MSL Rating and Packaging Requirements of PCBs used in Board Mounted Power Assemblies

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Abstract

In recent years there has been an increasing emphasis on miniaturization of Board Mount Power (BMP) modules and electronic subassemblies. In addition there has been a shift from predominately through hole to predominately surface mountable modules using FR4 substrates. This trend coupled with the recent transition to Pb-free products has led to questions regarding Moisture Sensitivity Level (MSL) ratings of Power Modules and subassemblies. Attempts to apply J-STD-020 ratings to subassemblies may not be appropriate and has major implications on the packaging and handling of these products. In addition, there continue to be questions and concerns from manufacturers of power products related to MSL ratings of bare PCBs. Failure to properly protect PCBs from moisture induced damage during the fabrication of PCBs and PCB assemblies can lead to costly yield and reliability problems.

IPC-9592 was released in the Fall of 2008. It addresses Quality and Reliability issues related to Power Products. This document highlights the concern with potential reliability risks due to moisture sensitivity of BMP assemblies. Since there are no established industry standards to address this concern, it is left up to the manufacturer and supplier to take appropriate precautions. The PCB is one of the most moisture sensitive components in BMP assemblies. Vulnerability to delamination especially during Pb-free reflow soldering will be one of the main driving forces in determining BMP module MSL ratings. This paper will present results of moisture studies performed on Lineage Power PCBs and Modules. It will also suggest methods that will reduce the vulnerability of the PCB and the PCB assemblies to moisture induced damage.

Introduction

Most electronic components have been modified to comply with RoHS Lead Free restrictions. This applies to Board Mounted Power (BMP) power supplies as well. This change has a major impact on PCB materials and processes. The impact is felt in raw materials, (laminate), PCB manufacturing, subassembly and system assembly. One of the major concerns is moisture sensitivity of the PCB when exposed to high temperature lead free reflow.

Many OEMs take precautions with bare PCBs similar to other components with MSL > 1, although PCBs do not carry an official MSL designation. OEMs should also be aware that all BMP modules contain PCB materials that are sensitive as well. The PCBs used in these BMP subassemblies have often gone through 2 to 3 reflow cycles prior to OEM assembly. The additional processing seen at the OEM can lead to moisture induced degradation, especially if adequate packaging and handling procedures for the BMP module are not followed.

Moisture sensitivity of electronic components is addressed in a number of industry standards:

- J-STD-020D Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
- J-STD-033B Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
- J-STD-075 Classification of Non-IC Electronic Components for Assembly Process
- IPC-1601 PCB Storage/Handling is in draft.
- IPC-9592 Performance Parameters for Power Conversion Devices

In addition, iNEMI and SMTA have specifically addressed PCB MSL recommendations:

- iNEMI: Paper on High Reliability Task Force Position Statement on RoHS5 & RoHS6 Subassembly Modules
- SMTA (Surface Mount Technology Association)MSD Council Agenda Wednesday 10/10/2007: Moisture Sensitive Device Council meeting discussed guidelines for handling PCBs. Meeting Minutes indicate PCBs should be treated as MSL Classification 4.

MSL Hierarchy of Electronic Components/Subassemblies

Associated Standards are shown below for components and categorized into Groups. Group I covers all Discrete and IC Components. Group II components are the Terminals and Terminations. Groups III and IV are the Unpopulated Daughter Card or Subassembly PCB and the Unpopulated System PCB. A BMP module/Subassembly is constructed from components using Group I (ICs/Discretes), Group II (Terminations), and Group III (Unpopulated PCB). A System Assembly may contain Groups I, II and Group IV in their virgin form in addition to a BMP module/Subassembly.

- Group I: ICs/Discrete Components
  - J-STD-020D Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
  - J-STD-033B Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
  - J-STD-075 Classification of Non-IC Electronic Components for Assembly Processes
- Group II: Terminations, Terminals
  - Not Moisture Sensitive
- Group III is the Unpopulated Subassembly or Daughter Card PCB
  - At present there is no standard method or practice of handling and storing of the Bare Unpopulated PCB. IPC 1601 is in Draft to address this need.
- Group IV is the Unpopulated Final Assembly or System PCB
  - As is the case with the Group II Unpopulated Subassembly PCB there is no standard method or practice of handling and storing this PCB. IPC 1601 is in Draft to address this need.

This paper will focus on concerns with Group III and Group IV; unpopulated PCBs Subassembly and System Level. We will not address the MSL issues of Group I components.

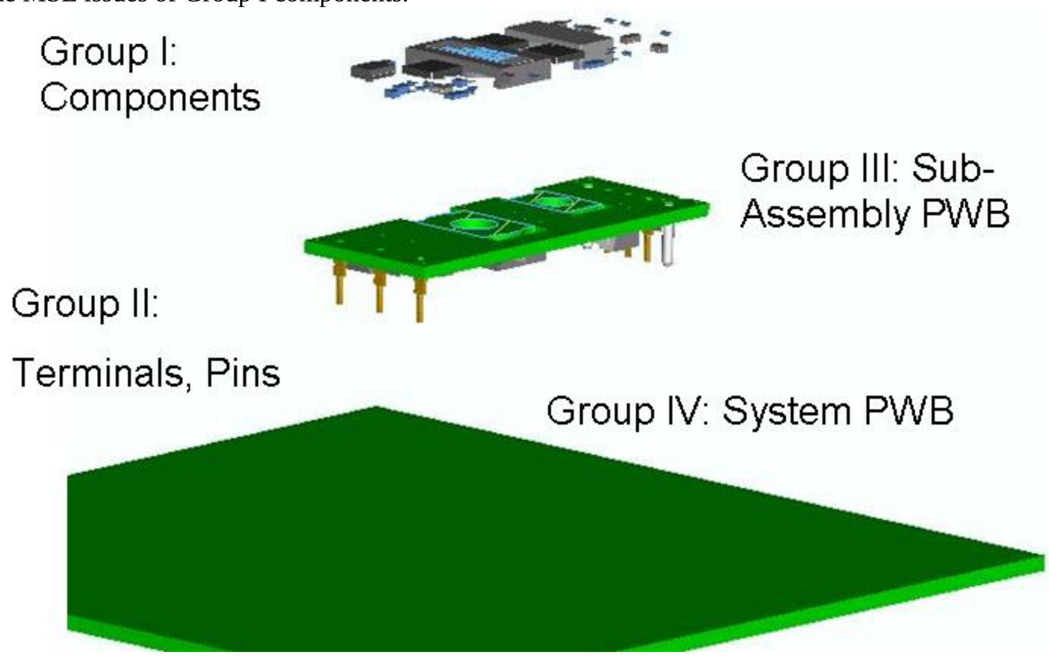

Figure 1 Breakdown of Components related to Assemblies

Review of PCB Processing and Packaging Impact on Moisture

When left up to the PCB manufacturer there is no standard or best practice for processing and packaging PCBs to protect from moisture absorption. The user should specify the packaging, storage and process conditions of the PCB. Table 1 represents four PCB Manufacturers and the results of a survey regarding their factory conditions, perceived PCB moisture content, normal PCB process time to ship and standard packaging. The four suppliers in Table 1 are from North America, and Asia.

Table 1 - PCB Manufacturer Package & Moisture Survey

Supplier	Factory Environ ment	Final Test to Pack Time	Bake Prior Ship	Package Material	Vac Pkg	HIC Card	Desiccant Size	Believed Moisture Content at Pack
A	15 – 25°C <70% RH	Immersion Ag: 24 Hrs Immersion Sn & OSP: 48Hrs	No	PE*	Yes	Yes	Yes	Normal Tg: 0.25% High Tg: 0.20%
B	10 – 30°C 30 - 60% RH	24Hrs	No	PE	Yes	Yes	6cm x 3cm	<1.0%
C	15 – 25°C <75% RH	Immersion Ag: 24 Hrs Immersion Sn & OSP: 48Hrs	No	PE Triple Barrier	Yes Not Meas ured	Yes	Yes per EIA-583	<0.3%
D	15 – 25°C <70% RH	2Hrs – 12 Hrs	No	PE Bubble Wrap	Yes Not Meas ured	Yes	6.4cm x 2.7cm	<0.1%

*PE: Polyethylene

Environmental conditions in many PCB factories are not well controlled. The PCB manufacturers' main process controls in limiting moisture content are in the storage of the Pre-pregs and in the Lamination press. The lamination process is critical to removing volatiles (air and moisture) through vacuum while heat and pressure allows the resin to flow. Moisture present during the lamination process can adversely affect resin to copper bonding and can increase a PCB's subsequent vulnerability to moisture induced damage.

As seen in a survey of four PCB suppliers, the time from final finish to ship and pack is typically less than 48 hours. This limits the environmental exposure, protecting the surface finish and limiting the moisture absorption of the PCB. The PCB manufacturer does not bake the PCB prior to shipping as a standard practice. When the PCB user has concerns about moisture as may occur with extended storage, baking may be considered to drive off moisture. PCB Manufacturer's also strongly caution against the practice of pre-baking boards as this may affect surface finish.

PCB suppliers recognize PCB materials as being susceptible to moisture absorption. They attempt to provide users with some degree of confidence that an effort is made to reduce the impact of moisture. This is evidenced by various packaging methods used in the PCB industry. PCB shops acknowledge that moisture is an issue by using some moisture protection; vacuum packing, desiccant and moisture indicators. It is not clear that these methods are adequate.

There is a clear resistance to the use of metalized moisture barrier bags such as those used in the IC package industry. While all suppliers surveyed for this paper offered resistance to this method, the issue may not be the cost of the moisture barrier bag. The true cost may lie in the process time of heat sealing metalized bags. Isola in its Technical Bulletin titled "PCB Packaging for Lead Free Assembly" recommends the use of moisture barrier bags for all lead free solder boards.

Putting a HIC (Humidity Indicator Card) in the package will show when moisture has reached a certain level. Desiccant is added to absorb moisture that penetrates the package but there appears to be no understanding of the method used in determining amount of desiccant to be used. Many PCB suppliers use vacuum and desiccant in packaging. Desiccant does not work in the absence of air. So while pulling a vacuum to remove some air in packaging is a good practice removal of all air defeats the purpose of the desiccant. Desiccant storage must be tightly controlled or the desiccant will quickly reach equilibrium and be at factory conditions. The survey indicated there is no clear understanding of EIA-583 requirements for determining desiccant units based on surface area and desired relative humidity. The EIA-583 formula for calculating the Units (See Note 1) of desiccant required is:

$$\text{Units} = \frac{\underline{0.231 \times \text{Interior Bag Area (in}^2) \times \text{Bag MVTR} \times \text{Months (Storage Time)}}}{\text{Minimum Moisture Capacity of Desiccant at Maximum Interior Humidity}}$$

MVTR: Moisture Vapor Transmission Rate (grams/inch^2/24 hours)
Note 1: "Unit" is the unit of measurement for desiccant.

Table 2 – Moisture Capacity Desiccant Units

Moisture Capacity	10%	20%	30%	40%
Desiccant g/unit	3.0	4.8	5.8	6.2

The user of the PCB must work with the PCB manufacturer in providing the months of storage and desired moisture capacity. Some PCB assemblers may have inventory turn over times of 1 week, or 1 month while others may require inventories of 3 to 9 months. The PCB user must determine their storage and shelf life requirements and communicate these requirements to the PCB manufacturer.

