3-6.4	Continuous banging from inside the oven (slight)
11-18	Continuous banging from inside the oven (slight)
18-29	Resonant vibration of cabinet and cover
30-50	Noise from top (probably plates banging)
29-24	Resonant vibration of cover
24-16	Resonant vibration of cabinet and cover

Conditions: with corrugated base (double wall), oven components, with gas burners and supports taped to cover. With electric burners taped to cover. See Figure 35
Damage: no damage
Note: the rear electric plate tends to vibrate at different frequencies hitting the cover

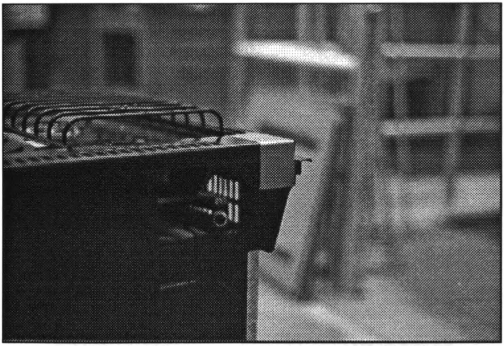


Figure 33 - Cover Attached to the cabinet with duct tape (sample EMC230)

Figure 34 - Sample EMC203

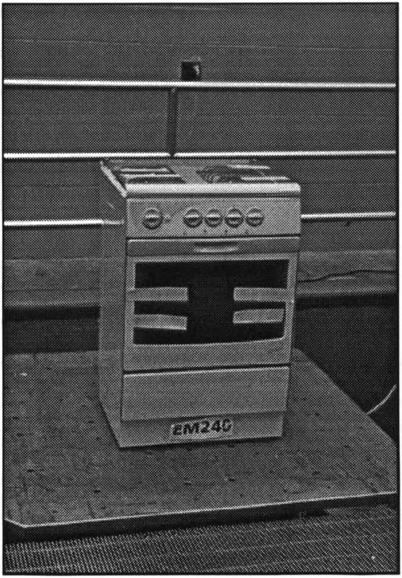


Figure 35 - Sample EMC203 with corrugated base

Improvements

Comparing the performance during vibration of the new products versus the prototypes tested previously, a big improvement was observed. Although there were still severe resonant vibrations of the cabinets in all the ranges, none produced any significant damage. It is important to mention that there is no data on the frequencies present during actual distribution of these products. This is one reason that dwells were not conducted for more than five minutes at individual resonant frequencies as recommended in the standard. Also, these products were to be used for further testing.

From these tests, the following recommendations were made:

1.- In all ranges, there was resonant vibration of the cabinet and oven. The ranges with back-guards (1504L, 42001 and EV201) require a proper package to store this and the other components inside the oven. This will prevent scratching of the oven walls and damage to the back-guard as well. Also, it is necessary to improve the assembly between the lid and the oven floor. The lid easily falls to the bottom of the range. The oven base in the new ranges tends to bend in the center of the oven floor, where the sheet metal is joined. On the other hand, the position of the rack over the oven floor may prevent the lid from moving from its original position.

2.- In the new ranges, the assembly between the cover and the rear part of the cabinet is not very strong. In the EV201 and EMC203 models there were clips that easily fall apart during vibration. In the EM240 model, the spring is not strong enough to prevent the cover from moving.

3.- For all ranges, it is necessary to have an additional fixture to ensure that the oven door remains closed. This can be tape or a piece of corrugated board.

4.- For model EM240, it is necessary to have additional protection for the glass lid.

5.- In general, the use of a base (corrugated or polystyrene foam) did not significantly help the effect of vibration on the products. However, the bases prevent the ranges from moving around on the vibration table, due to their higher coefficient of friction.

6.- Cover parts such as electric plates, burners, etc. have to be attached so they cannot move during vibration.

2.4.2 Compression

The compression strength of a packaged product is defined to be the force required to compress the package to failure [8]. Some times the product itself is the element that supports the stacking weight. This is often desirable because if the product is strong enough to support the stacking weight, then a costly box or corner posts are not needed. Therefore, it is important to know if the product is capable of withstanding these forces. The following tests were made according to ASTM Standard D642-90: Standard Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads [9].. The products tested are listed in Table 2. The purpose of this test is to determine if the product can support the stacking load without packaging protection, such as corner posts and a container. A Lansmont compression tester (model 152-30TTC) was used (Figure 36). Tests were made with a concentrated load off to the sides where it is more likely that people will step on the product.. A piece of wood was used for the concentrated load. The loads applied to the products were based on a stack of 5.5 units. These were pass/fail tests. Ranges with back-guards were tested without the back-guards in place because the back-guards go inside the oven in a package. The loads applied for each product are shown in Table 34.

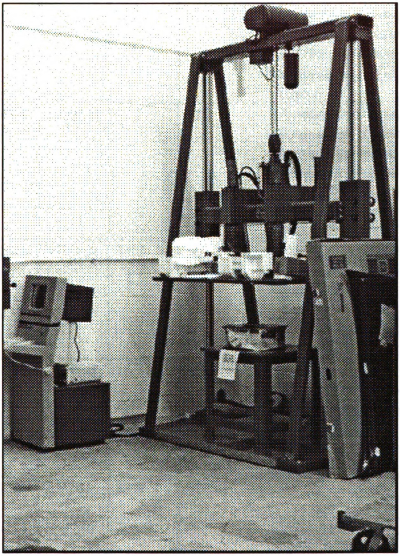


Figure 36 - Lansmont Compression tester

Table 33 - Compression loads applied to each product

Product	Model	Sample Code	Weight of product (lbs)	Minimum required load (lbs)	Remarks
20" Gas range	1504L	1504LA	93.7	422	Product was tested with honeycomb protection because the back-guard support was higher than the cover (did not use the protection for the concentrated load test). See Figure 37
20" Gas range	1504L	1504LB	93.7	422	Product was tested with honeycomb protection because the back-guard support was higher than the cover (we did not use the protection for the concentrated load test. See Figure 37
20" Gas range	42001	42001A	84.9	382	Product was tested with upper PS cushion because the back-guard support was higher than the cover (did not use the protection for the concentrated load test). See Figure 38
20" Gas range	42001	42002B	84.9	382	Product was tested with upper PS cushion because the back-guard support was higher than the cover (did not use the protection for the concentrated load test. See Figure 38
20" Gas range	EV20 1	EV201	83.8	377	
24" Gas range	EM24 0	EM240	106.9	481	Did not do the concentration load test.
20" Dual Fuel Range	EMC2 03	EMC20 3	75.4	339	

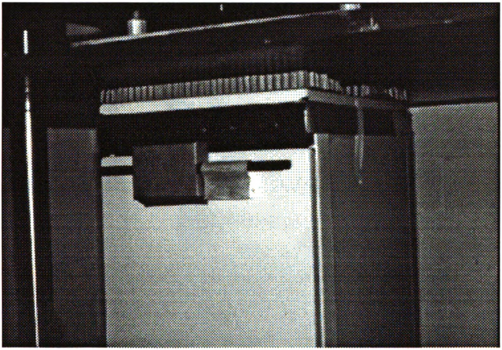


Figure 37 - Sample 1504L with honeycomb protector

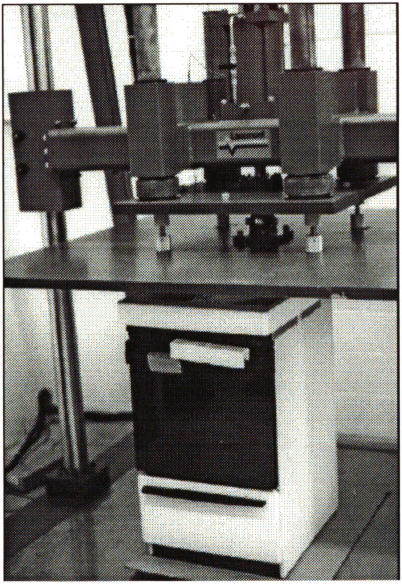


Figure 38 - Sample 42001 with PS protector

The results of the compression tests are shown in the force versus deflection graphs (see Figures 40-52) and also in Table 34. In Figure 39, the constant rate configuration for one of the samples is shown.

CONSTANT RATE CONTROL CONFIGURATION

	Current Status
Preload for Deflection Auto Zero:	50.0 Lbs
Yield Detection Percentage:	20.0 %
Stop Force:	377.0 Lbs
Stop Deflection:	8.00 In
Test Velocity:	0.50 In/M
Auto Sample Number:	ON
Auto Log on Test Completion:	OFF
Overlay Auto Copy Test Interval:	OFF
Auto Print Test Interval:	EVERY 1

Figure 39 - Example of constant rate control configuration

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 1504L, Sample A	1	427.0 Lbs	0.24 in	66.89 °F	44.12 % RH	13:33:09	12-16-1996

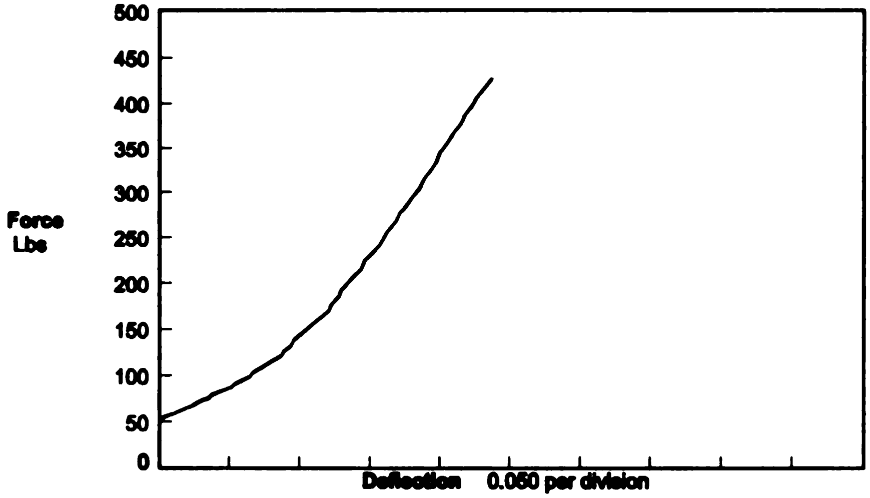


Figure 40 - Force vs. deflection graph for sample 1504L-A

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 1504L, Sample A-C	1	422.4 Lbs	0.20 in	66.93 °F	44.15 %RH	13:35:54	12-16-1996

