ECE 510, Lecture 10
Plastic Package Reliability, and Qualification Methodology

Glenn Shirley
Scott Johnson
Outline

- Plastic Packages
  - Stress and Test Flows
  - Thermal Mechanisms
  - Moisture Mechanisms
  - Thermo-mechanical Mechanisms
  - Moisture-mechanical Mechanisms
  - Technology Update
Plastic-Encapsulated Microcircuits

- The course covers plastic-encapsulated microcircuits.
- Molding compound (MC) in PEMs comes in direct contact with the die and chip connections.
Plastic-Encapsulated Microcircuits

- Die is mounted on a lead frame (A42 or Cu).
- Bonds are made by.
  - Wirebond: Au or Al; mostly Au.
  - TAB: Tape-Automated Bonding.
  - C4: Controlled Collapse Chip Connect.
- Assembly is encapsulated in molding compound.
  - Molding compound is in direct contact with die, wire bonds, etc.
- External leads are trimmed and solder plated.

Alloy 42
Fe 58% Ni 42% alloy with CTE matching Si.
Molding Compounds

• MC is thermoset (curing) epoxy, typically novolac.
  – Cures at ~ 170-180°C.
  – Silica “filler” controls CTE and increases thermal conductivity.
  – MCs are (now) free of ionic contaminants.

• Glass Transition ~ 140°C.

• Moisture properties of MC:
  – Permeable to moisture.
  – Absorbs moisture. “Hygroscopic.”

Note distinction between thermoset and thermoplastic.
Molding Compound Properties

- At the glass transition (> 140 °C).

**MC strength decreases**

**CTE increases**

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**FIGURE 4-16** Shear modulus versus temperature data for an epoxy molding compound. Data show the effect of postcure on the thermomechanical properties. Frequency is 1 rad/sec.

**FIGURE 4-1** A plot of expansion versus temperature for an epoxy molding compound. The dashed line is the temperature derivative of expansion, which is defined as the coefficient of thermal expansion. Note the higher CTE above the glass transition temperature.

Molding Compound Properties, ct’d

• Molding compound strongly absorbs water.
  – *Saturation* uptake is proportional to RH, and *independent of temperature*.
  – *Rate* of uptake *depends strongly on temperature*.

![Graph](image)

**Figure 4-24** Plot of water uptake of epoxy molding compound preforms as a function of relative humidity of the conditioning atmosphere after three weeks of exposure at room temperature. K. Fisher is a hydrolysis technique for measuring water content. (Data of D. J. Boyle, J. T. Ryan and H. E. Bair, AT&T Bell Laboratories.)

Outline

• Plastic Packages
• Stress and Test Flows
• Thermal Mechanisms
• Moisture Mechanisms
• Thermo-mechanical Mechanisms
• Moisture-mechanical Mechanisms
• Technology Update
Life of an Integrated Circuit

Assembly → Shipping → Storage → OEM/ODM Assembly → End-user Environment

- Desktop
  - Shipping Shock
  - Temperature Cycle
  - Bend
  - Reflow
  - Handling
  - Temp, RH
  - Bent Pins, Singulation
  - Power Cycle

- Mobile PC
  - Shipping Shock
  - Temperature Cycle
  - Bend
  - Reflow
  - Handling
  - Temp, RH
  - Bent Pins, Singulation
  - User Drop & Vibe
  - Power Cycle

- Handheld
  - Shipping Shock
  - Temperature Cycle
  - Bend
  - Reflow
  - Handling
  - Temp, RH
  - Bent Pins, Singulation
  - User Drop & Vibe
  - Keypad press

Source: Eric Monroe, 2003

Slide by Scott C. Johnson.
Stress/Test Flow

1) Base Component Reliability

2) Base Board Reliability

3) 2nd Level Interconnect

Preconditioning

Environmental Stress

Electrical Test, Failure Analysis

Simulate shipping, storing, and OEM board mounting process.

Simulate in-service end use conditions.

Determine pass/fail. Diagnose failures.