Using a bag of 8" x 10" with a MVTR of 0.02 g/in^2/24hrs for a 12 month storage condition with Moisture Capacity of 40% would require two units of desiccant. (Bag Area = 80sq in. x 2 sides) The recommended maximum moisture content of a PCB should be less than 0.20% for Solder Reflow Temperature of 230°C to less than 0.15% maximum moisture content for Solder Reflow Temperature of 260°C (Ref 2).

As indicated from the survey of PCB manufacturers, the moisture content at shipping is on the processing edge for Solder Reflow Temperatures above 230°C. **It is critical that the PCB Assembler communicate to the PCB manufacturer the total number of Lead Free Reflow Solder Profiles the PCB will be exposed to during its life.** Depending on the PCB type and its application, a PCB may see a total of four lead free reflows before it is put on the Group IV System PCB (See Table 3).

Table 3 - PCB Solder Reflow Exposures

PCB Type	Surface Finish	PCB Start Count	Top Side	Bottom Side	Sub Total Reflow Count	Additional Reflows	Total Reflow Count
Group III Sub –Assembly PCB	Wet Process	0	X	X	2	1*	3*
Group III Sub –Assembly PCB	Pb Free Solder	X	X	X	3	1*	4*
Group IV System PCB	Wet Process	0	X	X	2	*	2
Group IV System PCB	Pb Free Solder	X	X	X	3	*	3

* Some Subassembly PCB's may be exposed to additional reflows if the subassembly is put on first. Also Subassembly or System PCBs may occasionally require solder rework which must be taken into consideration.

As illustrated in Table 3, a Group III Subassembly PCB can be exposed to four lead free solder profile exposures, more if rework is involved. A Group IV System PCB typically sees less than three lead free solder profile exposures. The fact the Group III Subassembly PCB (BMP Power Module/Daughter Card Subassembly) has had multiple reflow exposures prior to assembly onto the Group IV System PCB is often overlooked. Subassemblies (BMP Modules or Daughter Cards) can see a total of five or six reflows if located on the bottom of a System PCB or if rework is involved.

Table 4 indicates how a typical Contract Manufacturer (CM) handles the incoming PCB. This survey was conducted on three manufacturers; two in Asia and one in North America. CM factory environmental controls are similar to the PCB manufacturers. Unlike PCB manufacturers the CMs surveyed consider putting PCBs in Moisture Barrier Bags (MBB) as standard practice. All CMs surveyed put any unused PCB in a moisture barrier bag and resealed the bag. CMs also use the HIC as an identification method for pre-baking the PCB prior to assembly.

Table 4 – Survey of Contract Manufacturer (CM) PCB Assembly Practices

CM	Factory Environment	PCB Shop Handling	Bake Prior To Build	Open to Ship Time	Bake Prior To Ship	Believed Moisture At Pack
A	15 – 28°C <70% RH	MBB Vacuum Reseal	Only if Pink HIC Card	1 week	No	Unknown
B	18 – 27°C 30% - 60% RH	MBB Vacuum Reseal	Only if Pink HIC Card	HASL: 72 Hrs Immersion Ag: 36 Hrs OSP: 16 Hrs	No	Unknown
C	15 – 28°C 40% - 70% RH	MBB Vacuum Reseal	Only if Pink HIC Card	24 – 72 hours	No; Only if Customer Directed	Unknown

One CM limited the complete PCB assembly process to 72 hours, another limited exposure based on surface finishes with as little as 16 hours for OSP finish to a maximum of 72 hours for HASL and another allowed up to one week before final reflow. No CM did a pre-assembly bake nor did the CM have any idea of the moisture content of the PCB assembly. CMs only packaged completed SMT BMP Modules in moisture barrier bags when directed by the purchase order. Surface mount subassemblies were specified to use packaging such as tape and reel or thermoform trays. These packaging methods are indicators of further assembly processing such as pick and place and additional solder reflow profile exposure.

<u>As Received PCB Moisture & Bake Study</u>

A study of two different industry standard Board Mounted Power Modules with two different layer counts and PCB thicknesses will be discussed. The industry standard circuit sizes are the Eighth Brick and the Quarter Brick (Figure 2). The Eighth Brick is 2.28" x 0.896" (57.9mm x 22.8mm). The Quarter Brick is 2.28" x 1.45" (57.9mm x 36.8mm).

The bare PCBs are received in an 8" x 11" array (Figure 3). The circuits are assembled in this array form for ease of manufacturing. The circuits are later routed and packaged. The actual manufacturing process minus components and solder paste was used to record weight loss of the array during the lead free solder profile process. The typical weight loss of an array ranged from 0.077% to 0.123% change from the opened package weight (Table 5).

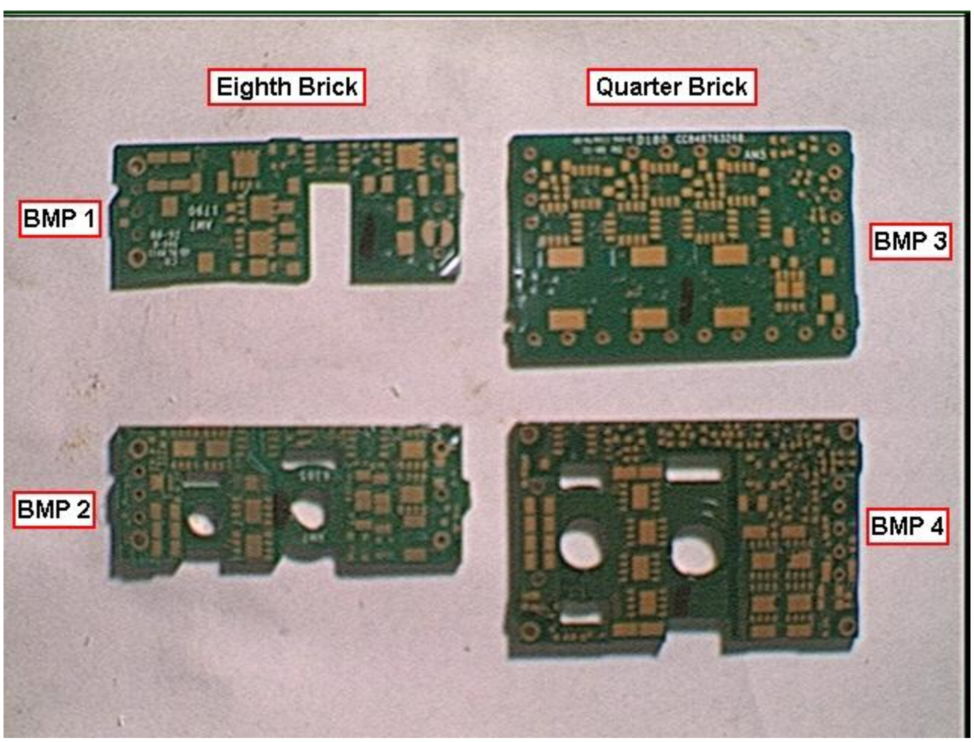

Figure 2 BMP Brick PCB: Group III

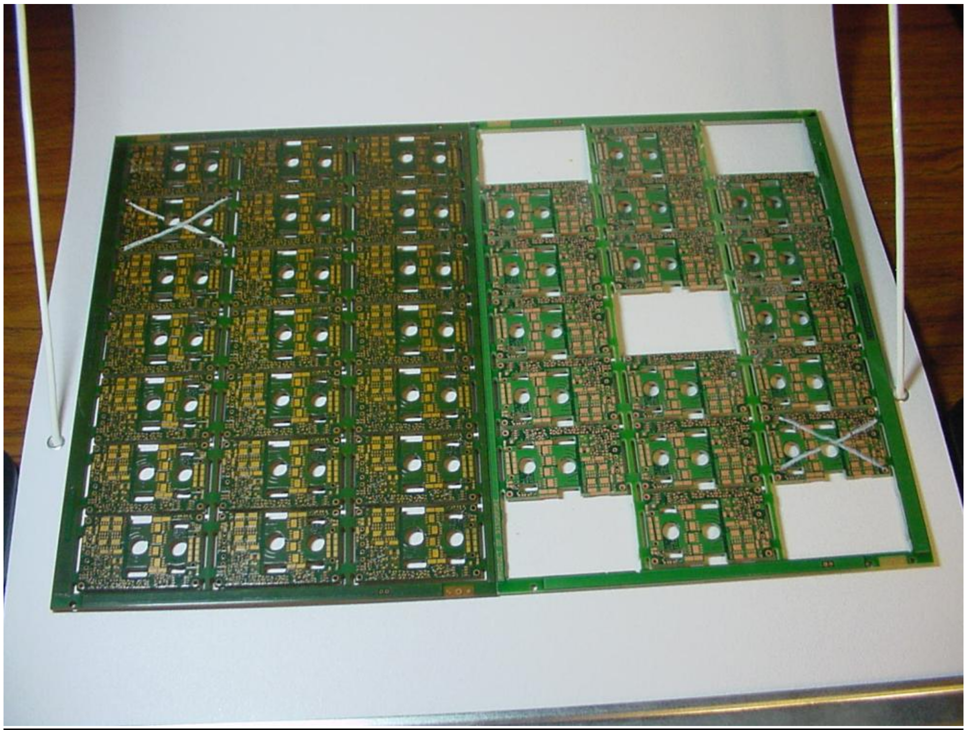

Figure 3 PCB Array

Table 5 - Array Weight Loss due to Lead Free Solder Profile Process

PCB Thk/Layer Count:Cu Wt	Array 8 Start Wt (Grams)	Array 8 1st Pb Free Reflow	2 Hr Wait	Array 8 2nd Pb Free Reflow	24 Hr Wait	Array 8 3rd Pb Free Reflow	Array % Wt Loss	Gross % Copper Content
0.042”/6L:2oz	162.3g	162.1g	162.2g	162.1g	162.2g	162.1g	0.123%	33.57%
0.062”/6L:2oz	269.0g	268.8g	268.9g	268.8g	268.9g	268.8g	0.112%	26.94%
0.100”/12L:3oz	457.6g	457.3g	457.4g	457.3g	457.4g	457.3g	0.087%	43.68%
0.126”/12L:5oz	653.2g	652.8g	652.9g	652.7g	652.9g	652.7g	0.077%	57.67%

All packaging utilized PCB Industry Standard Polyethylene bags. The first bag was Vacuum packed with a second bag overwrap. The higher layer count and thicker PCB packaging had some pinholes in the corner of the bag where the vacuum pulled very tight to the package on the heavy copper 0.126” thick array being torn at the corners. The HIC did indicate moisture content present in the torn packaging and as indicated in pre and post bake of the desiccant, the weight of the desiccant changed considerably compared to the drier desiccant. Table 6 lists key characteristics of the BMP Group III PCBs. It also measures desiccant moisture content and HIC condition.

Since our scales used to measure array weights lacked sufficient resolution, we focused on the individual PCB weights. To assess as received PCB moisture content, samples of individual circuits were removed using a diamond saw and weighed with 0.10 milligram (mg) resolution. Parts were baked at 125°C for 96 hours and weighed at increments. By comparing initial and final weights, as received moisture content was assessed. Figure 4 plots weight loss vs. time.