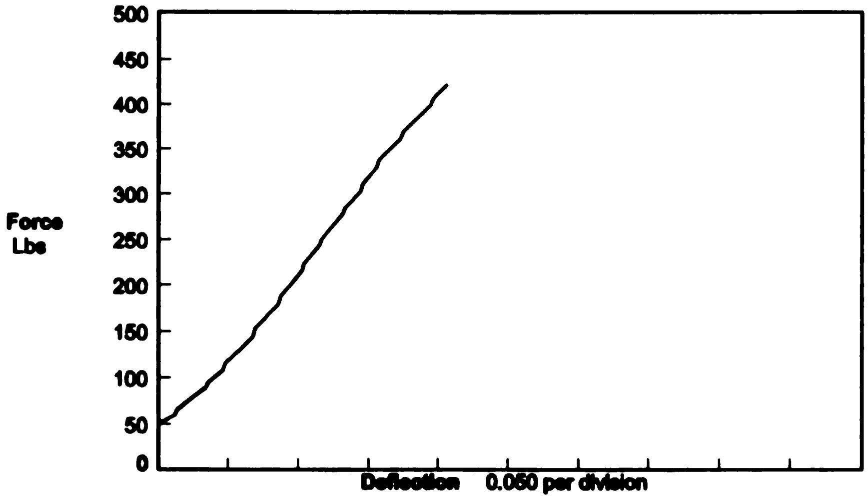
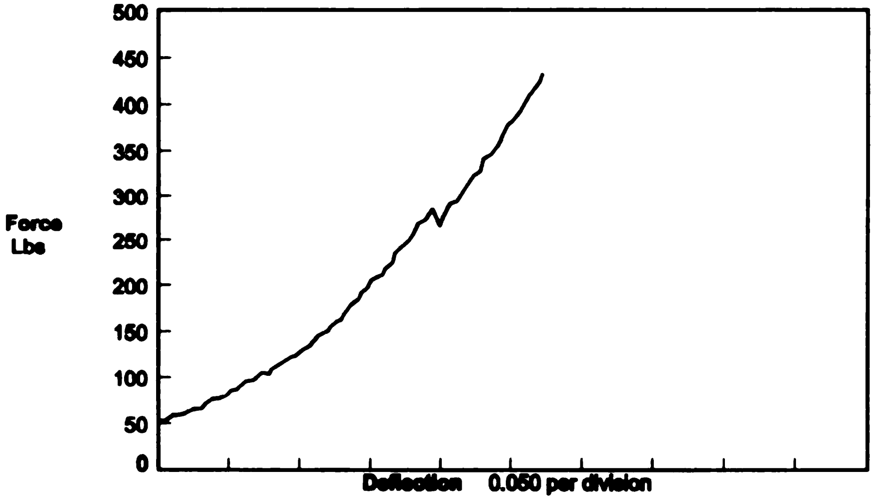


Figure 41 - Force vs. deflection graph for sample 1504L-A with concentrated load

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 1504L, Sample B	1	432.1 Lbs	0.27 In	66.84 °F	44.12 %RH	13:20:13	12-16-1996



42 - Force vs. deflection graph for sample 1504L-B

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 1504L, Sample B-C	1	427.1 Lbs	0.21 In	66.89 °F	44.12 %RH	13:28:30	12-16-1996

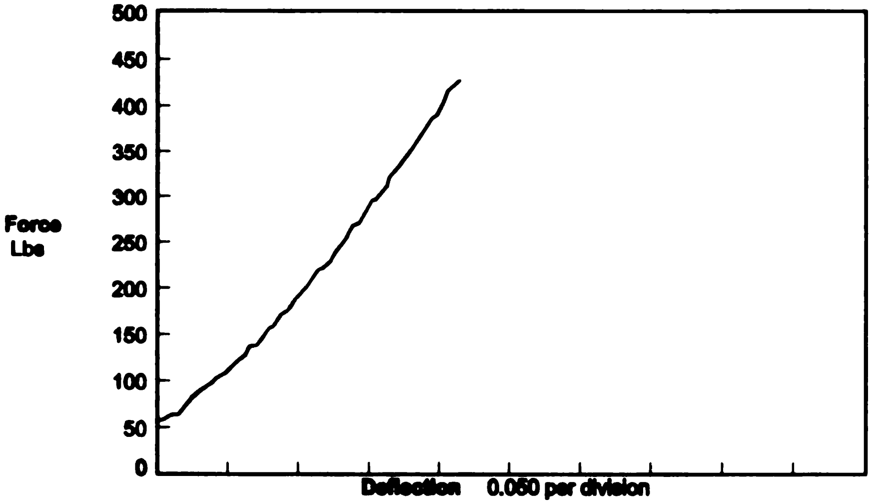


Figure 43 - Force vs. deflection graph for sample 1504L-B with concentrated load

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 42001, Sample A	1	384.4 Lbs	0.20 In	66.93 °F	44.12 %RH	13:40:55	12-16-1996

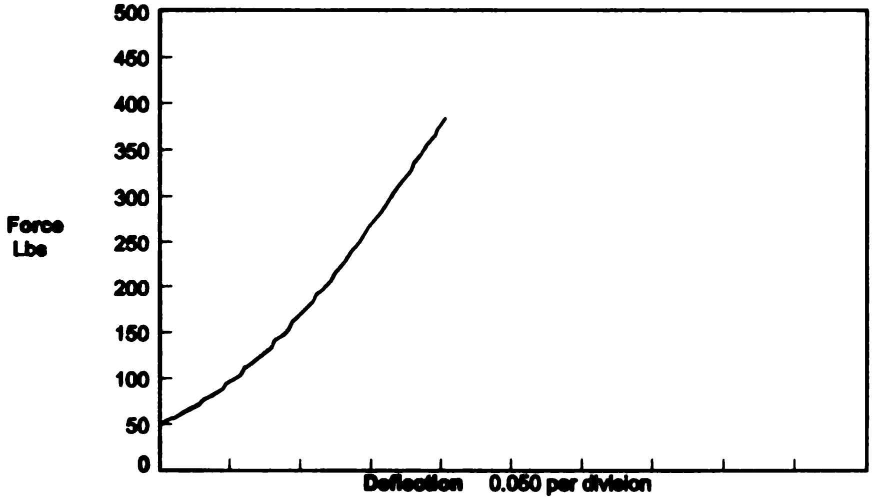


Figure 44 - Force vs. deflection graph for sample 42001-A

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 42001, Sample A-C	1	394.0 Lbs	0.18 In	66.96 °F	44.12 %RH	13:43:42	12-16-1996

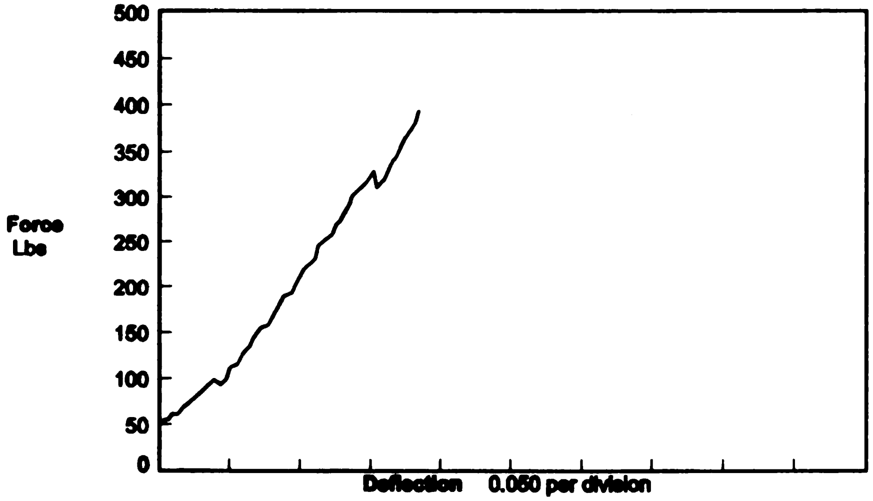


Figure 45 - Force vs. deflection graph for sample 42001-A with concentrated load

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 42001, Sample B-C	1	385.0 Lbs	0.18 In	66.96 °F	44.12 %RH	13:50:06	12-16-1996

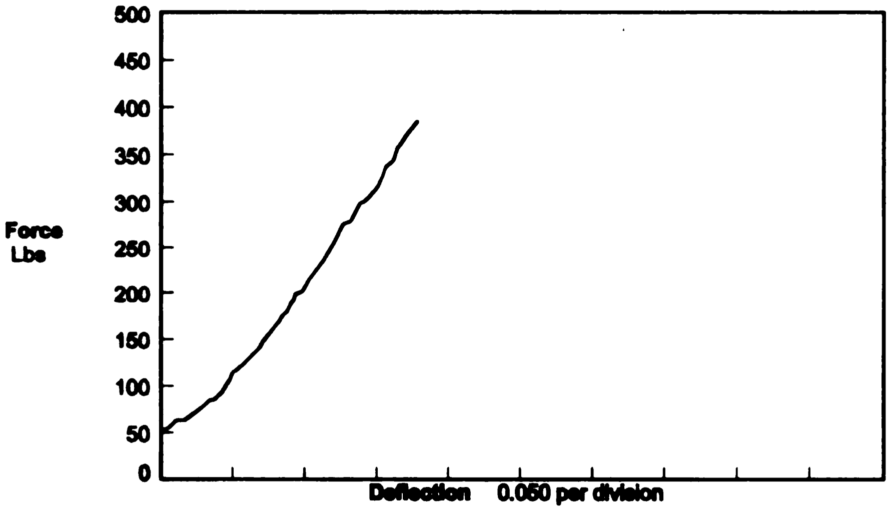


Figure 46 - Force vs. deflection graph for sample 42001-B

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, 42001, Sample B	1	386.1 Lbs	0.22 In	66.93 °F	44.12 %RH	13:47:42	12-16-1996

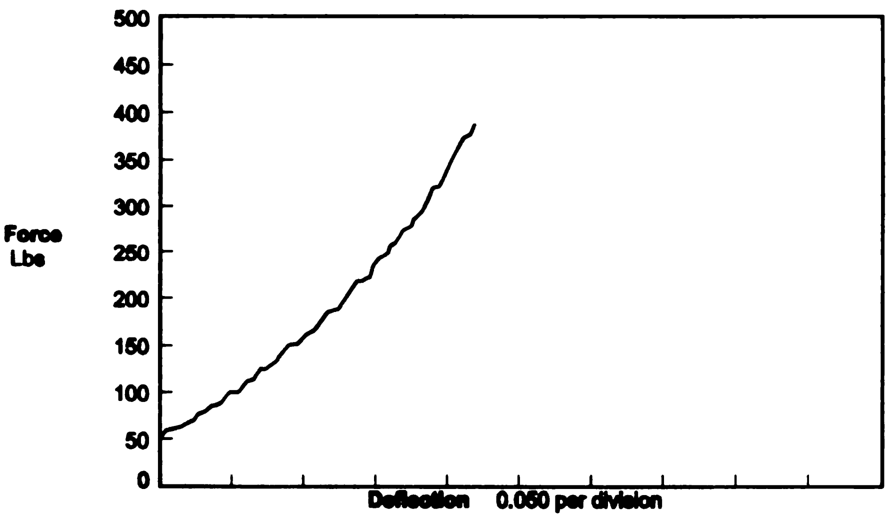


Figure 47 - Force vs. deflection graph for sample 42001-B with concentrated load

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, EV201	1	378.2 Lbs	0.11 In	66.41 °F	44.29 %RH	12:12:49	12-16-1996