From: JEP150 “Stress-Test-Driven Qualification of and Failure Mechanisms Associated with Assembled Solid State Surface-Mount Components” (JEDEC)
Industry Reliability Standards

• International
  – ISO International Standard Organization
  – IEC International Electrotechnical Commission

• Europe
  – CEN, CENELEC Comité Européen de Normalisation Électrotechnique

• Japan
  – JIS Japanese Industrial Standard, EIAJ

• US
  – MIL (US Department of Defense), EIA/JEDEC

For US commercial products JEDEC standards have mostly superseded MIL standards.
Preconditioning

- Preconditioning simulates board assembly.
- Specified by

http://www.jedec.org/

Free downloads, registration required.
### Preconditioning Flow

#### JESD22-A113F

**Annex A Typical Preconditioning Sequence Flow**

<table>
<thead>
<tr>
<th>Step</th>
<th>Item</th>
<th>Details</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial Electrical</td>
<td>- Replace any failing devices</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Test</td>
<td>- Optional for testing by Supplier</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Visual Inspection</td>
<td>- Replace any failing devices</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by Supplier</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Temperature Cycling</td>
<td>- 5 cycles -40 °C to 60 °C</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional shipping simulation based on product requirements</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bake</td>
<td>- 24 h at 125 °C</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by Supplier</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Moisture Soak</td>
<td>- Soak time and conditions per IPC/JEDEC J-STD-020 based on device MSL level</td>
<td>4.5</td>
</tr>
<tr>
<td>6</td>
<td>Reflow</td>
<td>- 5 reflow cycles using profile per IPC/JEDEC J-STD-020, document rev of J-STD-020 used</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- SnPb or Pb-free profile based on device end use process</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Flux Application</td>
<td>- 10 s full immersion dip in activated water soluble flux</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by User or second level configuration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Not required for BGA, CGA and LGA packages</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cleaning</td>
<td>- DI water rinse</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Remove all flux residual</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by User or second level configuration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Not required for BGA, CGA and LGA packages</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Drying</td>
<td>- Room ambient drying</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by User or second level configuration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Not required for BGA, CGA and LGA packages</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Final Electrical Test</td>
<td>- If all devices pass then ready for Reliability Testing</td>
<td>4.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- If valid failures are found then devices may have been tested to the wrong MSL level or something is substandard with the devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optional for testing by Supplier</td>
<td></td>
</tr>
</tbody>
</table>
Environmental Test

- Stress-based testing (traditional).
  - Pro:
    • Well-established standards. Lots of historical data. Good for comparisons.
    • Little information about mechanism or use is required.
  - Con:
    • Overstress: May foreclose a technology.
    • Understress: Misses a mechanism.
      – May not accurately reflect a use environment.

- Knowledge-based testing.
  - Risk assessment of Use and Mechanism guides test.

To keep things simple, we’ll follow this approach.
Knowledge-Based Test

• Knowledge-Based Testing
  – Stress depends on knowledge of use conditions and mechanisms.
  – Risk assessment, using methods
    • JEDEC: JESD94, JEP143, JEP148
    • Sematech: “Understanding and Developing Knowledge-based Qualifications of Silicon Devices” #04024492A-TR

  – Pro:
    • Stresses fit the product and its use. May make a product feasible.

  – Con:
    • Easy to miss mechanisms in new technologies and overlook use conditions in new applications.
    • Tempting to misapply to “uprate” devices, relax requirements.
### 5.5 Device qualification requirements

