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Evaluation of a custom designed plastic pallet

William Colaiaco

Evaluation of a Custom Designed Plastic Pallet

By

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1999

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Certificate of Approval

M.S. DEGREE THESIS

The M.S. Degree thesis of William P Colaiaco
has been examined and approved
by the thesis committee as satisfactory
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Master of Science Degree.

Daniel Goodwin

David R. Olsson

Signature Illegible
October 15,1999

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ABSTRACT

This study addresses the methodology; testing and evaluation of a custom designed plastic pallet. This study describes the methodology used to determine robustness and the structural integrity of the pallet. The methodology took into account existing testing standards and added to them a group of screening tests and supplemental test procedures. The purpose of the study was first to evaluate the attributes of the pallet and the likelihood of the pallet surviving normal distribution environments. The second purpose of the study was to determine the feasibility of implementing more stringent test procedures that may better indicate the attributes of plastic pallets and similar platforms It was determined that the pallet design was adequate for its intended use.

Table of Contents

List of Figures

List of Tables

INTRODUCTION

Bullet Pallet Systems has designed and built a specialty pallet platform for a large copier company. Structural aspects of the new design need to be quantified. This study is a systematic evaluation of the functional performance testing and the evaluation of the final design of that platform.

Initial assessment of the platforms was conducted using a series of screening tests. This testing included; sine vibration testing, dynamic compression testing and drop testing.

Testing and evaluation of the pallets were conducted according to A.S.T.M. D 1185-94 Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping. This test standard takes into account: conditioning, static load compression testing, drop testing, sine vibration and incline impact testing.

Supplemental testing was conducted on the platform to help establish the performance limits of the specialty pallet. These tests included: random vibration, dynamic compression and a thirty-day loaded static compression test.

There are several questions associated with the design and possible implementation of the pallet design. This study will start the process of quantifying the performance characteristics of the design as well as show any potential problems in the design or materials of the pallet.

TEST METHODOLOGY

The equipment in the Dynamics Laboratory of the Department of Packaging Science at Rochester Institute of Technology was used in the study. The equipment used was:

Lansmont Model 7000-10 Vibration Test Machine

Lansmont Model 122-15K Compression Testing Machine

Lansmont Model PDT-56E Drop Tester

L.A.B. Model 4000-CI Incline Impact Tester

P.G.C. Environmental Test Chamber

It was determined that a series of tests needed to be done on the pallets to determine the robustness of the design.

In addition to the evaluation of the pallets the study was also used to start in the development of additional testing standards to help evaluate the characteristics of different pallets and similar structures.

PRELIMINARY EVALUATION OF THE PALLETS

The methodology of the preliminary testing was to evaluate and prescreen the pallets before a larger commitment to testing was applied. The prescreening included A.S.T.M.D 999-96 Standard Methods for Vibration Testing of Shipping Containers, A.S.T.M. D 5276-94 Standard Test Method for Drop Test of Loaded Containers by Free Fall and dynamic compression testing.

Vibration Analysis

In the initial evaluation sine vibration testing was utilized to help screen any potential problems with the design of the pallets. This screening would also help establish any design flaws or characteristics of the platforms.

The procedure to evaluate the pallet resonance characteristics was derived from procedures outlined in A.S.T.M. D-999. An accelerometer was placed on several different locations on the platform to help measure the different resonance points of the platform. Results form the resonance search showed levels of resonance in the 30-Hertz range. These assessments were made on both collected data from the systems station, visual observations using a strobe light and audio noise heard when dwelling on the resonant frequencies.

Drop Testing

To evaluate the robustness of the design of the pallets it was decided upon to subject the sample platform to a series of freefall drop tests. The pallets were to be dropped in the following sequence: three corner drops, one adjacent corner drop, one pallet end edge drop and one pallet side edge drop. The pallet was to be dropped from a height of forty inches. All of the perimeters for the drop testing were derived from A.S.T.M. D-5276-94 and A.S.T.M. D 1185-94, section 9.3.1.4.

When conducting the drop sequence to evaluate the pallet the steel support rails that run the length of the platform failed. Through further examination it was determined that the fasteners that held the steel supports to the pallet had failed. It was also determined that the brackets that attached to the bottom of the platform were not large enough to support the reinforcing bars in the proper manner.

The supporting rails brackets were redesigned and a larger attaching screw was specified and installed to help better attach the rails to the pallet. The drop test sequence was then repeated on the pallet with the redesigned attaching brackets. The resulting observations after drop testing showed no failure or major stresses upon the pallet or the brackets. A second platform that had the new bracket design installed was then tested to help screen any problems. This pallet also showed no major failures or stresses on the platform or the redesigned brackets.

Compression Testing

The sample pallet was subjected to a dynamic compression test. The pallet has an applied load of fifteen hundred pounds with a rate of deflection of one inch per a minute. This amount was decided upon because the product that the pallet is designed to carry weighs approximately that much.

The pallet withstood the dynamic compression test with an applied load of fifteen hundred pounds. There was no visible catastrophic damage to the pallet. The only damage that was observed was slight and it could be attributed to the platen of the compression tester.

Summary of the Preliminary Evaluation of the Pallets

The initial evaluation of the pallets proved to be invaluable. The sine sweeps and vibration analysis showed some significant resonance points that could require further study. The drop testing of the pallet showed some design flaws that if not corrected, could have effected the performance characteristics of the pallets.

Compression Testing showed that the pallet was robust enough to handle the minimum requirements of the product's weight. Compression evaluation also indicated that some sort of fixture or jig was needed to help estimate any damage that may be caused by the test equipment.

The preliminary testing helped to screen out any major design flaws or shortcomings associated with the pallet and the pallet design. Based upon the preliminary tests and the observations of the testing, it was decided upon to subject the pallets to A.S.T.M. D 1185-94, Standard Test Method for Pallets and Related Structures Employed in Materials Handling and Shipping.

PRINCIPAL ANALYSIS OF PALLET DESIGN

Preface

A.S.T.M. D-1185-94, Standard Test Method for Pallets and Related Structures Employed in Materials Handling and Shipping is a test methodology that helps to evaluate systematically the performance characteristics of pallets and other similar shipping and handling devices. The test standard incorporates both dynamic and static testing of the samples. The testing of a sample in compliance with the test standard does not address the performance of a sample in its distribution environment. It is a general starting point to help screen out potential shortcomings of a product or design in a laboratory environment.

Preparation

A wooden container was built to represent the product that would be used on the pallet. The finished simulated product weighed approximately three hundred pounds and was designed to have the same points of contact as the actual product. Fifteen hundred pounds of steel weights were then added to represent the weight of the product. The actual weight of the product is about fifteen hundred pounds, the additional three hundred pounds was a engineered safety factor and was utilized for all parts of the testing where applicable.

Sampling

It was decided that a sample of six pallets would be utilized to evaluate the performance characteristics of the pallet. It was also determined that additional testing would be done with more samples to help evaluate the pallets. This additional testing is in supplemental testing section five.

Conditioning

Conditioning of the samples was done in accordance with Table I of A.S.T.M. D-1185-94. The standard specifies that pallets made of plastic must be conditioned in conditioning environments A and B for a duration of twenty four hours. Environment A specifies a constant applied temperature of 60* C and relative humidity uncontrolled. Environmental B specifies a constant temperature of -25* C and relative humidity uncontrolled. Three samples each were conditioned in each environment.

Testing Sequence

Each of the hot and cold sample lots were tested according to the following sequence:

1) Compression Testing

A)Flat Compression – 2 Hours

B) Fork Tine – 2 Hours

C) Rack Suspension – 2 Hours

2) Drop Testing

A) Three Corner Drops

B) One Adjacent Corner Drop

C) Pallet End Edge

D) Pallet Side Edge

3) Inclined Impact Testing

A) Side Impact

B) Opposite Edge Impact

C) End Impact

D) Opposite End Impact

4) Vibration Testing

A) Sine Sweep to Find Resonance Frequency

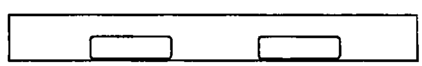
B) Thirty Minute Dwell at Established Resonance Frequency

Compression Testing

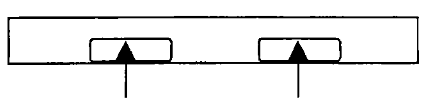
The cold and hot conditioned pallets underwent static compression testing and prescribed in Section Eight of A.S.T.M. D-1185-94. Each pallet was tested in three different orientations for a duration of two hours per sample. A wooden jig was placed between the platen of the compression tester and the sample pallet. This was done to stress the exact points of contact that the actual product would on the pallet mounting points. The samples were also supported by jigs to evaluate the different characteristics of the pallet to various supported locations. These simulated orientations were to reproduce the following: flat compression, suspension by fork tine, and suspension in pallet racks. The pallet deflection was measured at three different intervals during the test.

FIGURE 1 PALLET SUPPORT LOCATIONS

(1) Flat Compression



(2) Suspension by Fork Tine



(3) Suspension in Rack

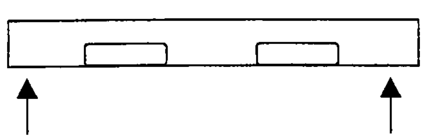


Table 1

Compression Test Data

Pallet 1 (Cold)	Initial (inches)	1 Hour (inches)	Final (inches)
1 2 3	None 6.13 7.68	None 6.06 7.53	None 6.06 7.53
Pallet2 (Cold)			
1 2 3	None 6.50 7.68	None 6.13 7.50	None 6.13 7.50
Pallet 1 (Hot)			
1 2 3	2.2.5 6.00 7.75	2.25 6.00 7.75	2.25 6.00 7.75
Pallet 2 (Hot)			
1 2 3	None 5.88 7.81	None 5.88 7.75	None 5.88 7.69
Pallet3 (Hot)			
1 2 3	None 5.88 7.69	None 5.88 7.69	None 5.88 7.69

Drop Testing

Drop testing procedures were those outlined in section 9.3 of A.S.T.M. 1185-94. The pallets were dropped a total of six times each. In accordance with the standard, each pallet was dropped from a height of 40 inches. The drop sequence was three drops on one corner of the pallet, one drop on the adjacent corner, one drop on pallet end edge, and one drop on the pallet side edge. For a diagram of pallet orientation see figures 6 and 7 of the test standard.

Incline Impact Testing

Each pallet was subjected to incline impact testing in accordance with section 9.4 of A.S.T.M. 1185-94. The sled and pallet system had an impact speed of 50 in/sec. A block was placed between the pallet and the sled wall in order to isolate the impact to the pallet. This applied because of the type of pallet being tested as well as the custom application of the pallet.

Vibration Testing

The three hot and cold conditioned pallets all underwent vibration testing as specified by section 9.5.2 Method A – pallet resonance test of A.S.T.M. 1185-94. A sine sweep of 3-100 Hz. was conducted in order to locate any resonant frequencies. This was done three times for each pallet. Once any resonant frequencies were determined the pallet was dwelled at that frequency for a period of thirty minutes as described in the test standard. The following table outlines the mean resonant frequencies determined in this portion of the testing.

Table 2

Pallet Resonance Frequencies

Cold pallet	Mean resonant frequency
1	16.68 Hz
2	19.99 Hz
3	32.65 Hz
Hot pallet	
1	43.04 Hz
2	46.21 Hz
3	60.23 Hz

Summary of the Evaluation of the Pallets using A.S.T.M. 1185-94

There was no substantial pallet damage noted during testing. The amount of pallet deflection observed during compression testing was determined to be not significant enough to compromise the integrity of the platform. The pallets did incur minor denting during the drop testing and incline impact portions of the testing. Slight movement of the simulated product was also observed. This movement was less than one inch and observed after incline impact testing. There was no observable damage to the platform after the vibration testing. A significant amount of noise was recorded during sinusoidal vibration testing. This noise was mainly in the range of thirty hertz. This can be attributed to the movement of the steel weights that were used to simulate the actual weight of the product. Overall evaluation of the product to this point is that the pallet successfully met all the minimal requirements that are prescribed in A.S.T.M. 1185-94. The pallet at this point should be ready to perform additional testing or field testing of the unit.

SUPPLEMENTAL TESTING

Additional testing was performed in order to further evaluate the pallets. A.S.T.M. 1185-94 did not require these procedures. Three additional pallets were preconditioned to ambient temperatures and added to six previously tested pallets. Three of the pallets were previously used as the cold conditioned samples and three were the hot conditioned samples.

VIBRATION TESTING

Random Vibration

In order to get a more comprehensive view of how the pallet system would withstand the distribution environment, random vibration testing was performed. The three ambient pallets were tested in accordance with A.S.T.M. 1185-94 method B. The profile used was A.S.T.M. 4728-95, truck profile .52 Grms. Each pallet was tested for one hour sine vibration

Supplemental sine vibration tests were run due to concerns with the elevated noise levels found in the range of approximately 30 hertz. Nine pallets underwent sine sweeps without a load.

Table 3

Supplemental Resonance Search Results

Pallet number	Resonance frequency Marker 1	Resonance frequency Marker 2
1	29.79	65.54
2	35.77	27.76
3	31.07	-------
4	45.45	-------
5	27.37	19.80
6	24.11	40.04
7	40.04	59.39
8	25.51	52.32
9	43.57	36.79

Compression Testing

Dynamic compression was conducted to establish the maximum load that the pallet would withstand before failure. Sample one had the reinforcing steel rods in the channels on the pallet. Sample two had the steel rods removed. The dynamic compression testing was set to achieve the maximum peak applied force and the maximum deflection of the pallet at that point.

Table 4

Dynamic Compression Results

Sample Pallet	Peak force (Lbs.)	Deflection at peak (inches)
1	3732.4	1.38
2	3396.9	1.99

STATIC COMPRESSION

A thirty-day static compression test was performed. This test was designed to help determine if the pallet would deflect or deform over time. The pallet was loaded with the simulated product and then placed upon support casters. Casters are used to maneuver the product and pallet internally throughout production and testing of the actual product in the manufacturing facility.

Table 5

Static Compression Test Results

Day	Measurement (inches)	Deflection Total
1	7.5	0
2	7.5	0
3	7.5	0
4	7.5	0
5	7.5	0
6	7.5	0
7	7.5	0
8	7.5	0
9	7.5	0
10	7.5	0
11	7.4375	0.0625
12	7.4375	0.0625
13	7.4375	0.0625
14	7.4375	0.0625
15	7.4375	0.0625
16	7.4375	0.0625
17	7.4375	0.0625
18	7.4375	0.0625

19	7.4375	0.0625
20	7.4375	0.0625
21	7.4375	0.0625
22	7.4375	0.0625
23	7.4375	0.0625
24	7.4375	0.0625
25	7.4375	0.0625
26	7.4375	0.0625
27	7.4375	0.0625
28	7.4375	0.0625
29	7.4375	0.0625
30	7.4375	0.0625

Summary of Additional Testing

The supplemental testing helped to reconfirm the robustness of the platform. This was done by subjecting the sample to additional random vibration testing. The sinusoidal vibration testing established a baseline of the resonant frequencies of the pallets without a load

SUMMARY AND CONCLUSIONS

There was no substantial damage to the pallet during the study. The amount of deflection experienced in the compression analysis of the evaluation was not significant enough to compromise the integrity of the pallet. The design proved to be robust enough to withstand more than two times the weight of the product that is meant to utilize it. During static load compression tests the platform deflected less then an inch..

