PACKAGING DYNAMICS #2 of 5
Defining and Quantifying the Distribution Environment
Through Which All Products Must Travel

Herb Schueneman
President & CEO
Presenter

Edmund Tang
Laboratory Manager
Presenter

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Agenda

• Review of Webinar #1
• Introduction to the Five Step Method
• Step 1: Define the Environment
• Predefined Distribution Environment
• Obtaining and Collecting Data
Review of Webinar #1

• History and background of packaging dynamics
• Background terminology
  – Time domain Vs frequency domain
  – Single degree of freedom spring mass system
Review of Webinar #1

• Common packaging dynamic hazards
  – Vibration
  – Impact (shocks and drops)
  – Compression (static and dynamic)
Review of Webinar #1: Shock Input and Response

Graph showing the relationship between Acceleration (G's) and Time (msec). The blue line represents the Input, and the red line represents the Response.
Review of Webinar #1: Vibration Input and Response

1:1 Coupling
- Response = Input
- Q = 1

Amplification
- Response > Input
- Q > 1
- Damage occurs

Attenuation
- Response < Input
- Q < 1
- Vibration protection

Graph showing frequency response and amplification Q = R/I.
Introduction to the Five Step Method

- **Step 1**: Define the Environment
- **Step 2**: Define Product Fragility
- **Step 3**: Cushion Material Performance Evaluation
- **Step 4**: Package Design
- **Step 5**: Test the Product/Package System
Define the Environment

- To be covered in this webinar
- Characterization of a package’s distribution environment
Define Product Fragility

Step 2

• Identify exactly where and how your product breaks
  – Vibration
  – Drops
  – Compression
  – Temperature
  – Relative Humidity
  – Altitude (Pressure)
• Evaluate different cushioning materials for shock and vibration performance
Step 4

Package Design

- Design a package system to properly protect against its distribution environment
Test the Product/Package System

- Validate your designed package system by testing it.
QUESTIONS??
The Five Step Method

Step 1

• Define the Environment
Definition

• Characterization of a package’s distribution environment and hazards
  – Vibration
  – Drops
  – Compression
  – Temperature
  – Relative Humidity
  – Altitude (Low Pressure)
Why is this Important?

• Protect products to exactly what is experienced during the distribution environment
  – Eliminates the guesswork
• Prevents over and under packaging
• Saves packaging material and supply chain distribution costs
Four Product and Packaging Cases

- Case 1: Adequate Packaging
- Case 2: Under Packaging
- Case 3: Over Packaging
- Case 4: Product Improvements
  - Less Packaging
What Data is Obtained?

• Vibration
  – Intensities
  – Frequencies
  – Durations

• Drops
  – Heights
  – Numbers
  – Orientations
What Data is Obtained?

- Temperature
  - Hot and cold extremes
- Relative Humidity
  - Moisture extremes
- Altitude
  - Pressure extremes
Predefined Distribution Environment (Study #1)

• Forest Products Laboratory (FPL22) Studies (1979)
  – US Study A: 43-pound cleated plywood box
    • 49 trips using 13 packages
  – US Study B: 25-pound corrugated fiberboard box
    • 80 trips using 15 packages
• RESULTS of FPL22 Studies (1979)
  – US Study A: 43-pound cleated plywood box
    • Approximately 800 freefall drops recorded
    • Approximately 50% of the drops were recorded on the base down orientation
    • Less than 1% of packages dropped from over 36 inches
    • Approximately 18% of drops over 14 inches
    • Most drops from 6 inches
  – US Study B: 25-pound corrugated fiberboard box
    • Approximately 600 freefall drops recorded
    • Approximately 50% of the drops were recorded on the base down orientation
    • Approximately 6% of packages dropped from over 36 inches
    • Approximately 20% of drops over 14 inches
    • Most drops from 6 to 8 inches
Probability Distribution of Study

![Graph showing the probability distribution of study with two lines representing 43 lb box and 25 lb box.]

25 lb box

43 lb box
Number of Drops per Height

Figure 3. --Drop height versus number of drops (43-lb. container).

Figure 4. --Drop height versus number of drops (25-lb. container).

25-lb box

43-lb box
Predefined Distribution Environment (Study #2)

  – Collaboration between 74 companies and members led by Hewlett Packard (HP)
## MADE Members