<table>
<thead>
<tr>
<th>Stress</th>
<th>Ref.</th>
<th>Abbv.</th>
<th>Conditions</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temperature Operating Life</td>
<td>JESD22-A108 &amp; JESD22-A109</td>
<td>HTOL</td>
<td>Tj ≥ 125 °C &amp; Vcc ≥ Vccmax</td>
<td>3 Lots / 77 units</td>
</tr>
<tr>
<td>Early Life Failure Rate</td>
<td>JESD22-A108 &amp; JESD22-A109</td>
<td>ELFR</td>
<td>Tj ≥ 125 °C &amp; Vcc ≥ Vccmax</td>
<td>See ELFR Table</td>
</tr>
<tr>
<td>Low Temperature Operating Life</td>
<td>JESD22-A108 &amp; JESD22-A109</td>
<td>LTOL</td>
<td>Tj ≥ 50 °C &amp; Vcc ≥ Vccmax</td>
<td>1 Lot / 32 units</td>
</tr>
<tr>
<td>High Temperature Storage Life</td>
<td>JESD22-A103 &amp; JESD22-A104</td>
<td>HTSL</td>
<td>Ta ≥ 150 °C</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Non-Volatile Memory Cycling Endurance</td>
<td>JESD22-A117 &amp; JESD22-A118</td>
<td>NVCE</td>
<td>25 °C and 85 °C 2T ≥ 55 °C</td>
<td>3 Lots / 77 units</td>
</tr>
<tr>
<td>Data Retention for Non-Volatile Memory: High Temperature</td>
<td>JESD22-A117 &amp; JESD22-A118</td>
<td>HTDR</td>
<td>Option 1: Tj = 100 °C</td>
<td>3 Lots / 39 units</td>
</tr>
<tr>
<td>Non-Volatile Memory Low-Temperature Retention and Read Disturb</td>
<td>JESD22-A117 &amp; JESD22-A118</td>
<td>LTDR</td>
<td>Ta = 25 °C</td>
<td>3 Lots / 38 units</td>
</tr>
<tr>
<td>Latch-Up</td>
<td>JESD78</td>
<td>LU</td>
<td>Class I or Class II</td>
<td>1 Lot / 3 units</td>
</tr>
<tr>
<td>Electrical Parameter Assessment</td>
<td>JESD86</td>
<td>ED</td>
<td>Datasheet</td>
<td>3 Lots / 10 units</td>
</tr>
<tr>
<td>Human Body Model ESD</td>
<td>JESD-801</td>
<td>ESD-801</td>
<td>Ta = 25 °C</td>
<td>3 units</td>
</tr>
<tr>
<td>Charged Device Model ESD</td>
<td>JESD22-802</td>
<td>ESD-802</td>
<td>Ta = 25 °C</td>
<td>3 units</td>
</tr>
<tr>
<td>Accelerated Soft Error Testing</td>
<td>JESD89-2 &amp; JESD89-3</td>
<td>ASER</td>
<td>Ta = 25 °C</td>
<td>3 Lots / 3 units</td>
</tr>
<tr>
<td>System Soft Error Testing</td>
<td>JESD80-1 &amp; JESD80-2</td>
<td>SSER</td>
<td>Ta = 25 °C</td>
<td>Minimum of 15±66 Devices Hrs or 10 fails</td>
</tr>
</tbody>
</table>

Note: TS (JESD22-A106) and AC (Steam) (JESD22-A102) are not recommended. Very different from use.

### 5.6 Nonhermetic package qualification test requirements

<table>
<thead>
<tr>
<th>Stress</th>
<th>Ref.</th>
<th>Abbv.</th>
<th>Conditions</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSL Preconditioning Must be performed prior to: THB, HAST, TC, AC, &amp; UHAST</td>
<td>JESD22-A113</td>
<td>PC</td>
<td>Per appropriate MSL level per J-STD-020</td>
<td>Electrical Test (optional)</td>
</tr>
<tr>
<td>High Temperature Storage</td>
<td>JESD22-A103 &amp; JESD22-A113</td>
<td>HTSL</td>
<td>150 °C + Preconditioning if Required</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Temperature Humidity Bias (standard 85% RH)</td>
<td>JESD22-A103</td>
<td>THB</td>
<td>85 °C, 85% RH, Vccmax</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Temperature Humidity Bias (Highly Accelerated Temperature and Humidity Stress)</td>
<td>JESD22-A110 &amp; JESD22-A111</td>
<td>HAST</td>
<td>130 °C / 110 °C, 85% RH, Vccmax</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Temperature Cycling</td>
<td>JESD22-A104</td>
<td>TC</td>
<td>8 °C to +35 °C to +125 °C</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Temperature Humidity (Autoclave)</td>
<td>JESD22-A116</td>
<td>UHAST</td>
<td>130 °C / 85% RH / 110 °C / 85% RH</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Temperature-Humidity (Autoclave)</td>
<td>JESD22-A102</td>
<td>AC</td>
<td>121 °C / 100% RH</td>
<td>3 Lots / 25 units</td>
</tr>
<tr>
<td>Solder Ball Shear</td>
<td>JESD22-A117</td>
<td>SBS</td>
<td>Characterization</td>
<td>30 balls / 5 units</td>
</tr>
<tr>
<td>Bond Pull Strength</td>
<td>M2011</td>
<td>BPS</td>
<td>Characterization, Pre Encapsulation</td>
<td>30 bonds / 5 units</td>
</tr>
<tr>
<td>Bond Shear</td>
<td>JESD22-A108</td>
<td>BS</td>
<td>Characterization, Pre Encapsulation</td>
<td>30 bonds / 5 units</td>
</tr>
<tr>
<td>Solderability</td>
<td>M2003</td>
<td>SBS</td>
<td>Characterization</td>
<td>3 lots / 22 loads</td>
</tr>
<tr>
<td>Tin Whisker Acceptance</td>
<td>JESD22-A121</td>
<td>WSR</td>
<td>Characterization per JESD 201</td>
<td>See JESD 201</td>
</tr>
</tbody>
</table>
Example Stress Flow

This lecture.