There was no observable damage during vibration testing. There was a considerable amount of noise experienced in the 30 Hertz range but this can be attributed to the steel weight used to simulate the product. There was slight movement of the simulated product on the incline impact tests.

The test methodologies used in the study proved to be beneficial in the evaluation of the pallets attributes. The additional testing gave a more detailed method of quantifying the structural integrity of the pallet. Based on the testing conducted, it appears that the pallet would not have been properly analyzed and quantified by the sole use of A.S.T.M. D 1185-94. The test method is too generic in nature to give an in depth focused evaluation of the pallet.

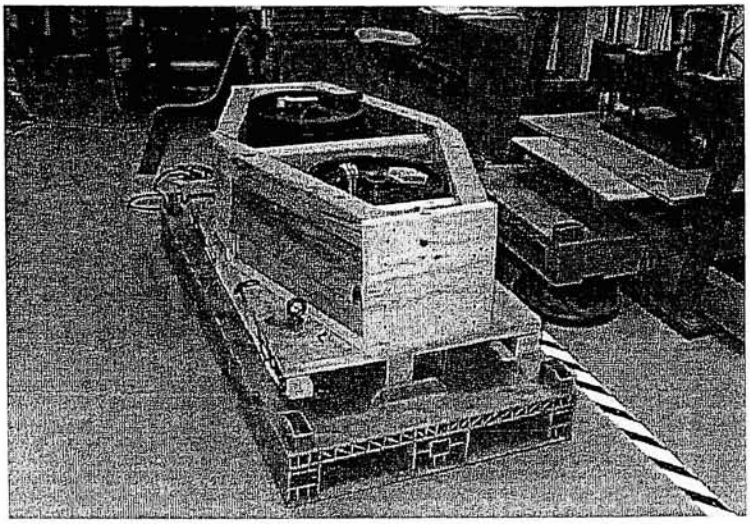
The methodology used to evaluate the pallet in this study proved to be very useful. If the pallet failed the preliminary testing, time and money could have been saved by stopping testing or by making a change or revision to the design of the pallet. The supplemental testing also proved beneficial. The additional vibration testing helped to eliminate possible problems in the lower vibration frequencies. The supplemental testing of the compression characteristics of the pallet showed the strength of the design. The pallet withstood a fully loaded test with less then one inch deflection occurring over a thirty-day period. This small amount of deflection should not effect the pallet during normal distribution .

Further Study

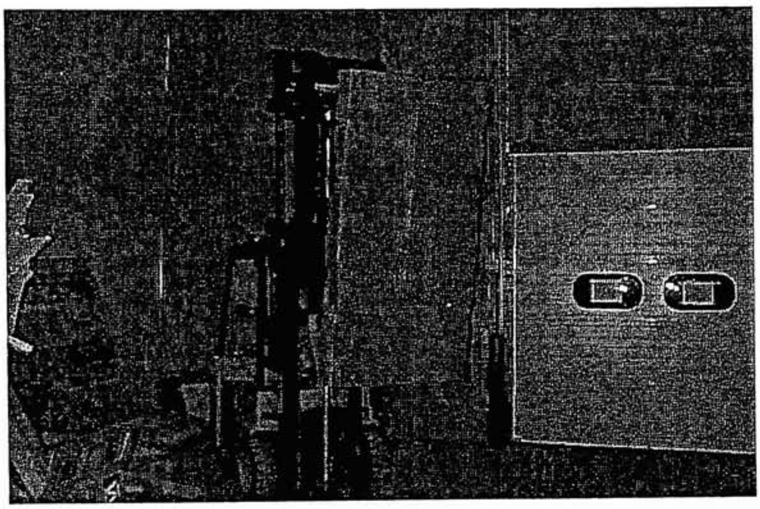
It would be advantageous to test a similar pallet to the same methodologies outlined in this thesis. If similar results were found, test method A.S.T.M D1185-94 should be reevaluated by starting with a round robin series of tests to help further prove the accuracy of the new test methodology. The new test methodology would be more focused in nature instead of generic. It would have a series of steps to help develop and quantify the pallet being evaluated.

Appendix A

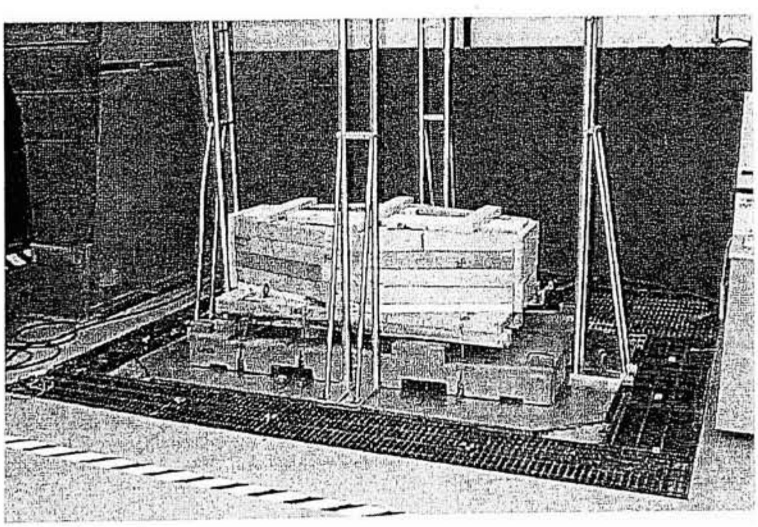
Photographs of Laboratory Testing



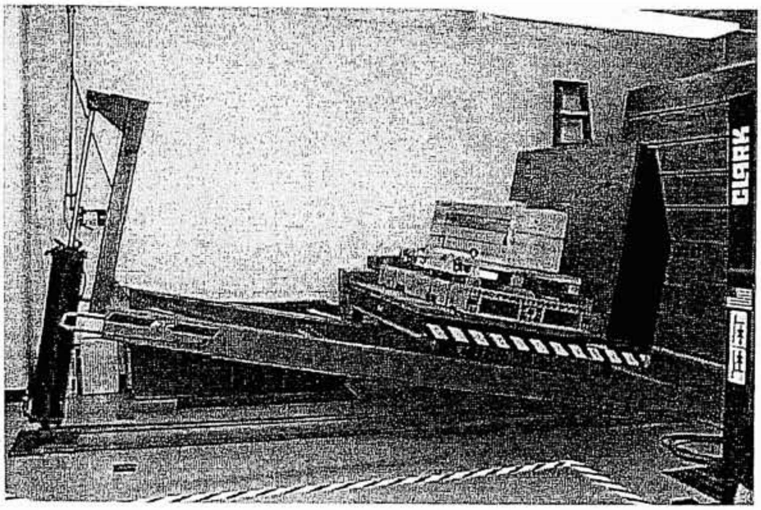
Simulated Product with 1500 lbs. of steel weight.



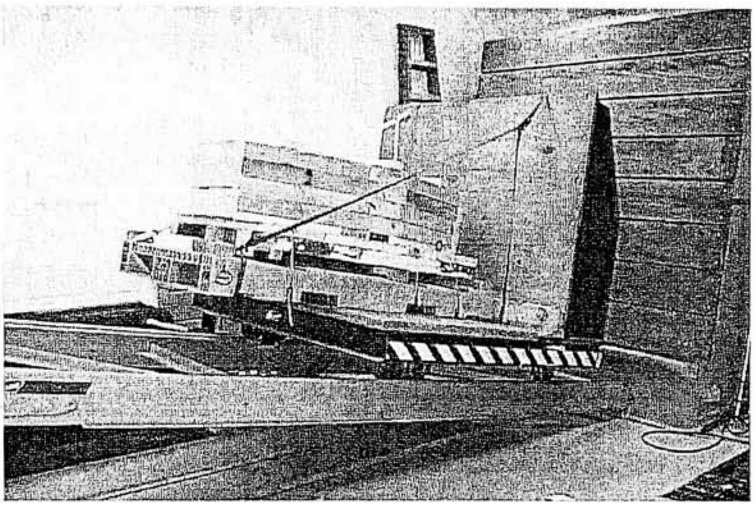
Drop testing from 40in height.



Vibration Testing.



Inclined Impact Testing.



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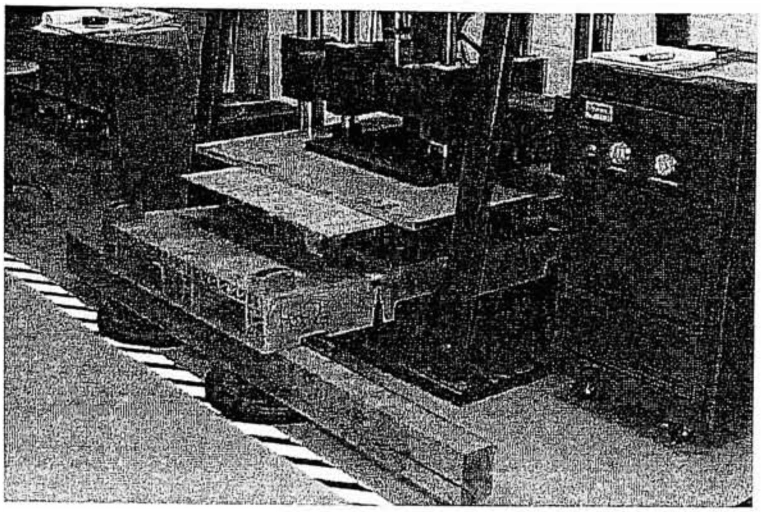
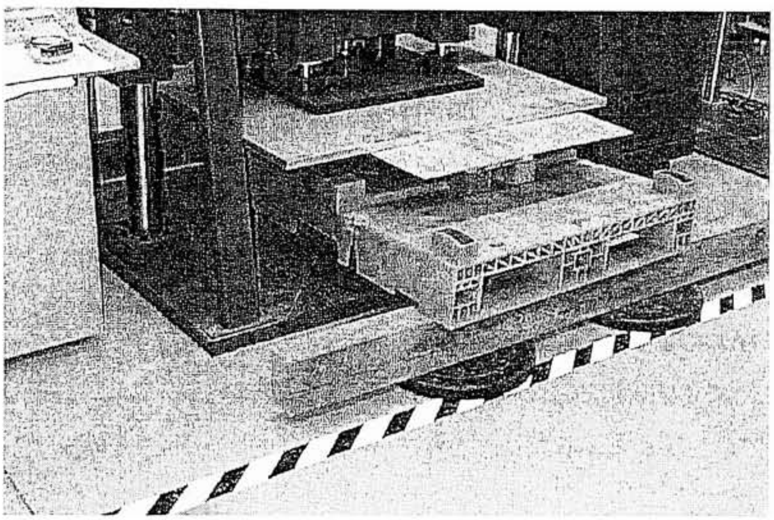


Supported Compression Testing.



Supported Compression Testing.

Appendix B

Compression Testing Control Configuration

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PROFILE CONTROL CONFIGURATION

Current Status

Preload for Deflection Auto Zero:	50.0 Lbs
Stop Force:	1900.0 Lbs
Stop Deflection:	1.00 In
Current Test Time Window:	1 Minutes
Auto Sample Number:	ON
Test Data Logging Interval:	AUTO

Appendix C

Vibration Testing Data Sheets

ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: cold pallet
1 of 3
sweep 1

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03-13-1999

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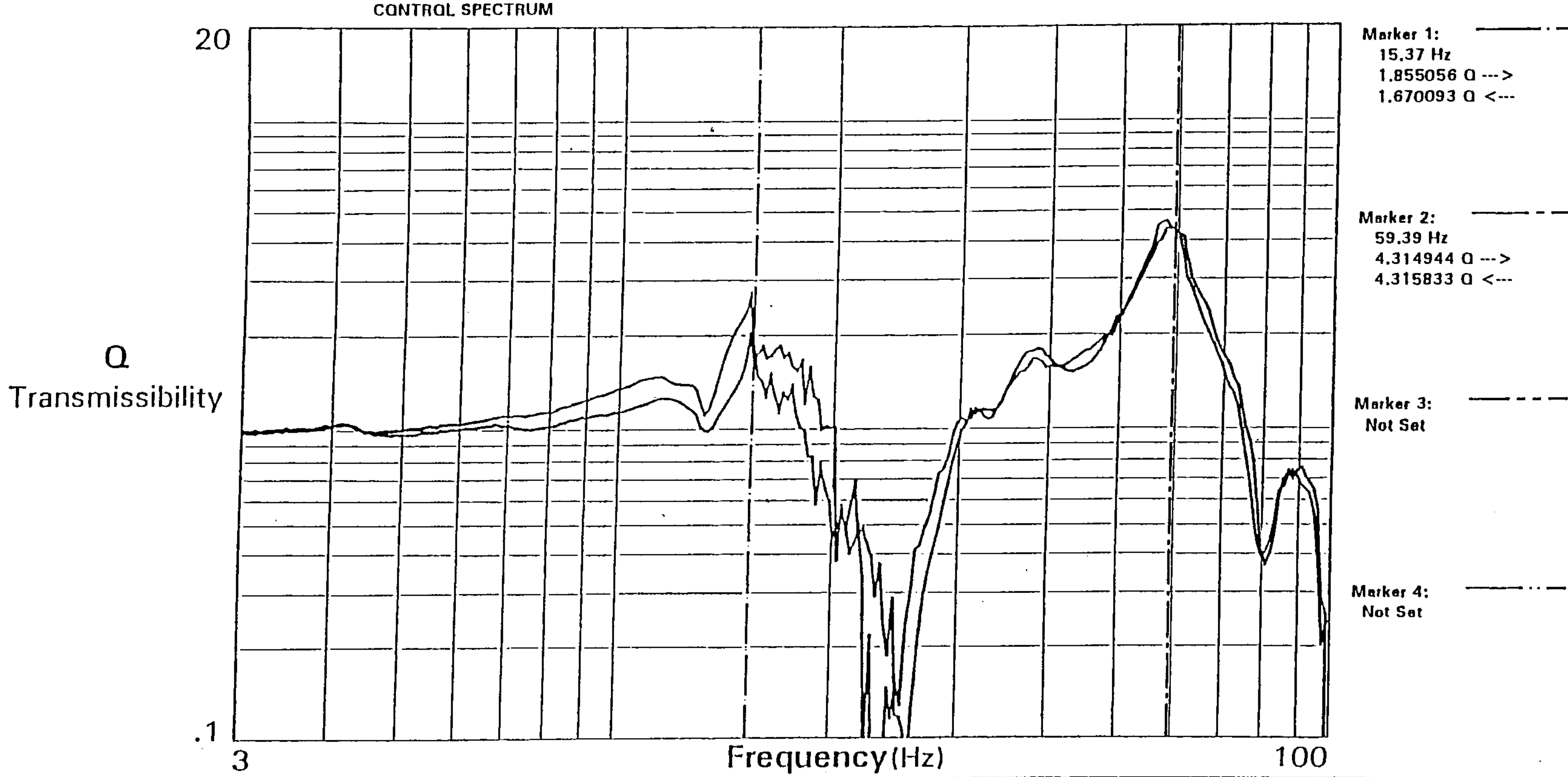
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



