Challenges with MSD Components and its Future

Ankan Mitra, SMTA India Chapter
SMTA Luncheon Meeting 26th October 2013
Hello Bangalore, How do you do?

Hello Bengaluru कसे आहात?

Hello bengaluru कसे आहात?

Hello Bengaluru तमे केवी रीते छ?

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SMTA Kick-Off Meeting

Create a technology platform

- Ensure SME growth to enhance Indian Supplier base
- Bring in Advanced Electronics Manufacturing best practices
India

Bangalore, India

Chapter News

Download slides and view photos from the Kick-Off Meeting
System Reliability and Challenges of Electronics Industry
Panjay Bansod, Debold, India

Frontiers in Electronics Manufacturing
Ankan Mita, Universal Electronics Training

PCB vs PCB Assembly Challenges & Solutions
Richard Puthoda, A怡ent - India

Alloy Element Analysis
Ryakathari Koorthodi, Indum Corporation
Agenda

- Introduction
- What are Moisture Sensitive Devices?
- Standards
- Typical Components at Risk
- Moisture Accumulation & Failure Mechanisms
- Critical Manufacturing Processes
- Non-Critical Assembly Process
- How MSD Level is determined
- MSD Levels & Floor Life Derating
- MSD Terminologies
- Shelf-Life of MSD Components
- Equipments related to MSD Compliance
- Retrieval Procedure of MSD Components
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Introduction: MSD

- Moisture Sensitive Device

- Surface Mount Devices

- Needs protection from environmental and factory moisture

- Component with moisture can become a major issue on Surface Mount Assembly
  - Reflow Soldering
  - Rework Operations
Introduction: MSD

- Increasing challenges with MSD components:
  - Continuous change in Packaging Technology
  - Increased temperatures with Lead-free soldering
Introduction: MSD

Key Take-aways:

- Proper Handling of Moisture Sensitive Devices
- What is Moisture sensitive?
- Why this can be a problem during Reflow Soldering/Rework?
- Materials used to protect MSDs
- How to prevent problems from occurring with MSDs
- What is a Moisture Sensitive Device?
Agenda

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What are Moisture Sensitive Devices?

**Moisture Sensitive Components** are referring to those **plastic molded** package IC, normally big size or thin packages, when left in the open air environment over a period of time will **absorb moisture** (water) from the air.

The moisture traps in the plastic molded package will cause process and reliability problem later during reflow process.

Electronic components encapsulated with plastic compounds and other organic materials that allow moisture from the atmosphere to enter the permeable package.
What are Moisture Sensitive Devices?

- There is no perfect seal between the Integrated Circuit die, the other interfaces and the package that surrounds it.

- These type of components are called non-hermetically sealed components.
What are Moisture Sensitive Devices?

I am MSD like to eat the moistures so much.

We are moisture in the air.

Any electronics devices which able to absorb or sensitize the moisture are classified as MSD.
What are Moisture Sensitive Devices?

Component Package Type

NON-HERMETIC PACKAGE = MSD

HERMETIC PACKAGE = Non-MSD
Standards

- Moisture Sensitive Device Management Technology

- Standards cover all aspects of the chain of Moisture Sensitive devices as well as its classification
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Standards

Rather than asking why we need standards, we might usefully ask ourselves what the world would be like without standards.

- Products might not work as expected
- Products may be of inferior quality
- Products incompatible with other equipment
- Non-standardized products may even be dangerous
- Standards bring in user 'confidence builders'

- Foundation for innovative communication features
- Opportunity to share and enhance existing practices
- Pivotal role in assisting Regulations
Standards

Why do we need a Standard?

• Help assure consistency of MSD sensitive products and consistency of MSD control products and services.

• Provides a means of objective evaluation and comparison among competitive MSD control products.

• Helps reduce conflicts between users and suppliers of MSD control products.

• Helps in developing, implementing, auditing, and certifying MSD control programs.

• Reduces confusion in the marketplace.

