IPC-1601A PRINTED BOARD HANDLING AND STORAGE GUIDELINES

FINAL DRAFT FOR INDUSTRY REVIEW – FEBRUARY 2016

1 INTRODUCTION

1.1 Background Historically, the printed board industry has relied on military specifications and guidelines to define packaging methods to preserve the quality and reliability of printed boards during shipment and storage. However, many of these documents are obsolete, incomplete, do not address lead-free assembly processes, or do not cover newer laminates or final finishes. Additionally, the proliferation of alternative final finishes has produced concerns and requirements for printed board packaging and handling to preserve the finish and assure good solderability.

1.2 Scope This document provides suggestions for proper handling, packaging materials and methods, environmental conditions, and storage for printed boards. These guidelines are intended to protect printed boards from contamination, physical damage, solderability degradation, electrostatic discharge (ESD) (when necessary), and moisture uptake. Moisture absorbed in printed board laminates expands at soldering temperatures, and in some cases, the resulting vapor pressure can cause internal delamination or excessive strain on plated-hole walls and other structures. This is especially challenging with the higher temperatures used for lead-free soldering.

This document covers all phases from the manufacture of the bare printed board, through delivery, receiving, stocking, assembly, and soldering. As a guideline, this information is to be used with, and is secondary to, the established requirements in such documents as the IPC-4550 series for alternate final finishes.

1.3 Application The target audience includes those involved in all phases of printed board design, manufacture, assembly, shipping, storage, and possible warranty activities. Information herein has been supplied for all of these functions.

1.4 Terms and Definitions The definition of all terms used herein are as specified in IPC-T-50 and as defined in 1.4.1 through 1.4.6.

1.4.1 Humidity Indicator Card (HIC) A card on which a moisture-sensitive chemical is applied such that it will make a significant, perceptible change in color (hue), typically from blue (dry) to pink (wet) when the indicated relative humidity is exceeded. The HIC is packed inside the moisture-barrier bag (MBB), along with a desiccant, to aid in determining the level of moisture to which the moisture-sensitive devices or printed boards have been subjected.

1.4.2 Moisture Barrier Bag (MBB) A bag designed to restrict the transmission of water vapor and used to pack moisture sensitive devices. An MBB is made of material with a low Water Vapor Transmission Rate (WVTR) (see 4.2.1). An MBB includes a metallized layer (aluminum), making the bag appear shiny and opaque.

1.4.3 Subcomposite – In sequential lamination, a structure composed of more than two layers that have been laminated together, and which will subsequently be laminated with other layers into a complete printed board.

1.4.4 Water Vapor Transmission Rate (WVTR) A measure of the permeability of plastic film or metallized plastic film material to moisture, an important rating for moisture barrier bags (MBBs).

1.4.5 Sulfur Free Chemicals that are unlikely to express corrosive sulfur compounds like H_2S or $S0_2$.

1.4.6 Dry Packaging Packaging that consists of desiccant material and a Humidity Indicator Card (HIC) sealed with the printed boards inside a Moisture Barrier Bag (MBB) (See 4.3.1).

1.5 Revision Level Changes Changes that were incorporated in the current revision of this standard are indicated throughout by gray shading of the relevant subsection(s). Changes to a figure or table are indicated by gray shading of the figure or table header and applicable content.

2 APPLICABLE DOCUMENTS

2.1 IPC[1]

IPC-HDBK-001 Handbook and Guide to Supplement J-STD-001

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-A-311 Process Controls for Phototool Generation and Use

IPC-TR-585 Time, Temperature and Humidity Stress of Final Board Finish Solderability

IPC-TM-650 Test Methods Manual[2]

2.6.28 Moisture Content and/or Moisture Absorption Rate, (Bulk) Printed Board

IPC-4552 Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Circuit Boards

IPC-4553 Specification for Immersion Silver Plating for Printed Circuit Boards

IPC-4554 Specification for Immersion Tin Plating for Printed Circuit Boards

IPC-5704 Cleanliness Requirements for Unpopulated Printed Boards

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-7092 Design and Assembly Process Implementation for Embedded Components

NCMS Solderability Component Long Term Storage Report

2.2 Joint Industry Standards[3]

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC/JEDEC J-STD-033 Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices

IPC/JEDEC J-STD-609 Marking and Labeling of Components, PCBs and PCBAs to Identify Lead (Pb), Lead- Free (Pb-Free) and Other Attributes

2.3 Electrostatic Discharge Association (ESD)[4]

EOS/ESD S8.1 Protection of Electrostatic Discharge Susceptible Items - Symbols - ESD Awareness

ANSI/ESD S20.20 Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

2.4 Europa[5]

DIRECTIVE 2011/65/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast)

2.5 International Aerospace Quality Group[6]

AS9100 Quality Management Systems - Requirements for Aviation, Space and Defense Organizations

2.6 International Organization for Standardization[7]

ISO 9001:2008 Quality Management Systems – Requirements

2.7 ASTM[8]

ASTM F1249 Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor

1. www.ipc.org
2. Current and revised test methods are available on the IPC website (www.ipc.org/html/testmethods.htm)
3. www.ipc.org
4. www.esda.org
5. www.ec.europa.eu
6. www.sae.org/iaqg
7. www.iso.org
8. www.astm.org

3 PRINTED BOARD FABRICATION AND PACKAGING (HANDLING)

3.1 Printed Board Materials All materials used in the manufacturing of printed boards should be protected from environmental, handling and storage damage. It is customary for manufacturers to have procedures in place that outline these preventive practices. Industry certifications such as ISO 9001:2008 and AS9100 require these procedures. Customers often flow down these requirements to suppliers in purchasing documents as well. A sample specification for flow-down is included as Appendix A.

3.1.1 Bonding Materials, Prepreg and Resin Coated Foils These materials are sensitive to damage from exposure to moisture, humidity and ultraviolet light, as well as physical damage. They should have a degree of protection starting from material manufacture and storage, through transportation to the using facility, to receipt and storage within the using facility. Typically, these materials are stored in sealed bags (or dry pack MBBs) and used in a controlled environment where the temperature and humidity are controlled within limits specified by their manufacturers. MBBs for prepreg should be vacuum sealed for ease of handling. Typical guidelines for handling and storage of prepregs (and resin coated foils) are:

- Handle prepreg by the edges using clean latex or nitrile gloves
- Store sealed bags of prepreg flat and in a cool, dry environment (< 23 °C [73 °F], < 50% RH). Manufacturers may recommend refrigeration for some prepreg
- Reseal opened bags of unused prepreg (using clips or heat seals as shown in Figure 3-1) or returning to dry storage
- In cases where the storage temperature is significantly below room temperature, allow prepreg to acclimate to ambient conditions prior to layup. Keep prepreg in a sealed package during the stabilization period to prevent moisture condensation
- Do not fold prepreg.