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1 of 3
sweep 2

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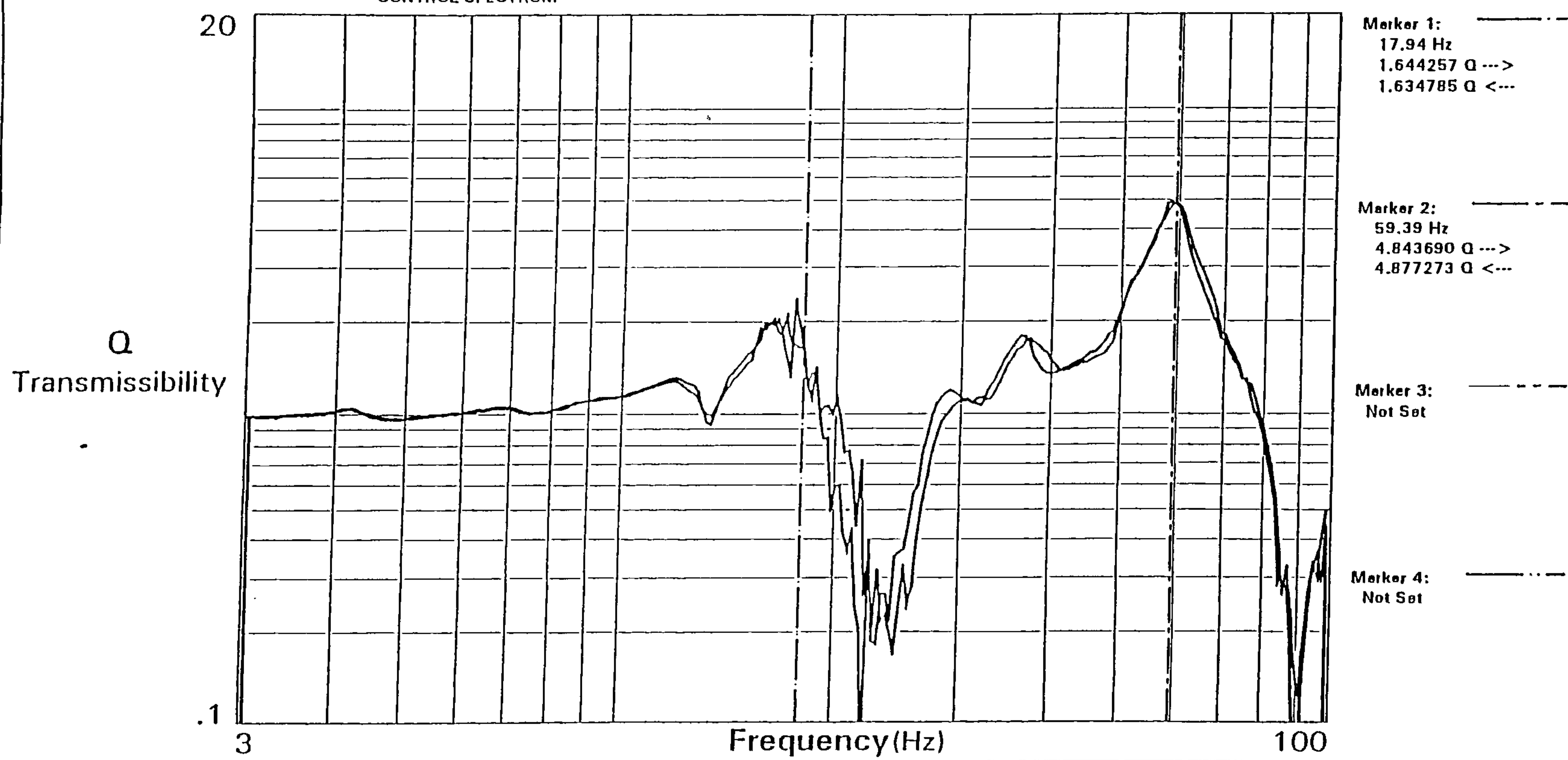
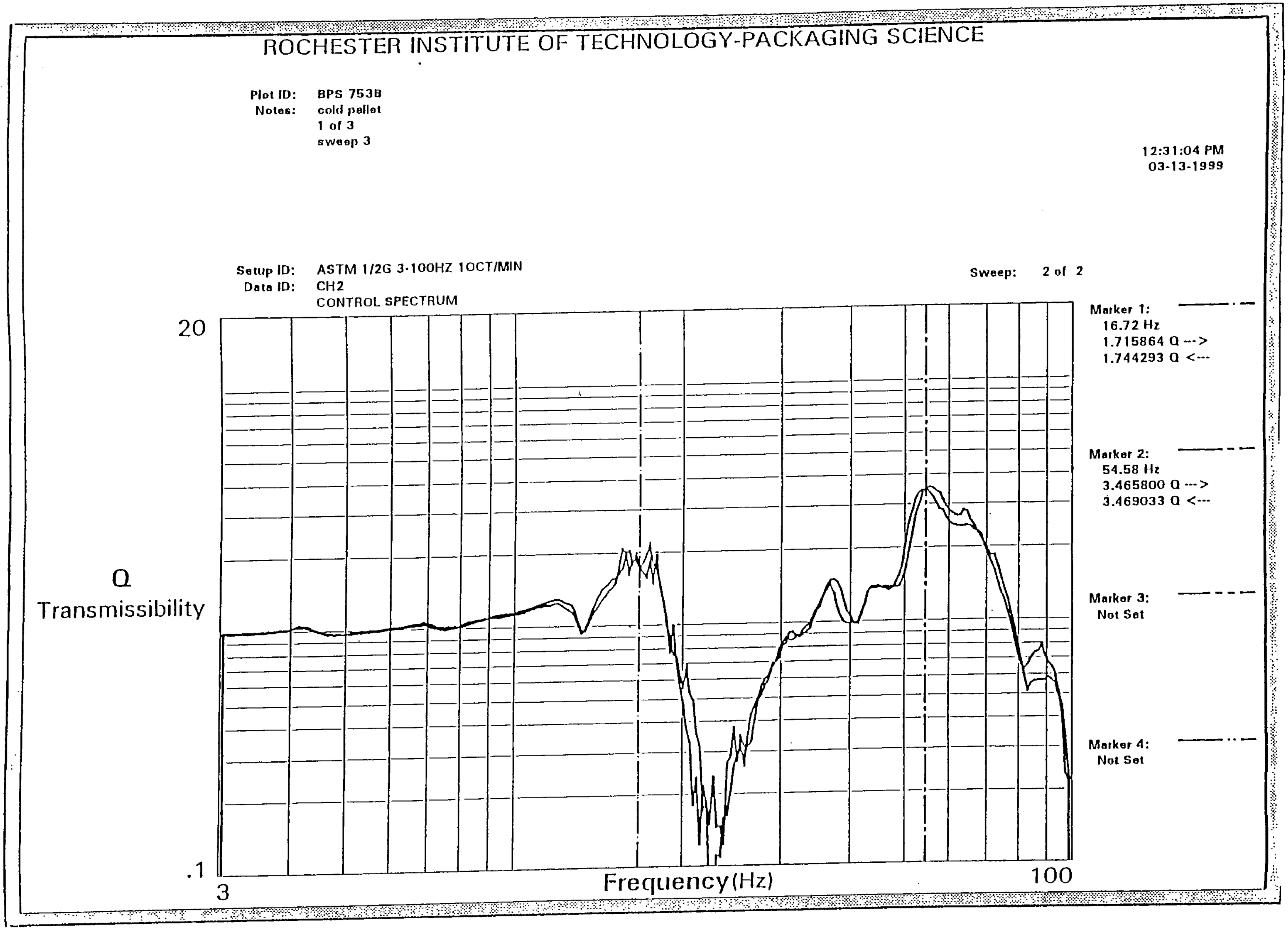
Sweep: 2 of 2

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1 of 3
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Data ID: CH2
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Sweep: 2 of 2
Marker 1:
16.72 Hz
1.715864 Q --->
1.744293 Q <---
Marker 2:
54.58 Hz
3.465800 Q --->
3.469033 Q <---
Marker 3:
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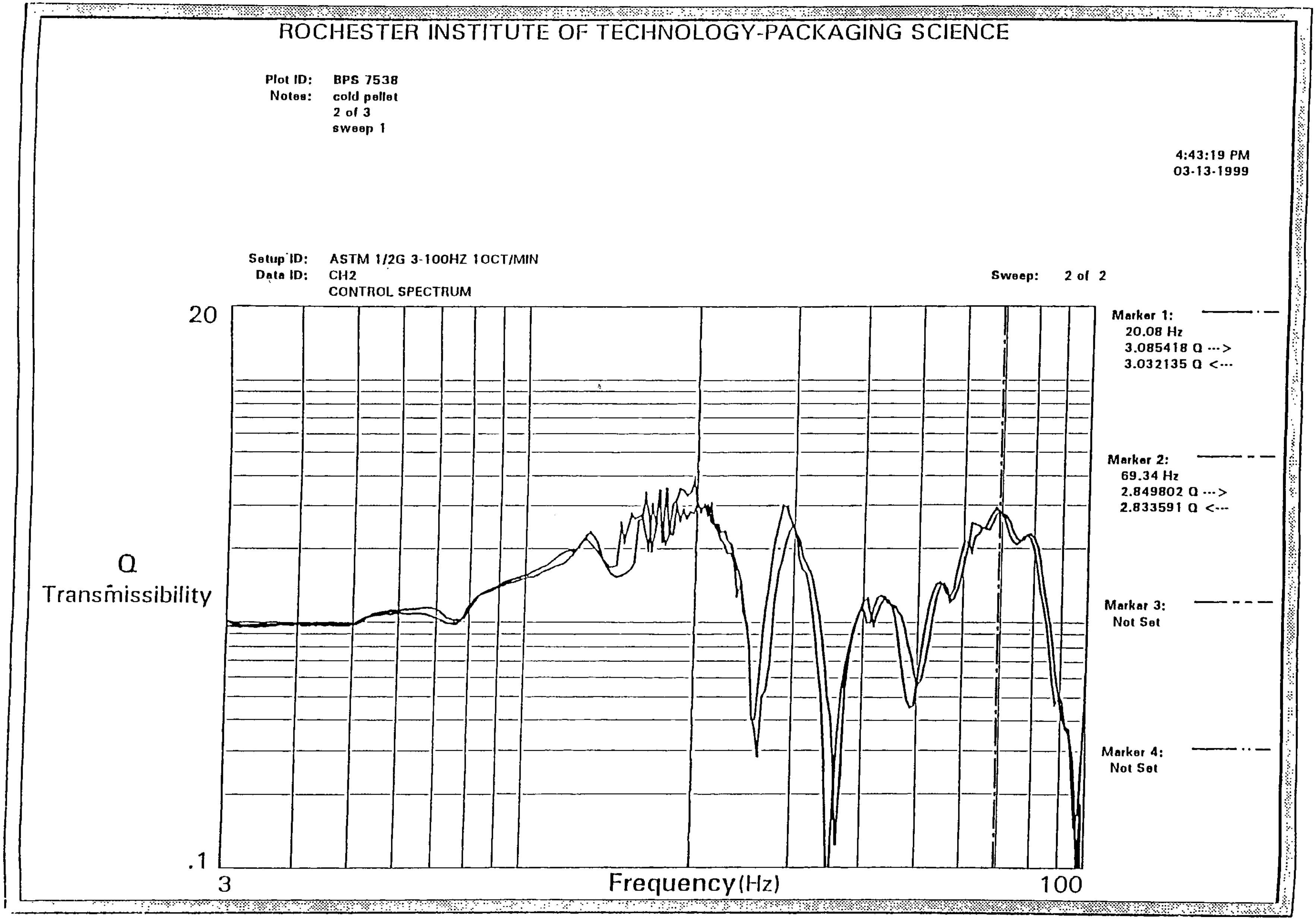
Marker 4:
Not Set
20
Q
Transmissibility
.1
3
Frequency (Hz)
100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Plot ID: BPS 7538
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2 of 3
sweep 1
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03-13-1999
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Data ID: CH2
CONTROL SPECTRUM
Sweep: 2 of 2
20
.1
Q
Transmissibility
3
100
Frequency(Hz)
Marker 1:
20.08 Hz
3.085418 Q --->
3.032135 Q <---
Marker 2:
69.34 Hz
2.849802 Q --->
2.833591 Q <---
Marker 3:
Not Set
Marker 4:
Not Set

ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: cold pallat
2 of 3
sweap 2

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03-13-1999

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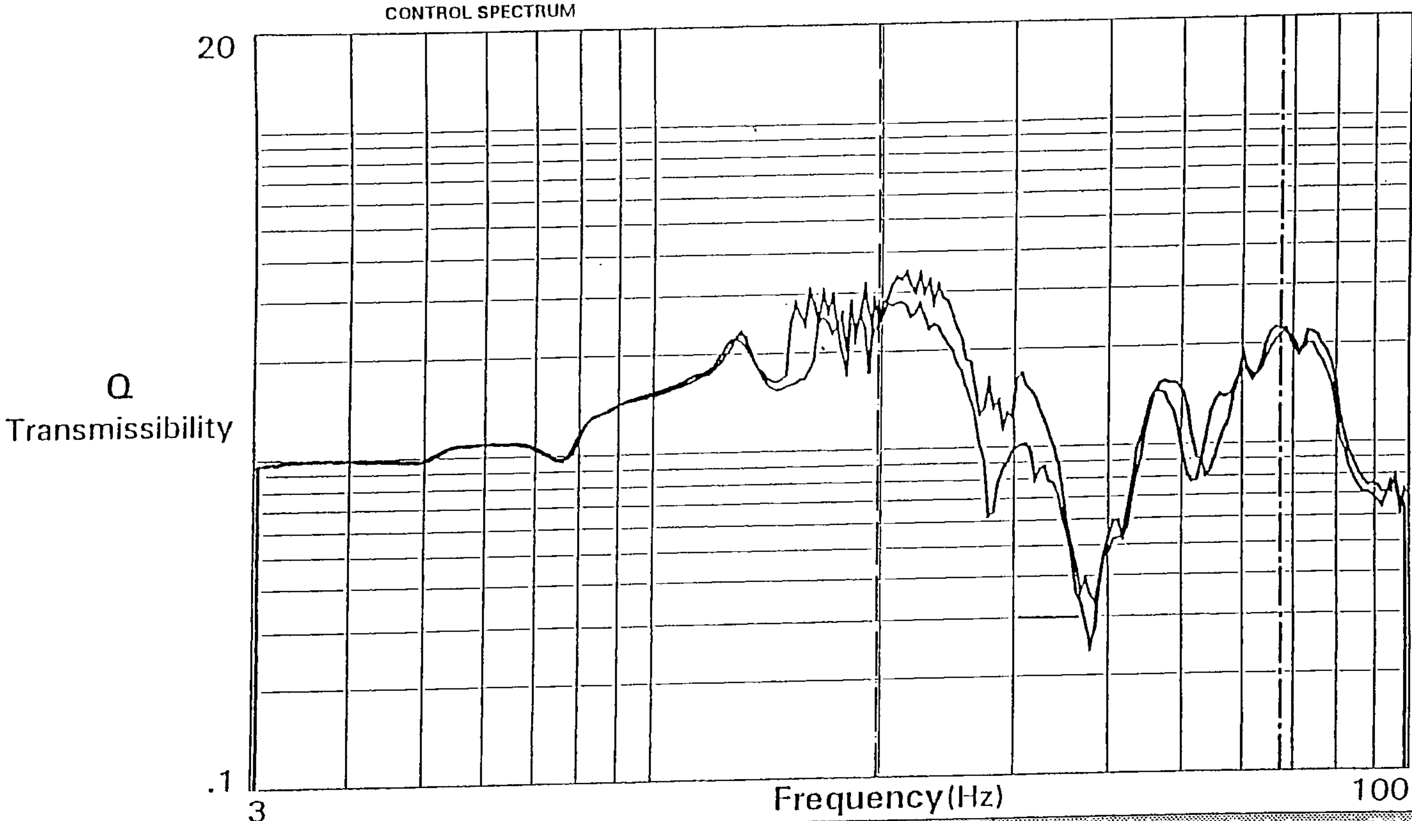