Use of standards is voluntary, although their use can be written into contracts or purchasing agreements between buyer and seller.
Standards

- 2 Principal Joint Standards of IPC-JEDEC

IPC/JEDEC J-STD-020C

- Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices

IPC/JEDEC J-STD-033B.1

- Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
Standards

- 2 other IPC Standards for MSD Components

**IPC-9503**
- Moisture Sensitivity Classification for Non-IC Components

**IPC-M-109**
- Component Handling Manual
Standards

- Standard for Symbols and Labels

JEP-113

- Symbol and Labels for Moisture Sensitive Devices
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Typical Components at Risk

- SOIC
Typical Components at Risk

- QFP
Typical Components at Risk

- PLCC
Typical Components at Risk

- BGA
Typical Components at Risk

- SMD LEDs
Typical Components at Risk

- PCB
Typical Components at Risk

- PCBAs – prior to rework
Typical Components at Risk

- In general, surface-mount devices (SMD's) are more prone to popcorn cracking
  - are thinner and therefore has lower fracture strength
  - absorb and retain moisture more easily
  - SMD board mounting also subjects the molding compound to the high temperature experienced by the leads
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Moisture Accumulation & Failure Mechanisms

- Considerations for Moisture Accumulation
  - Relative Humidity in the environment
  - Temperature
  - Duration of exposure of MSD components
  - Physical properties of the package materials
Moisture Accumulation & Failure Mechanisms

- **Failure Mechanism**

  - **Product failed in functions and/or long term reliability**
  
  - **Crack and/or delamination at die, lead-frame inside and/or outside of the package**
  
  - **Combination of rapid moisture expansion (vaporizing), material mismatch, material interface degradation**
  
  - **Moisture from atmosphere humidity enters to permeable component package**
  
  - **Entire package on printed-circuit-board heated up by <200°C from any type of soldering**
Moisture Accumulation & Failure Mechanisms

- Moisture Vapor Pressure is the key reason for failure of MSD components
- This gives “pop” sound when MSD components fail
Moisture Accumulation & Failure Mechanisms

- Even more prone to higher failure during Lead-free soldering due to higher temperatures
Moisture Accumulation & Failure Mechanisms

- What is the problem with moisture traps in the IC packages?

  During reflow process, the PCB with the IC mounted are sent through the reflow oven with the temperature gradually increases to as high as 230 °C or more. The moisture traps in the IC package will expand, evaporate and escape. When the moisture level is high, it will cause the IC to have micro-crack or the silicon chip may be lifted (pop-con) and other reliability problems.

- Defects created could be either catastrophic failure or latent failure.
Moisture Accumulation & Failure Mechanisms

- Reflow Profile Classification

![Reflow Profile Classification Diagram](image)

Extract from J-STD-020C
Moisture Accumulation & Failure Mechanisms

- Reflow Profile Classification

<table>
<thead>
<tr>
<th>Profile Feature</th>
<th>Sn-Pb Eutectic Assembly</th>
<th>Pb-Free Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average ramp-up rate (Tsmax to Tp)</td>
<td>3° C/second max.</td>
<td>3° C/second max.</td>
</tr>
<tr>
<td><strong>Preheat</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Temperature Min (Ts_min)</td>
<td>100 °C</td>
<td>150 °C</td>
</tr>
<tr>
<td>- Temperature Max (Ts_max)</td>
<td>150 °C</td>
<td>200 °C</td>
</tr>
<tr>
<td>- Time (Ts_min to Ts_max) (ts)</td>
<td>60-120 seconds</td>
<td>60-180 seconds</td>
</tr>
<tr>
<td>Time maintained above:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Temperature (T_L)</td>
<td>183 °C</td>
<td>217 °C</td>
</tr>
<tr>
<td>- Time (t_L)</td>
<td>60-150 seconds</td>
<td>60-150 seconds</td>
</tr>
<tr>
<td>Peak Temperature (Tp)</td>
<td>See Table 4.1</td>
<td>See Table 4.2</td>
</tr>
<tr>
<td>Time within 5°C of actual Peak Temperature (tp)</td>
<td>10-30 seconds</td>
<td>20-40 seconds</td>
</tr>
<tr>
<td>Ramp-down Rate</td>
<td>6 °C/second max.</td>
<td>6 °C/second max.</td>
</tr>
<tr>
<td>Time 25°C to Peak Temperature</td>
<td>6 minutes max.</td>
<td>8 minutes max.</td>
</tr>
</tbody>
</table>