ELFR

Early life failure rate.
168 hrs
JESD22-A108

Assumptions
168 h is equivalent to early life requirement
SS computed from goal. eg. 3x611 = 1833

Preconditioning. JESD22-A113

Environmental Stress

Electrical Test, Failure

Analysis

(3 x 77)

High temperature operating life.
168 -1000 hrs
JESD22-A108

HTOL

HTSL (Bake)

1000 hrs
JESD22-A103

HTSL (Bake)

1000 hrs (85/85)
JESD22-A101

TC

700 cycles
3 cycles/hr
233 hrs
JESD22-A104

Condition B or G
(C is too severe)

THB or HAST

1000 hrs (130/85)
JESD22-A110

Preconditioning.
Sampling

- **JESD47** sample requirements are minimal.
  - Single “snapshot” is a crude validation of the reliability of the product.
  - Small SS does not generate failures to give clues to process weaknesses.

- **Risks.**
  - Qualification hinges on single failures.
    - Moral hazard to “invalidate” a failure is high.
  - Lot-to-lot variation, excursions.
    - Incoming materials, fab lots, assembly lots, test lots.
Sampling, ct’d

• Number of lots covers risks of machine-to-machine, day-to-day, etc. variation.

• Often minimum SS to validate a goal is chosen.
  – Pro: Saves $, and there are no failures to explain.
  – Con: Pass/fail of the qual is at the mercy of a single failure.
    • Verrry tempting to invalidate a failure.
  – Con: No mechanism learning. (Accept/Reject ⇒ 0/1)

• eg. To validate 500 DPM at ELFR using minimum SS at 60% confidence, 1833 units are required.
  – 500 DPM is a typical goal (see ITRS)

\[
SS = \frac{-\ln(1 - cl)}{D}
\]

Useful “mental furniture”

\[
1833 = \frac{-\ln(1 - 0.6)}{500 \times 10^{-6}}
\]
Sampling, ct’d

• For environmental stress, 3x77 is a typical SS, why?

\[
\text{Fail Fraction UCL} = \frac{-\ln(1 - cl)}{3 \times 77} \text{; } \frac{-\ln(1 - 0.9)}{231} = \frac{-\ln(0.1)}{231} = \frac{2.3026}{231} = 1%
\]

— So, 0/1 accept/reject validates, to 90% confidence, a failure rate less than 1% at the accelerated condition.

• If the stress corresponds to the lifetime (eg. 7 years) then the average failure rate is

\[
FR = \frac{1 \times 10^{-2}}{7 \times 365 \times 24} \times 10^9 = 163 \text{ Fits}
\]

— This falls into the range of ITRS wearout goals.
### Table PIDS6  Reliability Technology Requirements

<table>
<thead>
<tr>
<th>Year of Production</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAM 1/2 Pitch (μm) (contacted)</td>
<td>52</td>
<td>45</td>
<td>40</td>
<td>36</td>
</tr>
<tr>
<td>MPU/ASIC Metal 1 (M1) 1/2 Pitch (μm)</td>
<td>54</td>
<td>45</td>
<td>38</td>
<td>32</td>
</tr>
<tr>
<td>Moore's physical gate length (μm)</td>
<td>25</td>
<td>24</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Long term reliability (FITs = failures in 1E9 hours) [2]</td>
<td>1.1000</td>
<td>1.1000</td>
<td>1.1000</td>
<td>1.1000</td>
</tr>
<tr>
<td>SRAM Soft error rate (FITs/MBit) [3]</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
</tr>
<tr>
<td>Relative failure rate per transistor (normalized to 2009 value) [4]</td>
<td>1.000</td>
<td>0.71</td>
<td>0.50</td>
<td>0.35</td>
</tr>
<tr>
<td>Relative failure rate per meter of interconnect (normalized to 2009 value) [5]</td>
<td>1.00</td>
<td>0.50</td>
<td>0.50</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Infant Mortality**