Table 6 - Test Array PCB Package Conditions

BMP ID	PCB Size	PCB Thk/Layer Count:Cu Wt	Desiccant Wt (grams)	Desiccant Wt Post Bake	Desiccant % Wt Change	Gross % Copper Content	%Max Moisture Content	Comment
BMP 1	2.28” x 0.896” 57.9mm x 22.8mm	0.042/6L: 2oz internals	10.886g	10.087g	7.34%	33.57%	0.400%	HIC ok Eighth Brick
BMP 2	2.28” x 0.896” 57.9mm x 22.8mm	0.100/12L: 3oz internals	12.227g	10.121g	17.23%	43.68%	0.335%	HIC 10% Pinholes Eighth Brick
BMP 3	2.28” x 1.45” 57.9mm x 36.8mm	0.062/6L: 2oz internals	11.715g	10.831g	7.55%	26.94%	0.340%	HIC ok Quarter Brick
BMP 4	2.28” x 1.45” 57.9mm x 36.8mm	0.126/12L: 5oz internals	5.444g 5.857g	4.736g 5.054g	13.01% 13.70%	57.67%	0.210%	HIC 20 – 30% Package Torn Quarter Brick

A crude approximation of % Maximum Moisture Content in a PCB to Gross % Copper Content is an attempt to see at what point will moisture impact a PCB.

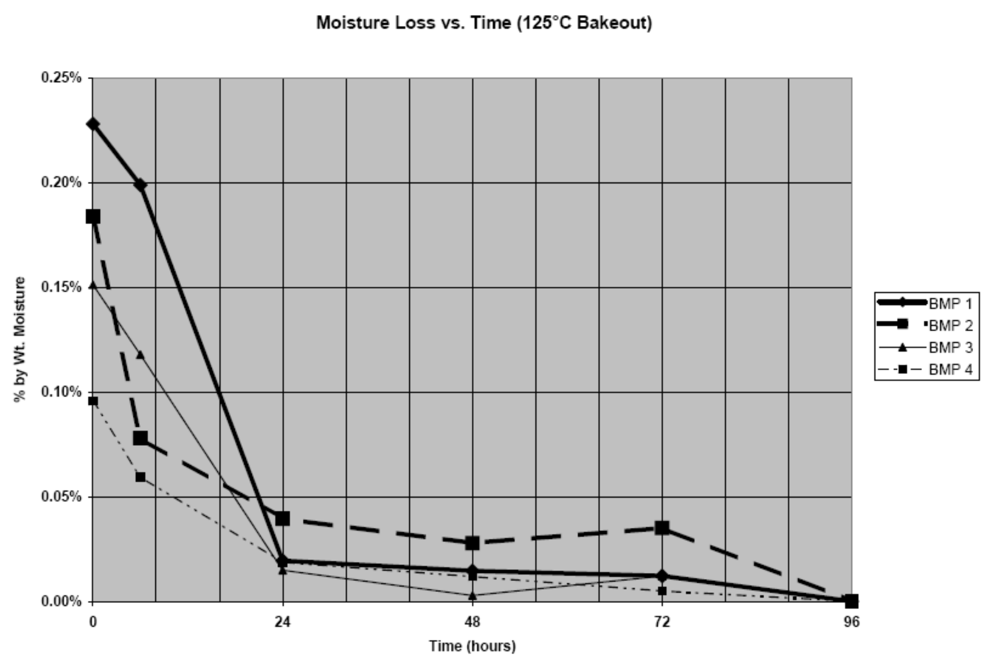

Figure 4 125°C Bake Out (%Moisture vs. Time)

PCB Moisture Absorption Rates

To determine moisture absorption rates, sample circuits were baked dry (125°C for 96 hours) and weighed. One set of samples was exposed to 85°C/85%RH (Figure 5) and the other set was exposed to a more typical environment of 30°C/60%RH (Figure 6).

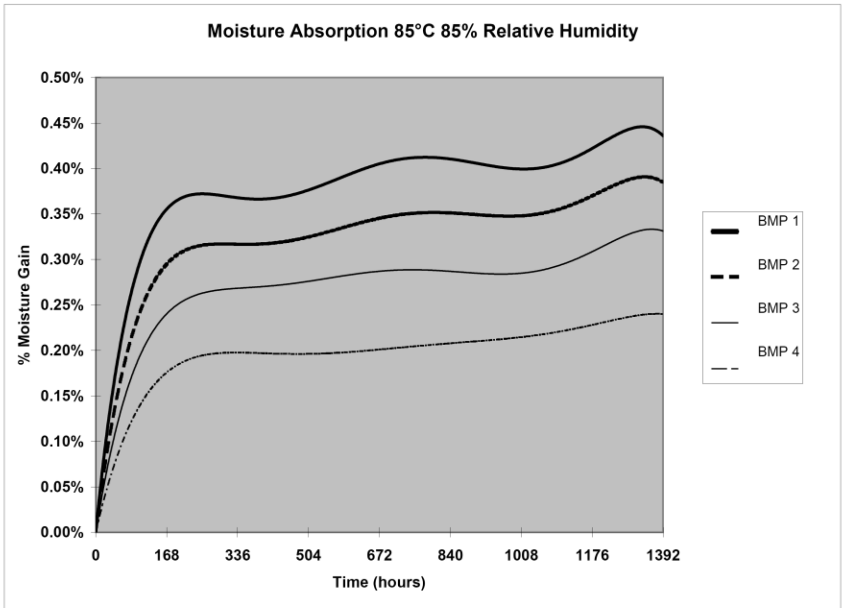

Figure 5 PCB Moisture Absorption Rates %Moisture vs. Time (85°C/85% RH Environment)

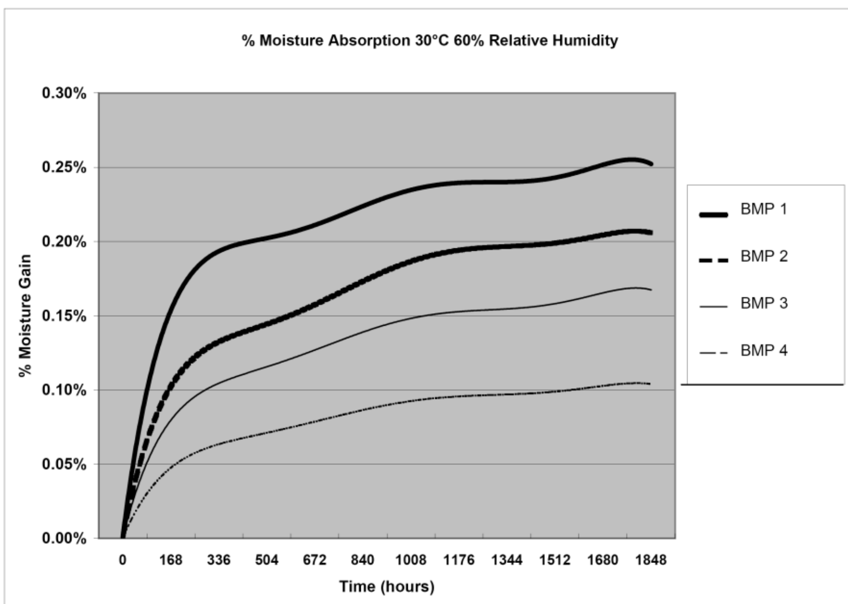

Figure 6 PCB Moisture Absorption Rates %Moisture vs. Time (30°C/60% RH Environment)

There is a difference in rate of absorption which is expected in boards of the same physical size but various thicknesses due to layer count and copper weight. In reviewing the board thickness and gross % copper content, the % moisture absorption decreases as % copper content increases. An attempt to correlate the Gross Percent Copper Wt to % Maximum Moisture Content is illustrated in Table 6.

The purpose of establishing a % Maximum Moisture Content is to determine the moisture content that will allow the PCB to survive numerous lead free solder reflow profiles. If we can establish a moisture threshold point in a PCB, we can establish moisture sensitivity levels and proper packaging of a PCB.

PCB moisture absorption rates at 85°C 85% relative humidity are greater than 2x than moisture absorption rates at 30°C 60% relative humidity.

The main failure mechanism in a PCB that contains excess moisture is delamination. Delamination is a separation of internal PCB layers. In some cases vias may crack resulting in immediate failure. More commonly, there may be a slight visual imperfection but no internal failure. However, delamination often results in a compromised dielectric integrity between points intended to be electrically isolated. This may result in time related failures, especially in humid environments or in PCB areas where high voltage is present. It may also result in immediate failure if delamination bridges primary and secondary boundaries when Hipot testing is performed in isolated BMP modules.

Time to Delamination or TTD is defined in IPC-TM-650 Method 2.4.24.1. This method may be used as a relative measure of vulnerability to delamination during reflow. This test is conducted on a TMA (Thermomechanical Analyzer). This study utilized a Perkin Elmer TMA-7e. The TMA uses a small glass furnace and a glass rod that is capable of measuring very slight expansion of the material under test. This test method can be used to provide a time to delamination at 260°C, also referred to as T260. This method is presently accepted by the PCB industry on laminate material only. However the IPC-TM-650 in paragraph **1.0 Scope** states; ***"This method describes the method for determining the time to delamination of laminates and printed boards through the use of a thermomechanical analyzer (TMA)."***

In applying this method to a laminated PCB there are concerns such as where in the array the sample is to be taken. In any PCB there are resin rich areas and areas in which copper planes are dominant. A standard area on the frame border needs to be defined. Consider the laminate test approach which tests the delamination between two planes of copper. For the purpose of this test, stacked copper plane areas were chosen. This was to remain consistent from sample to sample and from board to board. Our only difference will be the copper weight and pre-preg between solid copper plane cores. All samples were taken from the border frame of the array. In the frame there is only copper and resin similar to the laminate test but with pre-preg between all cores. The sample size is approximately 0.25" square which fits inside the furnace of the TMA.

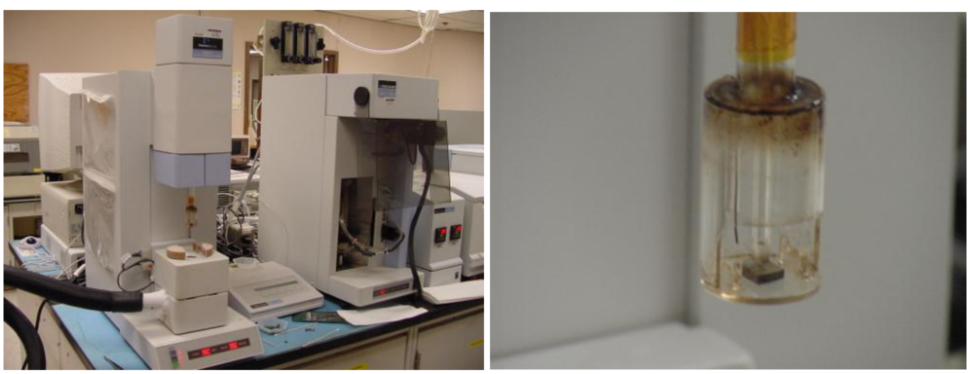

Figure 7 Photos of Perkin Elmer TMA-7e

<u>T260 Testing Results</u>

The purpose of these tests is to correlate moisture content to T260 and lead free survivability. A baseline T260 reading is established on a dry sample. Sample preparation consists of bakeout followed by cool down in desiccant chamber following the guidelines as per IPC. Once the time is established on a known dry sample, other samples in the same region are taken. The samples are baked and dry weights recorded. Samples are then put in a humidity chamber and allowed to absorb moisture. At various times the samples are removed and the weight measured to get a percent gain in moisture content. With increasing moisture, T260 generally decreases.