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67.41 Hz
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2.125755 Q <---

Marker 3:
Not Sat

Marker 4:
Not Sat

ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

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Notes: cold pallet
2 of 3
sweep 3

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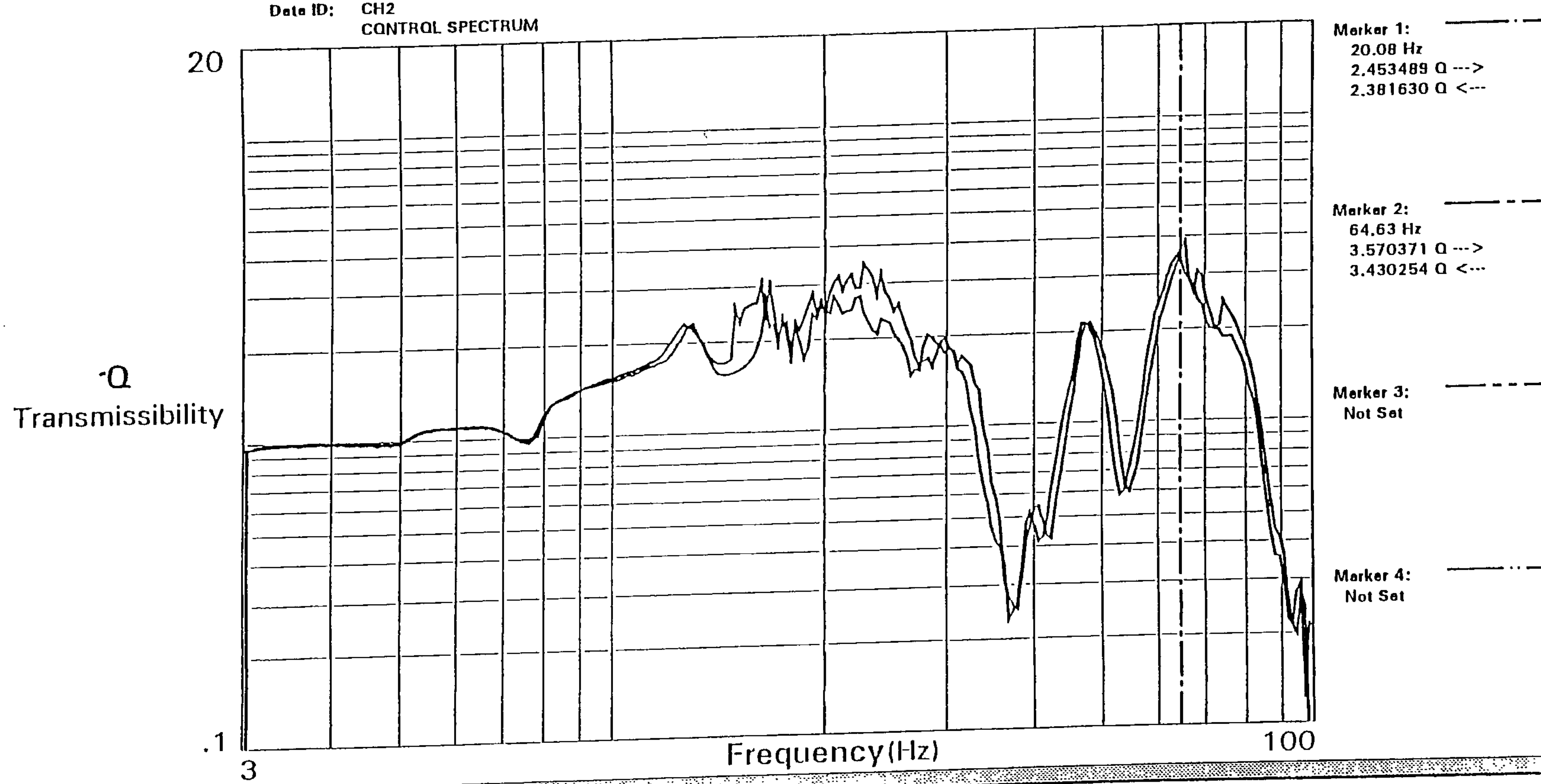

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3 of 3
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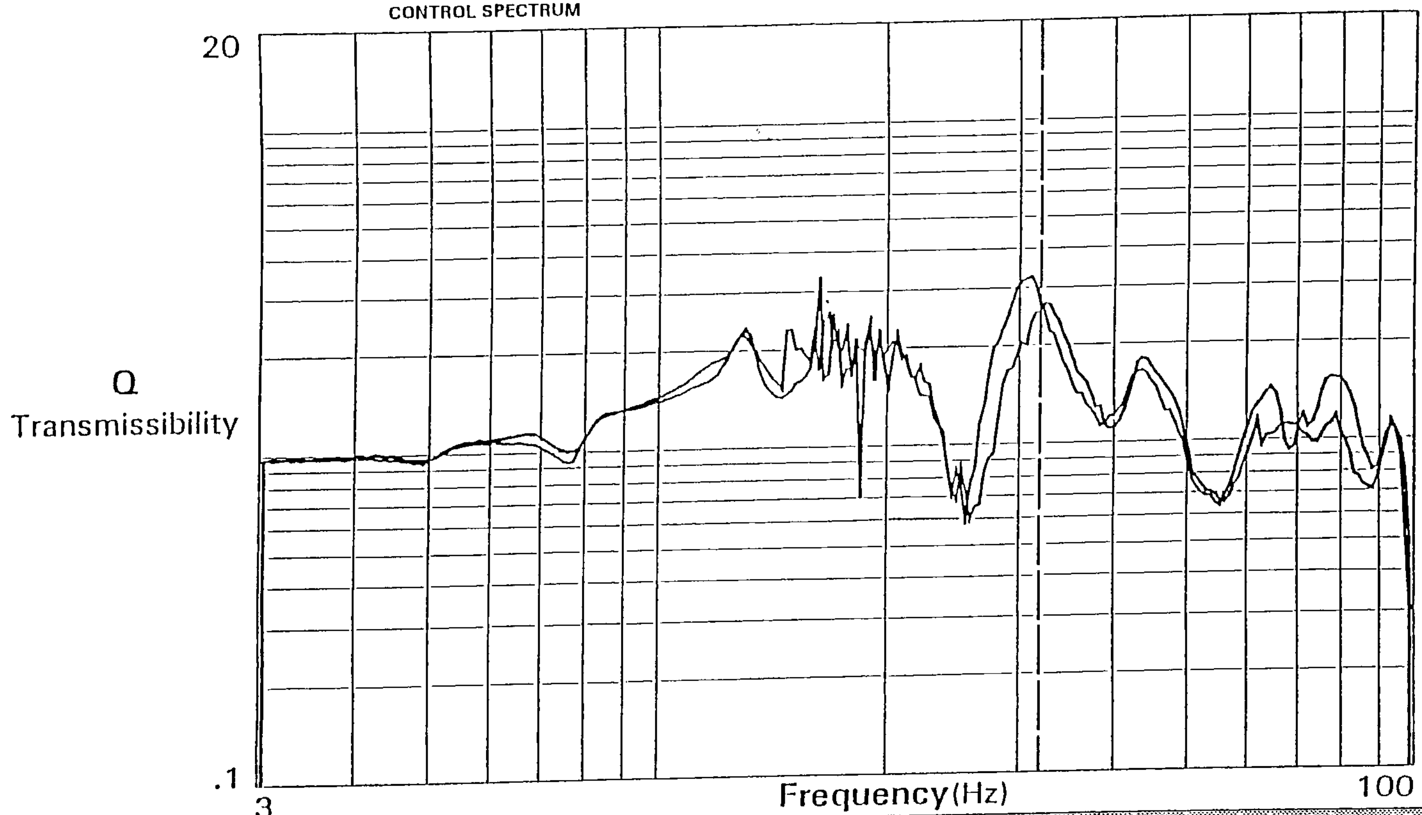
Sweep: 2 of 2



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2.700665 Q --->
2.522933 Q <---

Marker 2:
31.96 Hz
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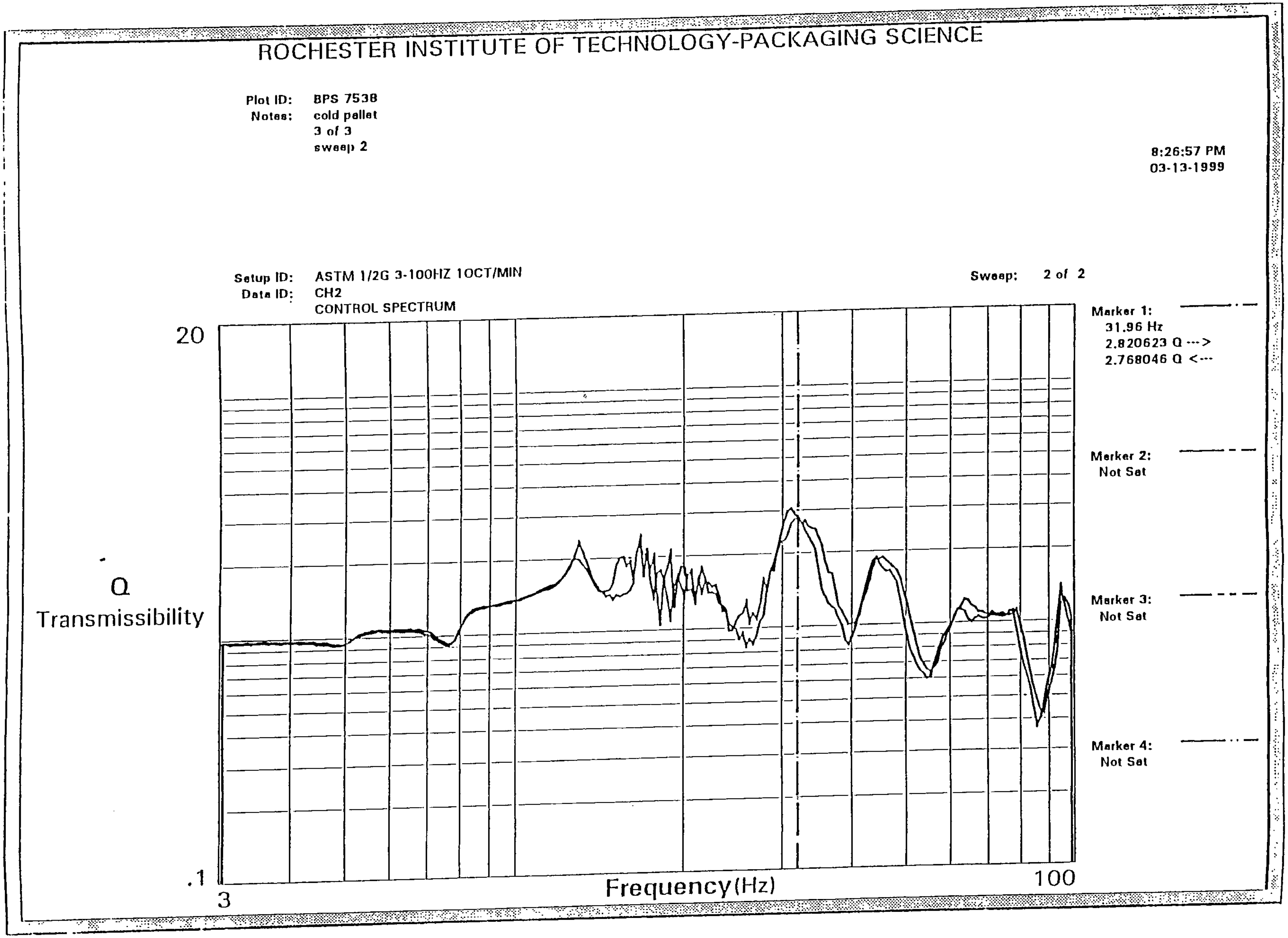
2.522933 Q <---

Marker 3:
Not Set

Marker 4:
Not Set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sweep 2
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Data ID: CH2
CONTROL SPECTRUM
Sweep: 2 of 2
Marker 1:
31.96 Hz
2.820623 Q --->
2.768046 Q <---
Marker 2:
Not Set
Marker 3:
Not Set
Marker 4:
Not Set
20
.1
Q
Transmissibility
3
100
Frequency(Hz)

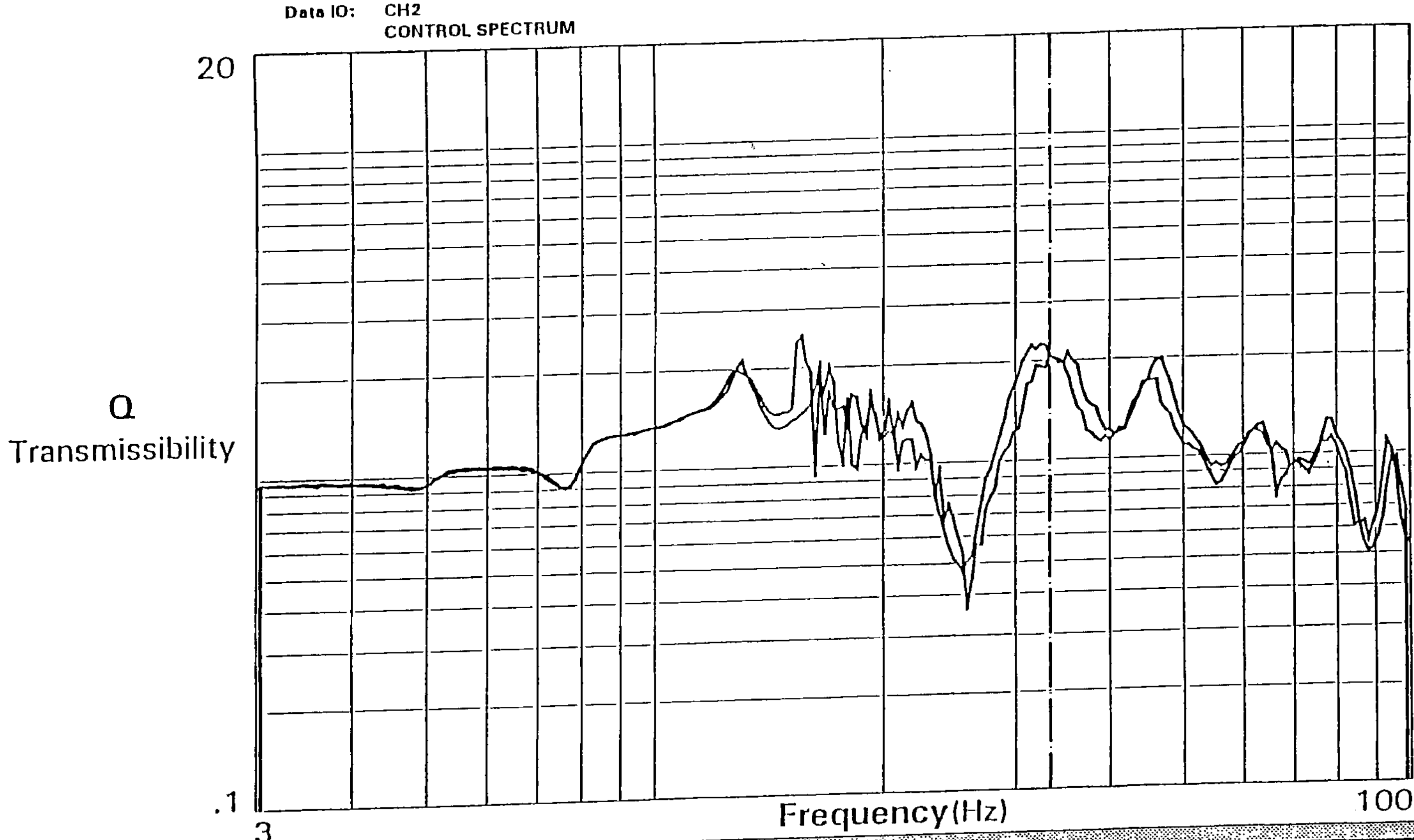
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: cold pallet
3 of 3
sweep 3