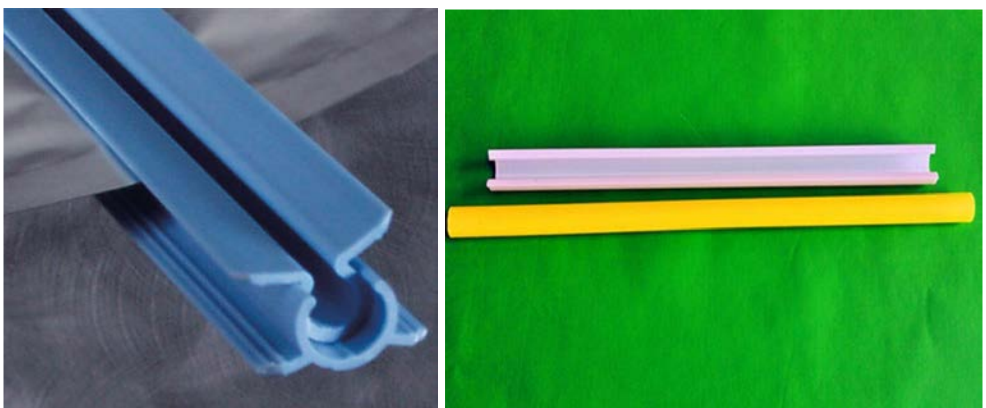

Figure 3-1 Examples of Clips used for Resealing Opened Bags

Temperature and humidity recorders are a common control process for storage and use locations, and may also be used during transportation of these materials. Please refer to your material manufacturer's recommendations for guidance on your materials.

3.1.2 Copper Clad Laminates

3.1.2.1 Handling and Foreign Object Concerns The infrastructure of the manufacturing location, as well as the equipment used to manufacture these materials, should be designed and evaluated to provide protection from damage and the introduction of foreign materials that may be detrimental to the finished product. Boxes, trays, and carts should be designed to protect these materials during transportation and use. Processing equipment should be evaluated to assure that it is capable of processing these materials reliably without causing damage to these materials or the finished product. Some guidelines are:

- Store laminates flat in an environment compatible with manufacturer's specifications
- Do not bend, scratch or dent laminate
- Maintain clean work areas and surfaces

- Prevent cross contamination of different resin types.

3.1.2.2 Environmental Concerns Prior to etching, cores are only subject to moisture absorption through the exposed laminate material of the panel edges. The amount of moisture absorption at this stage of production is negligible.

3.2 Inner Layer Production

3.2.1 Phototooling For additional information see IPC-A-311.

3.2.1.1 Temperature and Humidity The temperature and humidity in the area where the photo tools are used and stored should be in the same ranges as the area where the photo tools were manufactured. This will ensure that the scaling of the imaged product matches the intended scaling of the photo tooling. Excessive moisture may degrade the photo tool prematurely. Temperature and humidity recorders are typically used in these areas to assist in controlling this environment.

3.2.1.2 Handling and Storage Photo tools are usually placed into protective envelopes**,** and stored vertically in a manner that provides a reasonable amount of air movement around the photo tool to prevent entrapment of moisture. These protective envelopes also provide protection from abrasion and the introduction of foreign materials. Protective carriers may provide additional protection during transportation from the photo tooling manufacturing area to the point of use.

3.2.2 Process Equipment

3.2.2.1 Capability Equipment used for processing inner layers should be designed to handle the inner layer sizes, thicknesses, and material types being used. Processing equipment should be verified as being capable of processing these materials without causing damage. Statistical Process Control (SPC) should be used where applicable to control these processes.

3.2.2.2 Preventive Maintenance A preventive maintenance program should be developed and implemented to ensure the processes are capable of processing product reliably without causing damage.

3.2.3 Moisture Concerns for Etched Cores and Subcomposites After photo processing and etching, laminates are at a greater risk of moisture absorption. Process flow should be designed to minimize the time between baking and lamination to prevent moisture absorption into the laminated panel. Any moisture absorbed during lamination may need to be removed prior to packaging or assembly. Moisture embedded during this phase of manufacturing will require significantly more drying time to remove than from the individual etched cores.

Once the copper cladding is etched to create the desired circuitry of the cores, moisture absorption is of much greater concern due to the increased area of exposed laminate material.

3.2.3.1 Storage Conditions Storage conditions should be evaluated and controlled to minimize exposure of etched cores to moisture. Etched cores should be kept in dry storage, or exposed to ambient conditions for the least amount of time possible to minimize moisture absorption.

3.2.3.2 Pre-lamination The moisture content of cores may be determined for compliance to moisture levels described in 3.3.6 using test methods described in 5.8. This testing, or manufacturing recommendations, may dictate that a bake is required to meet these moisture levels. This bake may occur prior to or after adhesion promoting processes are completed. To prevent damage to the circuitry and adhesion promoting coatings, and to ensure even and effective drying in the shortest time possible, this bake is best accomplished by separating cores on racks. The length and temperature of this bake can vary depending on the laminate type (see laminate data sheet for moisture uptake characteristics), amount of copper cladding, and the type of adhesion promoter (oxide treatment).

Air flow in the oven is critical. Baking is less effective without circulation of air around the cores. See 3.4.2 for guidance on baking environments.

If circumstances require that cores must be baked in stacks, the maximum recommended stack height is 25.4 mm [1.0 in] to ensure that heating is uniform throughout the stack. Where slip sheets are used, they should be compatible with baking temperatures and should not promote cross contamination. Stacks are typically baked for two hours at 105 – 120 °C as measured in the middle of the stack. Consult with laminate and adhesion promoting process suppliers for specific baking recommendations.

The material should be cooled as rapidly as possible in a dry environment. Hot material in a humid environment will rapidly reabsorb moisture. For best results, cool in the oven if possible. After the layers have cooled, they should be put into dry storage or into the lamination stack as soon as possible. Some manufacturers of lead-free compatible laminates recommend a maximum hold time of 2 hours. This may be difficult to accomplish, but at ambient temperature and 50% RH, moisture content will return to previous levels in only a few hours.

Re-baking may damage oxide layers, and should be avoided if possible. Some oxide process suppliers recommend a maximum re-bake of 120 °C for one hour.

3.2.3.3 Subcomposite Cores (Sequential Lamination) Etching, drilling, and plating of subcomposites adds moisture absorption avenues. Minimizing hold times or controlling storage conditions will help reduce moisture uptake in the subcomposite.

Before laminating the subcomposite cores together, the moisture content may be determined for compliance to moisture levels in 3.3.6 using test methods as described in 5.8. This testing may determine that a bake is required to meet these moisture levels. The bake required will depend on the laminate material and the design of the subcomposite, e.g., two hours at 180 °C, eight hours at 150 °C, or 24 hours at 120 °C.

Adjustments may be required for some materials, panel thicknesses, or special processes. After subcomposites have cooled, they will begin to reabsorb moisture. Even within a few days, moisture levels may reach as high as 80% of equilibrium, and attain full equilibrium as quickly as one week. It is recommended to use moisture barrier packaging or dry storage to protect the subcomposites if lamination cannot be initiated within 24 hours.