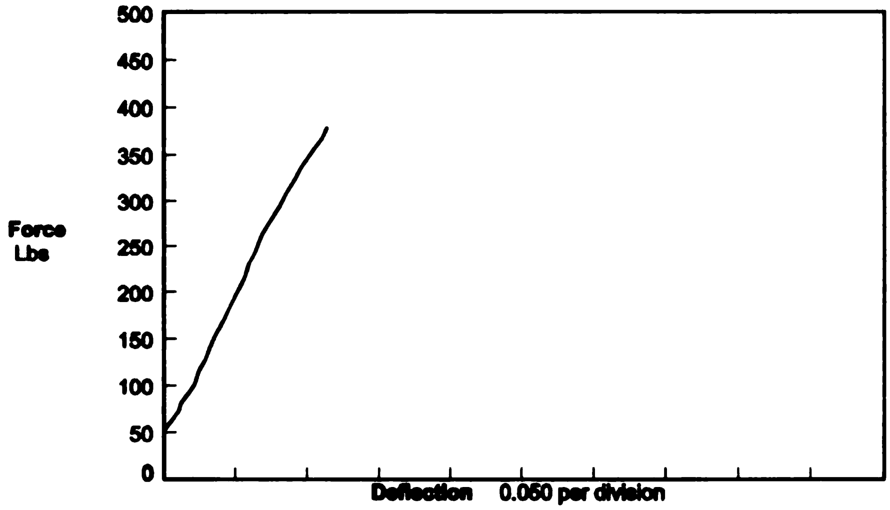


Figure 48 - Force vs. deflection graph for sample EV201

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, EV201, Conc Load	1	382.7 Lbs	0.21 In	67.02 °F	44.12 %RH	14:00:52	12-16-1996

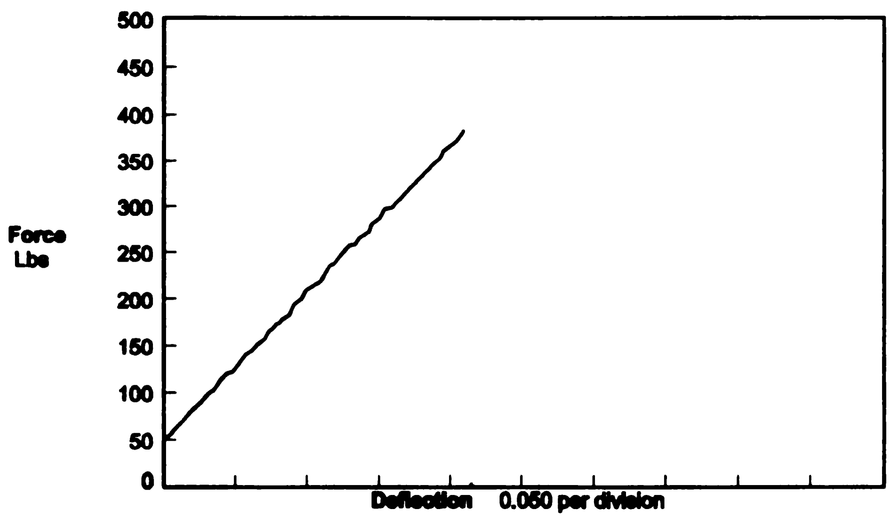


Figure 49 - Force vs. deflection graph for sample EV201 with concentrated load

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, EM240	1	482.8 Lbs	0.40 In	66.71 °F	44.15 %RH	12:53:09	12-16-1996

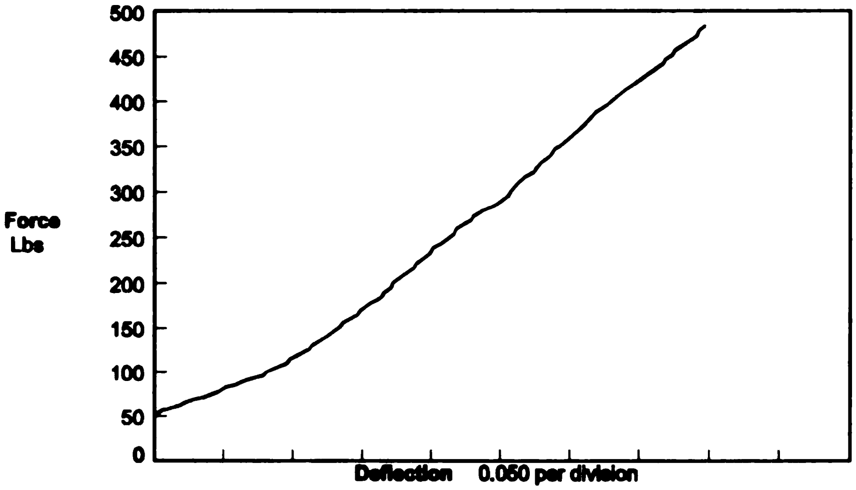


Figure - 50 - Force vs. deflection graph for sample EM240

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, EMC 203	1	348.3 Lbs	0.23 In	67.02 °F	44.12 %RH	14:07:10	12-16-1996

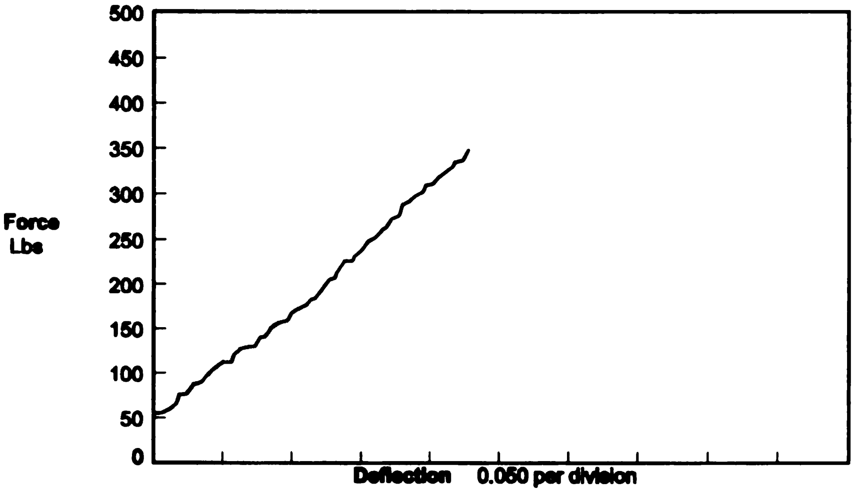


Figure - 51 - Force vs. deflection graph for sample EMC203

Sample ID	Sample #	Peak Force	Def @ PK	Temp	%RH	Time	Date
MABE, RANGE, EMC 203, Con Load	1	343.7 Lbs	0.27 In	67.02 °F	44.12 %RH	14:09:43	12-16-1996

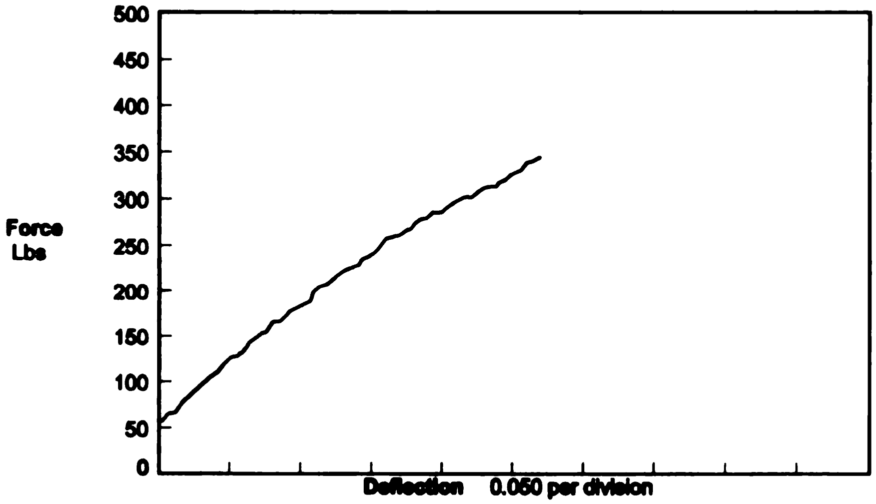


Figure 52 - Force vs. deflection graph for sample EMC203 with concentrated load

Table 34 - Results of compression tests

Product	Model	Concentrated load	Sample	Peak Force (lbs)	Deflection @ Peak (inches)	Remarks
20" Gas range	1504L	No	A	427.0	0.24	No damage
20" Gas range	1504L	Yes	A	422.4	0.20	No damage
20" Gas range	1504L	No	B	432.1	0.27	No damage
20" Gas range	1504L	Yes	B	427.1	0.21	No damage
20" Gas range	42001	No	A	384.4	0.20	No damage
20" Gas range	42001	Yes	A	394.0	0.18	No damage
20" Gas range	42001	No	B	388.1	0.22	No damage
20" Gas range	42001	Yes	B	385.0	0.18	No damage
20" Gas range	EV201	No		378.2	0.11	No damage
20" Gas range	EV201	Yes		382.7	0.21	No damage
24" Gas range	EM240	No		482.8	0.4	No damage
20" Dual Fuel Range	EMC203	No		348.3	0.23	No damage
20" Dual Fuel Range	EMC203	Yes		343.7	0.27	No damage

Improvements

The test results showed that the gas ranges were strong enough to withstand the anticipated compression forces. Only in two graphs is there a falloff in the strength. In the first case (see Figure 42), a slight drop is noticed for 280 lbs at 0.18 in. This is not failure of the product, but a slight buckling of the honeycomb protection used in sample 1504L-B. In the second case for sample 42001-A with concentrated load, there are two slight drop-offs on the curve, possibly due to buckling from the piece of wood because no damaged was observed in the product. From these results, the product should be able to support the stacking load with a fair safety margin. However, some protection is needed to make sure the enamel on the cover does not crack. Also, it is important to take into consideration a corner post or a similar element designed to protect the corners from impacts, not to help support the stacking loads.

2.4.3 Shock

The following tests were made according to ASTM Standard D3332-93: Standard Test Method for Mechanical-Shock Fragility of Products, Using Shock Machines. The products tested are listed in Table 10. The test is intended to provide data on product shock fragility that can be used in choosing optimum-cushioning materials or packaging components for shipping containers and for product redesign. It can also provide information about the performance of the product at different drop heights. For models EV201, EM240 and EMC203, Test Method A (Critical velocity Shock Test) was used because there was only one sample of each model. For models 42001 and 1504, both methods (A and B) were applied. The results are based on the calibration table for the MTS (model MTS 846 Shock Test System) shock machine (Figure 5). See tables 35 and 36. The results are shown in Tables 37 to 43.