8:39:42 PM
03-13-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data IO: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



Marker 1:
33.34 Hz
2.062679 Q --->
2.075501 Q <---

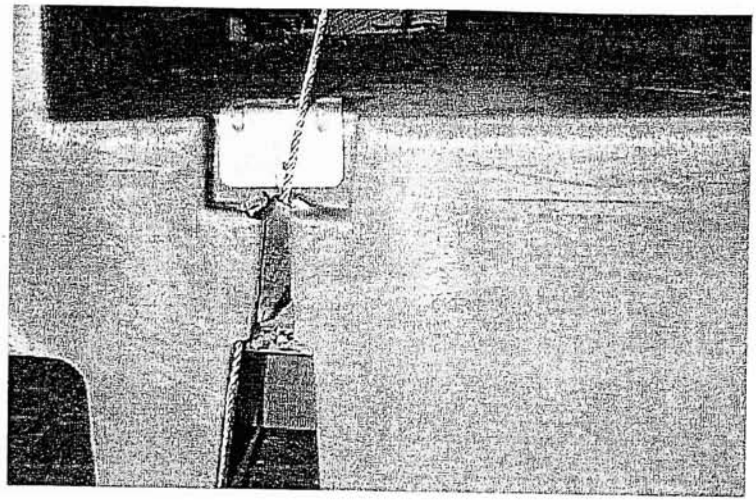
Marker 2:
Not Set

Marker 3:
Not Set

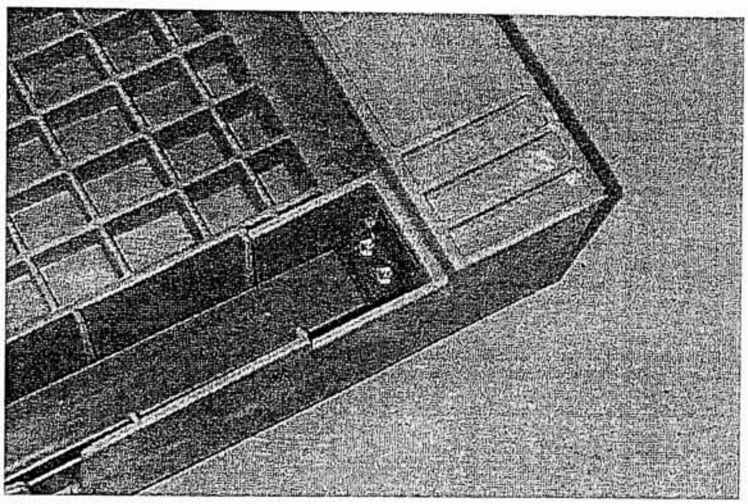
Marker 4:
Not Set

Appendix D

Supplemental Testing Photographs



Gripple Securing Load.



"L" Bracket on the Bottom of the Pallet.

Appendix E

Supplemental Vibration Testing Data Sheets

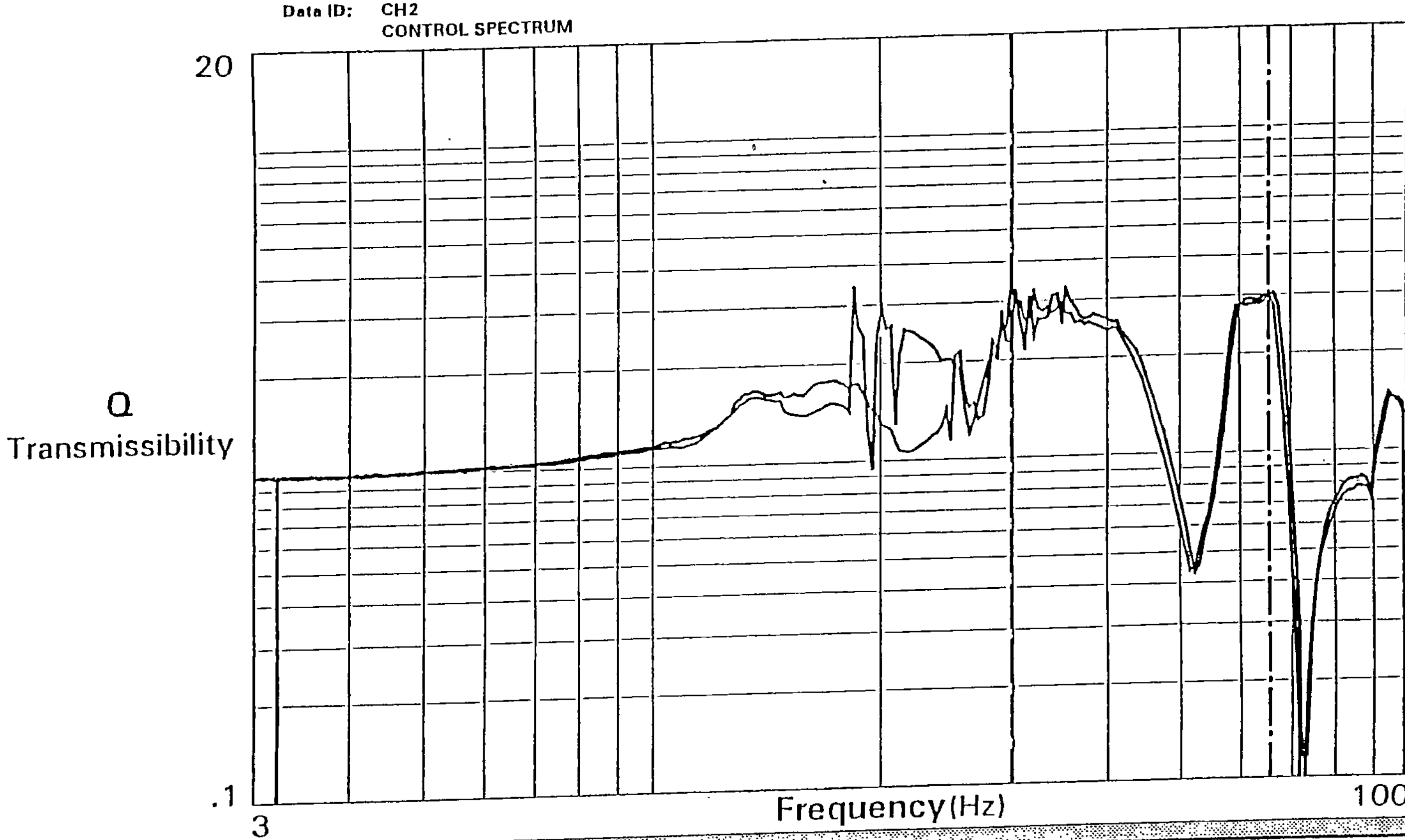
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: single pallet with no load

7:39:42 PM
03-13-1999

Setup ID: ASTM 1/2G.3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



Marker 1:
29.79 Hz
3.320876 Q --->
2.260651 Q <---

Marker 2:
65.54 Hz
2.977180 Q --->
2.998938 Q <---

Marker 3:
Not Set

Marker 4:
Not Set

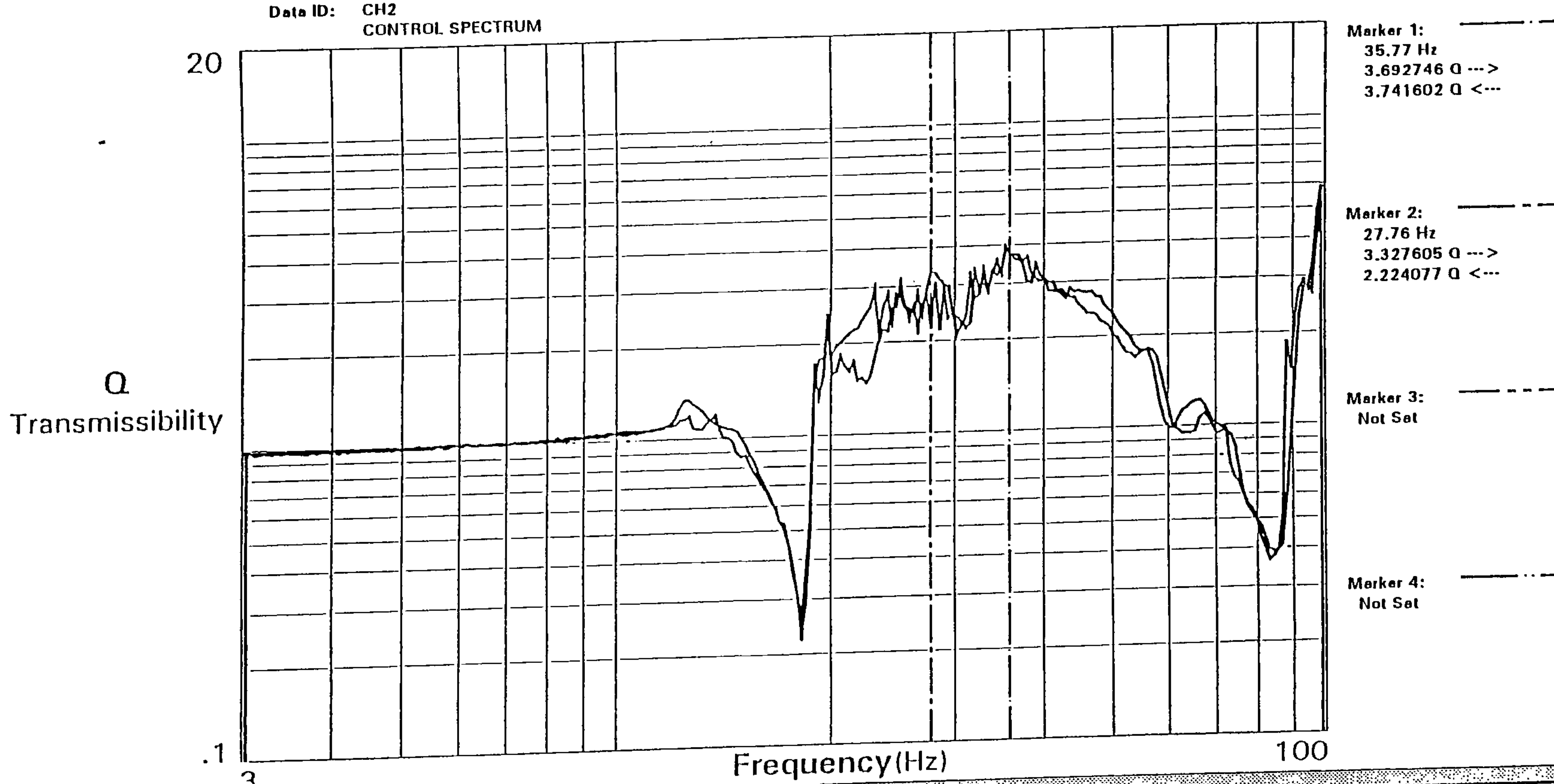
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: Pallet 2 No Load
Sine Test (front, over beam)

2:59:46 PM
03-16-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



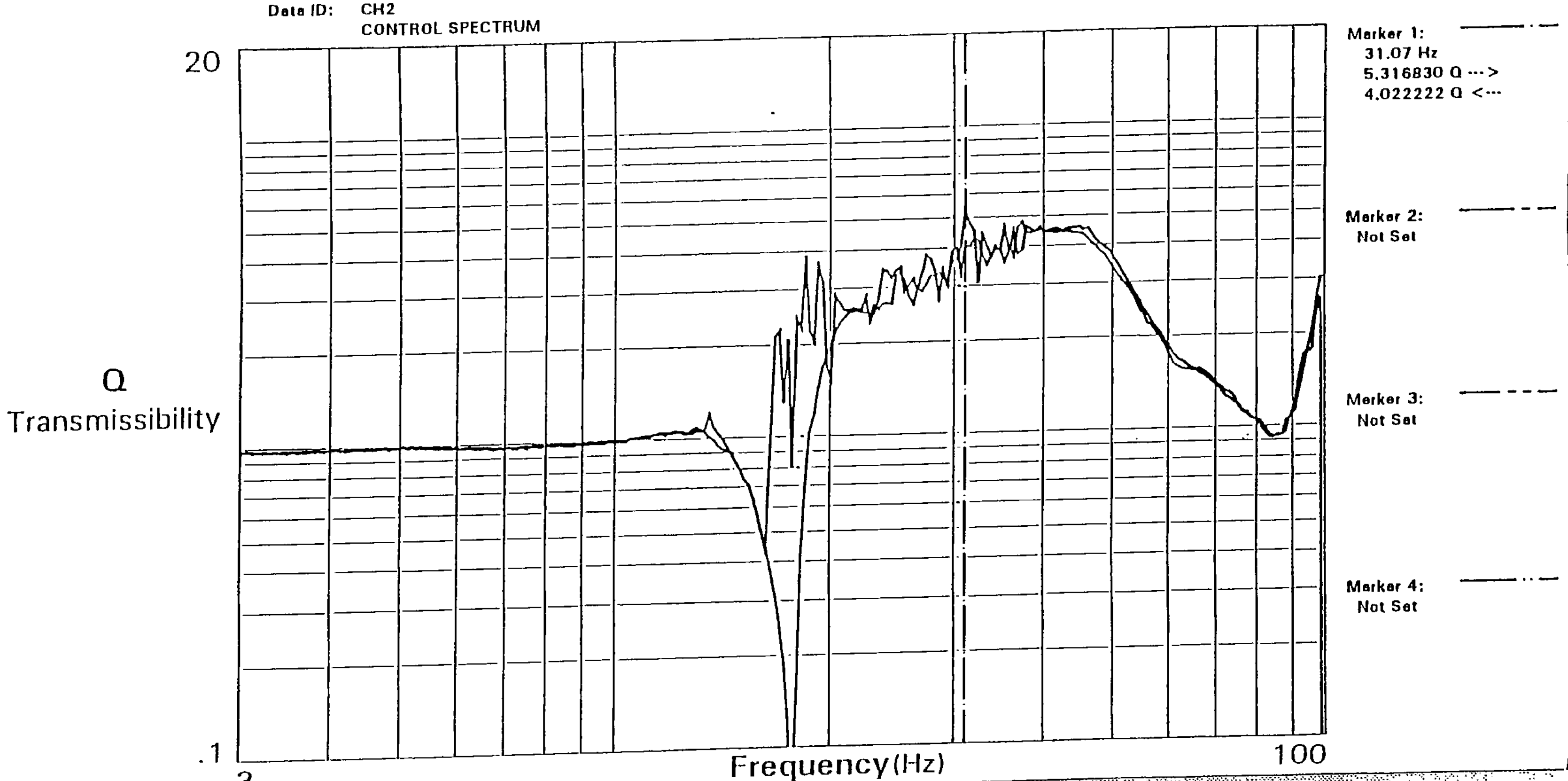
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: Pallet 3 No Load
Sine Test (front, over beam)