Premature T260 may be the result of poor oxide treatment of copper, glass stoppage (glass fiber contact with copper plane), or other manufacturing process defects. It is theorized that the presence of moisture during the solder reflow process creates internal stresses due to the rapid buildup of moisture vapor pressure which leads to weakened bonds internal to the PCB. Figure 8 shows a Scanning Electron Microscope (SEM) image of a delaminated sample from T260 testing.

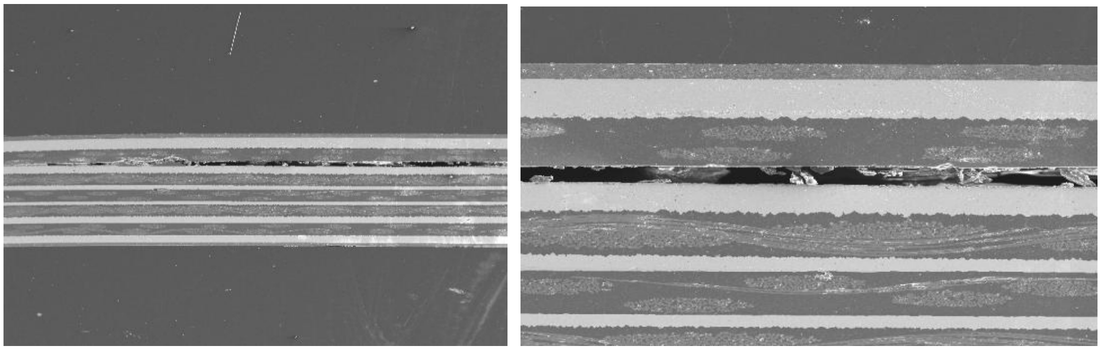

Figure 8 SEM view of Delamination

T260 results are shown in Table 7.

Table 7 – Time to Delamination T260

	BMP 1		BMP 2		BMP 3		BMP 4	
SN #	% Moisture	Time (minutes)	% Moisture	Time (minutes)	% Moisture	Time (minutes)	% Moisture	Time (minutes)
1	DRY	47	DRY	24	DRY	54	DRY	26
2	0.0878%	49	0.0624%	48	0.1059%	49	0.0944%	22
3	0.2432%	43	0.0952%	34	0.1909%	46	0.1117%	24
4	0.3256%	54	0.1386%	46	0.3046%	34	0.1336%	23
5	0.3606%	46	0.1732%	44	0.3832%	27	0.1668%	15
6	0.4017%	53	0.2590%	24	0.4049%	36	0.1752%	14
7	0.4265%	9	0.2662%	30	0.4335%	45	0.2007%	26

One should note that the PCB industry does not agree with IPC using this test method for finished PCBs. The PCB industry uses this method only for laminate. One OEM uses a T260 of 2 minutes. There is no industry accepted standard value for PCBs.

Lineage Power attempts to follow the laminate method and apply that to the frame of the array. The frame of the array (See Figure 3) is as close to a stack of laminate held together by pre-preg as one can get. Using the frame for individual laminate testing requires a minimum of 20 minutes for the T260 test. The 20 minute T260 requirement was reduced from 30 minutes after discussions with several PCB suppliers and Gauge R&R studies. Figure 9 shows graphs of two samples from BMP 1 with similar moisture content; one surviving 53 minutes and one surviving 9 minutes.

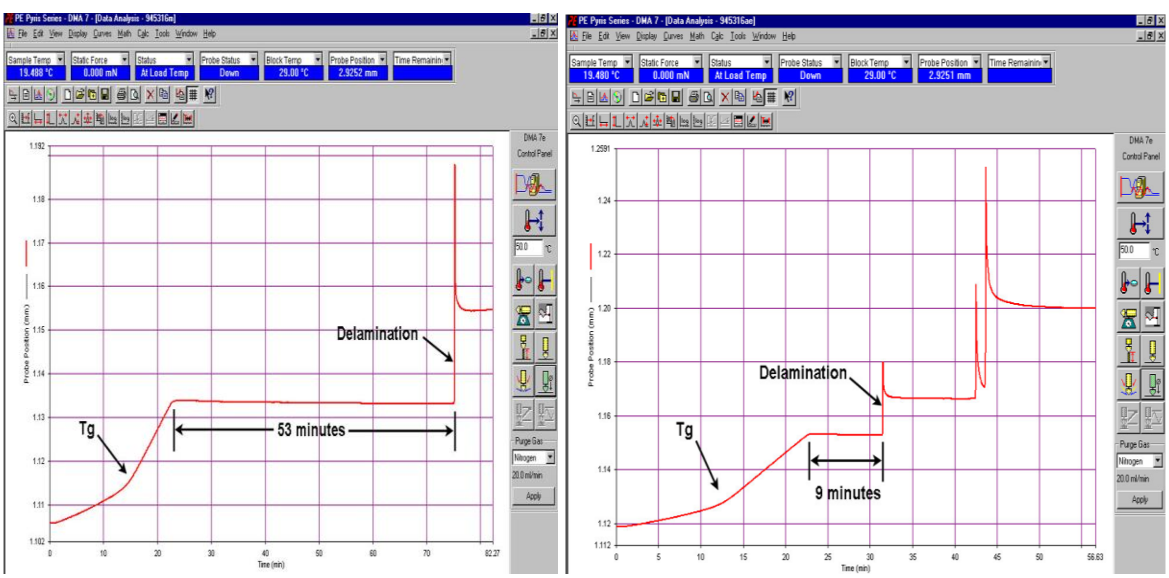

Figure 9 Typical T260 Graphs

Samples were cross sectioned to find the delamination site of the chip samples. Cross section of samples indicated that moisture had little impact on TTD for a PCB with sufficient resin buffer between the copper and the glass fiber. Samples with glass stoppage resulted in reduced bond strength.

Glass stoppage occurs during lamination press cycle. Glass stoppage is where there is no resin buffer between the glass fiber and the copper. Figure 10 illustrates an example of glass stoppage.

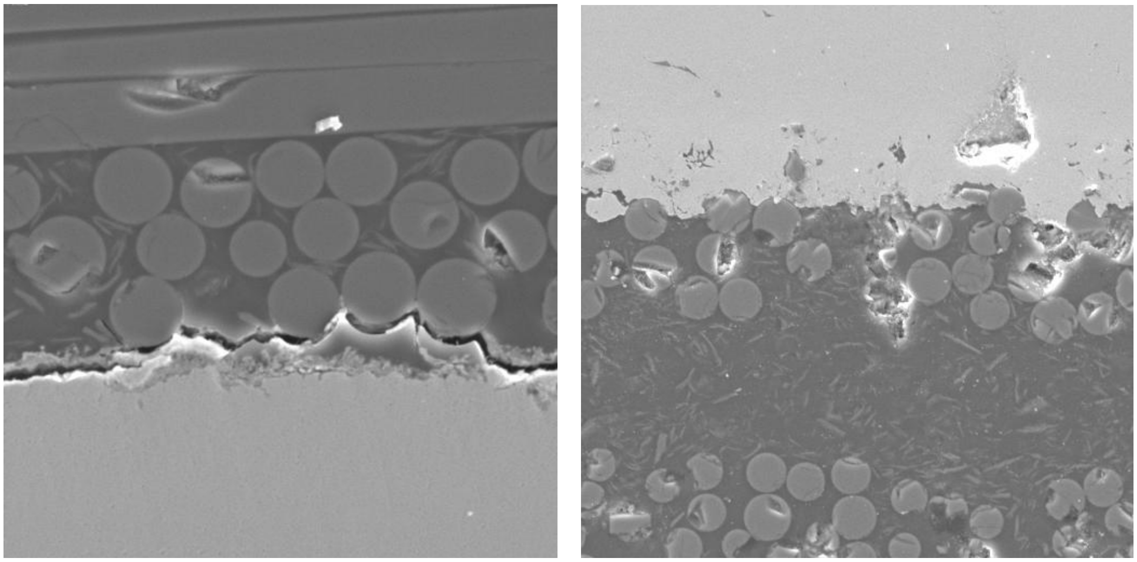

Figure 10 Glass Stoppage (Note delamination on left image)

Further study of glass stoppage and its effect on delamination and humidity was examined on a known low T260 panel. Samples of the rail were cross sectioned to verify glass stoppage before proceeding with T260 testing.

Several samples were taken to compare dry versus moisture exposed T260 times. The findings are in Table 8. All samples exhibited glass stoppage. Dry samples had T260 times of 15 to 20 minutes. Moisture exposed sample T260 times were all reduce by more than 50% of their dry times.

Table 8 – T260 of Glass Stoppage Samples

	Thin Section		**Thick Section**	
Sample	**% Moisture**	**T260 (minutes)**	**% Moisture**	**T260 (minutes)**
1	Dry	15	Dry	19
2	Dry	15	Dry	20
3	Dry	16	Dry	19
4	0.1817%	6.5	0.1979%	8
5	0.2878%	6	0.2552%	7

This data shows that even with high moisture content, some PCBs have sufficient time to delamination margin to be considered at low risk. However PCB manufacturing variations may increase moisture related risk of delamination during reflow. Past experience with delamination has attributed delamination as due to PCB variations such as insufficient copper tooth profile, improper oxide treatment of copper, and presence of glass stoppage. Another factor potentially impacting delamination is moisture content in pre-preg during the lamination press cycle.

Conclusions

There are no industry standards for packaging and MSL levels for PCBs. It is critical to discuss the PCB application, storage, and the number of lead free solder reflow profiles to the PCB supplier to determine the proper packaging.

T260 testing indicates that a PCB with glass stoppage will have shorter time to delamination compared to PCBs with no glass stoppage. PCBs with no glass stoppage are more robust and have exhibited much longer times to delamination even with high moisture content.

There are other factors that were found in the course of this study that contribute to bond strength of a finished PCB. Only one PCB laminate type was tested from two different PCB suppliers. Materials that improve bond strength and increase moisture resistance need to be further investigated. A further study in identifying material properties and processes to improve the bond strength of the PCB and its resistance to moisture when exposed to repeated high temperature solder reflow is necessary.

MSL ratings of PCBs are dependent on material, manufacturing process, construction and design. As indicated in this study, some PCBs may indeed be capable of an MSL 2 or possibly an MSL 1 rating.