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Company Name</th>
<th>Company Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Com Corp.</td>
<td>3M Packaging Systems</td>
<td>Amdahl</td>
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<td>AMP Inc.</td>
<td>Amtech Systems Corp.</td>
<td>Apple Computer Inc.</td>
</tr>
<tr>
<td>Applied Materials</td>
<td>AST Computer</td>
<td>Cal Poly State Univ.</td>
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<td>CargoPRO Services, Inc.</td>
<td>Cisco Systems</td>
<td>Clarion</td>
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<td>Compaq Computer Corp.</td>
<td>Consolidated Freightways</td>
<td>Dallas Instruments Division</td>
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<td>Data General Corp.</td>
<td>Dell Computer Corp.</td>
<td>Dennis Young &amp; Assoc.</td>
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<td>Digital Equipment Corp.</td>
<td>Dow Chemical</td>
<td>Dow Plastics</td>
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<td>Eastman Kodak Co.</td>
<td>Emery Worldwide</td>
<td>Equipment Reliability Institute</td>
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<td>Federal Express Corp.</td>
<td>Frigidaire Home Products</td>
<td>Hewlett-Packard Co.</td>
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<td>Hubbell Lighting Inc.</td>
<td>IBM</td>
<td>Industrial Boxboard Corp.</td>
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<td>Inhale Therapeutic Systems</td>
<td>Institute of Packaging Professionals (IoPP)</td>
<td>Instrumented Sensor Technology (IST)</td>
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<td>Intel</td>
<td>International Safe Transit Assoc. (ISTA)</td>
<td>Kohler Co.</td>
</tr>
<tr>
<td>Lam Research</td>
<td>Lansmont Corp.</td>
<td>Lexmark International</td>
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<tr>
<td>Micron Electronics, Inc.</td>
<td>National Semiconductor</td>
<td>National Electronic Distributors Association (NEDA)</td>
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<td>Oregon State Univ.</td>
<td>Packforsk</td>
<td>Quantum</td>
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<td>Republic Packaging Corp.</td>
<td>RW James Packaging Corp.</td>
<td>Sage Technologies</td>
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<td>San Jose State University</td>
<td>Seagate</td>
<td>Sealed Air Corp.</td>
</tr>
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<td>Shiva Europe Ltd</td>
<td>Silicon Graphics Computer Systems</td>
<td>Sony Corporation of America</td>
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<tr>
<td>Sun Microsystems</td>
<td>Tektronix Inc.</td>
<td>Tenneco Packaging</td>
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<tr>
<td>Teradyne Connection Systems</td>
<td>Tharco</td>
<td>Thomson Consumer Electronics</td>
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<tr>
<td>Unisys</td>
<td>United Parcel Service</td>
<td>University of Nebraska</td>
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<td>US Postal Service</td>
<td>Ventrifex</td>
<td>Watkins-Johnson Co.</td>
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<tr>
<td>Westpak, Inc.</td>
<td>William-Sonoma, Inc.</td>
<td>Xerox Corporation</td>
</tr>
<tr>
<td>Zellerbach</td>
<td>Zenith Electronics</td>
<td></td>
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WESKPAK, INC.
EXCELLENCE IN TESTING
• Results of M.A.D.E. Study (1996 – 1999)
  – 25-pound box to simulate a computer
• The Results
  – Highest drop found in all 40 round trips was 58 inches (one occurrence)
  – Approximately 1,500 freefall drops recorded
  – Approximately 50% of the drops were recorded on the base down orientation
  – Approximately less than 1.5% of drops over 36 inches
  – Approximately less than 5.0% of drops over 14 inches
  – Most Drops from 4 inches
Figure 3.2.5

Number of Impacts vs. Drop Height for FedEx & UPS
## FPL and MADE Comparison

<table>
<thead>
<tr>
<th>Study</th>
<th>Package Weight</th>
<th>Freefall Drops Recorded</th>
<th>% of Drops Greater than 14”</th>
<th>% of Drops Greater than 36”</th>
<th>Primary Drop Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPL (1979)</td>
<td>25 lbs</td>
<td>600</td>
<td>≈ 18%</td>
<td>≈ 6%</td>
<td>Base Down (50%)</td>
</tr>
<tr>
<td>FPL (1979)</td>
<td>43 lbs</td>
<td>800</td>
<td>≈ 20%</td>
<td>&lt; 1%</td>
<td>Base Down (50%)</td>
</tr>
<tr>
<td>MADE (1996)</td>
<td>25 lbs</td>
<td>1500</td>
<td>≈ 5%</td>
<td>&lt; 2%</td>
<td>Base Down (50%)</td>
</tr>
</tbody>
</table>
QUESTIONS??
How is data collected?

- Observation
- Damage Reports
- Direct Measurement
Typically, the distribution environment is measured with field data recorders that records every potentially hazardous event that occurs during distribution.
Direct Measurement Data Collection

- These tools also will time stamp each occurrence so therefore each specific event can be mapped to a certain time during distribution.
Direct Measurement Data Collection

• Drop data obtained
  – Drop number
  – Drop time
  – Drop orientation
  – Deceleration
    • G levels
  – Pulse duration
  – Velocity change (ΔV) / Drop height
Direct Measurement Data Collection

![Graph showing a time-domain analysis of acceleration](image)