Table 35 - Shock Machine Calibration Values: 2 ms Half-sine Programmers (Bare Table)

Drop Height (inches)	ΔV (in/sec)	g's
2	55	160
3	72	215
4	83	260
5	91	305
6	97	340
7	107	370
8	114	400
9	121	430
10	128	455
11	135	480
12	141	515
13	147	540
14	153	560
15	159	580
16	164	605
17	169	620
18	174	
19	179	
20	184	

Table 36 - Shock Machine Calibration Values: Gas Programmer (Bare Table)

Drop Height (inches)	ΔV (in/sec)
3	80
6	110
12	140
18	170
24	200
30	230
36	260
42	290

Gas pressure (psi)	g's
50	9
100	18
150	27
200	36
250	45
300	54
350	63
400	72
450	81
500	90
550	99
600	108
650	117
700	126
750	135

Table 37 - Shock test results for sample 42001-A (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	2	55	160	2	No damage (see Figure 53)
2	3 1/8	73	221	2	Rear bottom cabinet bent (see Figure 54)
3	4 1/8	84	266	2	Increase of rear bottom cabinet deformation
4	5 1/16	91	307	2	Slight deformation of cabinet at front bottom. Slight bend of guide pins of oven floor
5	6 3/16	99	346	2	Deformation of steel sheet from bottom. Slight bending of control panel support
6	7 1/16	107	372	2	Bottom door popped out (see Figure 55) Bottom frame was bent at front Oven floor popped out Control panel support was bent

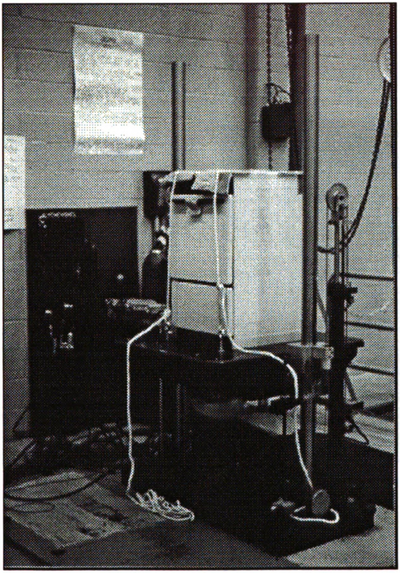


Figure 53 - Sample 42001-A over shock machine

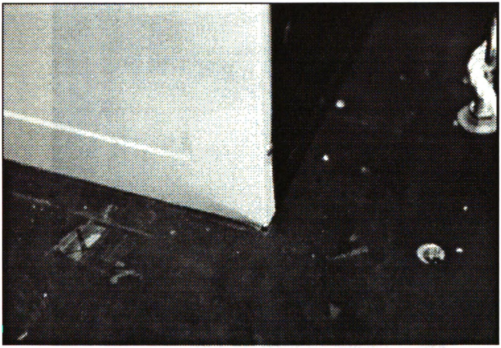


Figure 54 - Damaged corner of sample 42001-A

Figure 55 - Sample 42001-A after last drop

Table 38 - Shock test results for sample 1504L-A (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g´s	Duration (milliseconds)	Damage
1	2 1/8	57	166	2	No damage
2	3 1/16	73	218	2	Lower oven door was bent Slight bending of cabinet at the real bottom Deformation of back panel at bottom, close to the cabinet corner
3	4 1/16	84	263	2	Lower oven door opened during shock Increase of deformation in rear panel Increase of deformation of cabinet corner
4	5	91	305	2	Glass went out of place due to bending of the glass support Right oven door hinge was bent Oven door cannot be closed Lower frame at front was bent Cabinet sides deformed at bottom

Table 39 - Shock test results for sample EV201 (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	2	55	160	2	No damage
2	3	72	215	2	Oven door went out of place No damage (see Figure 56)
3	4	83	260	2	Very slight bent of base support Oven door went out of place (we taped it for next drops)
4	5	91	305	2	Oven floor was damaged Paint of cover went off slightly in some parts (see Figure 57) Hinge door was bent
5	6	97	340	2	Cabinet was damaged due to the impact force transmitted from lower frame The circular supports of the base were bent Frame is damaged Slight separation of assembly on oven floor
6	7	107	370	2	Increase of separation of the assembly on oven floor Severe cabinet damage

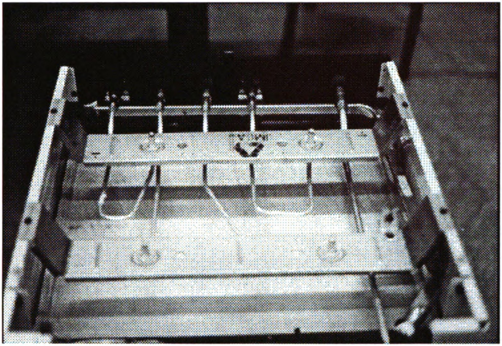


Figure 56 - Sample EV201 free of damage

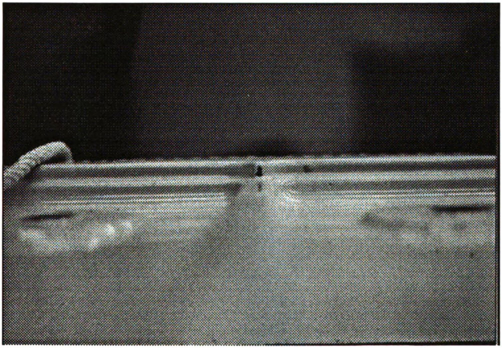


Figure 57 - Cover of sample EV201

Table 40 - Shock test results for sample EM240 (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	2	55	160	2	No damage
2	3	72	215	2	Base supports were bent (see Figure 58 Slight bending in bottom frame at front Feeding gas tube support was loose again
3	4	83	260	2	Cabinet was bent in front corner The frame was bent in the front and rear The oven door hinge was bent. It makes a scratchy noise when open Slight deformation of cabinet sides
4	5	91	305	2	Cabinet damage severe at bottom Frame was bent at rear Glass door and glass lid are OK

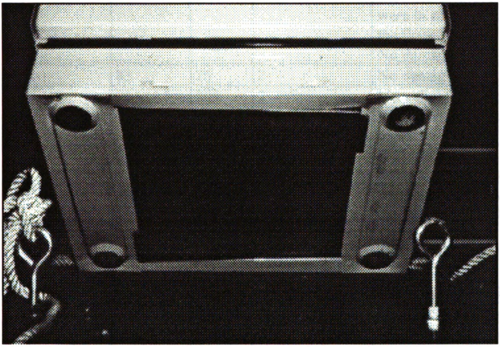


Figure 58 - Deformation of range base in sample EM240

Table 41 - Shock test results for sample EMC203 (Method A)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	g's	Duration (milliseconds)	Damage
1	2	55	160	2	No damage
2	3 1/16	73	218	2	Oven door hinge slightly bent Note: there was an assembly defect of the base; the base supports are not the only parts in contact with the floor. Also the cabinet sides were in contact with the floor No damage
3	4	83	26	2	No damage
4	5	91	305	2	Very slight bending of the lower right cabinet corner
5	6	97	340	2	Slight bending of cabinet (not critical)
6	7	107	370	2	Bending of rear panel corner (not critical)
7	8	114	400	2	Bending of cover; plates of electric burners did not fit well Deformation of cabinet
8	9 1/16	121	432	2	Rear panel was bent
9	10 1/16	128	457	2	Oven door glass went out of position
10	11 1/8	136	484	2	Increase of frame deformation and cover

Table 42 - Shock test results for sample 42001-B (Method B)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	Gas Pressure	g's	Damage
1	12	140	100	18	No damage
2	12	140	150	27	Slight bending of cabinet at bottom rear (no critical)
3	12	140	200	36	Slight bending of cabinet at bottom rear (no critical) (see Figure 59)
4	12	140	250	45	Increase of cabinet deformation Bending of oven floor pin
5	12	140	300	54	Increase of cabinet deformation
6	12	140	350	63	Increase of cabinet deformation
7	12	140	400	72	Increase of cabinet deformation

Figure 59 - Lower corner of sample 42001-B

Table 43 - Shock test results for sample 1504L-B (Method B)

Drop #	Machine Drop Height (in)	ΔV (in/sec)	Gas Pressure	g's	Damage
1	12	140	100	18	Deformation of front base support Rear panel bent at bottom (see Figure 60) Displacement of oven glass Bending of lower door hinge
2	12	140	150	27	Increase of same damages
3	12	140	200	36	Increase of same damages

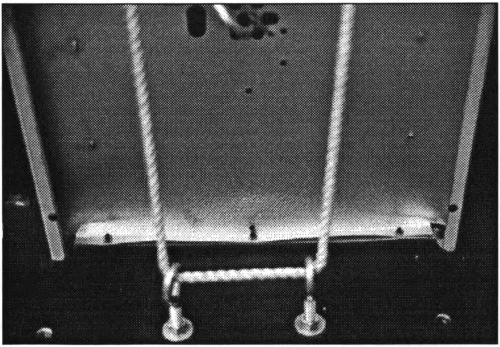


Figure 60 - Rear view of sample 1504L

Improvements

There were two types of product used in the shock tests: samples 42001 and 1504L were products directly off the production line, and samples EV201, EM240 and EMC203 were prototypes of the new product line. One advantage in testing products off the production line was the opportunity to develop a Damage Boundary Curve (DBC) for these two products [2]. A DBC is essentially a two dimensional index of fragility which takes both the amplitude and duration of the shock into account [11]. The DBC's for the products from the production line is useful because it gives the critical acceleration (g's) of the products, information necessary for the cushion design.

As in the first phase, these results determine if the products require cushioning or not. From the earlier conclusions of the first results (phase 1), an expected ΔV of 102.2 in/sec was obtained for a 6 inch drop design height. From the results shown in Tables 37 through 41, critical velocity changes less than 102.2 in/sec were observed for all products. Based on these results, the expected velocity change in a 6 in drop will exceed the critical velocity change of the products and, therefore, a cushion is needed.

The Damage Boundary Curves for the production line products are shown in Figures 61 and 62. The horizontal line of the graph (acceleration boundary) was determined with the gas programmers of the shock machine following the ASTM procedure. Figures 61 and 62 show the Damage Boundary Curves for the production products. For sample 42001, the fragility was determined to be 18 G and for sample 1504-B it was less that 18 G.

Similarly to the results from the first phase, information on the performance of each product after each impact was reported to the Mabe product designers to improve the design of the product.