Reference:

1. Pb-free IC Component Issues and IPC/JEDEC Specification Update, Rick Shook, Agere Systems
2. Isola Technical Bulletin: “PCB Packaging for Lead Free Assembly”
3. iNEMI: Paper on High Reliability Task Force Position Statement on RoHS5 & RoHS6 Subassembly Modules
4. SMTA (Surface Mount Technology Association): MSD Council Agenda Wednesday 10/10/2007 Moisture Sensitive Device Council meeting discussed guidelines for handling PCBs. Meeting Minutes indicate PCBs should be treated as MSL Classification 4. MSL Classification needs to be redefined if packages are used for Lead free reflow as every 10°C rise in peak reflow temp, MSL Class is reduced by 1 Class Level (e.g MLS2A (1 month floor life) to MSL 3 (7days floor life).
5. J-STD-033B Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
6. J-STD-075 Classification of Non-IC Electronic Components for Assembly Process
7. J-STD-020D Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
8. IPC-1601 PCB Storage/Handling Draft
9. IPC-9592 Performance Parameters for Power Conversion Devices
10. IPC-TM-650 Test Methods Manual

MSL Rating & Packaging Requirements of PWBs used in Board Mounted Power Assemblies

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MSL Rating of Components/Subassemblies

- There are standards that provide MSL ratings of components but no industry standard that currently rates subassemblies or PWBs.
- IPC-9592 adds precautions but no rules.
- iNemi suggests when rating subassemblies to rate the subassembly with the worst case component rating.
- There is no current MSL rating of the PWB even though it may be a major contributor to the Subassembly.

How do we Classify MSL of PWB?

- SMTA (Surface Mount Technology Association) MSD Council Agenda 10/10/2007:
- Moisture Sensitive Device Council meeting discussed guidelines for handling PWBs. Meeting Minutes indicate PWBs should be treated as MSL Classification 4.

Providing an MSL for a PWB

- The purpose of this paper was to study moisture sensitivity in a PWB and provide a rating for filled phenolic PWB (Lead Free Laminate).
- A case study of moisture in 2 different BMP Subassembly PWBs is presented.
- A look into Packaging, Baking, Moisture absorption, moisture content, % copper content and moisture impact on PWB delamination is looked at.

Component Grouping

What Specifications Apply to What Component Groups?

- Group I Components
- Group II Surface Mount Terminations
- Group III Sub-assembly PWB
- Group IV System PWB

Group I Components

Group I Component Specifications

- J-STD-033 Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
- J-STD- 075 Classification of Non-IC Electronic Components for Assembly Process
- J-STD-020 Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices

These Specifications address MSL and Packaging.

Group II –Solderabilty of Terminations to PWB

Two Solderability Documents

- Solderability Specifications controlling Surface Finish
- J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires
- J-STD-003 Solderability Tests for Printed Boards

MSL not necessary.

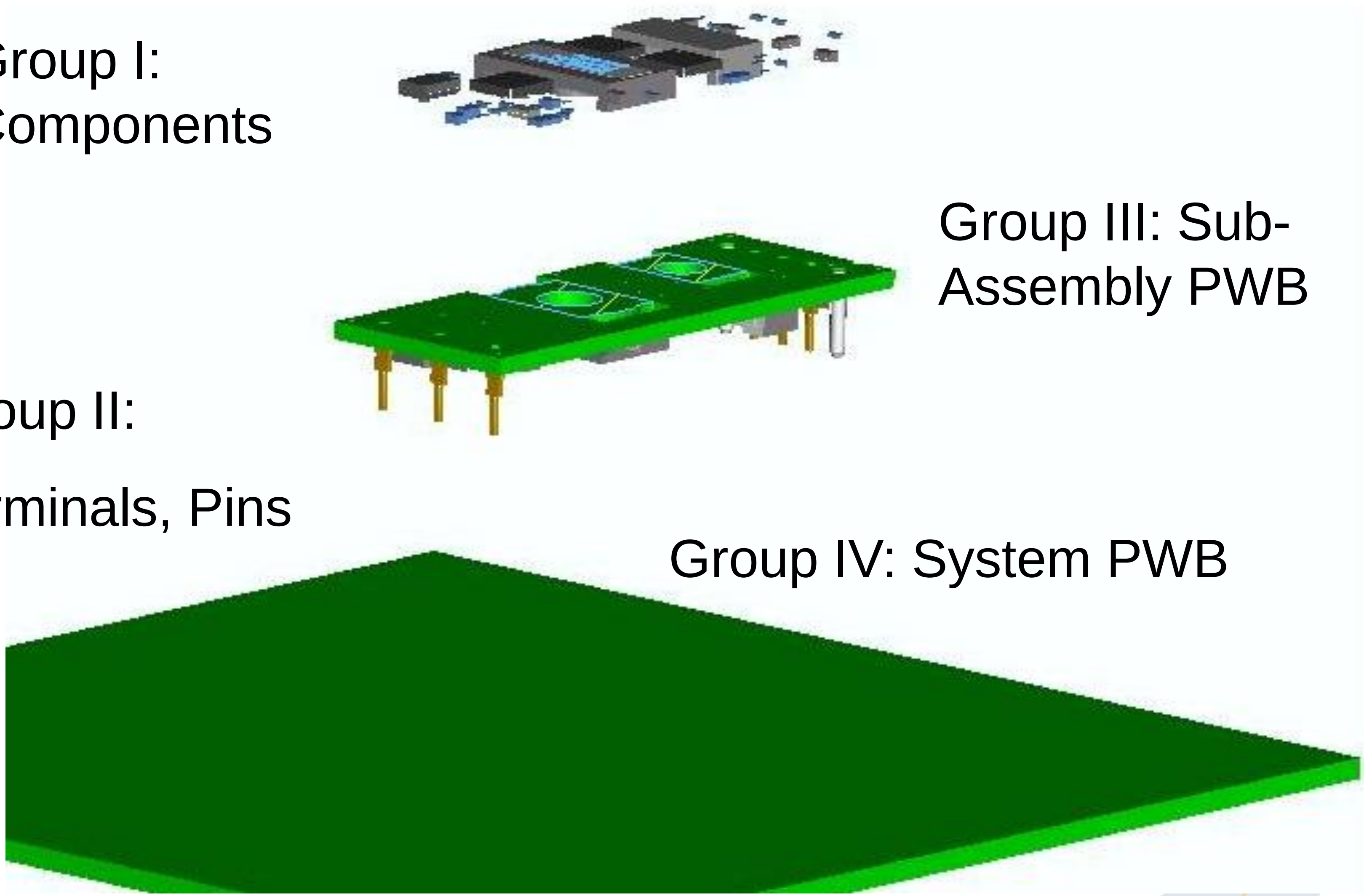
PWB – Group III & Group IV

PWB Group Definition

- Group III Sub-assembly PWB: Receiving Multiple Reflow Exposures Greater than 3
  - Daughter Cards, Sub-assembly Modules
- Group IV System PWB
- PWB Lacks Standard for MSL & Packaging
- IPC 1601 is in draft

MSL and Packaging needs to be addressed.

System View of Component Groupings



PWB Manufacturer Package & Moisture Survey

Supplier	Factory Environment	Final Test to Pack (Time)	Bake Prior to Ship	Pkg Material	Vacuum Package	HIC Card	Desiccant Size	Believed Moisture Content at Pack
A	Temperature: 15 - 25°C Relative Humidity: <70%	Immersion Ag: 24 hrs Immersion Sn & OSP: 48 hrs	No	Polyethylene	Yes, controlled limits	Yes	Yes	Normal Tg: 0.25% High Tg: 0.20%
B	Temperature: 10 - 30°C Relative Humidity: 30% - 60%	24 hrs	No	Polyethylene	Yes, controlled limits	Yes	6cm x 3cm	<1.0%
C	Temperature: 15 - 25°C Relative Humidity: <75%	Immersion Ag: 24 hrs Immersion Sn & OSP: 48 hrs	No	Polyethylene	Yes; Not Measured	Yes	Yes per EIA-583	<0.3%
D	Temperature: 15 - 25°C Relative Humidity: <70%	2 hrs - 12 hrs	No	Polyethylene Bubble Wrap 3mil 9mil PE Anti Stat	Yes; Not Measured	Yes	6.4cm x 2.7cm	< 0.1%

How Much Desiccant?

EIA-583 Packaging Material Standard for Moisture Sensitive Items

Units of Desiccant =

$$\frac{0.231 \times \text{Bag Area} \times \text{Bag MVTR} \times \text{Month}}{\text{Moisture Capacity}}$$

Bag Area: (2 Sides) Time: Months of Storage

MVTR: Moisture Vapor Transmission Rate (grams/in^2/24hours)

Moisture Capacity: 10%:3g/unit, 20%:4.8g/unit 30%:5.8g/unit

How Many Pb Free Solder Reflow Exposures is your PWB exposed to?

PWB Type	Surface Finish	PWB Start Count	Top Side	Bottom Side	Sub Total Reflow Count	Additional Reflows	Total Reflow Count
Group III Sub Assembly PWB	Wet Process	0	X	X	2	1*	3*
Group III Sub Assembly PWB	Pb Free Solder	1	X	X	3	1*	4*
Group IV System PWB	Wet Process	0	X	X	2	NA	2*
Group IV System PWB	Pb Free Solder	1	X	X	3	NA	3*

* Occasional Rework should be considered as well as additional reflows for Group II Sub Assembly PWB

Group III BMP PWB Assembly Survey

CM	Factory Environment	PWB Shop Handling	Bake Prior To Build	Open to Ship Time	Bake Prior To Ship	Believed Moisture At Pack
A	15 – 28°C <70% RH	MBB Vacuum Reseal	Only if Pink HIC Card	1 week	No	Unknown
B	18 – 27°C 30% - 60% RH	MBB Vacuum Reseal	Only if Pink HIC Card	HASL: 72 Hrs Immersion Ag: 36 Hrs OSP: 16 Hrs	No	Unknown
C	15 – 28°C 40% - 70% RH	MBB Vacuum Reseal	Only if Pink HIC Card	24 – 72 hours	No; Only if Customer Directed	Unknown

PWB Packaging for Study Test Samples

BMP ID	PWB Thk/Layer Count:Cu Wt	Desiccant Wt (grams)	Desiccant Wt Post Bake	Desiccant % Wt Change	Gross % Copper Content	Comment	Size
BMP 1	0.042/6L:2oz internals	10.886g	10.087g	7.34%	33.57%	HIC ok Eighth Brick	Eighth Brick: 2.28" x 0.896" (57.9mm x 22.8mm)
BMP 2	0.100/12L:3oz internals	12.227g	10.121g	17.23%	43.68%	HIC 10% Pinholes Torn Eighth Brick	
BMP 3	0.062/6L:2oz internals	11.715g	10.8305g	7.55%	26.94%	HIC ok Quarter Brick	Quarter Brick: 2.28" x 1.45" (57.9mm x 36.8mm)
BMP 4	0.126/2L:5oz internals	5.4440g 5.8570g	4.7356g 5.0544g	13.012% 13.703%	57.67%	HIC 20 - 30% Package Torn Quarter Brick	