**Wear-out**

**Constant fail rate**

http://www.itrs.net/reports.html
<table>
<thead>
<tr>
<th>Reliability Calculator</th>
<th>Fail Fraction Calculator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence (%)</td>
<td>60</td>
</tr>
<tr>
<td>Number of Failures</td>
<td>1</td>
</tr>
<tr>
<td>Device Hours</td>
<td>200</td>
</tr>
<tr>
<td>FR (%/h)</td>
<td>1.01</td>
</tr>
<tr>
<td>FR (%/kh)</td>
<td>1011.16</td>
</tr>
<tr>
<td>FITs</td>
<td>10111566.23</td>
</tr>
<tr>
<td>Number of Units</td>
<td>200</td>
</tr>
<tr>
<td>Fail %</td>
<td>1.01</td>
</tr>
<tr>
<td>DPM</td>
<td>10111.57</td>
</tr>
</tbody>
</table>
Excel Reliability Calculator

• Handy tool for quick calculations.
• Has user-functions “binomial upper/lower confidence limits (one-sided)” that can be used in a worksheet.
• Doubles as a failure rate calculator if the sample size is taken as device hours.
  – Used for calculating average failure rates (AFR).
• Failure rates are computed assuming constant failure rate. FR = # Fails ÷ Device Hours.
Best Estimate AFR

• A “best estimate” defined in TT is

\[ AFR_{BE} = \frac{\text{Number of Failures}}{\text{Device Hours}} \]

\[ \text{Device Hours} = \text{Hours of Stress} \times \text{Number of Devices} \]

• Reliability Ruler Best Estimate
  – Because of the difficulty with zero failures, the reliability ruler uses the 50% one-sided UCL as the best estimate.
  – BUCL1(Number of Failures, Device Hours, 0.5)

• There are uses for either way of specifying “BE”.
  – Neither is “wrong”.

Homework 10

• Use “Rel Ruler” to answer the following 3 questions.
  – Type and explain answers on a copy of the rel ruler tool and send in the tool.

1. The goal for 1000 h of 85/85 testing is 1% or less.
  – What is the minimum sample size to validate the goal at 90% confidence?
  – What is the accept on 1, fail on 2 SS at 90% confidence?

2. The goal for ELFR is AFR < 1000 FITs in the first year.
  – What is the minimum sample size to validate the goal at 90% confidence?
  – What is the accept on 1, fail on 2 SS at 90% confidence?
3. 100 units are stressed for 1000 hours, failures occur at 100 hours, 400 hours, 700 hours. (An example of “time-censored” data, or “Type I censoring”.)

– Compute the following estimates of the average failure rate: BE(TT), BE(50% UCL), 60% UCL, 90% UCL
Example Data

- Additional attributes enhance value of data.
  - Device type
  - Date code
  - Package type
  - Readouts
  - Failure analysis

Maxim product reliability report RR-1H
Test and Failure Analysis

- Moisture-related tests (85/85, HAST, Steam) have specific test/FA reqt’s.
  - Test must be done while unit contains moisture.
    - Within 48 hr.
  - Units must not be “wet”.
    - Wet = liquid water.
- Diagnostic Bake.
- Risk decision before destructive analysis.
HAST versus 85/85

• Moisture MUST be non-condensing. (RH < 100%).
• Both require about < 1% fail. Typical SS ~ 100.
• 130/85 HAST duration is 10x less than 85/85 duration. We’ll see how this was justified.

• 85/85 (JESD22-A101)

<table>
<thead>
<tr>
<th>Temperature (dry bulb °C)</th>
<th>Relative Humidity (%)</th>
<th>Temperature (wet bulb, °C)</th>
<th>Vapor Pressure (psia/kPa)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 ± 2</td>
<td>85 ± 5</td>
<td>81.0</td>
<td>7.12/49.1</td>
<td>1000(-24,+168)</td>
</tr>
</tbody>
</table>

• HAST (JESD22-A110)

<table>
<thead>
<tr>
<th>Temperature (dry bulb °C)</th>
<th>Relative Humidity (%)</th>
<th>Temperature (wet bulb, °C)</th>
<th>Vapor Pressure (psia/kPa)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130 ± 2</td>
<td>85 ± 5</td>
<td>124.7</td>
<td>33.3/230</td>
<td>96 (-0,+2)</td>
</tr>
<tr>
<td>110 ± 2</td>
<td>85 ± 5</td>
<td>105.2</td>
<td>17.7/122</td>
<td>264 (-0,+2)</td>
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</table>

\[
\frac{33.3 - 14.2}{14.2} = 1.34 \text{ atmospheres} \Rightarrow \text{Pressure vessel required.}
\]

6 week bottleneck in information turns.