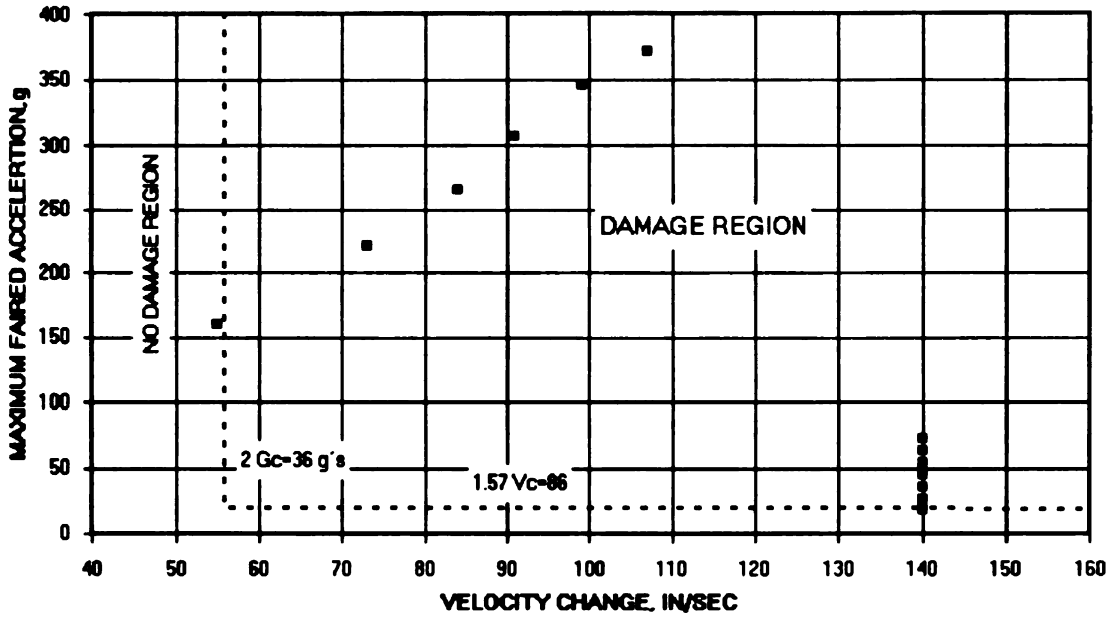


Figure 61 - Damage Boundary Curve for Sample 42001

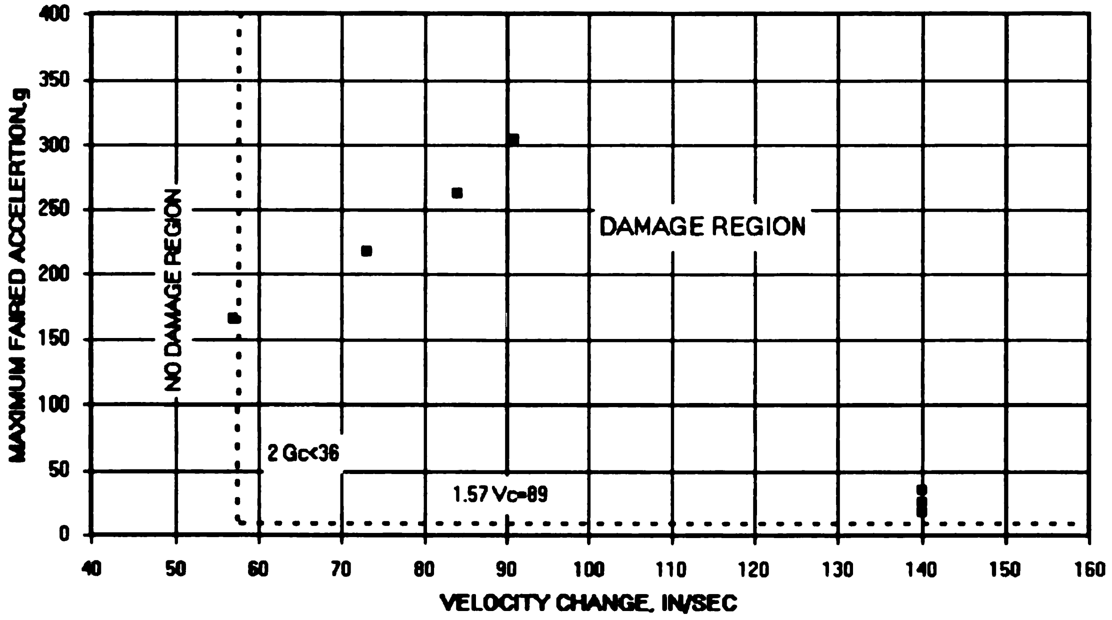


Figure 62 - Damage Boundary Curve for Sample 1504L

2.5 Product improvement from fragility tests results.

Any improvements to the design of the product or components of the product have to take into consideration several factors, such as cost, functionality, appearance, etc. One of these factors is the fragility of the component or product. Some of the changes made from the functionality and fragility results and also the marketing studies, are described in this section. All of these changes are still in the development stage.

- In order to improve the appearance of the range, the lower front support was eliminated and this lower section will be part of the cabinet range. This will help to improve the rigidity of the range and will help to decrease the fragility of the product.
- Instead of a lid for the oven floor, a completely removable floor will be used. This will improve the appearance of the oven. However, further testing of this element is necessary to see the effect of vibration and impacts during transportation (see Figure 63)
- A new design of the supports of the glass for the oven door will improve the attachment of the glass to the door (see Figure 64)
- The electric burners (cal-rod) will have a special element to fix on the burner. This element will prevent repetitive shock during transportation of the burner against the burners supports (see Figure 65)
- The knob controls will have a clip to prevent the knob from popping out of place during distribution (see Figure 66).

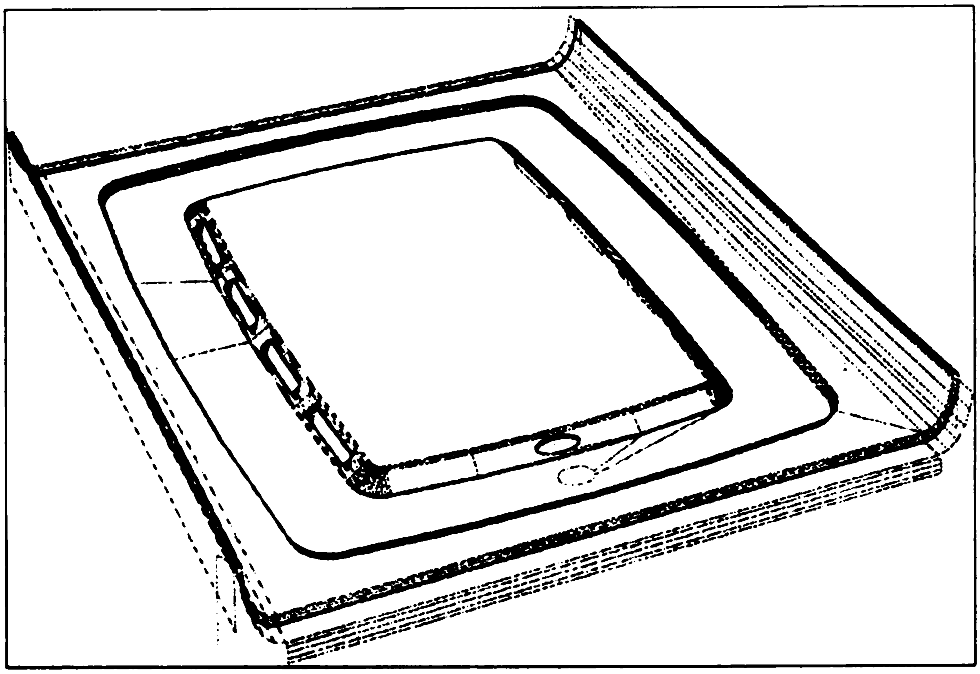


Figure 63 - New oven floor design

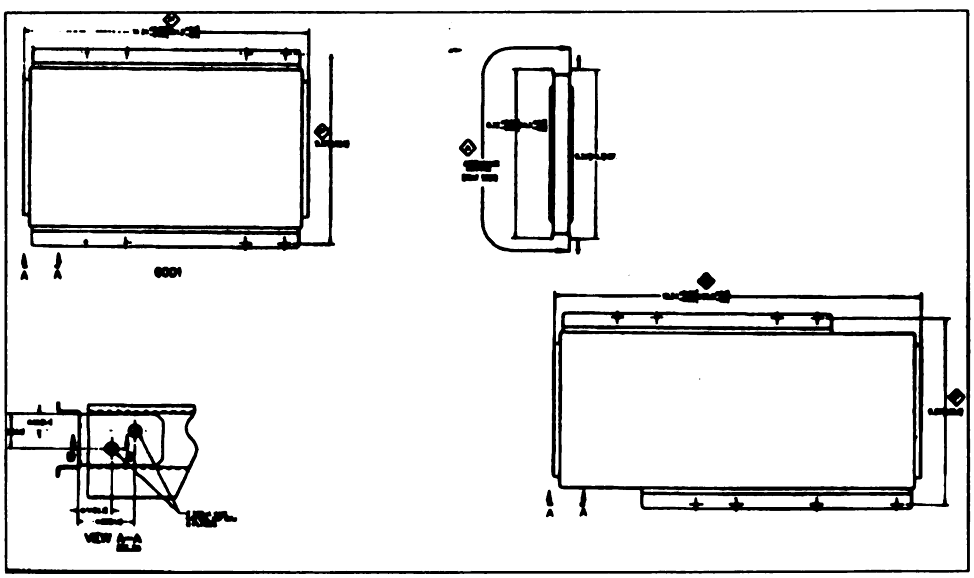


Figure 64 - New supports of the glass for the oven floor

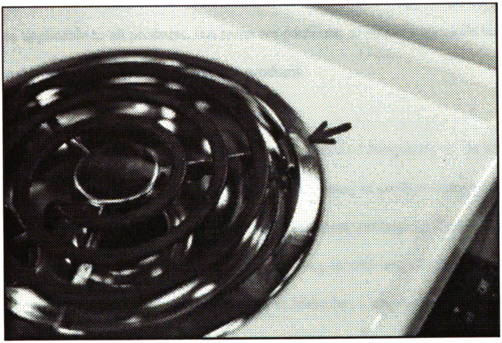


Figure 65 - Electric burners clip

Chapter 3

PACKAGING REQUIREMENTS

In this chapter, some of the aspects that Mabe has to take into consideration when designing a package for a new line of products will be covered. Many of these are general principles applicable to all products, but some are particular to Mabe's concerns in order to define the best alternative to package the products.