Excessive moisture in subcomposites may drive moisture into the prepreg during secondary lamination, which may depress the T_g of the laminate package, cause breakdown of the laminate, or cause delamination or blowholes during high temperature assembly.

3.3 Manufacture of the Laminated Panels/Printed Boards

3.3.1 Processing Validation and Control Equipment used for processing laminated panels/printed boards should be designed to handle the sizes, thicknesses, material types, and final finishes used. Processing equipment should be verified as being capable of processing the laminated panels/printed boards without causing damage. SPC should be used where applicable to control these processes.

3.3.2 Handling and Transport of Product Handling practices for moving product between processes should be evaluated and procedures established. Transport of product between work cells may involve movement between work areas some distance apart, possibly even between different buildings or sites. Unique racking or packaging should be designed and implemented to protect the product during transportation and storage. This is especially true if the product is contracted out to a supplier for processing. Handling practices at these suppliers should also be verified. Return shipments should be checked for damage.

Conveyors, racks, pans and bags used to transport and store laminated panels/printed boards during manufacture should be designed to protect the product from damage both predictable and unforeseen. Printed board sizes and weights should be considered. Although unusual in bare printed board manufacture, ESD protection may also be needed for some products.

Fingerprint contamination may interfere with electrical test, cause visual workmanship rejections, and reduce solderability of the finish. Clean gloves or finger cots may help.

3.3.3 Environment Protection from the work and storage environment should be established. Etching, drilling, and plating of laminated panels add moisture absorption avenues. To prevent moisture uptake, control copper diffusion, and preserve solderability, the temperature and humidity in the environment should be controlled. Solderability of these finishes may also be degraded by fumes from processing chemicals or contact with sulfur bearing materials.

Long hold times between process steps will allow moisture absorption into the laminate material. After through-hole drilling and feature milling, but prior to plating and solder mask application, baking may be beneficial (see 3.4).

Controlling storage conditions for complete laminated panels will help minimize moisture uptake prior to dry packaging. If not, moisture may need to be removed prior to packaging, especially for lead-free processing (see 3.3.6).

3.3.4 Test Bare printed board electrical testing is another possible source of handling or machine damage. Surface damage may result from incorrect or worn-out fixtures, damaged probes, incorrect pressure settings, and careless handling practices. Preventive maintenance should be established for equipment and probes. Correct contact pressures should be planned and controlled by the testing protocol when possible. ESD procedures may also be needed for some product.

3.3.5 Inspection Work surfaces should be evaluated for contamination, and be cleaned on a frequent basis. Careless handling practices may cause physical damage to the printed boards.

3.3.6 Recommended Moisture Levels Prior to Packaging To ensure that printed boards are sufficiently dry when they are ready to solder, both the printed board fabricator and the user should protect them from moisture uptake. Both parties should implement effective process controls and protective packaging to limit the exposure of printed boards to ambient humidity during processing and storage.

The printed board fabricator should control the moisture content of the printed board before placing it into protective packaging (see 4.3). This will ensure prolonged shelf life in the dry packaging by preventing any excess moisture in the printed boards from saturating the desiccant prematurely. This will also ensure that the user will receive the printed board in a sufficiently dry state to allow normal processing, while avoiding the need to bake (see 3.4).

The moisture sensitivity of any printed board design will depend on the resin system, details of design and construction, and the assembly processes and soldering temperatures that the printed board will be exposed to by the user. The sensitivity of a particular design to moisture-induced delamination may be characterized by thermal stress testing. The preferred method for thermal stress testing is IPC-TM-650 test method 2.6.27. Additional reflow cycles may be specified, or samples may be cycled through thermal stress to the point of failure to provide useful data or validate design margin. For most designs, the maximum acceptable moisture content, or MAMC, will be somewhere between 0.1% and 0.5% of moisture weight to resin weight. See 5.7 for additional clarification on the influence of printed board construction on moisture content and resin weight. To allow for some ambient exposure during normal assembly and processing at the user, the printed board fabricator should ensure that moisture content is below the MAMC before placing the printed board into protective packaging.

The printed board fabricator is encouraged to develop a test methodology and statistical process control plan that best suits the designs, materials, and constructions of the printed boards, and the processing conditions that they will be exposed to. Because many of these variables are known only by the user, and because they may affect cost and schedule, any limitation on moisture content prior to packaging, and any required verification of moisture content, should be as agreed between user and supplier (AABUS).

Some users and suppliers may consider limiting moisture content before packaging to 0.1% by weight for a printed board that will be subjected to a high temperature soldering process (up to 260 °C, such as lead-free), or a maximum of 0.2% for low temperature assembly soldering (maximum 230 °C). These limits should be achievable by many board fabricators with industry standard process controls, and without significant extra expense. However, these limits will not apply in all cases, and should not be imposed without due consideration of the particular design and process requirements.

The moisture content of a printed board may be determined using methods specified in 5.8. When moisture content of a printed board exceeds the specified limit, fabricators should review their processes for potential improvements (see 3.1.1, 3.1.2.2, 3.2.3, and 3.3.3). If necessary to meet a moisture goal, consultation with the user and printed board designer may allow for changing of the laminate materials or printed board requirements. Baking should be avoided whenever possible (see 3.4), but may be necessary if the measured moisture content in a printed board exceeds the specified limit. To preserve solderability of some final finishes, it may be preferable to perform this bake before the final finish is applied.

3.4 Baking for Moisture Removal A baking operation may be necessary to remove any residual moisture that may have been absorbed into the printed board during the time between completion of the printed board fabrication process and exposure to the assembly soldering profile.

3.4.1 Problems Caused By Baking If process controls are ineffective**,** and printed boards have absorbed excessive moisture, baking is the most practical remedy. However, baking not only increases cost and cycle time, it can also degrade solderability of the printed board (see 4.1.3), which requires extra handling and increases the likelihood of handling damage or contamination. In general, both the printed board fabricator and the user should strive to avoid baking by practicing effective handling, packaging, storage, and process controls as defined elsewhere in this document. Solderability testing may need to be repeated after the final bake.

Completed printed boards held before shipment (e.g. finished goods) should be packaged in dry pack to prevent the need for baking prior to shipment (see Appendix A Example 2).

3.4.1.1 Effects on Organic Solderability Preservative (OSP) Finishes Baking is NOT recommended for OSP coatings, as it deteriorates the OSP finish. If baking is deemed necessary, it is recommended to use the lowest possible temperature and dwell time. One hour at 105 °C is suggested as a starting point for unstacked printed boards. Extended dwell times will have a negative impact on solderability, which will depend on the complexity of the assembly process and the subsequent number of thermal exposures. If extended dwell times are required to drive out excessive moisture, it may be necessary to strip the coating, bake the printed boards, and then re-coat.

3.4.1.2 Oxidation Effects In some circumstances, even a surface that is not normally prone to oxidation can be affected. With an Electroless Nickel/Immersion Gold (ENIG) finish, oxygen can eventually penetrate a thin gold layer, oxidizing the underlying nickel. Some oxidation may be avoided by baking in a low-oxygen environment, such as in a vacuum or nitrogen-inert oven.