**Note 1:** All temperatures refer to topside of the package, measured on the package body surface.

**Note 2:** Time within 5 °C of actual peak temperature (tp) specified for the reflow profiles is a “supplier” minimum and “user” maximum.

Extract from J-STD-020C
Exposure to high temperatures can result in Package Cracking
Moisture Accumulation & Failure Mechanisms

- Delamination of internal interfaces within the package
Moisture Accumulation & Failure Mechanisms

- Delamination of internal interfaces within the package
Moisture Accumulation & Failure Mechanisms

- Popcorning
Moisture Accumulation & Failure Mechanisms

- Internal damages in the die or interfaces can not be identified through external visual inspection

- The damage can result in a latent failure also, in that case the partially damaged assembly has high reliability issues in the field
Moisture Accumulation & Failure Mechanisms

- Moisture Absorption During Storage
- Moisture Vaporizing During Heating
Moisture Accumulation & Failure Mechanisms

- Moisture saturates the package to a level determined by storage RH, temperature, time and plastic moisture equilibrium solubility.
Moisture Accumulation & Failure Mechanisms

- Vaporization of entrapped moisture and plastic expand during heat up then delamination and crack. It is directly impact to product functionality and also long run reliability.
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Critical Manufacturing Processes

- Mass Reflow Soldering

All components on PCB heated up.
Critical Manufacturing Processes

- Localized Reflow Soldering or Hot Air Rework

Heat up on specific device to be reworked.
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Non-Critical Assembly Process

- **Point to Point Soldering**
  
  Only leads to be soldered by iron tip.

- **Wave Soldering or Solder Fountain**
  
  Leads exposed in molten solder
Non-Critical Assembly Process

- **ERSA Selective Soldering**
  - Molten solder nozzle used.

- **Socketed Components**
  - MSD put into socket after soldering.
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How MSD Level is determined

- **IPC-SM-786**
  - Procedures for Characterizing and Handling of Moisture/Reflow Sensitive ICs

- **IPC-TM-650 Test Methods Manual**
  - 2.1.1 Microsectioning
  - 2.1.1.2 Microsectioning-Semi or Automatic Technique Microsection Equipment (Alternate)
How MSD Level is determined

- IPC/JEDEC J-STD-020D.1
  - Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
    - Performance in the Qualification Reflow Profile (as per Package Thickness and application)
    - Verification: Visual Inspection (40x)
    - Verification: Electrical Test
    - Verification: Delamination
    - Analysis: Weight Gain/Loss (Moisture)
How MSD Level is determined

- IPC/JEDEC J-STD-020D.1 Classification Process Flow

Perform Initial Visual, Electrical & Acoustic Microscopy Moisture Loading, Reflow Simulation

- Pass Electrical Test?

- No

FAIL Classification for Level Tested

- Yes

External Visual Inspection

- External Cracks?

- No

Evaluate/Obtain Internal Damage Information
Acoustic Microscopy Images, Cross-sections, etc.

- Yes
How MSD Level is determined

- IPC/JEDEC J-STD-020D.1 Classification Process Flow

Evaluate/Obtain Internal Damage Information
Acoustic Microscopy Images, Cross-sections, etc.