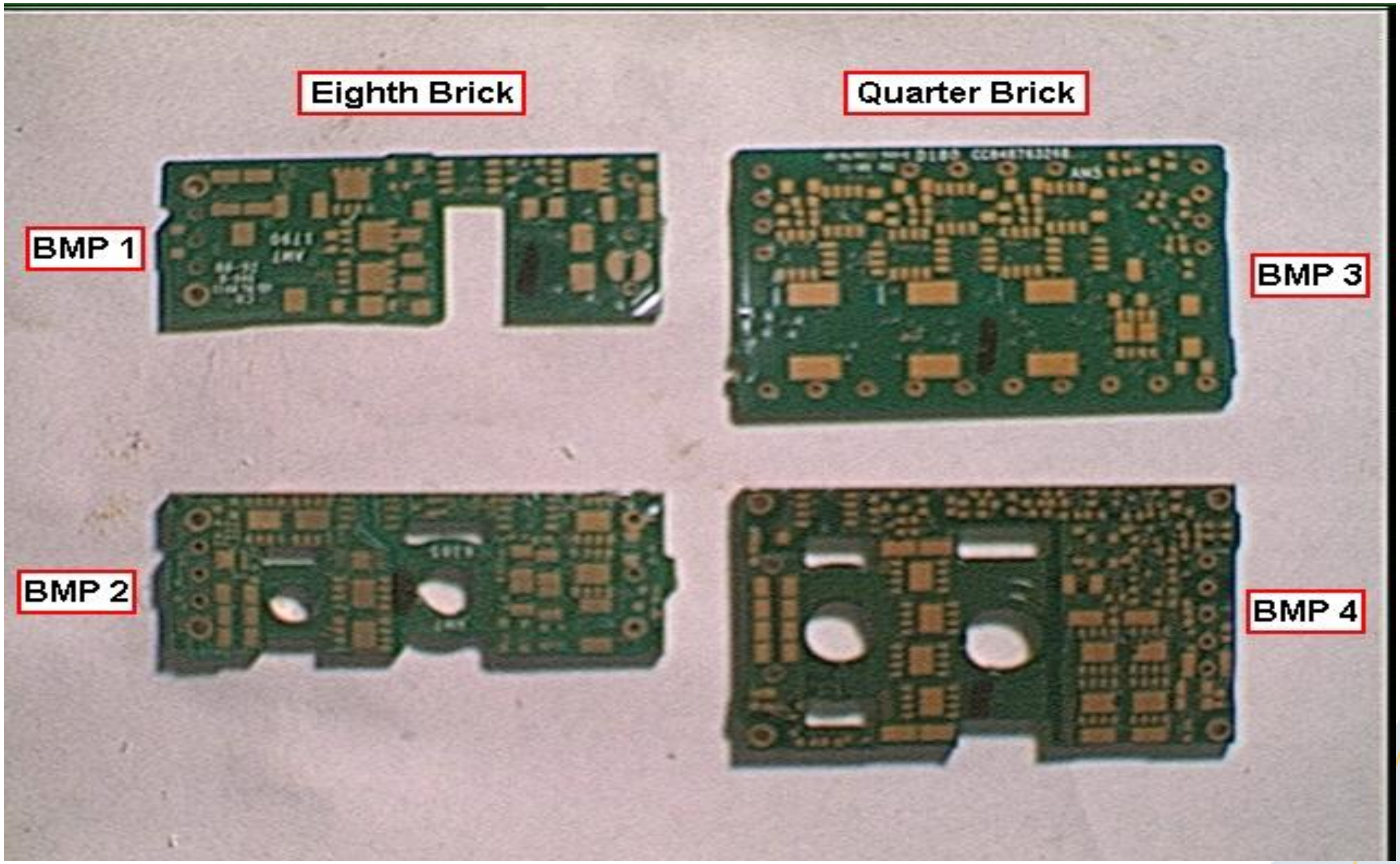
Weight Loss due to Pb Free Processing

PWB Thk/Layer Count/Cu Wt	Array 8 Start Wt (Grams)	Array 8 1st Pb Free Reflow	2 Hr Wait	Array 8 2nd Pb Free Reflow	24 Hr Wt	Array 8 3rd Pb Free Reflow	Array Wt Loss due to Pb Free Reflow	%Copper Content
0.042/6L:2oz	162.3	162.1	162.2	162.1	162.2	162.1	0.123%	33.571%
0.062/6L:2oz	269.0	268.8	268.9	268.8	268.9	268.7	0.112%	26.935%
0.100/12L:3oz	457.6	457.3	457.4	457.3	457.4	457.2	0.087%	43.680%
0.125/12L:5oz	653.2	652.8	652.9	652.7	652.9	652.7	0.077%	57.674%