6:27:47 PM
03-16-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



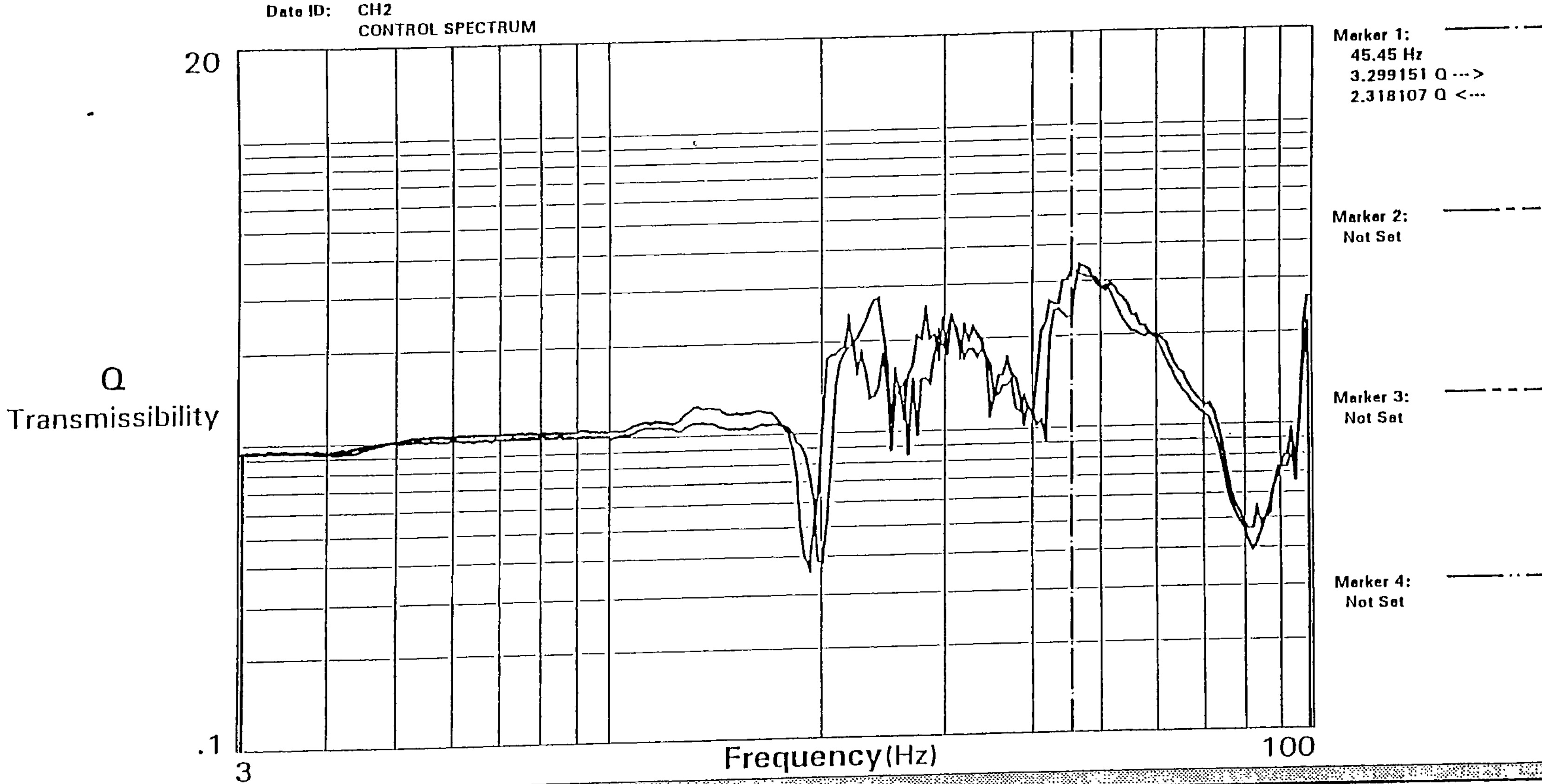
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7530
Notes: Pallet 4 No Load
Sine Test (front, over beam)

6:54:13 PM
03-16-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Date ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



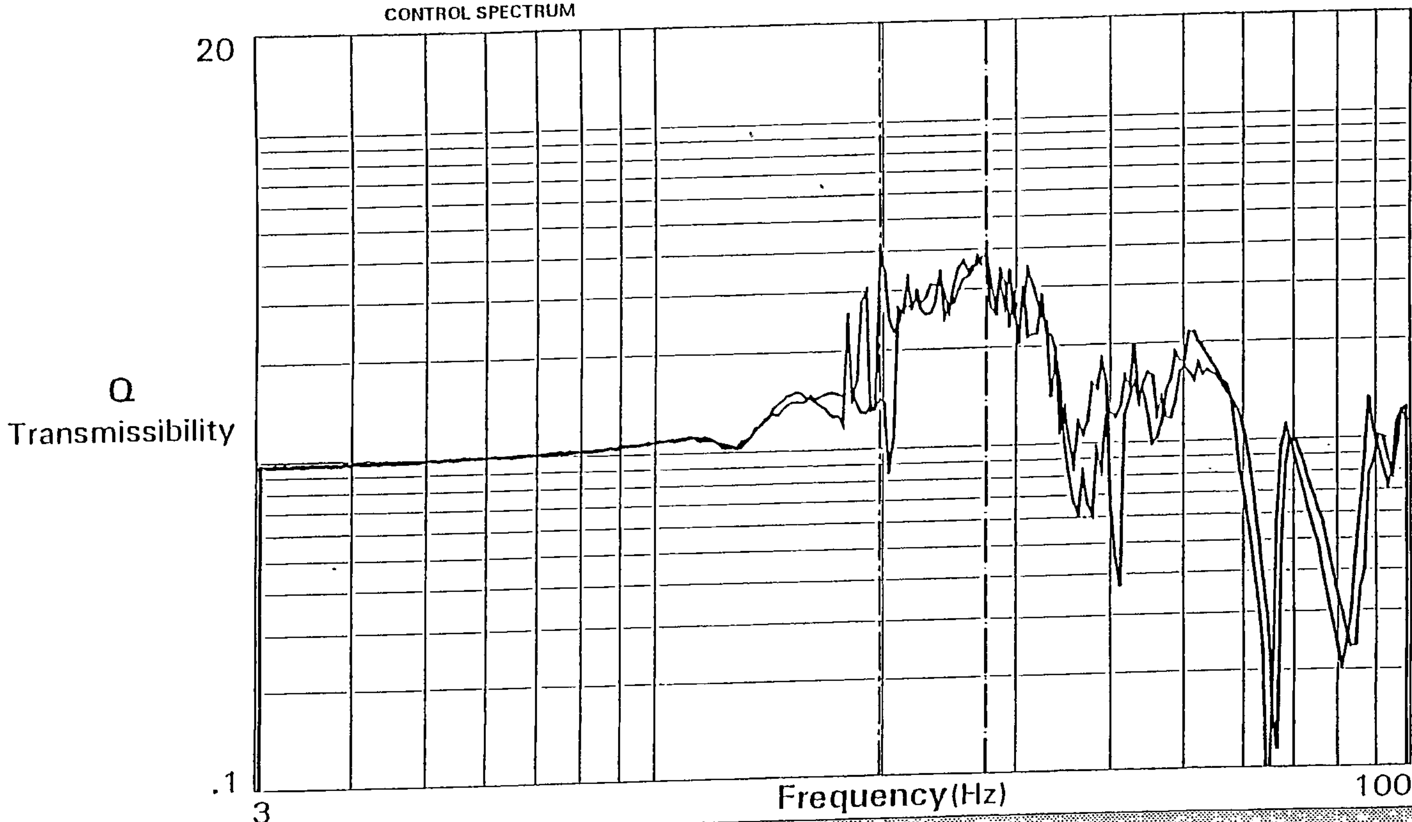
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: Pallet 5 No Load
Sine Test (front, over beam)

7:16:17 PM
03-16-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2

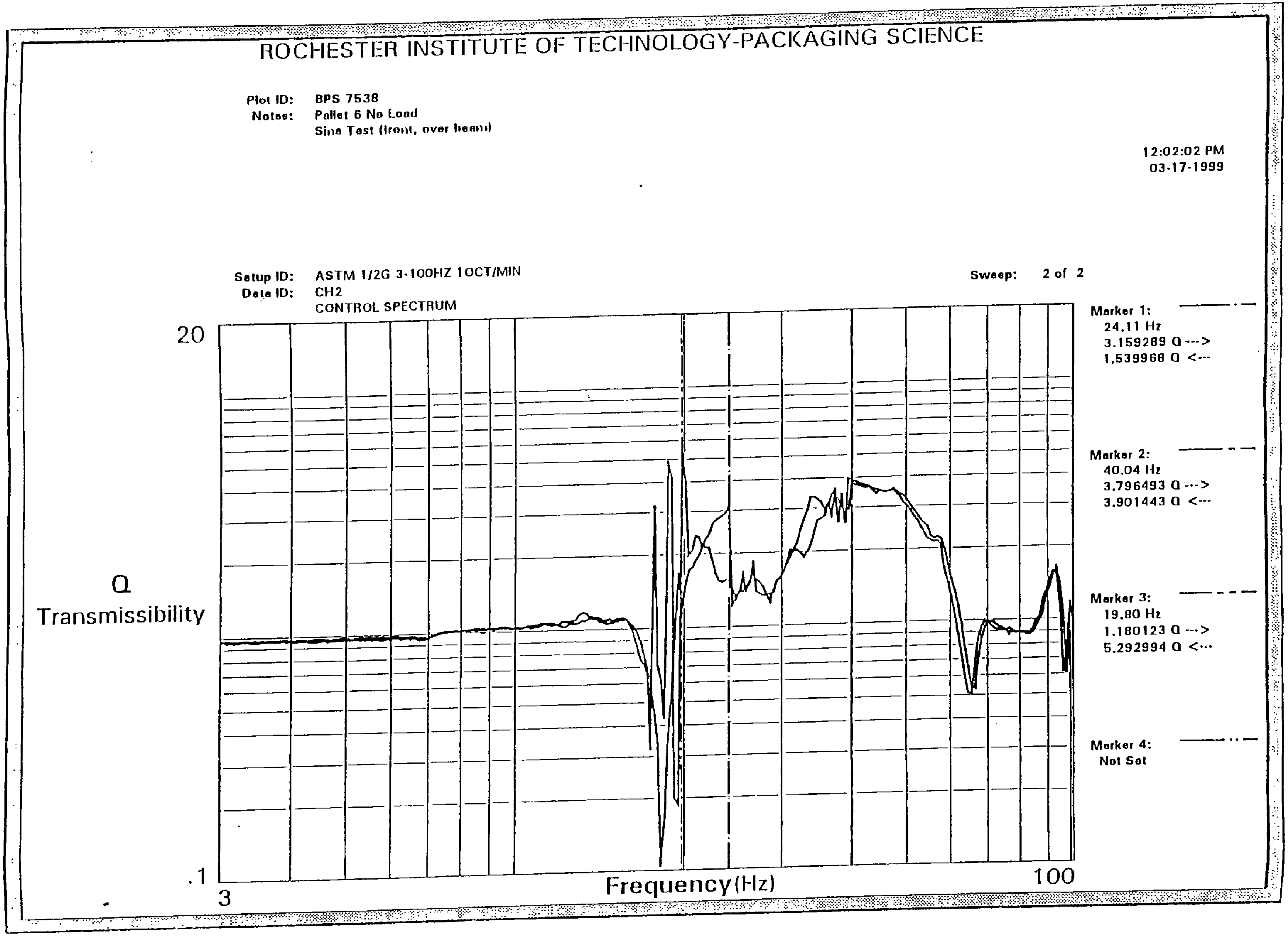


Marker 1:
27.37 Hz
3.569547 Q --->
3.803446 Q <---

Marker 2:
19.80 Hz
1.403827 Q --->
3.939146 Q <---

Marker 3:
Not Set

Marker 4:
Not Set


ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE
Plot ID: BPS 7538
Notes: Pallet 6 No Load
Sine Test (front, over beam)
12:02:02 PM
03-17-1999
Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM
Sweep: 2 of 2
Marker 1:
24.11 Hz
3.159289 Q --->
1.539968 Q <---
Marker 2:
40.04 Hz
3.796493 Q --->
3.901443 Q <---
Marker 3:
19.80 Hz
1.180123 Q --->
5.292994 Q <---
Marker 4:
Not Set
20
.1
Q
Transmissibility
3
100
Frequency(Hz)

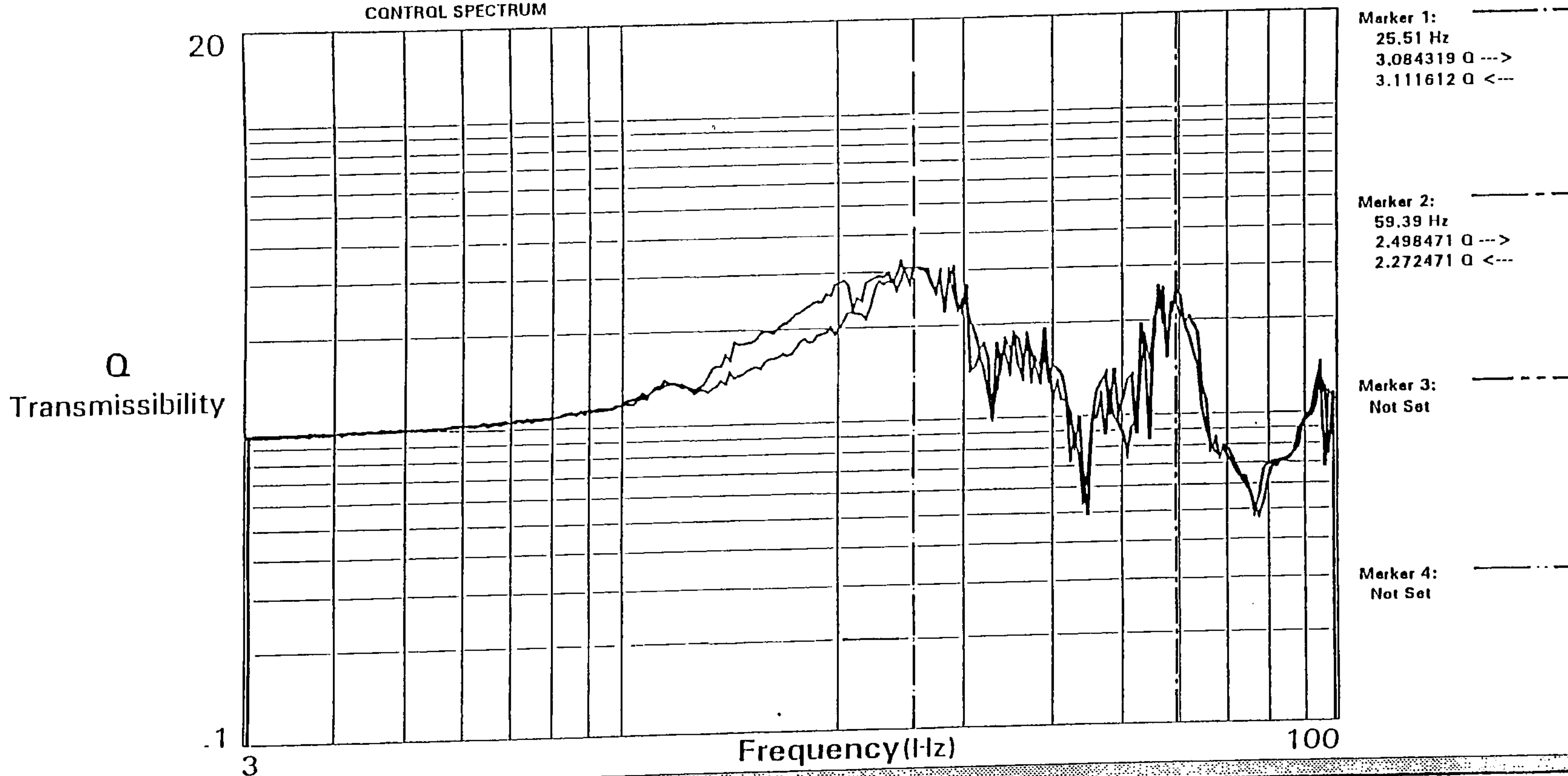
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7530
Notes: Pallet 7 No Load
Sine Test (front, over beam)