- Crack or Delamination?
  - No

- Crack or Delamination Change (Other Than Heat Spreader or Backside Paddle)?
  - No

PASS Classification for Level Tested
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# MSD Levels & Floor Life Derating

## Table 5-1 Moisture Sensitivity Levels

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>FLOOR LIFE</th>
<th>SOAK REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td>TIME</td>
<td>CONDITIONS</td>
</tr>
<tr>
<td>1</td>
<td>Unlimited</td>
<td>≤30 °C/85% RH</td>
</tr>
<tr>
<td>2</td>
<td>1 year</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td>2a</td>
<td>4 weeks</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>696&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>168 hours</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td>4</td>
<td>72 hours</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td>5</td>
<td>48 hours</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td>5a</td>
<td>24 hours</td>
<td>≤30 °C/60% RH</td>
</tr>
<tr>
<td>6</td>
<td>Time on Label (TOL)</td>
<td>≤30 °C/60% RH</td>
</tr>
</tbody>
</table>

Extract from J-STD-020C
MSD Levels & Floor Life Derating

**Note 1:** CAUTION – The “accelerated equivalent” soak requirements shall not be used until correlation of damage response, including electrical, after soak and reflow is established with the “standard” soak requirements or if the known activation energy for diffusion is 0.4 - 0.48 eV. Accelerated soak times may vary due to material properties, e.g., mold compound, encapsulant, etc. JEDEC document JESD22-A120 provides a method for determining the diffusion coefficient.

**Note 2:** The standard soak time includes a default value of 24 hours for semiconductor manufacturer’s exposure time (MET) between bake and bag and includes the maximum time allowed out of the bag at the distributor’s facility.

If the actual MET is less than 24 hours the soak time may be reduced. For soak conditions of 30 °C/60% RH the soak time is reduced by 1 hour for each hour the MET is less than 24 hours. For soak conditions of 60 °C/60% RH, the soak time is reduced by 1 hour for each 5 hours the MET is less than 24 hours.

If the actual MET is greater than 24 hours the soak time must be increased. If soak conditions are 30 °C/60% RH, the soak time is increased 1 hour for each hour that the actual MET exceeds 24 hours. If soak conditions are 60 °C/60% RH, the soak time is increased 1 hour for each 5 hours that the actual MET exceeds 24 hours.

**Note 3:** Supplier may extend the soak times at their own risk.

Extract from J-STD-020C
7 DERATING DUE TO FACTORY ENVIRONMENTAL CONDITIONS

Factory floor life exposures for SMD packages removed from the dry bags will be a function of the ambient environmental conditions. A safe, yet conservative, handling approach is to expose the SMD packages only up to the maximum time limits for each moisture sensitivity level as shown in Table 5-1. This approach, however, does not work if the factory humidity or temperature is greater than the testing conditions of 30°C/60% RH. A solution for addressing this problem is to derate the exposure times based on the knowledge of moisture diffusion in the component packaging materials (ref. JESD22- A120). Recommended equivalent total floor life exposures can be estimated for a range of humidities and temperatures based on the worst case exposure conditions and the nominal plastic thickness for each device. Table 7-1 lists equivalent derated floor lives for humidities ranging from 5-90% RH for temperatures of 20°C, 25°C, 30°C and 35°C. This table is applicable to SMDs molded with novolac, biphenyl or multifunctional epoxy mold compounds. The following assumptions were used in calculating Table 7-1:

1. Activation Energy for diffusion = 0.35eV (smallest known value).
2. For ≤60% RH, use Diffusivity = 0.121exp (- 0.35eV/kT) mm²/s (this uses smallest known Diffusivity @ 30°C).
3. For >60% RH, use Diffusivity = 1.320exp (- 0.35eV/kT) mm²/s (this uses largest known Diffusivity @ 30°C).