3.1 Cost Analysis

The goal is to design a package which will protect the product adequately at the lowest cost possible. Under-packaging will cost the company money in product damage, and over-packaging will cost the company money in throw-away packaging. There are also other type of considerations to keep in mind. Packaging, as with any other part of the product, represents a cost. The project manager at Mabe has a single cost goal for the material, for the tools, and for molds for all parts. This information is important because it will help to decide the best overall. Also, it is important to keep in mind the cost of the actual product and to know its fragility. If we can reduce the cost (or at least maintain the same cost) and reduce the damage level at the same time, then we will have a better packaging system than before. Table 44 shows an example of the packaging cost breakdown of one of the current models.

Table 44 - Packaging costs for a 20 inch range (current model)

No.	Description	Cost (US dollars)
1	20 in corrugated board box	$1.884
2	PE 20 in PE bag	$0.117
3	Upper protector (20 in x 7 in x 1 ¼ in)	$0.240
4	Upper protector (20 in x 4 in x 1 ¼ in)	$0.121
5	2 in tape	$0.010
6	Yellow tape	$0.039
7	Fiber tape	$0.067
8	Glue	$0.029
9	Staples	$0.011
10	Handle protector	$0.060
11	20 in back protector	$0.075
12	Cover side protector	$0.102
	Total	$2.754

Similar to the example shown in Table 44 there are costs for every model which vary depending on the size of the product and the type of package (currently there are two types: one for domestic products and another type for export products). For this new line of products, Mabe has decided to have only one type of package. Having only one type will have some advantages:

-Volumes for all packaging will increase and this should lower the price of the materials.

-Dealing with just one type of package will help the production line to work in a more efficient way.

Having one type of package will help, but depending on the type and size of the product, the costs will have some variations. Based on the cost goal for the package system and current model practice, the project manager makes an estimate of the package cost for each new model. From these figures he calculates a weighted cost where he takes into consideration the volumes of the new products. These volumes are based on forecasts of the production for the new line of products. In this study I cannot include the weighted cost because this information is confidential. However, from this protocol, we anticipate a target packaging cost of $2.918 USD, which represents a 5.62% of the total cost of the product. This objective cost is an average cost over all models. Obviously, there will be products with a packaging cost higher than the $2.918 USD and others will have a lower cost.

Finally, the product improvement from the fragility studies will help us to reach this goal because if the new product line is less fragile than the current product line, then we can design a better package for these ranges.

3.2 Maximum packaging sizes.

Package size is related to the package cost: the bigger the package, the more costly. Also if package size is increased, utilization of warehouse space and containers for transportation will be affected.

For a line of products like this new line of ranges, with a lot of different models (70 models approximately), it is very cost effective to make a detailed analysis and try to select the best options to decide on the least amount of different sizes needed for the entire line. Table 45 shows a brief analysis of the product size.

Table 45 - Product sizes according to the product line characteristics

	Free-standing						Built-in			
	Flat with glass lid		Flat with-out glass lid		Up-swept		Flat with glass lid		Flat with-out glass lid	
Height (in)*	A	A	B	B	C	C	D	D	E	E
Depth (in)	26.4	23.7	26.4	23.7	26.4	23.7	26.4	23.7	26.4	23.7
Widths (in)	20 21.2 24 25.2	20 21.2 24 25.2	20 21.2 24 25.2	20 21.2 24 25.2	20 21.2 24 25.2	20 21.2 24 25.2	21.2 25.2	21.2 25.2	21.2 25.2	21.2 25.2

*Height dimensions are not yet defined

From the table, there are 5 different heights. We can use dimension C for all free standing models, since it is the highest dimension. For the built-in models, we can use dimension E. This will allow us to have just two sizes of cornerposts or boxes, depending on the type of package. For the product depth we have two different sizes: 26.4 inches and 23.7 inches. Since there is a difference of 2.7 inches, it is convenient to have two different depths. For the widths, there are four different dimensions for the free-standing models because some models will have two end caps on the side of the control panel. We can use the dimensions of 21.2 inches and 25.2 inches in a similar way as we did for the heights.

From this study, we have a total of 8 different sizes, which is good considering the total number of different models.

3.3 The distribution environment.

Defining the environment is a very important part of the package development process. Only by knowing the environmental conditions that the product will encounter can the process of developing and evaluating effective protective packaging to enable the product to survive the distribution environments begin [12]. Distribution of these products changes according to the different places where the ranges will be sold. For instance, some products will be shipped from Mexico City to other cities within Mexico, other products will be shipped to Central America, other products will go to South America, etc. Mabe currently has undertaken a project to develop a performance specification based on recorded environmental data for these areas. This plan will cover the most critical routes for each different kind of product (range, washing machine, and refrigerator). In Figure 66 we include a Gantt chart for this plan. Since this plan will take some time to develop Mabe will use the General Electric Appliance Test Procedure (512-B125 Product Capability-Shipping) as a reference. Even though this test is not based on the specific distribution environment of Latin America, it is currently used in Mabe to test their products. The next part of this section is a fragment of part A of the procedure of the GEA test procedure.

A. MINIMUM PERFORMANCE SPEC. TESTS:

Below is a listing of the Minimum Performance Specification (MPS) tests that must be passed by all GEA products. Shown are both the E50L series test nomenclature and the number of units recommended for each test. In addition, there are other tests recommended for refrigerator products that follow this listing and are specific to refrigerators and freezers. Products should be subjected to these tests during the early development phases to define vulnerability to different conditions that may be experienced in the shipping environment, and the degree of margin to damage under these conditions. Product sold to SEARS must receive additional testing as identified under SPECIAL TESTS - SEARS.

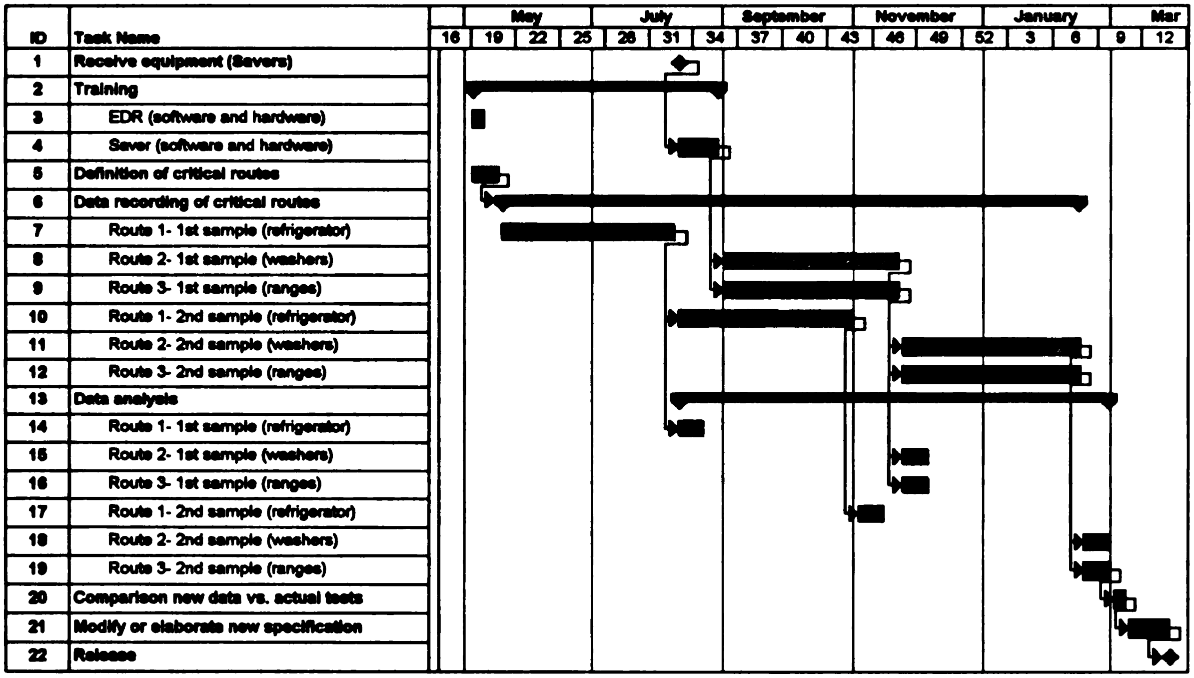


Figure 66 - Gantt chart of a project to record environmental distribution events

Table 46 - List of Minimum Performance Specification tests

	TEST	QTY
E50L1	REPETITIVE SHOCK- (shake table)	3
E50L2	SWEPT VIBRATION & RESONANCE	1*
E50L3	STACKED REPETITIVE SHOCK (top-laydown)	5**
E50L4	INCLINED IMPACT (conbur)	3
E50L5	INCLINED IMPACT W/HAZARD	2
E50L6	BASILOID HANDLING	6
E50L7	SQUEEZE CLAMP HANDLING	1
E50L8	FREE-FALL DROP (edge or corner drop)	3
E50L9	SHOCK/FRAGILITY	2*
E50L10	DYNAMIC COMPRESSION	3
E50L13	SHIP TEST FOR KITS & ACCESSORIES	3

* Combine E50L2 & E50L9 for a total of 2 units. Should plan for 2 units to conduct S/F due to fact that damage may be encountered on first unit.

** Normal test to utilize 5 units in each orientation to be shipped. If sample size is restricted or there is a concern regarding 'wear & abrasion', then 3 units may be tested in each orientation as a minimum, with the test modified to run the normal 1-hour vibration followed by the 15-minute resonant dwell. The product is unpacked and inspected the same a normal procedure. It is then repackaged and tested for another hour, inspected, repackaged, and tested for the third hour and inspected [6]

Finally, there are some considerations that apply specifically to the Mabe products:

1. The stack height for Mabe products is five and a half units: five products stacked in a column and one product between two columns.

2. The most critical temperature and humidity conditions are shown in Table 47

Table 47 - Most critical conditions of temperature and humidity in Mexico warehouses

Warehouse (City)	Temperature (°F)	Average relative humidity
Merida, Yuc	82.4in winter 95 in summer	80%
Cd. Juárez, Chih.	104 to 116 in summer 32 to 50 in winter	5 to 10 % in summer 25 to 30 % in winter

3. The maximum time a product is stored in a warehouse is seven months.

4. Sometimes there are wet floors in the warehouses.

5. On average, the product is handled 5 or 6 times during the distribution cycle. It can be handled with handling trucks with basiloid or squeeze clamp trucks.

3.4 Analysis of different alternatives.

The most common package for appliances is a corrugated board box with protectors. However according to a packaging engineer at Signode Packaging Systems, the "appliance OEM profitability is greatly affected by the rising cost of corrugated fiberboard components, such as containers, fillers, pads, multi-wall formed corner protectors, and cushioning. To reduce costs, many OEMs are looking for ways to eliminate or decrease the amount of corrugated materials used in their packaging"[13]. In Mabe there are several product lines that are changing from the corrugated fiberboard box to other systems to improve packaging performance and reduce costs. Some alternatives that Mabe has for packaging its product line are:

1. Corrugated fiberboard box with packaging protectors. This is the current system for the current ranges (see Table 44 and Figure 67). Domestic products use honeycomb protectors and export products use polystyrene protectors. The advantages are low cost and ease of assembly in the production line. The domestic package has the smallest size. The disadvantages are that quality materials are not always good and, damage level is some times high. If there is a damage during distribution, it is almost impossible to detect. The honeycomb package does not have any cushion at the bottom.