3.4.1.3 Effects on Solid Diffusion Baking accelerates solid diffusion between metals, and increases intermetallic growth. This can lead to a "weak knee" or other solderability issues if the intermetallic layer reaches the surface and oxidizes. See IPC-HDBK-001 for information on diffusion rates.

3.4.1.4 Effects On Immersion Silver Finishes During baking, silver tarnish will form if sulfur or chlorine are present in the air, or contaminating the bake oven. Tarnish becomes visible when it grows to approximately 5 nm in thickness, but does not degrade solderability until it reaches about 50 nm. If tarnish is visible after baking, solderability should be verified.

3.4.1.5 Effects On Immersion Tin Finishes Solderability shelf life of immersion tin depends on thickness, but typically is specified as one year (see IPC-4554). Baking increases the growth of CuSn intermetallics, shortening the solderability shelf life. Baking may render a printed board unsolderable, especially if it is already near the end of its solderability shelf life. Before baking printed boards with immersion tin finish, it may be advisable to bake a sample at the target time and temperature, and then verify solderability.

3.4.1.6 Stripping and Refinishing It may be possible to restore solderability of some final finishes by stripping and refinishing, but in many cases, it will be more cost effective to scrap the printed boards and start over.

3.4.2 Baking Environment Baking should be performed in a forced air recirculating oven, though effectiveness may be improved by reducing the relative humidity or vapor pressure of water in the oven, such as through baking in vacuum or nitrogen atmosphere. The oven used for baking should be vented and capable of maintaining the required temperatures at less than 5% RH. The oven environment should be free of contamination that can deposit on printed board surfaces, such as silicones. Sufficient space should be maintained between printed boards for heated air to circulate and remove moisture.

3.4.3 Baking Considerations The times and temperatures required for effective bake out depend on many factors, including:

- The moisture content of the printed board
- The desired degree of dryness after the bake (should be below the MAMC for safe reflow, see 5.7)
- The moisture desorption characteristics of the laminate
- The overall printed board thickness
- The locations and structures of copper plane layers
- Design features such as plated edges.

To minimize damage to internal structures, baking should be performed at a temperature below the T_g of the laminate. Utilizing temperatures above 125 °C (105 °C for OSP) may degrade the printed board final finish, solder mask, or laminate. Baking may also degrade any assembled components.

3.4.4 Establishing Baking Profiles The baking schedule may be established by performing sample testing per methods described in 5.8. It is recommended to bake a printed board sample to a known "bone dry" condition, and then weigh it to establish the known dry "baseline" weight. The sample can then be saturated in a humid environment and weighed, or allowed to absorb a known amount of moisture, which can also be established by weighing. To determine the rate of moisture loss at a given bake temperature, place the "wet" sample in an oven, and then take it out briefly at periodic intervals (e.g., once every hour) and weigh it.

Note: Laminate suppliers may offer general baking recommendations and limits. If the final finish is prone to oxidation, the supplier of the final finish chemistry may offer additional recommendations that should be considered.

The times and temperatures in Table 3-1 below are offered as guidelines for development of baking profiles, and will not apply in all cases.

Table 3-1 Recommendations for Printed Board Baking Profiles

Final Finish	Temperature	Time	Comments
Tin	105 – 125 °C	4-6 Hours	Baking may reduce solderability. See 3.4.1.5
Silver	105 – 125 °C	4-6 Hours	Silver may tarnish. See 3.4.1.4
Nickel/Gold	105 – 125 °C	4-6 Hours	See 3.4.1.2
ENEPIG	105 – 125 °C	4-6 Hours	
Organic Coating	See 3.4.1.1		
HASL/HAL	105 – 125 °C	4-6 Hours	Final surface thickness below 0.77 µm [30.0 µin] may turn into pure intermetallics and render the printed board unsolderable

4 PACKAGING, STORAGE, AND SHIPMENT

4.1 Packaging Evaluation The method of packaging finished printed boards for storage and shipment should be evaluated against multiple factors and concerns. Consistent packaging techniques and materials should be used from point of laminate fabrication through assembly.

4.1.1 Moisture Absorption Packaging considerations should include the moisture sensitivity of the laminate materials, moisture controls during printed board manufacturing processes, and the anticipated storage conditions (time, temperature, and humidity). Some laminate materials, such as polyimide, absorb moisture more readily than others, and baking may be necessary prior to packaging (see 3.3.6).

For most polymeric laminates, packaging should include MBBs, desiccant materials to absorb any moisture that enters the bag, moisture detecting strips (Humidity Indicator Cards, or HICs) to provide a visual indication of moisture level when the package is opened, and heat-sealing of the bag. In some cases the use of a laminate witness card may also be advisable (see 4.2.5).

Dry packaging and moisture control may not be necessary for some designs that are tolerant of moisture uptake before soldering, or where elapsed time between fabrication and soldering is “very short”, to be defined by user. See Appendix A Example 1.

4.1.2 Physical Attributes The rigidity and the configuration of the bare printed board should be considered. Thin printed boards (usually less than 1.4 mm [0.055 in]), printed boards manufactured from flexible materials, or those with complex contours may need a rigid protective package, or be vacuum laminated or secured by some other method to a rigid backing material. This protective material may be inside or outside the primary packaging (e.g., the moisture barrier or ESD bag).

4.1.3 Effects on Final Finish Solderability The final finish on the printed board may dictate the type of packaging required. Consult the manufacturer of the final finish for specific recommendations. Some final finishes have more limited storage life to assure good solderability. The following IPC specifications contain industry requirements for some printed board final finishes:

- IPC-4552 Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Circuit Boards
- IPC-4553 Specification for Immersion Silver Plating for Printed Circuit Boards
- IPC-4554 Specification for Immersion Tin Plating for Printed Circuit Boards.

As other finishes require specifications, they will be addressed by the IPC 4-14 Plating Processes Subcommittee as part of the IPC-4550 specification family. As this and other applicable specifications are under continuous review, the subcommittee will add appropriate amendments and make necessary revisions to these documents.

IPC-TR-585 documents a study to identify stress factors for evaluating solderability of several final finishes: fused tin/lead, organic solderability preservative (OSP) over copper, immersion silver, immersion tin, ENIG, and bare copper. Samples were conditioned in a controlled temperature/humidity chamber, and then solderability was evaluated by wetting balance testing, Sequential Electrochemical Resistance Analysis (SERA) testing, and “dip and look” visual inspection for solder coverage. The purpose was to develop a stress test with analytics to determine the robustness and potential shelf life of those finishes, but the document includes valuable information on the effects of time, temperature, and humidity on solderability.

Some packaging materials may contain chemicals that degrade solderability. Interactions between dissimilar packaging materials need to be evaluated, e.g., separator sheets and enclosure bags. Sulfur free pH neutral paper may be used on the outside of printed boards to act as a protective layer between the final finish and the packaging material, including the desiccant and HIC.