<table>
<thead>
<tr>
<th>Event #</th>
<th>Event Time</th>
<th>Order</th>
<th>Event Type</th>
<th>Acceleration G</th>
<th>Delta V in/sec</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal 1</td>
<td>11/6/2014 1:30:29 PM</td>
<td>0</td>
<td>Shock</td>
<td>119.17</td>
<td>91.23</td>
<td>Flat - Bottom</td>
</tr>
<tr>
<td>Signal 2</td>
<td>11/6/2014 1:31:25 PM</td>
<td>0</td>
<td>Shock</td>
<td>133.18</td>
<td>245.73</td>
<td>Flat - Bottom</td>
</tr>
<tr>
<td>Signal 3</td>
<td>11/6/2014 1:31:26 PM</td>
<td>0</td>
<td>Shock</td>
<td>45.79</td>
<td>80.90</td>
<td>Edge - Bottom Back</td>
</tr>
<tr>
<td>Signal 4</td>
<td>11/6/2014 1:32:05 PM</td>
<td>0</td>
<td>Shock</td>
<td>171.38</td>
<td>292.96</td>
<td>Flat - Bottom</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel</th>
<th>Acceleration G</th>
<th>Duration msec</th>
<th>Delta V in/sec</th>
<th>Max G</th>
<th>Min G</th>
<th>Soft Filter hz</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>19.17</td>
<td>6.40</td>
<td>24.72</td>
<td>19.17</td>
<td>-3.94</td>
<td>---</td>
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<tr>
<td>2</td>
<td>5.48</td>
<td>2.60</td>
<td>-6.89</td>
<td>3.02</td>
<td>-5.48</td>
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<tr>
<td>3</td>
<td>171.38</td>
<td>8.00</td>
<td>292.96</td>
<td>171.38</td>
<td>-20.61</td>
<td>---</td>
</tr>
<tr>
<td>Resultant</td>
<td>171.78</td>
<td>8.00</td>
<td>324.37</td>
<td>171.78</td>
<td>0.03</td>
<td>---</td>
</tr>
</tbody>
</table>
Direct Measurement Data Collection

• Vibration data obtained
  – Overall vibration intensity
  – Intensity at each frequency
  – Active vibration and idle times
  – G levels

Directly Mounted to Truck Bed – NO CUSHIONING
Direct Measurement Data Collection

TIME DOMAIN
Direct Measurement Data Collection

FREQUENCY DOMAIN (SPECTRUM)
Direct Measurement Data Collection

• Temperature and humidity data obtained
  – Max temperature
  – Min temperature
  – Max relative humidity
  – Min relative humidity
### Measured Data Vs Test Standards Utilizing a 25-lb box

<table>
<thead>
<tr>
<th>Study</th>
<th>Average Freefall Drops per Trip</th>
<th>% of Drops Greater than 14”</th>
<th>% of Drops Greater than 36”</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPL (1979)</td>
<td>8</td>
<td>≈ 18%</td>
<td>≈ 6%</td>
</tr>
<tr>
<td>MADE (1996)</td>
<td>19</td>
<td>≈ 5%</td>
<td>&lt; 2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard</th>
<th>Freefall Drops Required</th>
<th>% of Drops Greater than 14”</th>
<th>% of Drops Greater than 36”</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D4169 AL I</td>
<td>12</td>
<td>100% (12 of 12)</td>
<td>8.33% (1 of 12)</td>
</tr>
<tr>
<td>ASTM D7386 AL I</td>
<td>18</td>
<td>100% (18 of 18)</td>
<td>5.56% (1 of 18)</td>
</tr>
<tr>
<td>ISTA 2A</td>
<td>10</td>
<td>100% (10 of 10)</td>
<td>0% (All 32 Inch Drops)</td>
</tr>
<tr>
<td>ISTA 3A</td>
<td>17</td>
<td>100% (17 of 17)</td>
<td>5.88% (1 of 17)</td>
</tr>
</tbody>
</table>

**Why So Different!??**
What About Vibration?!

### Measured Data Vs Test Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Profile 1</th>
<th>Profile 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D4169 AL I</td>
<td>0.73 G rms (Truck)</td>
<td>1.49 G rms (Air)</td>
</tr>
<tr>
<td>ASTM D7386 AL I</td>
<td>0.54 G rms (Over the Road)</td>
<td>0.46 G rms (Pickup and Delivery)</td>
</tr>
<tr>
<td>ISTA 2A</td>
<td>1.15 G rms</td>
<td>n/a</td>
</tr>
<tr>
<td>ISTA 3A</td>
<td>0.54 G rms (Over the Road)</td>
<td>0.46 G rms (Pickup and Delivery)</td>
</tr>
</tbody>
</table>
Conclusions

• Define your distribution environment to properly package your product!!
#1: Overview and Definition of Terms – Jan 2015  DONE!

#2: Defining & Quantifying the Distribution Environment Through Which All Products Must Travel – March 2015  DONE!

#3: Determining the Vibration Sensitivity & Shock Fragility of Products; Test Methods, End Results, and Significant Insights – May 2015


#5: Design and Testing of the Protective Package System; How We Know When the Job Was Done Correctly – Oct 2015
About WESTPAK, INC.

Two Locations:

San Jose Laboratory
83 Great Oaks Boulevard
San Jose, CA 95119
408-224-1300

San Diego Laboratory
10326 Roselle Street
San Diego, CA 92121
858-623-8100

www.westpak.com/

Contact Us
THANK YOU!

Please feel free to Contact Us with any questions or assistance with your testing needs.

Herb Schueneman
President & CEO

Edmund Tang
Laboratory Manager