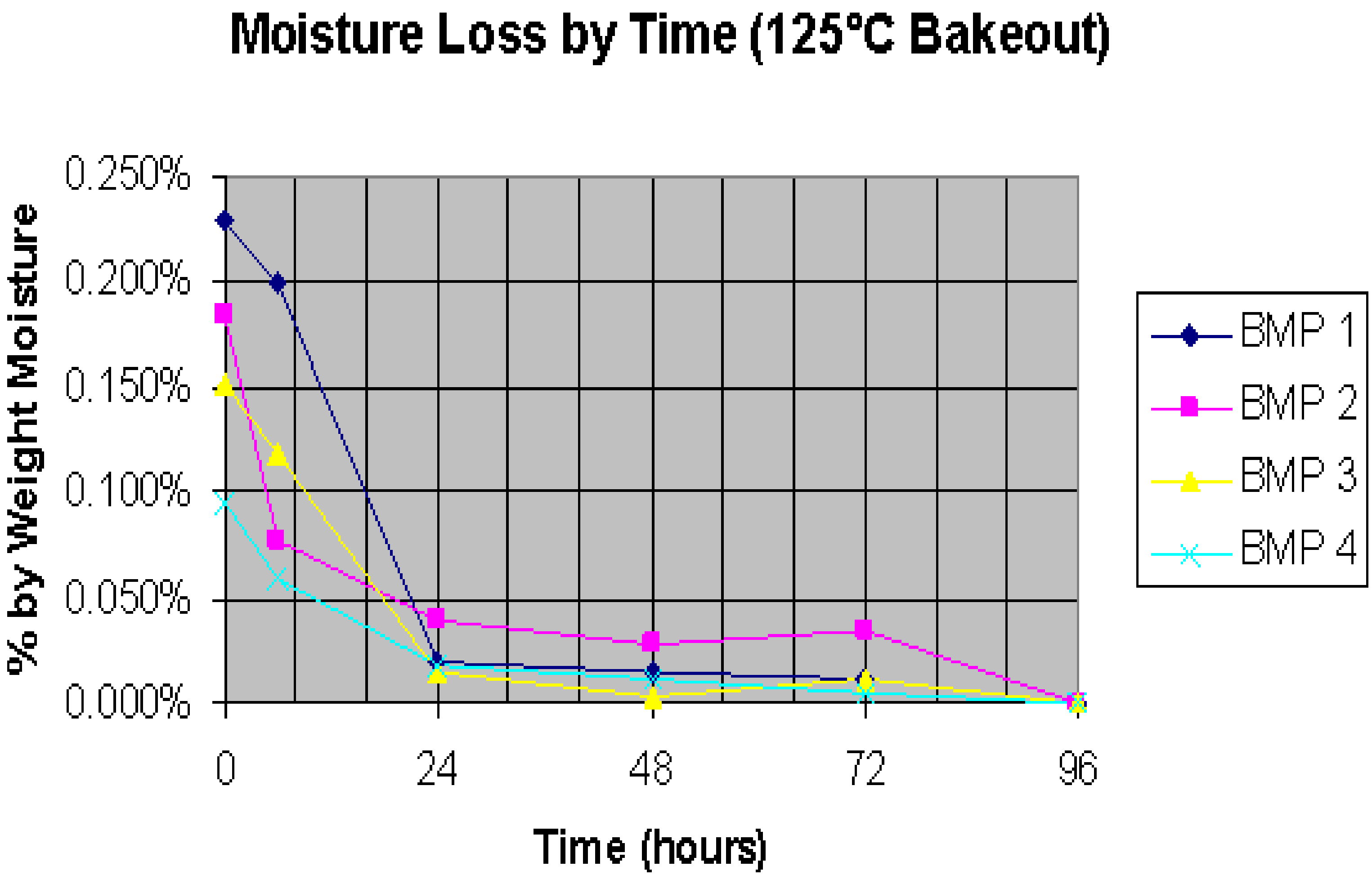
Subject Circuits

Eighth Brick

Quarter Brick

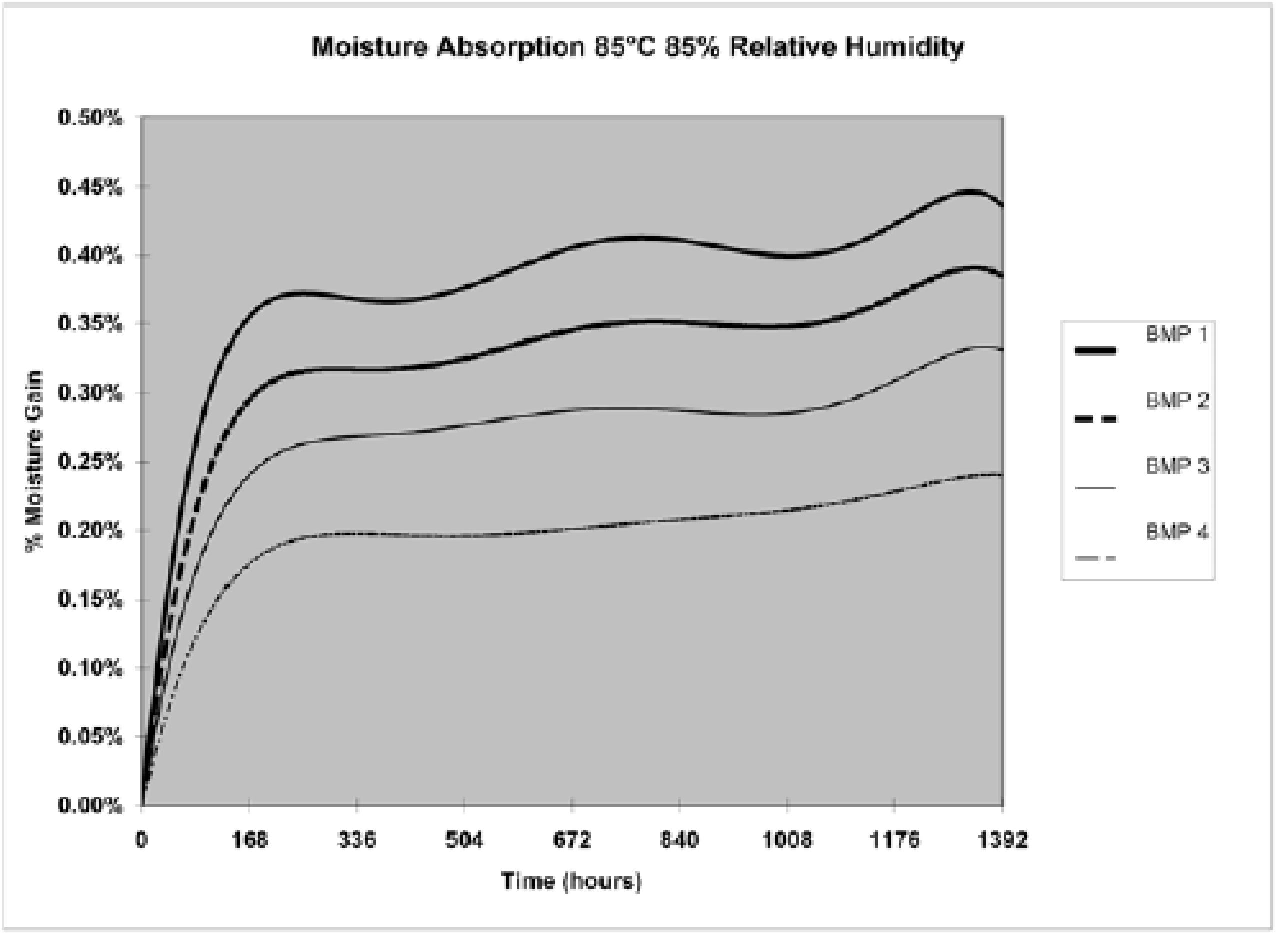


125° C Bakeout



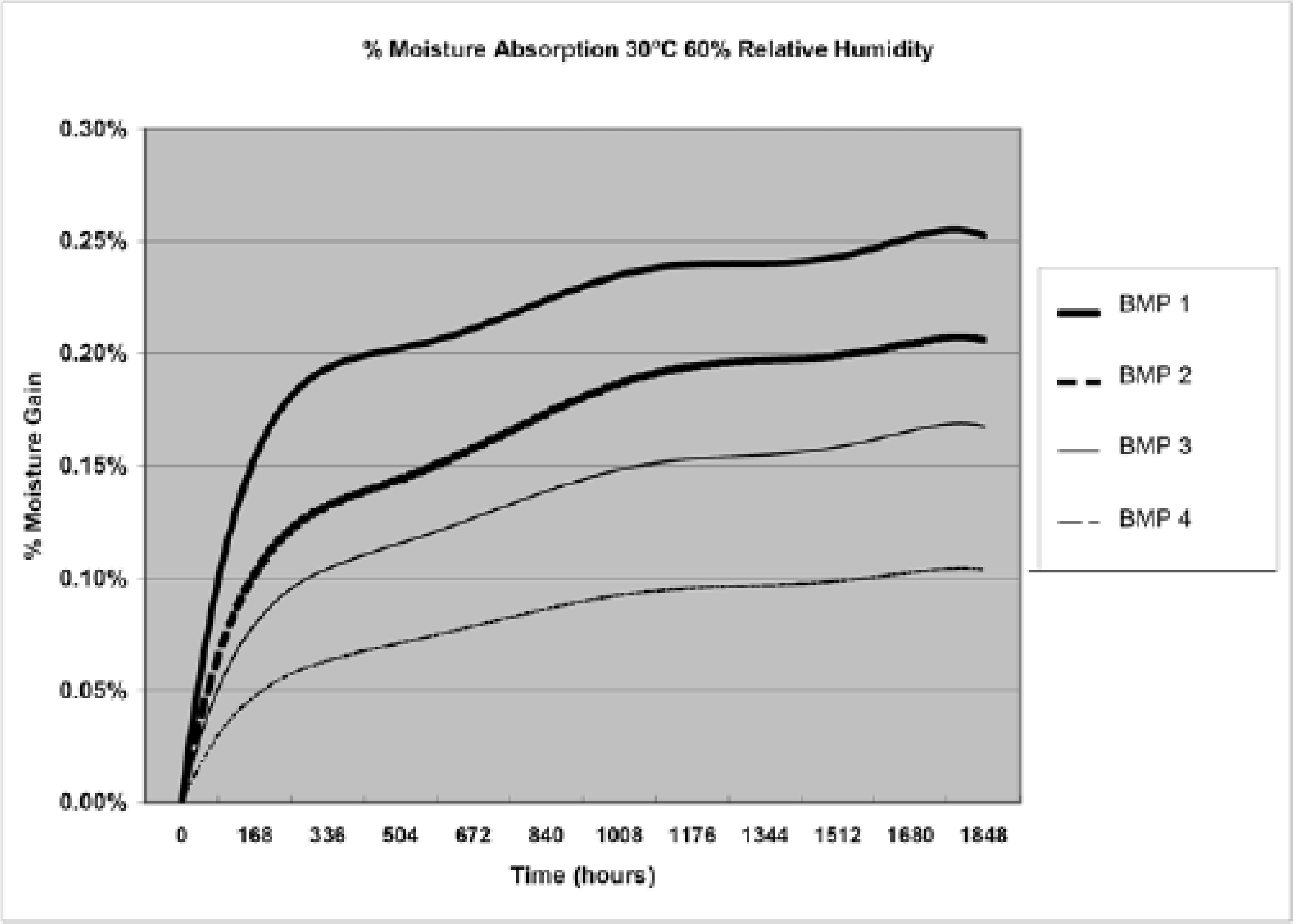
Moisture Absorption 85˚ C 85% RH

<u>% Moisture Absorption vs. Time</u>



Moisture Absorption 30˚ C 60% RH

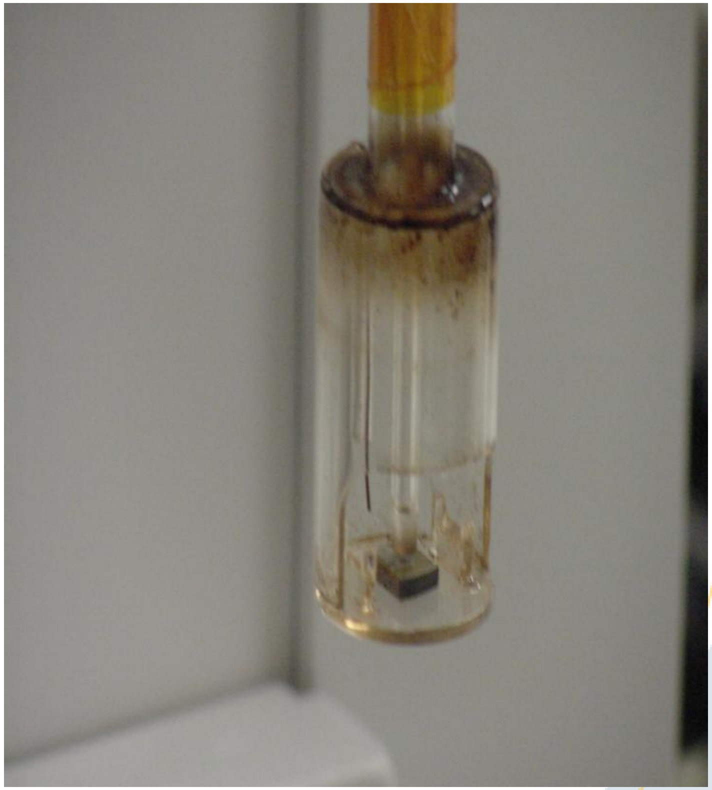
% Moisture Absorption vs. Time



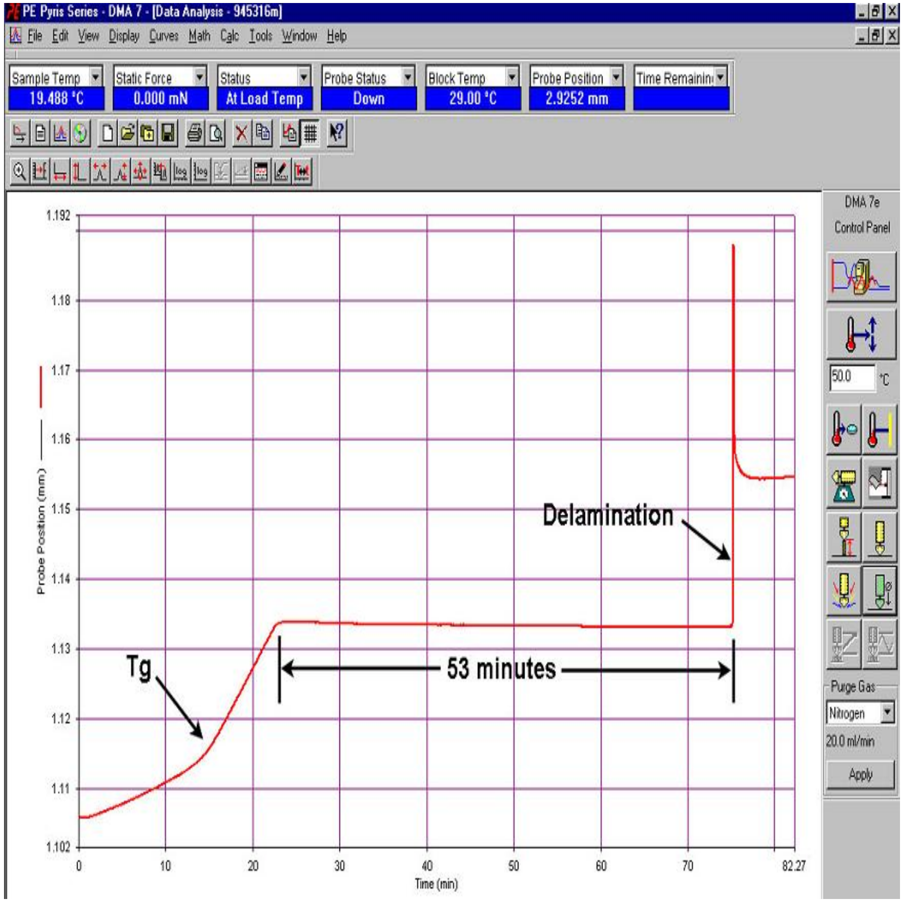
T260- Testing

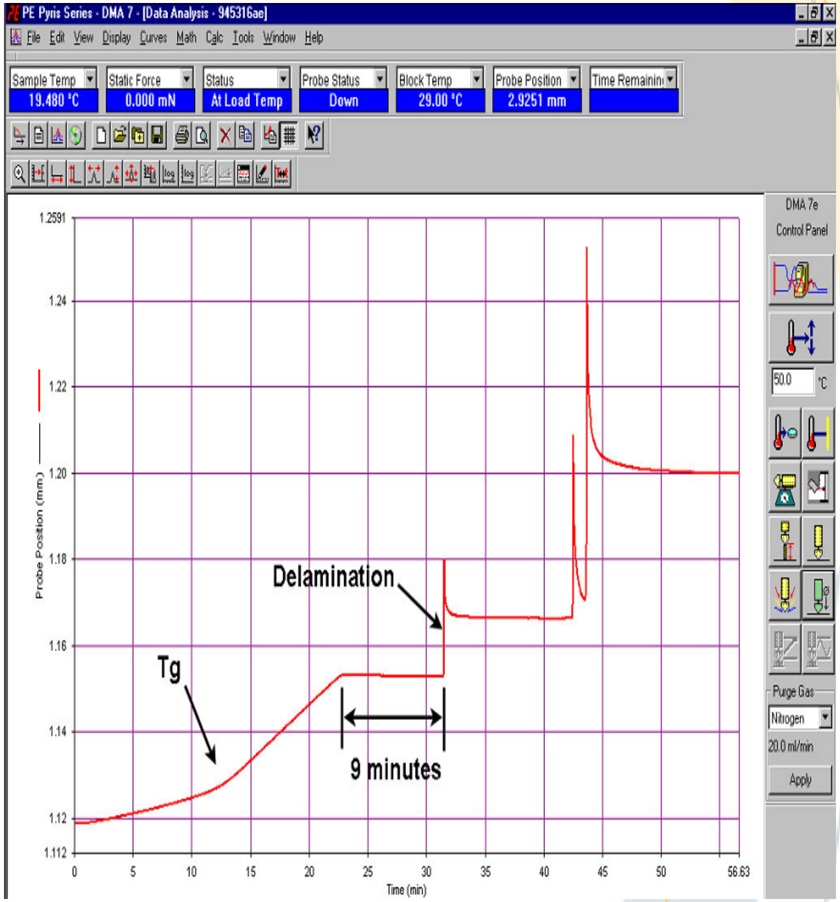
- Time to Delamination Detection through Thermomechanical Analyzer. TMA uses a small glass furnace and a glass rod capable of measuring slight expansion of material under test.
- IPC TM-650 Method 2.4.24.1