Extract from J-STD-033B
## MSD Levels & Floor Life Derating

**Table 7-1** Recommended Equivalent Total Floor Life (days) @ 20°C, 25°C & 30°C, 35°C
For ICs with Novolac, Biphenyl and Multifunctional Epoxies (Reflow at same temperature at which the component was classified) Maximum Percent Relative Humidity

| Package Type and Body Thickness | Moisture Sensitivity Level | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |  
|--------------------------------|---------------------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
|                                | Level 2a                   |    |     |     |     |     |     |     |     |     |     | 35°C |
|                                |                            | 88 | 124 | 167 | 231 |     |     |     |     |     |     | 30°C |
| Body Thickness ≥3.1 mm         |                            |    |     |     |     |     |     |     |     |     |     | 25°C |
| including PQFPs >84 pins,      |                            |    |     |     |     |     |     |     |     |     |     | 20°C |
| PLCCs (square)                 |                            |    |     |     |     |     |     |     |     |     |     |      |
| All MQFPs                      |                            |    |     |     |     |     |     |     |     |     |     |      |
| or All BGAs ≥1 mm             |                            |    |     |     |     |     |     |     |     |     |     |      |
| Level 3                        |                            | 86 | 10  | 13  | 17  |     |     |     |     |     |     | 35°C |
|                                |                            | 86 | 10  | 13  | 17  |     |     |     |     |     |     | 30°C |
|                                |                            | 86 | 10  | 13  | 17  |     |     |     |     |     |     | 25°C |
| Level 4                        |                            | 86 | 5  | 6  | 8  | 12 |     |     |     |     |     |      |
|                                | Level 5                    | 86 | 5  | 6  | 8  | 12 |     |     |     |     |     |      |
| Level 5a                       |                            | 86 | 5  | 6  | 8  | 12 |     |     |     |     |     |      |

Extract from J-STD-033B
# MSD Levels & Floor Life Derating

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<thead>
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<th></th>
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<td><strong>Level 2a</strong></td>
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<td><strong>Level 5a</strong></td>
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</tbody>
</table>

- *Body 2.1 mm ≤ Thickness < 3.1 mm including PLCCs (rectangular) 18-32 pins SOICs (wide body) SOICs ≥20 pins, PQFPs ≤60 pins*
# MSD Levels & Floor Life Derating

<table>
<thead>
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<th>0.5</th>
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<th>35°C</th>
<th>30°C</th>
<th>25°C</th>
<th>20°C</th>
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<td>8</td>
<td>5</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>35°C</td>
<td>30°C</td>
<td>25°C</td>
<td>20°C</td>
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<td>Level 4</td>
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<td>4</td>
<td>3</td>
<td>2</td>
<td>0.5</td>
<td>0.5</td>
<td>35°C</td>
<td>30°C</td>
<td>25°C</td>
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<tr>
<td>Level 5</td>
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<td>0</td>
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<td>18</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>0.5</td>
<td>0.5</td>
<td>35°C</td>
<td>30°C</td>
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<tr>
<td>Level 5a</td>
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<td>10</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>35°C</td>
</tr>
</tbody>
</table>

- Body Thickness <2.1 mm including SOICs <18 pins, All TQFPs, TSOPs or All BGAs <1 mm body thickness

∞ Represents indefinite exposure time allowed at conditions specified.
Agenda

- Introduction
- What are Moisture Sensitive Devices?
- Standards
- Typical Components at Risk
- Moisture Accumulation & Failure Mechanisms
- Critical Manufacturing Processes
- Non-Critical Assembly Process
- How MSD Level is determined
- MSD Levels & Floor Life Derating
- MSD Terminologies
- Shelf-Life of MSD Components
- Equipments related to MSD Compliance
- Retrieval Procedure of MSD Components
MSD Terminologies

- **Floor life**
  - Allowable time period, after removal of device from moisture barrier bag and before reflow soldering. For MSD, exposed in control factory ambient not exceeding 30°C 60% RH

- **Humidity indicator card (HIC)**
  - A card printed in blue moisture-sensitive chemical. It will be changed color from blue to pink if indicated relative humidity exceeded. The HIC is packed inside the moisture-barrier bag, along with a desiccant, to aid in determining the level of moisture to which the moisture-sensitive devices have been subjected.
MSD Terminologies

- **Manufacturer’ exposure time (MET)**
  - The maximum cumulative time after bake that components may be exposed to ambient conditions prior to shipment to end user

- **Accelerated equivalent soak**
  - A soak at a higher temperature for a shorter time (compared to the standard soak), to provide roughly the same amount of moisture absorption.
MSD Terminologies

- **Classification temperature (Tc)**
  - The maximum body temperature at which the component manufacturer guarantees the component MSL as noted on the caution and/or bar code label per J-STD-033.