12:34:54 PM
03-17-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



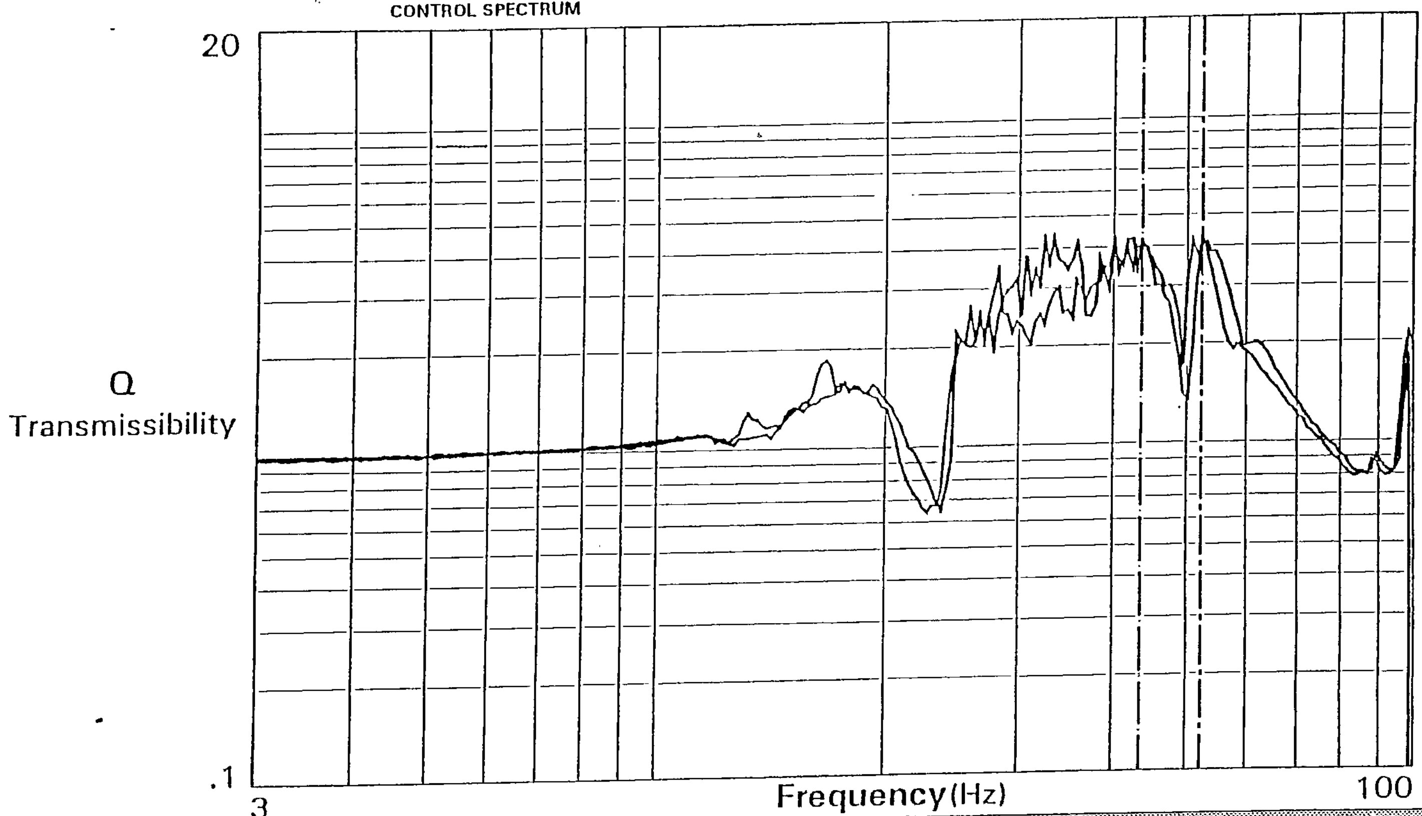
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: 8PS 7538
Notes: Pallet 8 No Load
Sine Test (front, over beam)

1:04:29 PM
03-17-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



Marker 1:
43.57 Hz
4.156366 Q --->
4.031269 Q <---

Marker 2:
52.32 Hz
4.253548 Q --->
4.029806 Q <---

Marker 3:
Not Set

Marker 4:
Not Set

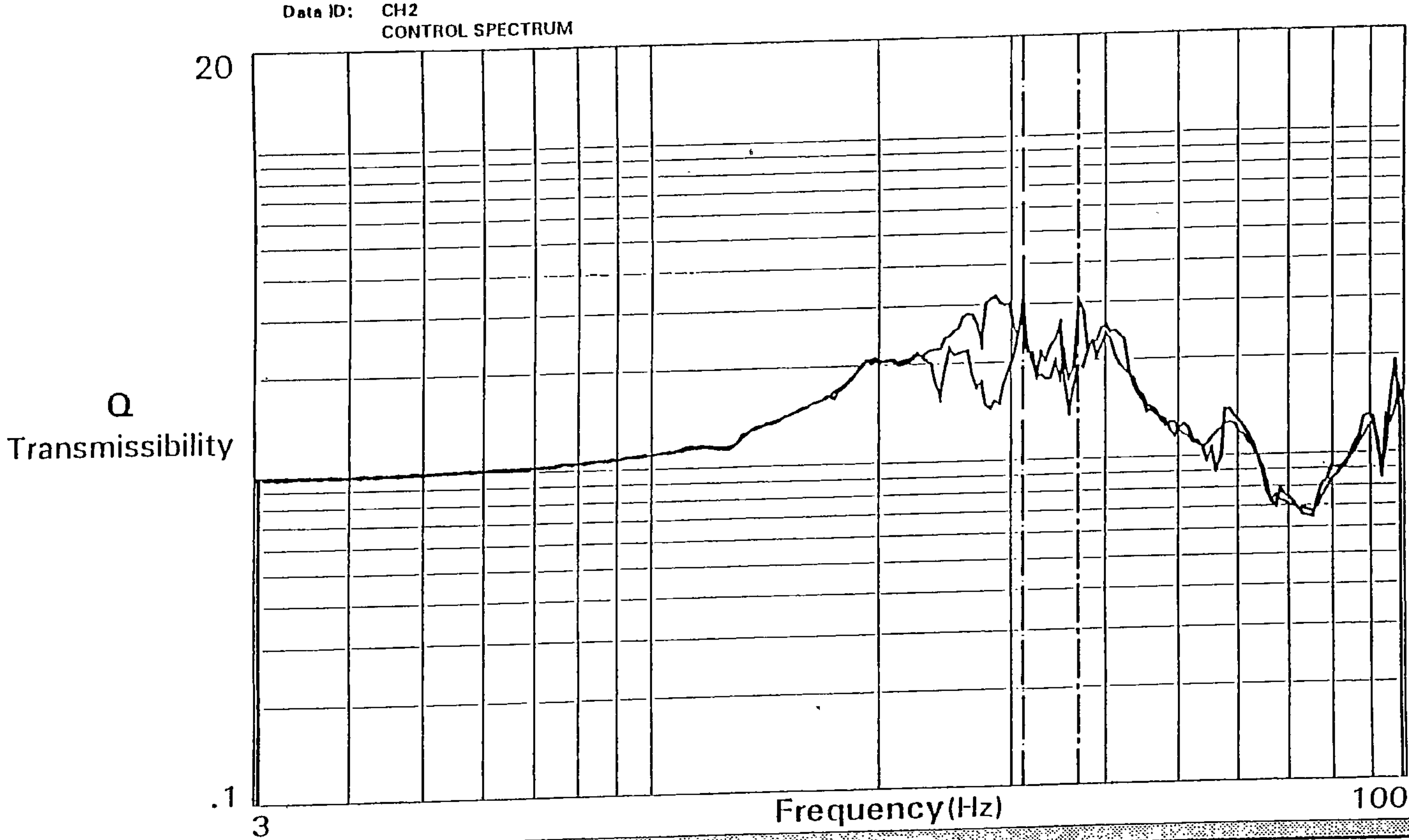
ROCHESTER INSTITUTE OF TECHNOLOGY-PACKAGING SCIENCE

Plot ID: BPS 7538
Notes: Pallet 9 No Load
Sine Test (front, over beam)

1:23:13 PM
03-17-1999

Setup ID: ASTM 1/2G 3-100HZ 1OCT/MIN
Data ID: CH2
CONTROL SPECTRUM

Sweep: 2 of 2



Marker 1:
31.07 Hz
3.127028 Q --->
2.457909 Q <---

Marker 2:
36.79 Hz
3.028603 Q --->
1.931214 Q <---

Marker 3:
Not Set

Marker 4:
Not Set

Appendix F

Supplemental Compression Testing Data Sheets

R.I.T. - PACKAGING SCIENCE

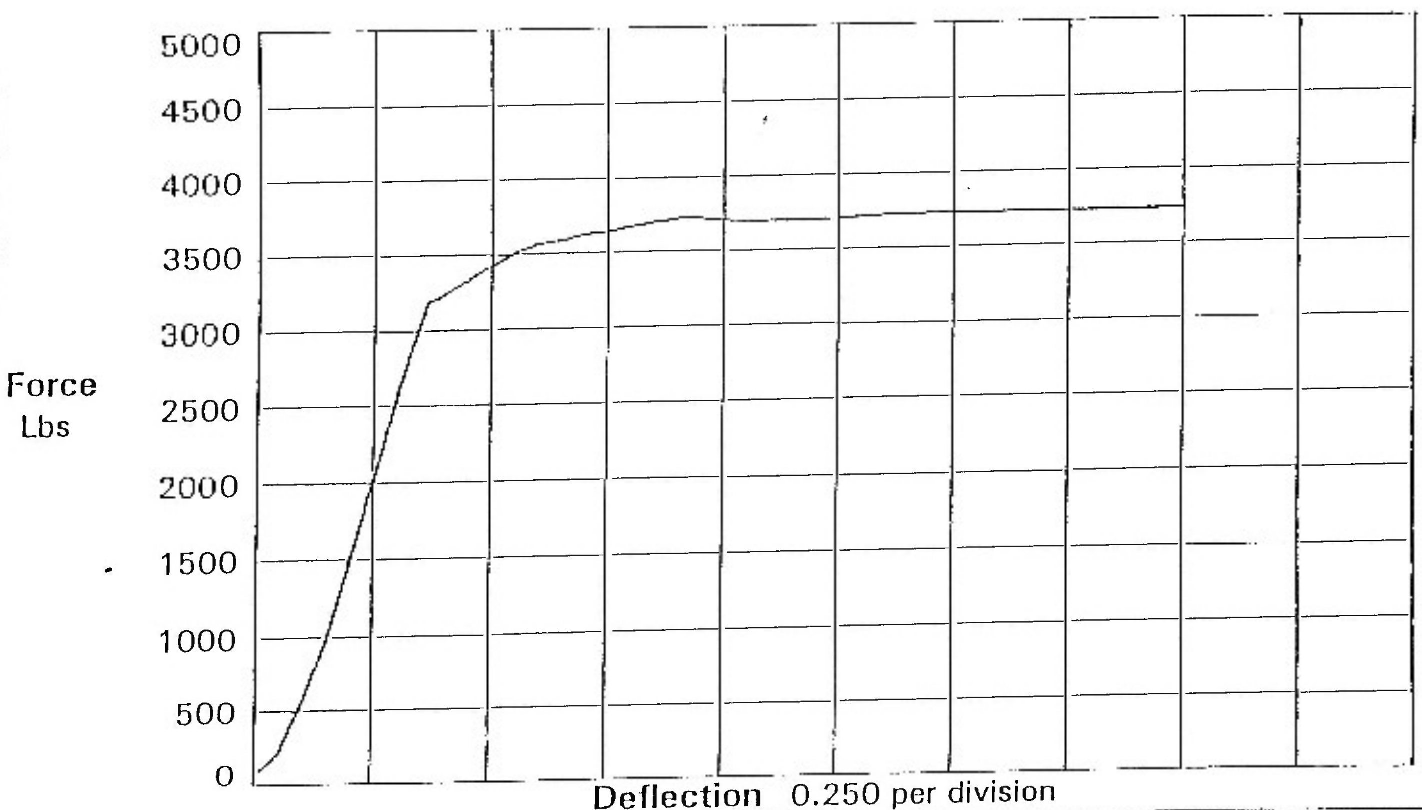
CONSTANT RATE CONTROL CONFIGURATION

Current Status

Preload for Deflection Auto Zero:	50.0 Lbs
Yield Detection Percentage:	25.0 %
Stop Force:	25000.0 Lbs
Stop Deflection:	2.00 In
Test Velocity:	0.50 In/M
Auto Sample Number:	ON
Auto Log on Test Completion:	AUTO
Overlay Auto Copy Test Interval:	EVERY 1
Auto Print Test Interval:	OFF