The solderability degradation of a printed board final finish can result from three fundamental causes:

(1) Final finish oxidation,
(2) Diffusion of base metal layer through the final finish and subsequent oxidation interactions,
(3) External contamination.

The following paragraphs summarize the common industry printed board final finishes.

4.1.3.1 Tin/Lead Industry investigations [NCMS Solderability Component Long Term Storage Report] have stated “The data shows a slow decline in wettability with an indication of a plateau after 8 to 9 months.” This degradation was independent of packaging material and even between packaging and not packaging. The root cause of solderability loss is growth and oxidation of Cu_6Sn_5 and Cu_3Sn intermetallic phases. When these intermetallic compounds (IMCs) reach the surface and oxidize, solderability is lost. Thinnest areas (knees of PTH's for HASL finishes) lose solderability fastest (6 months to a year typical). Remaining surfaces typically remain solderable for 1-2 years depending on SnPb thickness. Refer to IPC-6012 for suggested minimum HASL/HAL thicknesses for long-term storage.

4.1.3.2 Immersion Tin Tin oxidizes relatively quickly compared to other metallic final finishes. Packaging that limits and/or inhibits exposure to environmental humidity and atmosphere will reduce the oxidation rate of immersion tin final finish. However, as with tin/lead finishes (see 4.1.3.1), the more common cause of solderability degradation is growth and oxidation of Cu_6Sn_5 and Cu_3Sn intermetallic phases, which is unaffected by packaging.

4.1.3.3 Immersion Silver Immersion silver solderability is mostly unaffected by exposure to oxygen. However, chlorine and sulfur compounds have a strong affinity for immersion silver final finishes causing significant solderability degradation. Packaging of immersion silver final finishes should prevent exposure to atmospheric contaminates and humidity. The use of sulfur absorbent, pH neutral materials, e.g., Silver Saver™ paper, as part of printed board packaging is widely used in the electronics industry.

4.1.3.4 Electroless Nickel Immersion Gold (ENIG) The immersion gold is a thin, porous deposit that, when applied correctly, reduces oxidation of the underlying nickel solderable surface. Packaging for ENIG final finish is often similar to the packaging protocols utilized for Tin/Lead final finishes.

4.1.3.5 Electroless Nickel/Electroless Palladium/Immersion Gold (ENEPIG) This is a multifunctional surface finish that features many of the advantages of ENIG, but it is gold wire bondable, and is not susceptible to “black pad” problems. The immersion gold deposit over the palladium may be thinner than that applied in the ENIG process. Plating involves more complex chemistries and more steps than ENIG. For finishes that will be soldered, the same packaging requirements as for ENIG should be used. For wire bonding applications, surfaces should be protected from scratches and mechanical damage that may occur during shipping and handling, using interleaf papers that are pH neutral and sulfur free.

4.1.3.6 Electrolytic Gold (GS) Electrolytic gold provides better protection of the underlying nickel than ENIG due to reduced porosity. Packaging for GS final finish is often similar to the packaging protocols utilized for Tin/Lead final finishes.

4.1.3.7 Organic Solderability Preservative (OSP) OSP is normally the last process step and printed boards may be packaged directly at the end of the OSP line. If printed boards are not completely dry, the OSP deposit could be damaged. Likewise, printed boards should not be packaged while still warm from drying, because condensation may form inside the package upon cooling, which will also be detrimental to the OSP deposit. Packaging materials should be sulfur free.

4.1.3.8 Final Finish Requirements Composition, thickness and solderability requirements for the following final finishes can be found in IPC-6012:

- Electrodeposited Tin
- Electrodeposited Tin-Lead
- Hot Air Solder Leveling (HASL)/Solder Coating (Eutectic Tin-Lead Solder Coating or Lead-Free Solder Coating)
- Electrodeposited Nickel
- Electrodeposited Gold
- Electroless Nickel Immersion Gold (ENIG)
- Electroless Nickel/Electroless Palladium/Immersion Gold (ENEPIG)
- Immersion Silver
- Immersion Tin
- Organic Solderability Preservative (OSP).

4.1.4 Storage and Packaging Environment The environment for packaged printed boards should also be evaluated by the user. Environmental contamination, e.g., hydrogen sulfide, chlorine, etc., as well as high temperature and humidity levels, may cause the packaging to fail. Default packaging methods cannot account for conditions exceeding the expected storage conditions. If the user can be confident that printed boards are dry when packaged (by baking if necessary), and then packaged with desiccant and a HIC into an MBB, they will have useful information for how well the packaging has performed in the environment into which it was placed.

4.1.5 ESD Concerns Traditionally**,** printed boards are not considered ESD-sensitive, although many users prefer to have them packaged in appropriate ESD protective bags so that the printed boards may proceed directly into the user's assembly environment without needing to be re-packaged. With the appearance of printed boards containing embedded passive, active, or networks of components, the printed board as received may require ESD packaging and handling consideration. Please see IPC-7092 for more information. Many varieties of "ESD" bags are available, and some are only static resistant, not static dissipative or static shielding. The user should specify the appropriate type of bag needed.

4.2 Packaging Materials Bags and other packaging are available in a variety of materials and forms of construction. The selection of packaging material and construction directly influence the longevity and preservation of printed boards with regard to moisture absorption, especially those destined for exposure to the higher temperatures and longer dwell times associated with lead-free processing.

Packaging materials and quantities described in 4.2.3 are based on IPC-J-STD-033. Other packaging may be used, depending on the printed board design and production requirements, see Appendix A and Appendix B.

4.2.1 Water Vapor Transmission Rate (WVTR) The WVTR is the rate that water vapor passes through a specific area of barrier material, expressed in grams of water vapor, per surface area, for a 24 hour period, at 40°C. The bag WVTR capability should be chosen in light of the assembly use consumption rate and if pre bake prior to assembly is a consideration (see 3.4.1). These variables should be a consideration when specifying a specific bag WVTR rating. The WVTR for dry packaging of printed boards should meet the requirements of IPC/JEDEC J-STD-033, which specifies a WVTR of ≤ 0.002 g/100 in^2/24 hrs (or 0.031 g/m^2/24 hrs). MIL-PRF-81705 Type 1 requires 0.0005 g/100 in^2/24 hrs. at 40 °C. Bags with higher or lower WVTR may be considered depending on the moisture sensitivity of the printed board material and the required shelf life, or to reduce the amount of desiccant required. The WVTR is measured using ASTM F1249.

4.2.2 Typical Packaging Material Types

a) Nylon/Foil/Polyethylene – A commonly available MBB construction that incorporates an outer layer of static dissipative nylon, aluminum foil middle layer, and an inner layer of polyethylene. This structure provides very good moisture barrier characteristics with typical WVTR values of < 0.0005 gm/100 in^2/24 hrs).

b) Tyvek™/Foil/Polyethylene – This is a legacy MBB structure type, similar in construction to Nylon/Foil/Polyethylene, with typical WVTR values of < 0.0005 gm/100 in^2/24 hrs.

c) Aluminized Polyester/Polyethylene – Typically, this structure consists of two layers of 48 gauge aluminized polyester laminated to sealable polyethylene. For 0.09 mm [0.0036 in] thick materials, WVTR is about 0.02 gm/100 in^2/24 hrs. Structures that are 0.18 mm [0.007 in] thick can achieve a WVTR of about 0.005 gm/100 in^2/24 hrs.

d) Clear Plastics/Polymers (non-metallic) - Plastics that do not incorporate a metallic layer in the construction provide limited moisture barrier performance, and should not be used for dry-packaging of printed boards, especially those destined for lead-free assembly.