Figure 67 - Corrugated fibre box package

2. A see-through package with PS protectors, corrugated fiberboard caps, cornerposts and steel banding. A PE bag protects the range from dust and humidity. The advantages are adequate protection of the product; some damage can be detected during distribution; cost can be competitive depending on the design. The disadvantages are that the PE bag does not have a good appearance and can be ruptured easily.

3. A see-through package with PS protectors, corrugated fiberboard caps, steel banding cornerposts, and shrink wrapped with PE film. The advantages are a good design can adequately protect the product; damages can be detected during the distribution; can be handled with truck with basiloid and squeeze clamp trucks. The disadvantages are that it requires investment in special machinery for the shrink wrap process. A competitive cost is hard to achieve.

4. A see-through package with PS protectors, corrugated fiberboard caps, cornerposts and shrink wrapped, without steel banding. The corrugated fiber caps go inside the shrinked bag. The advantages are a good design can adequately protect the product. Some damage can be detected during distribution. Cost can be competitive depending on the design. The disadvantages are that it cannot be handled with truck with basiloid. It requires investment in special machinery for the shrink wrap process

5. A see-through package with PS protectors, PS cornerposts and shrink wrapped, without steel banding (see Figure 68). The advantages are a good design can adequately protect the product. Some damage can be detected during distribution; very good appearance. The disadvantages are that it cannot be handled with a truck with basiloid; it requires investment in special machinery for the shrink wrap process and investment in several molds. A competitive cost is hard to achieve.

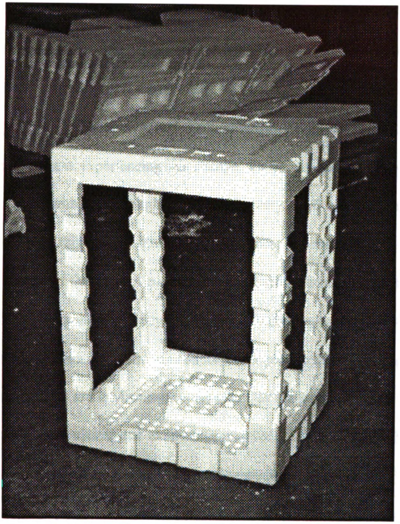


Figure 68 - PS package

3.5 Proposal using see through packaging

From the list of alternatives, see that a see-through package can be used in different ways and still offer good advantages. The use of "invisible" packaging will reduce concealed damage by increasing the awareness and inspection ability of the leader, freight carrier and customer [14]. Perlick in his article "A Change to See-Through Packaging" wrote, "when was the last time you saw a refrigerator being shipped-not by reading the identifying print on the carton but seeing the actual refrigerator? More shippers are implementing see-through packaging for their products, and the distribution environment is accepting them". Mabe is a company that is experiencing this change. So far, a product line of washer machines is packaged with see-through package with very good results. The refrigeration line is in the process of this change. From this experience, the implementation for the new product line of ranges of this type of package system looks convenient. As the consumption of EPS (expanded polystyrene) tends to increase, better prices can be obtained from the suppliers. This also applies for other parts such as cornerposts. One concern about using EPS are environmental aspects. "In the past , EPS molded-foam packaging has received criticism due to assumptions that it is filling up landfills. In truth, however, EPS is 95 percent air and only 5 percent polystyrene, and therefore produces less solid waste, and represents less than 1 percent of the volume and weight of the municipal solid waste . In fact, the National Post-Consumer Plastics Recycling Study by R. W. Beck found consumers who packaged with EPS are recycling more than ever, with 23.3 million lb of EPS packaging recycled in 1993, which is 2.2 million lb more than what was recycled in 1992 [13].

Whatever the type of see-through package system used, the need for a cushion to protect the product from shocks is evident from the shock test results. The next section covers the cushion design of the range base.

3.6 Cushion design

The key to selecting the most economical cushion protection is the use of published cushion curves. Two types of data are needed and must be used simultaneously: shock cushion curves and vibration transmissibility data [2]. This section will focus on cushion curves because there is no information available on vibration transmissibility data (vibration natural frequency vs. static stress curve). Curves like this are neither commonly available nor always reliable. In most cases, you must conduct your own tests and develop your own cushion vibration data. By mounting cushion material on a shaker, weighing it to various static stress levels, and monitoring both table and weight accelerations, a curve may be generated during a frequency sweep [2].

To determine a standard cushion for all products, Mabe decided to design the cushion for the most fragile range, in this case for sample EM240. In section 2.4.3, it was determined that a cushion was needed for all products. The problem is that for the new products, there was just one sample of each model. The results show that the products from the current production line are more fragile. Sample 42001 has a fragility of 18 G. Even though this number seems small for the new products, we can use it to be sure that the products will be protected. Tests of prototypes in phase three will give us the information necessary to adjust the cushion design.

Mabe decided to design a cushion using EPS with a density of 1.25 PCF. The only dynamic cushion performance curves available were for DYlLITE® D195B. These curves do not cover a 6 inch drop and also there are no curves available for all thicknesses. For this reason, a "dynamic stress vs. energy density curve" (stress vs. energy curve) for this material [7].was generated The stress vs. energy curve is a single curve which replaces all of the published cushion curves for the material. It can be used to reproduce the published cushion curves as well as to generate cushion curves for any other drop height and thickness. Hence, it embodies much more than the published information. Energy density is a measure of the severity of the drop and dynamic stress is a measure of the way the material reacts to this.

Using the DYlLITE® D195B 12" drop (h), 1st impact I selected different choices of s (static stress) and t (cushion thickness) to generate the energy density (sh/t) and dynamic stress (Gs) data (see Table 48).

Table 48 - Energy Density and Dynamic Stress Data for DYlLITE® D195B 12"

s (psi)	h (in)	t (in)	Energy Density sh/t (psi)	Peak G	Dynamic Stress Gs (psi)
0.5	12	5	1.2	41	20.5
1	12	5	2.4	22	22
0.5	12	2	3	50	25
1.5	12	5	3.6	15	22.5
0.5	12	1.5	4	51	25.5
2	12	5	4.8	12	24
2.5	12	5	6	10	25
1	12	2	6	27	27
0.5	12	1	6	55	27.5
3	12	5	7.2	9	27
1	12	1.5	8	30	30
1.5	12	2	9	21	31.5
1.5	12	1.5	12	25	37.5
1	12	1	12	38	38
2	12	2	12	19	38
2.5	12	2	15	18	45
2	12	1.5	16	22	44
1.5	12	1	18	32	48
3	12	2	18	17	51
2.5	12	1.5	20	20	50
3	12	1.5	24	19	57
2	12	1	24	33	66
2.5	12	1	30	34	85
3	12	1	36	39	117

From this data I generated three tables for three different cushion thicknesses (0.75, 1.00 and 1.25 in) and a drop height of 6 inches (see Tables 49 to 51). The final result is presented in a graph as a cushion curve (see Figure 69).

For the ranges, a static stress of 1.2 psi was established according to the following equation:

$$\text{Static Stress} = \frac{\text{Product weight}}{\text{CushionArea}} \qquad [3]$$

The design will use two PS bases. Each base will have a contact area of 18.15 in x 2.5 in = 45.375 sq in x 2 = 90.75 sq in. The weight of sample EM240 is approximately 110 lb. Therefore the static stress will be 110 lb / 90.75 sq in = 1.2 psi. In the graph we see that the curve for the 1.25 in thickness almost intercepts with 20 G's at 1.25 psi. Since the fragility of the product should be bigger than 18 G's and considering that this is the most fragile product, I will select this thickness for the bases. In Figure 70 shows a proposed base design. This base will have two versions for the two depths determined in section 3.2.

Table 49 - Energy Density and Dynamic Stress Data for a 1.25 in Cushion

Static stress (psi)	Height (in)	Thickness (in)	Energy density sh/t (psi)	Gs (psi)	G	Cushion area (sq in)
0.25	6.00	1.25	1.20	20.50	82.00	340.00
0.50	6.00	1.25	2.40	22.00	44.00	170.00
0.75	6.00	1.25	3.60	22.50	30.00	113.33
1.00	6.00	1.25	4.80	24.00	24.00	85.00
1.25	6.00	1.25	6.00	25.00	20.00	68.00
1.25	6.00	1.25	6.00	27.00	21.60	68.00
1.25	6.00	1.25	6.00	27.50	22.00	68.00
1.50	6.00	1.25	7.20	27.00	18.00	56.67
1.75	6.00	1.25	8.40	30.60	17.49	48.57
2.00	6.00	1.25	9.60	32.22	16.11	42.50
2.50	6.00	1.25	12.00	37.50	15.00	34.00
2.50	6.00	1.25	12.00	38.00	15.20	34.00
3.00	6.00	1.25	14.40	43.60	14.53	28.33

Table 50 - Energy Density and Dynamic Stress Data for a 1.00 in Cushion

Static stress (psi)	Height (in)	Thickness (in)	Energy density sh/t (psi)	Gs (psi)	G	Cushion area (sq in)
0.25	6.00	1.00	1.50	21.00	84.00	340.00
0.50	6.00	1.00	3.00	25.00	50.00	170.00
0.75	6.00	1.00	4.50	24.00	32.00	113.33
1.00	6.00	1.00	6.00	27.50	27.50	85.00
1.00	6.00	1.00	6.00	27.00	27.00	85.00
1.00	6.00	1.00	6.00	25.00	25.00	85.00
1.25	6.00	1.00	7.50	28.00	22.40	68.00
1.50	6.00	1.00	9.00	31.50	21.00	56.67
1.75	6.00	1.00	10.50	34.50	19.71	48.57
2.00	6.00	1.00	12.00	37.50	18.75	42.50
2.00	6.00	1.00	12.00	38.00	19.00	42.50
2.50	6.00	1.00	15.00	45.00	18.00	34.00
3.00	6.00	1.00	18.00	51.00	17.00	28.33
3.00	6.00	1.00	18.00	49.00	16.33	28.33