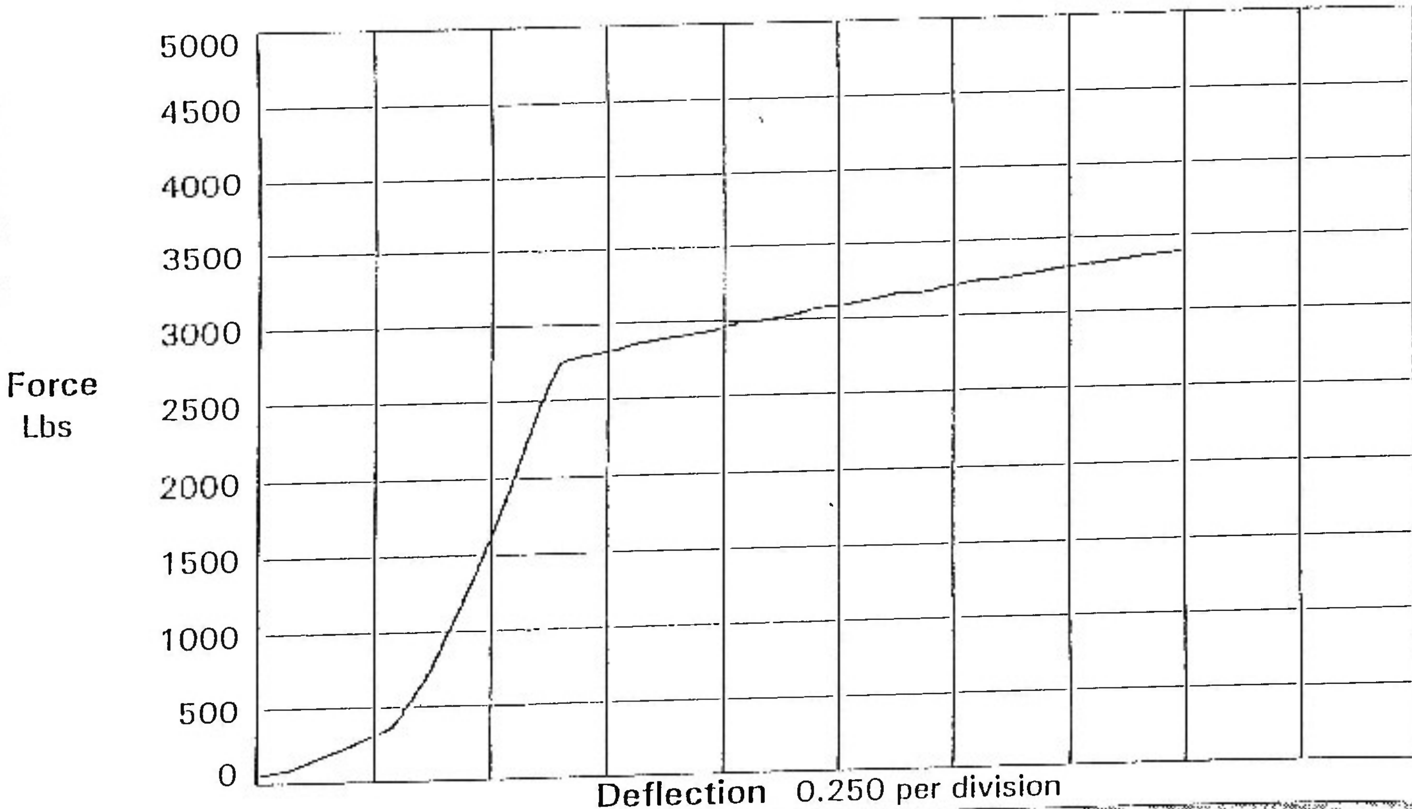
R.I.T. - PACKAGING SCIENCE

Sample ID:	Sample #	Peak Force	Def @ Pk	Temp	%RH	Time	Date
BPS 7538	1	3732.4 Lbs	1.38 In			17:53:35	06-16-1998



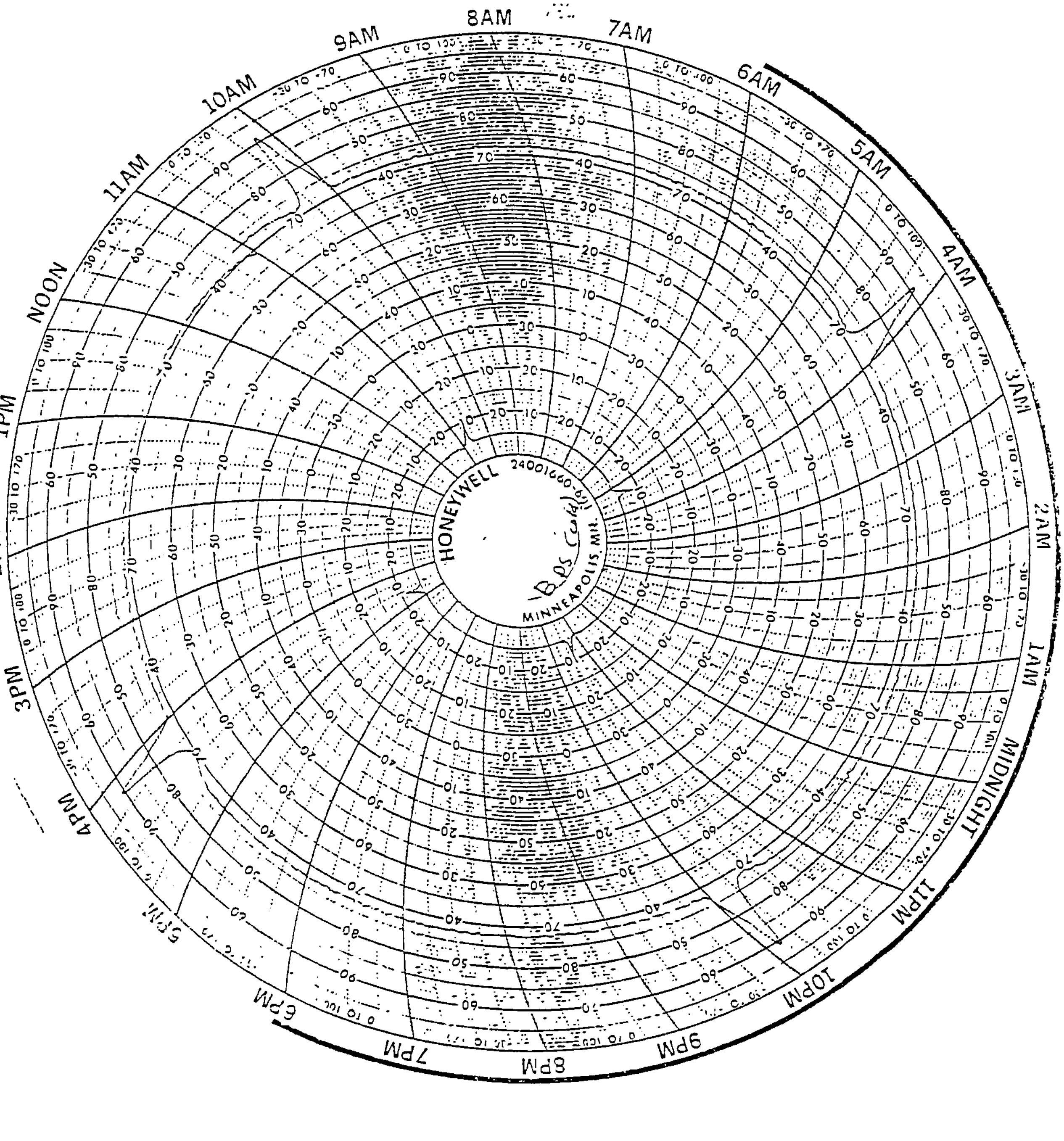
R.I.T. - PACKAGING SCIENCE

Sample ID:	Sample #	Peak Force	Def @ Pk	Temp	%RH	Time	Date
BPS 7538	2	3396.9 Lbs	1.99 In			18:09:23	06-16-1998

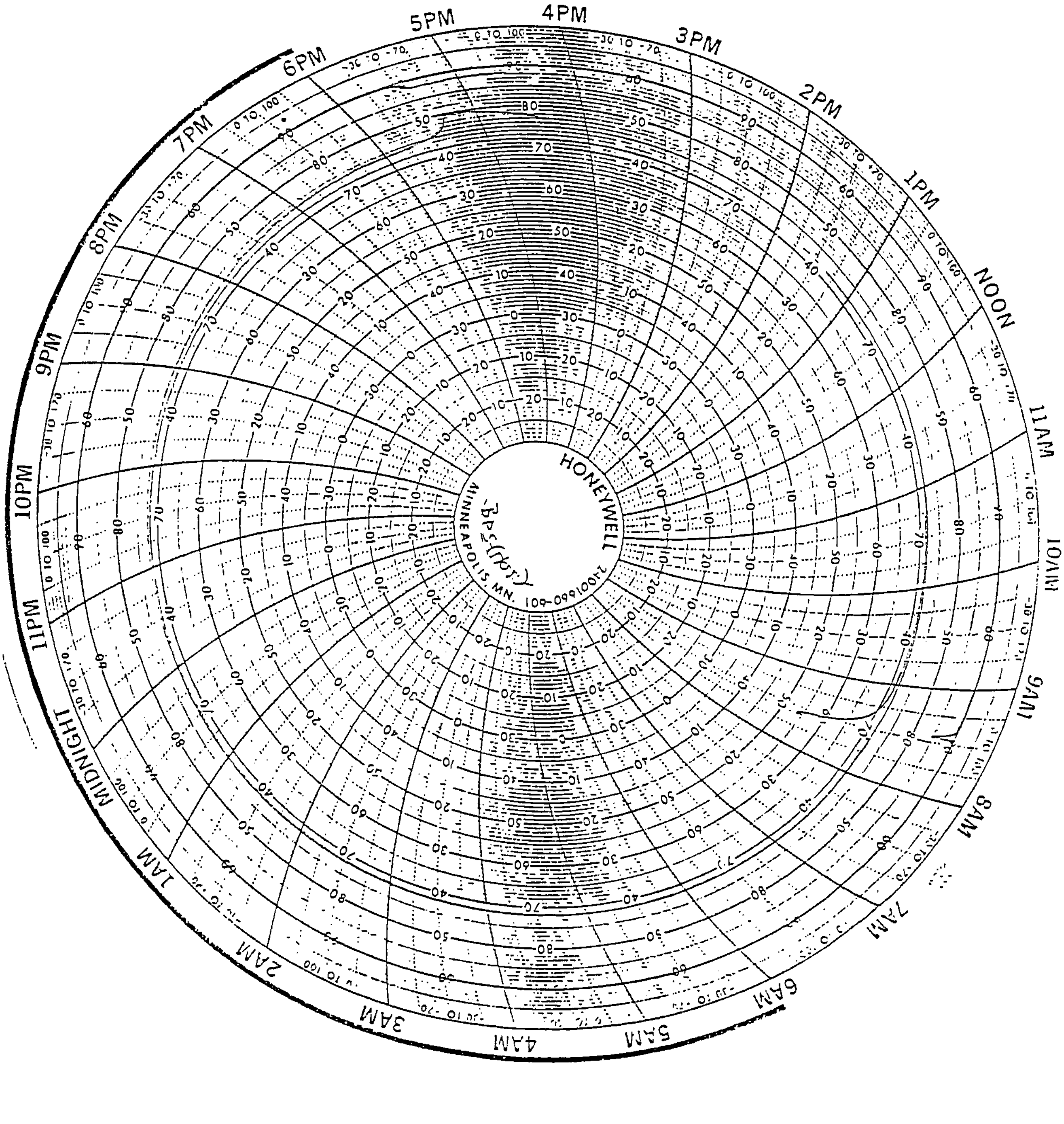


Appendix G

Conditioning Charts



HONEYWELL
24001660
MINNEAPOLIS MN.
8AM
7AM
6AM
5AM
4AM
3AM
2AM
1AM
MIDNIGHT
11PM
10PM
9PM
8PM
7PM
6PM
5PM
4PM
3PM
2PM
1PM
NOON
11AM
10AM
9AM



HONEYWELL
MINNEAPOLIS, MN.
NOON
1PM
2PM
3PM
4PM
5PM
6PM
7PM
8PM
9PM
10PM
11PM
MIDNIGHT
1AM
2AM
3AM
4AM
5AM
6AM
7AM
8AM
9AM
10AM
11AM

Appendix H

Equipment Calibration Sheets

Lansmont
Corporation

CERTIFICATE OF CALIBRATION

Customer:	R.I.T.	Lansmont Job #:	80034
Customer P.O. #:	N/A	Traceability Certificate #:	99030300

Description: TouchTest Vibration Control Engine	Model Number: 701212	Serial Number:
Procedure: Instructions for Calibration of TouchTest Vibration Electronics. November 1993: Software. ver 1.71		
Technician: ACB	Calibration date: 20 July 1998	Recommended interval: 1 year

DATA								
PARAMETERS:		AS FOUND:				RECAL: DVM reading: 2.700		
Chan	DCLevel	DVM	ADC Meas	ADC Err	DAC Err	ADC Meas	ADC Err	DAC Err
1	2.7V	2.674	2.6546V	-0.72%	-0.96%	2.6991V	0.01%	-0.04%
1	0.0000 V	0.005	0.0364V	31.4mv	31.4mv	0.0001V	0.1V	0.0mv
2			2.6499V	-0.89%		2.6985V	-0.02%	
2	0.0000 V		0.0291V	21.4mv		-0.0004V	-0.4V	
3			2.6681V	-0.22%		2.6982V	-0.03%	
3	0.0000 V		0.0610V	56.0mv		-0.0006V	-0.6V	
4			2.6144V	-2.21%		2.6985V	-0.02%	
4	0.0000 V		0.0183V	13.3mv		-0.0002V	-0.2V	
5			2.6231V	-1.89%		2.6989V	-0.00%	
5	0.0000 V		0.0322V	27.2mv		-0.0005V	-0.5V	
6								
6	0.0000 V							
7								
7	0.0000 V							

The above instrument has been calibrated using the original equipment manufacturer's governing procedure and utilizing standards traceable to NIST, in compliance with ANSI/NCSL Z540-1-1994.

Certified by: ______ (Tech) ______ (Mgr) Date: 20 July 1998

CALIBRATION INSTRUMENTS DATA				
Manufacturer	Model	Serial or Tag No.	Calibration Due Date	Traceability Cert #
Tektronix	THS720	B010576	06/05/99	481270

NIST Test Numbers:	254431 – 254368 – 254367 – 251971

E4 TEST MACHINE VERIFICATION REPORT

Calibrating Agency :LANSMONT CORP Date :07-21-1998
Loading Direction :COMPRESSION Range :50k

Verification method:Elastic Device/Load Cell

Test Machine Make :TTC Location :RI
T
Test Machine Model :122-15k Output Device :

Test Machine Serial :m-1952 Serial :

Load Cell Model :1610AJH-5K
Load Cell Serial :78342

Standard Cell Make :1610AJH-50K Cal Cert :

Standard Cell Serial:78342 Cal Date :9-
16-97
Class A load range :0.000 to 50.000 mV/V
Temperature : (Cell is temperature compensated)

NOMINAL FORCE	INDICATED FORCE #1	CAL STD #1
0.000	0.000	0.000
2.500	2.500	2.498
5.000	5.000	5.002
10.000	10.000	10.027
12.500	12.500	12.509
15.000	15.000	15.044
0.000	0.000	0.000

NORMAL CAL STD	NORMAL IND #1	MEAN IND	MAX ERROR	MAX ERROR%	1% STATUS
0.000	0.000	0.000	0.000	0.00	
2.500	2.502	2.502	0.002	0.08	
5.000	4.998	4.998	-0.002	-0.04	
10.000	9.973	9.973	-0.027	-0.27	

12.500	12.491	12.491	-0.009	-0.07
15.000	14.956	14.956	-0.044	-0.29

Range of error :.37 %

Operator ____________________________ Checked By ________________________

References

REFERENCES

ASTM D 4728-95 Standard Test Method for Random Vibration Testing of Shipping Containers. . Philadelphia : American Society of Testing and Materials,1998.

ASTM D 1185-94 Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping . Philadelphia : American Society of Testing and Materials,1998.

ASTM D 999-96 Standard Methods for Vibration Testing of Shipping Containers. Philadelphia: American Society of Testing and Materials. 1998.

ASTM D 642-94 Standard Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads. Philadelphia: American Society of Testing and Materials. 1998.

Brody, Marsh The Wiley Encyclopedia of packaging Technology second edition. New York: John Wiley and sons

Brandenburg, Richard K. Ph.D. and Lee, Julian, Ph.D. Fundamentals of Packaging Dynamics 5th ed. Skaneatelas: L.A.B. 1991