4.2.3 Desiccant Material The quantity and quality of the desiccant material selected should be in accordance with IPC/JEDEC J-STD-033 and should be sulfur free. The following equation describes the quantity of desiccant to be included in the dry package.

$$U = (0.304 * M * WVTR * A)/D$$

Where:
U = Amount of desiccant in UNITS, where one unit can absorb at least 2.85 grams of moisture at 20% RH and 25°C.
M = Shelf life desired in months (see Clause 3.3.6 for shelf life)
WVTR = Water vapor transmission rate in grams/m^2 in 24 hrs.
A = Total exposed surface area of the MBB in square decimeters
D = The amount of water in grams, that a UNIT of desiccant will absorb at 10% RH and 25 °C

When the desiccant capacity at 10% RH and 25 °C is not known a conservative value of D = 1.40 can be used.

Additional examples of desiccant quantities and various bag sizes are provided in Appendix B.

Desiccant that has been exposed to moisture and may be saturated should not be reused.

4.2.4 Humidity Indicator Card (HIC) The type and usage of the HIC should have three (3) color spots with sensitivity values of 5%, 10%, and 60% RH as shown in Figure 4-1 and should be sulfur-free in accordance with IPC/JEDEC J-STD-033. The HIC is packed inside the MBB, along with a desiccant, to aid in determining the level of moisture to which the moisture-sensitive devices or printed boards have been subjected.

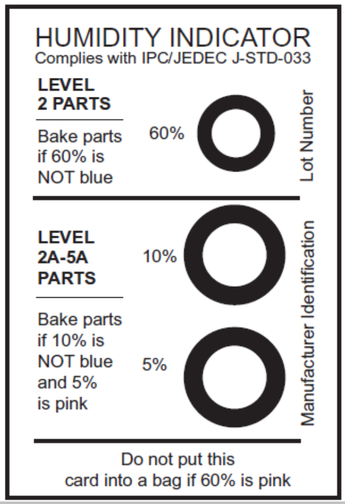

Figure 4-1 Humidity Indicator Card (HIC) Example

4.2.5 Laminate Witness Coupons Witness coupons are intended to evaluate relative moisture absorption and the integrity of the packaging. The use of a witness coupon in the packaging is desirable for printed boards that are subjected to lead-free assembly processing. The coupon should be placed in the dry packaging, and may be used to determine the moisture level or condition of the printed boards upon receipt, after storage, and during assembly processing, e.g., in accordance with IPC-TM-650 Method 2.6.28. The use of a witness coupon would be AABUS.

Witness coupons can be manufactured by the printed board fabricator either as a representative break-off coupon from the manufactured panel, or fabricated from clad laminate which has a resin content of at least 50% and a minimum thickness of at least 0.50 mm [0.020 in]. The clad laminate material should be of the same or similar resin system as the printed boards it will be packaged with. Coupons should have an area of at least 76.2 x 76.2 mm [3.0 x 3.0 in] so that adequate resin volume exists. Coupons should be thoroughly dried by baking them after fabrication. The bake time should be adequate to bring the sample weight to equilibrium. After the drying bake, the samples should be stored in a dry environment such as a dry box or storage container until ready for packaging.

Just prior to inserting the coupon into the printed board package, the coupon weight should be determined using an analytical balance and the weight recorded to the nearest 0.0001 g. The coupon should be placed on the top of the stack of printed boards and the recorded weight should be communicated to the user.

4.3 Packaging Methods

4.3.1 Internal (Dry Packaging)

4.3.1.1 Prepackage Conditions Prior to packaging, the printed boards should be clean (see IPC-5704) and dry (see 3.3.6).

4.3.1.2 Immersion Silver Printed Boards Printed boards using Immersion Silver as the final finish should include protective sulfur absorbing paper (e.g., Silver Saver™ paper) in the package, covering any exposed silver surface. Any separation sheets placed between printed boards should be sulfur free (see 1.4.5) and pH neutral, or sulfur absorbing paper (treated on both sides). See IPC-4553 for additional information.

4.3.1.3 Moisture Barrier Bag Sealing The bag should be heat sealed to keep out moisture. Full air evacuation is not recommended as it may cause board warpage or lead to MBB punctures. Light air evacuation will reduce the packaging bulk and facilitate carton packing. Excessive evacuation or sealing of the desiccant away from the printed boards may impede, or completely negate, desiccant performance in the packaging.

4.3.1.4 Desiccant Placement Desiccant(s) should be placed along the edges of printed boards inside the MBB. This will avoid stress that can warp the printed boards if packages are stacked within the shipping carton, and will prevent desiccant from interacting with the printed board final finish.

4.3.1.5 Bulk Packaging Printed boards of approximately 0.093 m^2 [144 in^2] or less may be grouped in quantities of up to 25 printed boards per package. Printed boards greater than 0.093 m^2 [144 in^2] should be grouped in quantities no greater than 10 per package. Appropriate slip sheet separators should be used and should be free of sulfur and chlorine. Dependent on weight or shape of the printed board, other requirements may be AABUS.

4.3.2 External Packaging

4.3.2.1 Sulfur/Chlorine Content in Packaging Material Materials used for external packaging are not required to be free of sulfur and chlorine. However, the use of sulfur and chlorine free material may provide benefits for some printed boards.

4.3.2.2 Packaging Concerns for Transportation Empty space in the box should be filled with appropriate packing material so that the product cannot shift within the packaging, and will be protected during shipment. The total weight of printed boards and packaging material should be limited so that the load rating of the box is not exceeded. When necessary, especially with large printed boards, corner protectors should be used. Materials used should be free of contaminants. Use of anti-static or static dissipative materials may provide for direction transportation to, and opening within, an ESD Protected Area (EPA) for assembly.

4.3.2.3 Support Material Support materials may be added to provide additional protection for thin, flexible, or oddly shaped printed boards (see 4.1.2).

4.3.2.4 Packaging Container Gross Weight Each container's gross weight should be identified when required by local regulations.

4.4 Marking

4.4.1 Lead-Free/ RoHS compliance Where required by statute or by the user, packaging must be marked in accordance with RoHS Directive 2002/95/EC, with exceptions noted in the Annex, or other applicable statutes. This applies to printed boards that only contain permissible levels of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers.

A suitable identification symbol such as the following may be used on packaging or packaging labels:

RoHS

Where required by the user, final finish and other attributes of printed boards and packaging must be marked in accordance with J-STD-609.