Perkin Elmer TMA



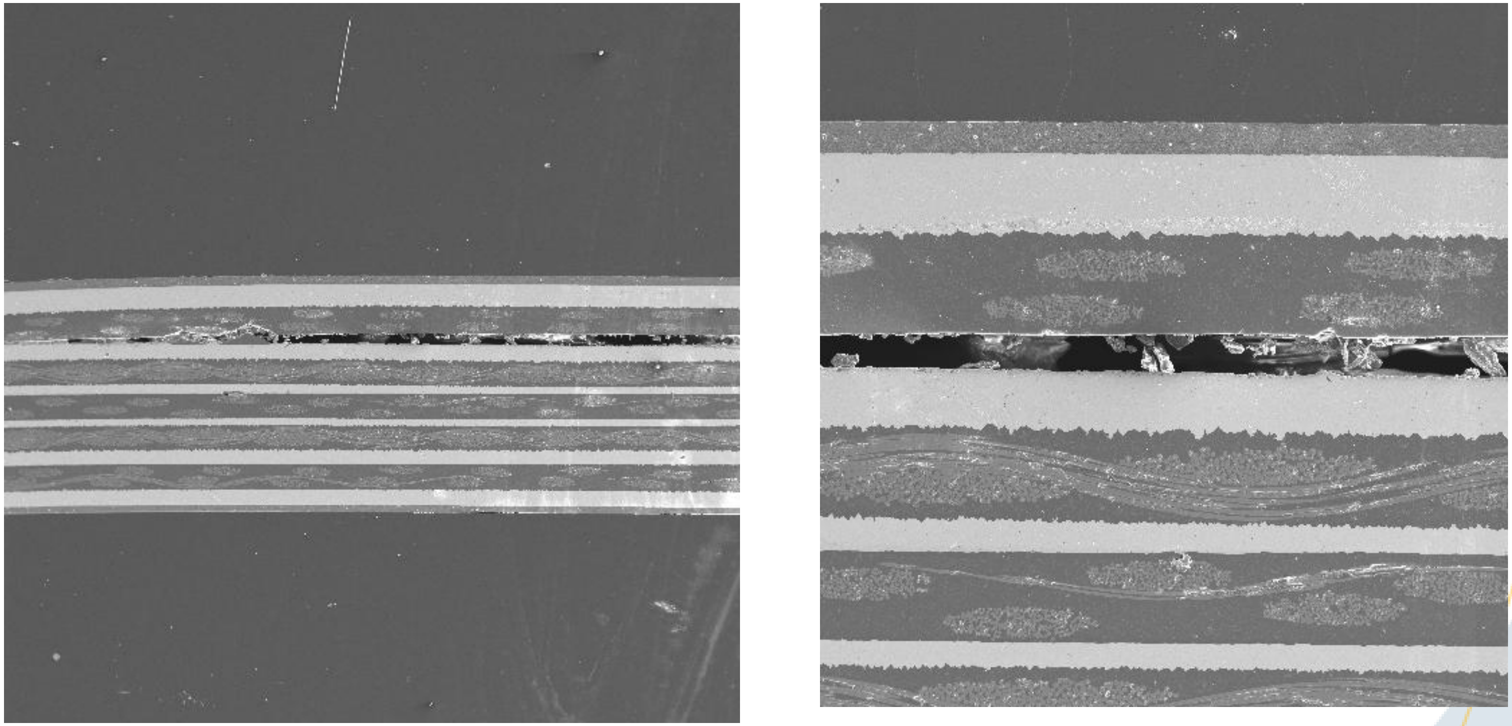
T-260 Graphs


PE Pyris Series - DMA 7 - [Data Analysis - 945316m]
Sample Temp 19.488 °C
Static Force 0.000 mN
Status At Load Temp
Probe Status Down
Block Temp 29.00 °C
Probe Position 2.9252 mm
Delamination
Tg
53 minutes
Probe Position (mm)
Time (min)
DMA 7e Control Panel
Purge Gas
Nitrogen
20.0 ml/min
Apply


PE Pyris Series - DMA 7 - [Data Analysis - 945316ae]
Sample Temp 19.480 °C
Static Force 0.000 mN
Status At Load Temp
Probe Status Down
Block Temp 29.00 °C
Probe Position 2.9251 mm
Delamination
Tg
9 minutes
Probe Position (mm)
Time (min)
DMA 7e Control Panel
Purge Gas
Nitrogen
20.0 ml/min
Apply

Delamination

Delamination results in compromised dielectric integrity.



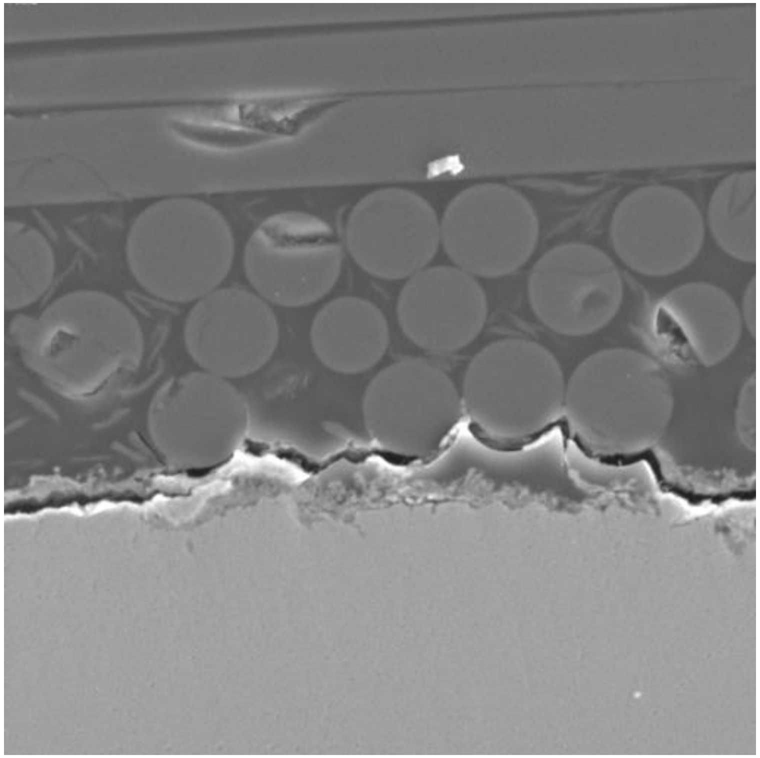
Delamination Photo and Close Up

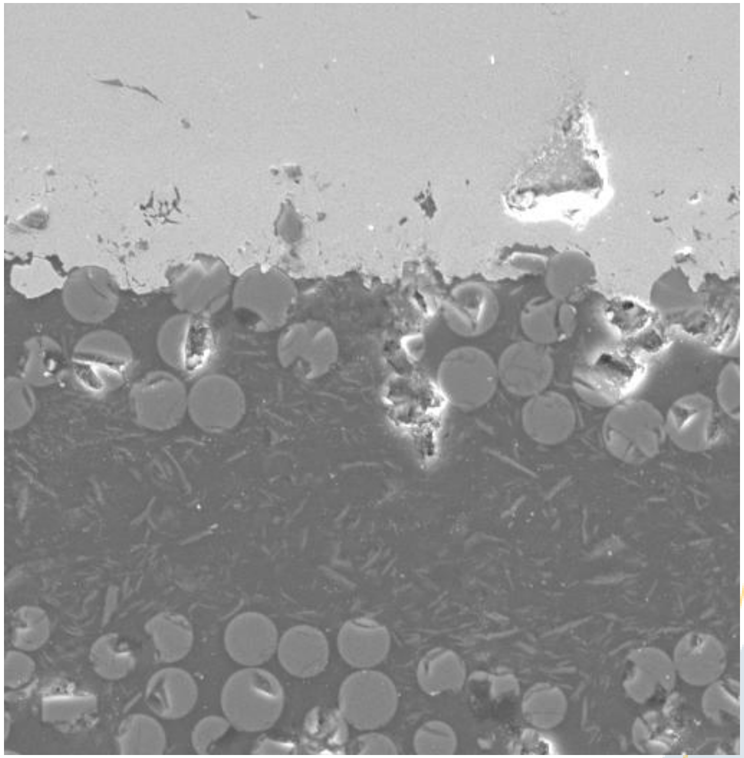
T260 Times Dry and with Moisture

	BMP 1		BMP 2		BMP 3		BMP 4	
SN #	% Moisture	Time (minutes)	% Moisture	Time (minutes)	% Moisture	Time (minutes)	% Moisture	Time (minutes)
1	DRY	47	DRY	24	DRY	54	DRY	26
2	0.0878%	49	0.0624%	48	0.1059%	49	0.0944%	22
3	0.2432%	43	0.0952%	34	0.1909%	46	0.1117%	24
4	0.3256%	54	0.1386%	46	0.3046%	34	0.1336%	23
5	0.3606%	46	0.1732%	44	0.3832%	27	0.1668%	15
6	0.4017%	53	0.2590%	24	0.4049%	36	0.1752%	14
7	0.4265%	9	0.2662%	30	0.4335%	45	0.2007%	26

Glass Stoppage

Delamination and Close-up





T260 Times with Glass Stoppage

Sample	THIN SECTION		THICK SECTION	
	% Moisture	T 260 (Minutes)	% Moisture	T 260 (Minutes)
1	DRY	15	DRY	19
2	DRY	15	DRY	20
3	DRY	16	DRY	19
4	0.182%	6.5	0.198%	8
5	0.288%	6	0.252%	7

T260 Time reduced by >50% with Glass Stoppage and Moisture

T260 Test Only may not be a good indicator of Moisture Vulnerability

Conclusions

- PWB Application and Storage need to be discussed with PWB Supplier to determine MSL and Packaging.
- T260 Testing (Time to Delamination) alone may not be a good indicator of Moisture Vulnerability
- Presence of Glass Stoppage and Moisture has a dramatic impact on Delamination
- Other possible contributors to delamination are: Moisture Content in Pre-preg, Lamination Press Cycle, Copper, Oxide Treatment and %Copper Content of PWB Board Construction.
- MSL rating of PWB should be a design consideration and discussed with PWB Supplier

Thank You

MSL PACKAGING AND PWB

Questions and Answers!