Table 51 - Energy Density and Dynamic Stress Data for a 0.75 in Cushion

Static stress (psi)	Height (in)	Thickness (in)	Energy density sh/t (psi)	Gs (psi)	G	Cushion area (sq in)
0.25	6.00	0.75	2.00	22.00	88.00	340.00
0.50	6.00	0.75	4.00	25.50	51.00	170.00
0.75	6.00	0.75	6.00	27.50	36.67	113.33
0.75	6.00	0.75	6.00	27.00	36.00	113.33
0.75	6.00	0.75	6.00	25.00	33.33	113.33
1.00	6.00	0.75	8.00	30.00	30.00	85.00
1.25	6.00	0.75	10.00	33.50	26.80	68.00
1.50	6.00	0.75	12.00	38.00	25.33	56.67
1.50	6.00	0.75	12.00	37.50	25.00	56.67
1.75	6.00	0.75	14.00	42.60	24.34	48.57
2.00	6.00	0.75	16.00	44.00	22.00	42.50
2.50	6.00	0.75	20.00	50.00	20.00	34.00
3.00	6.00	0.75	24.00	57.00	19.00	28.33
3.00	6.00	0.75	24.00	66.00	22.00	28.33

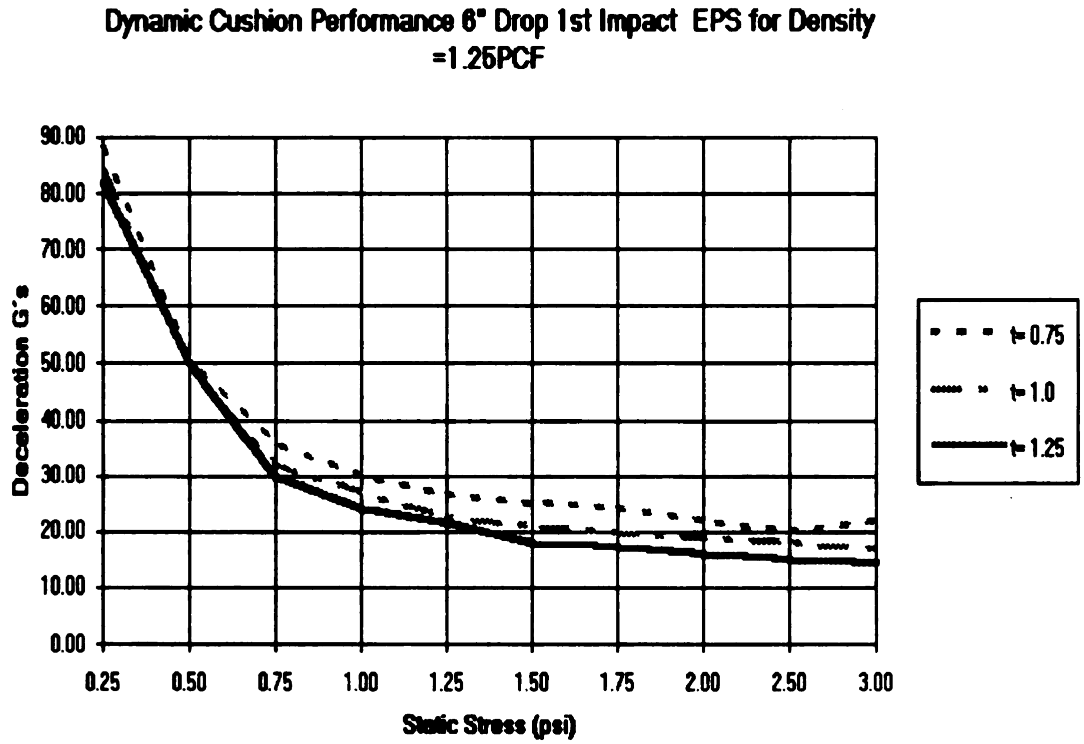


Figure 69 - Dynamic cushion for a 6 in drop

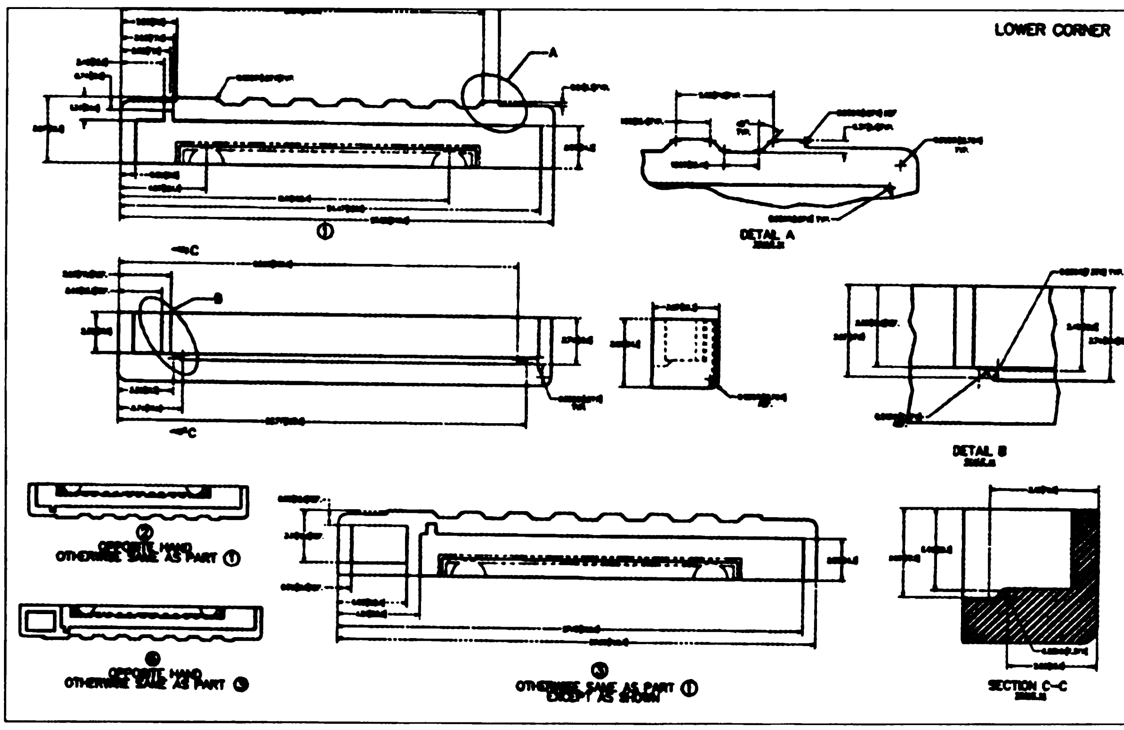


Figure 70 - PS base design

3.7 Packaging description

At this point, it is a little difficult to describe the package design in detail, because Mabe has not yet defined which will be the best option. Several factors are involved in selecting the best option, and one of those factors is the product design, which is still in development. However, the see-through packaging options have some similarities. Figure 71 shows a proposed see-through package with its components. A package like this consists of two PS bases (see Figure 70), two upper PS protectors, four corner posts (there are several material options and designs for these corner posts), two corrugated fiberboard caps, a PE bag which can be heat-shrunk, steel banding, and protectors for the oven door. Also we have to design an adequate system for the free-standing ranges to attach the back-guard adequately inside the oven. The cost of a package like this is approximately $4.00 USD. This is about $1.10 USD more than the cost objective. This is an indication that future work needs to be done to achieve the objective cost with this type of packaging.

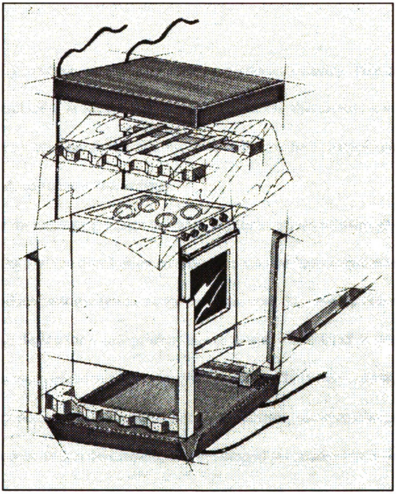


Figure 71 - See-through package

Chapter 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Mabe is a leading Mexican company in the home appliance industry. This company has facilities in several cities in Mexico and Latin America. For this reason, it is very important for Mabe to have a package design that protects its the products cheaply and conveniently in the different distribution environments.

A methodology for packaging design has been proposed where knowledge of the product's fragility and the distribution environment are two basic requirements to achieve an effective product/package system at the optimum cost. To develop this methodology in Mabe, a package design for a new product line of ranges was started. Prototypes from two generations were tested in two testing/design phases. In the first phase, vibration and shock tests were performed. From the results of these tests, some recommendations were given to the product design department, which changed the product to make it less fragile. In the second phase, vibration, compression and shock tests were performed on both the improved product from phase one and on production line samples of existing models. The recommendations given to the design team for improving the prototypes from phase one did in fact strengthen the product, which will ultimately lead to lower packaging costs. At this point then, it is possible to say that the proposed methodology for incorporating the product testing and packaging functions into the design process for the product does in fact work. Data from these tests on production line samples gave Mabe information to further improve that product. The results obtained will improve these products and also help to define the optimum design of different package components.

A see-through type of packaging was proposed due to the advantages that this system has over the traditional corrugated fiberboard package.

This study did not cover the complete design of the product line because this line is still in a design development stage. However, the work done up to this point has been useful to the project team as they are more aware of the importance of looking at the product as a product/package system. It was also proved that the proposed methodology gives several benefits to the Mabe design process. It helps to improve the quality of the product and offers an adequate package for the product at minimum cost.

Some future work that will be done to conclude this project is:

- Further testing of improved prototypes will help Mabe define the best options for cushioning and protectors for the different critical parts of the ranges.

- More detailed analysis of options for the packaging components will be evaluated in order to achieve the optimum packaging system.

- Identification of new suppliers and negotiations with current suppliers of the different packaging components will help Mabe to bring down packaging costs.

- Personnel from industrial engineering will be involved in this process to insure the feasibility of the package in the production line.

- Testing of the product/package system will be performed to ensure that the system will not have problems in the distribution environment. These tests will take place in a packaging lab which is now in development in the Mabe Technology and Development Center.

- It is to early to tell how well the proposed methodology works from start to finish because data on the distribution environment is not yet available.

APPENDIX A

APPENDIX A

LIST OF CODES FOR TABLE 2

TYPES

A- Built-In Gas Range

B- Built In Gas and Electric Range

C- Free Standing Gas Range (European Style)

D- Free Standing Gas and Electric Range (European Style)

E- Free Standing Gas Range (American Style)

F- Free Standing Gas and Electric Range (American Style)

SPECIAL DIFFERENCES

1. TOP BURNERS

1.1 Electric
CRI-. Coil Heating Element (Cal Rod)
PE- Plate Heating Element (Hot Plate)

1.2 Gas
QTS- Die Press Steel Body (3 in Diameter)
QAS- Die Casting Aluminum Body (3 in Diameter)
SQA- Die Casting Aluminum Body (4 in Diameter)

2. OVEN BURNERS

2.1 Electric
CR2- Coil Heating Element

2.2 Gas
QTT- Cold Rolled Steel Tubing

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