4.4.2 ESD Packaging for ESD-sensitive printed boards should be marked per ANSI/ESD S20.20, including the ESD protective symbol as shown in Figure 4-2.

Figure 4-2 EOS/ESD S8.1 Protective Symbol

4.4.3 Moisture Printed boards enclosed in dry packaging may be marked with a suitable warning or moisture sensitivity caution symbol in a similar fashion to the marking requirements of IPC/JEDEC J-STD-033, as shown in Figure 4-3.

NOTE: Use of the moisture sensitivity caution symbol in this application does not imply that all requirements of IPC/JEDEC J-STD-033 apply.

Figure 4-3 Moisture Sensitivity Caution Symbol

4.4.4 Other Markings Other markings (e.g., date codes, U.L.) may be as specified by the user.

5 PRINTED BOARD RECEIVING, STORAGE AND ASSEMBLY

5.1 Before Opening Dry packed packages should be inspected to verify there are no tears, punctures, or openings of any kind that expose the contents. If openings are found, and the HIC indicates that the dry environment of the bag has been compromised (see 5.3), then the printed boards should be evaluated for excessive moisture content per 5.8. Printed boards may also be visually inspected for any changes to the final finish that may indicate that solderability has been degraded.

If physical inspection is required, intact bags may be opened for inspection by cutting at the top of the bag near the seal (as close to the seal as possible if the bag is to be resealed). Time of exposure to ambient conditions should be controlled to minimize moisture uptake. If bags are opened under factory ambient conditions (not exceeding 30 °C/60% RH), then either:

a) Place printed boards in dry storage at 10% RH or less within one hour, or

b) Return them to dry packaging (see 4.3.1) within 30 minutes. In this case, the original desiccant and HIC may be reused.

Note: If the 60% spot on the HIC indicates wet, the HIC and desiccant should be replaced.

If ambient conditions of temperature, humidity, or exposure time are exceeded, printed boards should be evaluated for excessive moisture per 5.8.

5.2 Storage Location (Stock Room) Dry packaging will be effective for at least one year if stored at less than 40 °C and 90% RH (see IPC/JEDEC J-STD-033). See 4.2 and 4.3.1.

5.3 Upon Opening A Moisture Barrier Bag The HIC should be read immediately upon removal from the MBB. For best accuracy, the HIC should be read at 23 ± 5 °C. If there is a significantly perceptible change to the color (hue) on the 10% dot on the HIC (see IPC/JEDEC J-STD-033 for guidance on changes to the hue), this indicates that the dry pack conditions have been compromised. This can occur due to misprocessing (e.g., missing or inadequate desiccant, wet printed boards, poor sealing), mishandling (e.g., tears or rips in the MBB), excessive elapsed time in the bag, or improper storage (moisture absorbed through the bag has saturated the desiccant). In this case, printed boards should be evaluated for excessive moisture per 5.8.

Note: Color key code cards may be available from the HIC manufacturer if needed to confirm the wet/dry colors.

Any witness coupons (see 4.2.5) should be evaluated for moisture uptake per 5.8 by weighing the coupon using an analytical balance, and comparing the result to the dry weight recorded by the supplier. Coupons should be weighed within 10 minutes of opening the package. If necessary, the coupon may then be baked until dry and then re-weighed to validate the result. If the absorbed moisture exceeds the values recommended in 3.3.6 or AABUS, the user should consult with the printed board fabricator to determine the appropriate corrective action.

5.4 Production Environment (Temperature, Humidity, and Atmosphere) During assembly operations, printed boards should be protected from moisture uptake, contamination, and extremes of temperature. Temperature and humidity in the shop environment should be in accordance with IPC J-STD-001 guidelines.

To control moisture uptake and prevent contamination, printed boards should be kept in sealed dry packaging until they are ready for assembly. When opening bags, it is recommended to follow the procedures in 5.3. Once bags are opened, moisture content in printed boards will increase while they are exposed to ambient conditions of temperature and humidity. If hold times between assembly or process steps are prolonged (e.g., between soldering operations), printed boards should be kept in dry storage (e.g., dry nitrogen or desiccator cabinets) when they are not being worked on. Storage at elevated temperatures (bake ovens) may control moisture uptake, but can degrade solderability and increase the rates of copper diffusion and intermetallic growth (see 3.4.1).

Printed boards should be protected from contamination by silicones, greases, oils, salts, corrosives, and fingerprints. This is particularly critical for no-clean operations. Handle printed boards by the edges only, and if necessary, using clean gloves or finger cots.

To maintain solderability, some printed board final finishes may require protection from processing chemicals, fumes, sulfur, or contact with sulfur-bearing materials. Some final finishes, e.g., OSP, Immersion Silver and Immersion Tin, may be degraded by some cleaning operations.

Printed boards that are ESD sensitive should be handled in accordance with ANSI/ESD S20.20 or equivalent.

5.5 Storage Containers (Shop Floor) Containers used for storing and transporting printed boards should protect the contents from contamination and handling damage. Containers should be maintained free of contamination. Some printed board final finishes may require sulfur-free containers to avoid degrading solderability. Printed boards that are ESD sensitive require ESD protection in accordance with ANSI/ESD S20.20 or equivalent.

5.6 Soldering Operations Before commencing mass soldering operations, the MAMC should not be exceeded (see 5.7 and 5.8). This applies whenever soldering temperatures are encountered, including initial soldering operations, desoldering, solder touchup (rework), or modifications.

5.7 Maximum Acceptable Moisture Content (MAMC) During soldering operations, excessive moisture within the printed board can expand, causing delamination or other damage (see 1.2). Recommended maximum moisture levels may be established for printed boards prior to dry packaging (see 3.3.6). These levels are intended to ensure that a printed board will be received in a known dry condition when it is removed from an effective, functioning dry pack system (per 4.3.1). However, these moisture levels may not be appropriate for some designs when soldered during assembly processing.

With the exception of especially challenging designs, many printed boards should be capable of mass soldering at higher moisture levels; however, this is not a given and should be evaluated. If there are doubts as to whether the printed board design is capable of mass soldering at these moisture levels, then an MAMC should be established. The MAMC is an estimate of the maximum amount of absorbed moisture that the printed board can tolerate without damage when exposed to soldering heat, and is expressed as a percentage of the dry weight of the printed board. MAMC will vary depending on the characteristics of the laminate and other details of the construction.

Note: Densities of copper, glass, and resin are significantly different, and depending on construction (e.g., planes and layer count), printed boards that appear similar may have very different MAMC’s.

Copper does not absorb moisture, and is nearly six times denser than the same volume of resin, so a 10-layer design with ½ oz. copper layers will not have the same moisture gain or loss, when expressed as a percentage, as a similar printed board with some 1 oz. layers. Furthermore, even if only the resin and glass are considered, there may be significant differences due to the construction and the stackup. For example, a printed board constructed of 7628 glass may have about 40% resin by weight, while a similar board with 1080 glass could have about 60% resin by weight. These factors need to be considered when assessing MAMC, or constructing coupons for moisture absorption testing.