- **Full body hot air rework**
  - The process of heating a package by directing heated gas at the package body in order to melt only that package’s solder connections.
MSD Terminologies

- **Soak**
  - The exposure of a component for a specified time at a specified temperature and humidity.
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Shelf-Life of MSD Components

- The time that dry-packed MSD in an unopened MBB could maintain interior bag ambient humidity.

**MSD in unopened DRY PACK**

- Storage condition of < 40°C / 90% RH, non-condensing atmosphere environment

**Minimum shelf life = 12 months after sealed date**
Shelf-Life of MSD Components

- The time that dry-packed MSD in an unopened MBB could maintain interior bag ambient humidity.

!!!! Moisture sensitive devices, MSD must be packed in DRY PACK !!!!
Shelf-Life of MSD Components

- **Dry Pack**

  MSD’s held in carriers and secured.

  Desiccant and HIC put into MBB.

  Vacuum sealed the MBB and labeling.
Shelf-Life of MSD Components

- Dry Pack Materials
  - MBB
  - HIC
  - Desiccant
Shelf-Life of MSD Components

- Dry Pack Materials

Caution Label

1. Calculated shelf life in sealed bag: 12 months at <40°C and <90% relative humidity (RH).

2. Peak package body temperature: __________°C
   If blank, see adjacent bar code label.

3. After bag is opened, devices that will be subjected to reflow solder or other high temperature process must
   a) Mounted within: __________ hours of factory conditions
      If blank, see adjacent bar code label
      <30°C/60% RH, OR
   b) Stored at <10% RH

4. Devices require bake, before mounting, if:
   a) Humidity Indicator Card is >10% when read at 23 ± 5°C
   b) 3a or 3b not met

5. If baking is required, devices may be baked for 48 hours
   at 125 ± 5°C
   Note: If device containers cannot be subjected to high temperature or shorter bake times are desired,

Bag Seal Date: __________
   If blank, see adjacent bar code label

Note: Level and body temperature defined by IPC/JEDEC J-STD-020.
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Equipments related to MSD Compliance

- **Dry Cabinets**
  - For prolonged storage of the MSC / MSD in Vendor’s packing condition as per the Shelf-Line guidelines.

- **Climate Chambers**
  - To control 1% RH dry cabinets combined with cooling for long term storage, or Climatic Test Cabinets (0°C - +70°C, -30°C - 70°C)
Equipments related to MSD Compliance

- **Desiccator**
  - to be purge with N2 to maintain a dry environment of less than 10% RH and temperature of 25 + 5°C

- **Vacuum Sealer**
  - to seal the MBB’s along with Dessicator Bag and HIC.
Equipments related to MSD Compliance

- **Laser Soldering Equipments**
  - to ensure focussed soldering of components

- **Dry Tower**
  - For Bulk storage of components
Equipments related to MSD Compliance

- **Tracking and Compliance Software**
  - to control compliance of exposure requirements of MSD components
  - vManage Software MES System

- **Component Selection / DFM Calculators**
  - Software tools for verification of MSD Level of components being selected for assembly, based on package, material, pin count etc.
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Retrieval Procedure of MSD Components

MSD AFTER EXPOSED IN FACTORY AMBIENT

CHOICES TO GO

USE UP

STOP FLOOR LIFE CLOCK

RESET FLOOR LIFE

DRY PACK

DRY CABINET

BAKE

SHORT DURATION
Retrieval Procedure of MSD Components

- Floor life exceeding the stated.
- Reset floor life to zero.
- Localized reflow / hot air rework / removal / remounting.
- Unidentifiable level of moisture in packaging/bag.
- Packaging/bag leaking.
- HIC indicating <5% RH (5%RH dot changed to pink color and 10%RH dot is not blue.)
Wrap-up

Q&A
THANK YOU