10x less time

Winter 2013 ECE 510 C. G. Shirley, S. C. Johnson
# Example: Comparison of HAST Stds

<table>
<thead>
<tr>
<th>Table 4-9 Reliability Test Standards Comparison Table</th>
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<tbody>
<tr>
<td><strong>Sony</strong></td>
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**Intermittent Bias**

- Power-on guidelines: Minimum power consumption
- Apply alternating pins as much as possible
- Apply a potential difference to the entire metal wiring
- Apply the maximum allowable voltage
- Continuous power-on when the thermal loss is 200 mW or less or when the die pad temperature rise is 10°C or less
- Intermittent cycles at 50% duty (Power-on:Power-off = 1:1)
- 1 cycle period
  - t ≥ 2 mm: 2 h or less
  - t < 2 mm: 30 minutes or less (t: package thickness)

**Test and Failure Analysis Window**

- The temperature and humidity until arrival at the test conditions are prescribed.
- Measure within 48 h after placing in and removing from the chamber, and apply stress within 96 h. The time provision is relaxed to 3 times for storage using bags to prevent the escape of humidity.

From Sony Quality and Reliability Handbook

http://www.sony.net/Products/SC-HP/tec/catalog/qr.html
HAST System

• Large vessel (24” dia) requires forced convection.

![Diagram of HAST System]

Fig. 3 The NG HAST chamber operates on the principle of forced convection. This ensures efficient mixing, minimizing temperature gradients across the test volume. Reliability of the fan drive is ensured by a proven design of magnetic coupling feed through.

HAST System
HAST Development Team
HAST Ramp Up Requirements

- Ramp Up: Avoid condensation on load.

Fig. 4  Full-load ramp-up profile to 155/85 before (top) and after (bottom) optimization of fan. After optimization, the wet-bulb temperature is always below temperature at any point in the load.
HAST Ramp-Down Requirements

- Mechanical pressure relief must be slow (3 h).
- Vent when pressure reaches 1 atm.
- Hold RH at test value.
  - Units must retain moisture acquired during test.

![Graph showing temperature and humidity changes over time]
Vapor Pressure and Relative Humidity

Log scale

Temp (°C)

Pressure (Atm)

Coexistence of liquid and vapor

Q = 0.42 eV

Liquid Water

Water Vapor

Linear in 1/T (°K), with ticks placed at T (°C).
Vapor Pressure and Relative Humidity

\[ H = \frac{\text{Actual water vapor pressure at temperature } T}{\text{Saturated water vapor pressure at temperature } T} \]

or \[ P_{H_2O} = H \times P_{\text{sat}}(T) \]

What is \( P_{\text{sat}} \)?

\[ P_{\text{sat}}(T) = P_0 \exp\left(-\frac{\lambda M}{RT}\right) = P_0 \exp\left(-\frac{Q_P}{kT}\right) \quad Q_P = \frac{k\lambda M}{R} = 0.42 \text{ eV} \]

Where

\( \lambda = 2262.6 \text{ joule/gm} \) (latent heat of vaporization)

\( M = 18.015 \text{ gm/mole}, \quad R = 8.32 \text{ joules/(mole K)}, \quad k = 8.617 \times 10^{-5} \text{ eV/K} \)

This is a fair approximation. The main benefit is physical insight.
An accurate formula for $P_{\text{sat}}$ (in Pascals) is

$$P_{\text{sat}} (T) = 1000 \times \exp \left( \sum_{n=0}^{3} a_n \times x^n \right), \quad x = \frac{1}{273 + T(\degree C)}$$

$$a_0 = 16.033225, \quad a_1 = -3.5151386 \times 10^3, \quad a_2 = -2.9085058 \times 10^5, \quad a_3 = 5.0972361 \times 10^6$$

which is accurate to better than 0.15% in the range $5 \degree C < T < 240 \degree C$.

1 atm = 101325 pascals

This is an accurate formula.
Vapor Pressure and Relative Humidity

- Relative humidity at “hot” die in steady state.
  - Partial pressure of water vapor is the same everywhere:
    \[ P_{H_2O}(\text{die}) = P_{H_2O}(\text{ambient}) \]
  - So RH at die is given by:
    \[ H(\text{die}) \times P_{\text{sat}} \left( T_{\text{ambient}} + \Delta T_{ja} \right) = H(\text{ambient}) \times P_{\text{sat}} \left( T_{\text{ambient}} \right) \]
  - or
    \[ H(\text{die}) = H(\text{ambient}) \times \frac{P_{\text{sat}} \left( T_{\text{ambient}} \right)}{P_{\text{sat}} \left( T_{\text{ambient}} + \Delta T_{ja} \right)} \]