The MAMC should be established by the printed board designer or the user, though it may be AABUS. It may be established based on available data from laminate suppliers, analysis, previous experience, or through verification testing on printed board samples.

5.8 Evaluating Moisture Content Printed boards exposed to ambient conditions outside of a functioning dry pack system will absorb moisture at a rate that depends on their susceptibility to moisture absorption, which varies with the laminate material and other details of the construction. The amount of moisture absorbed will depend on the conditions of the exposure, including the relative humidity, temperature, and time. When the MAMC has been exceeded (see 3.3.6 or 5.7 as applicable), it is recommended that printed boards should be baked in accordance with Table 3-1, or dispositioned between user and supplier.

When moisture content is in doubt, it should be measured from a sample of the suspect population per IPC-TM-650, Method 2.6.28. An alternative test methodology is the Thermal Gravimetric Analysis (TGA) test. The TGA test method can be used to measure moisture content as either a primary analysis method or as a referee analysis method for suspect populations. The TGA test method requires more sophisticated equipment and skilled personnel, is a destructive test, and has different test specimen constraints in comparison to IPC-TM-650, Method 2.6.28.

Another alternative test methodology is the IPC-TM-650 Method 2.5.35 for printed board capacitance testing, which at the time of publication of this document is still in development. For further discussion of moisture uptake versus capacitance, the National Physical Laboratory (NPL) has a published paper entitled “Moisture Measurement in PCB’s and Impact of Design on Desorption Behaviour” that is available through IPC.

Appendix A
Example Flowdown Of Packaging/Handling Requirements To A Printed Board Supplier

The following examples illustrate typical packaging requirements that could be imposed on a supplier of finished printed boards, depending on circumstances. Requirements might be flowed down by contract, procurement documentation, or in the drawing. These examples are not intended to be definitive, they may not cover all situations, and tailoring is encouraged.

Example 1: Suggested Basic Requirements

These requirements might be imposed if printed boards will be shipped directly and without delay to the customer, the design is not especially prone to moisture uptake or sensitive to moisture damage during soldering, parts will be assembled and soldered within a few days after receipt, and will not be exposed to high temperature or humidity before soldering. In such cases, dry packaging might not be necessary, but packaging must protect the printed boards from physical damage during shipping.

> Parts shall be packaged in contaminant-free plastic bags. Packaging shall be marked with the manufacturer's name or CAGE Code, and part numbers of the parts enclosed. External packaging shall be sufficient to protect the contents in accordance with best commercial practice.

Example 2: Suggested Standard Requirements:

Dry packaging will be necessary if printed boards are especially sensitive to moisture, will be stored for up to a year or more, or might be exposed to high humidity during shipping or storage. Marking/labeling may be required. IPC-1601 is a guideline and should not be flowed down in its entirety, but it may be referenced or quoted in part for specific requirements.

> Unless otherwise specified in the drawing, printed boards shall be dry packed in a heat-sealed moisture barrier bag (MBB), with desiccant and HIC IAW IPC-J-STD-033. Each moisture barrier bag may contain up to 10 PBs of size 144 in^2 (per side) or greater, provided that printed boards are separated by slip sheets or other appropriate materials such as pink poly bags. Smaller printed boards may be packaged up to 25 per bag, with separators. Each moisture barrier bag shall be marked with the part number, date code and quantity of the printed boards enclosed. Moisture content prior to packaging shall not exceed 0.2% by weight of the printed board, IAW IPC-1601. Moisture content may be assured by documented process controls or appropriate testing.

Example 3: Possible Special Requirements:

Special requirements may apply for printed board designs that are especially fragile, sensitive to environmental conditions, high cost, or must be stored between 12-24 months. In the interest of clarity, instead of referencing specifications, requirements may be spelled out.

> 1. Prior to packaging, rigid and flexible printed boards shall be clean and dry.
>
> 2. Parts shall be packaged individually with desiccant, a humidity indicator card (HIC), and a corrosion control absorber patch (e.g. Silver Saver® paper) into a moisture barrier bag (MBB). Desiccant shall be sulfur-free Type II per MIL-D-3464, with quantity in accordance with IPC-

1601. The humidity indicator card (HIC) shall have 3 dots (5/10/60) in accordance with IPC-J-STD-033. The moisture barrier bag (MBB) shall have a water vapor transmission rate (WVTR) as received of 0.002 gm/100 in^2/24 hrs or less in accordance with IPC-J-STD-033. One sheet of oxidation arrest paper (minimum 2” by 3.5”) shall be included for every 140 in^2 of bag area (counting both sides). For printed boards with immersion silver finish, a sheet of Silver Saver® paper shall cover each silver surface.

3. Desiccant packs, HICs, oxidation arrest paper patches, and silver saver sheets shall be kept dry before being sealed into moisture barrier bags, and removed from dry storage and placed into the MBB just before it is sealed. The desiccant and oxidation arrest paper shall be kept separate from the product by either of the following means.

a. Place the desiccant packs and oxidation arrest strips into a secondary small polyethylene bag as shown in Figure A-1, which shall then be placed in the MBB. The polyethylene bag shall be partially heat-sealed to prevent the contents from shifting, but a gap must be left to allow air exchange to the inside of the polyethylene bag:

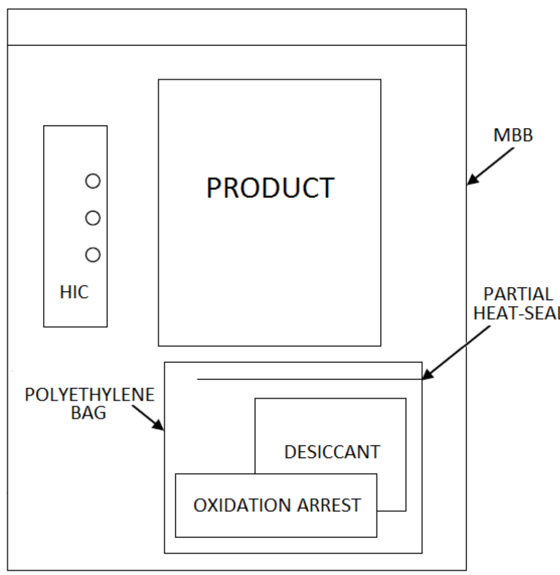

Figure A-1 Usage of Heat Sealed Polyethylene Bag in Conjunction with MBB

b. Place the desiccant and oxidation arrest paper in the bottom of the MBB, leaving room at the top for the printed board and HIC. Make a partial heat-sealed seam separating the desiccant and HIC from the printed board approximately as shown in Figure A-1.

4. The MBB shall be heat sealed at the top with light air evacuation (preferred); full vacuum is not allowed. The heat seal shall allow sufficient space for the bag to be cut open and re-sealed at least once. Examine the primary heat seal and verify that there is an uninterrupted dull gray line across the full width of the bag, with no folds, melting, or shriveling. A watery clear glaze indicates that heat has not sufficiently penetrated the bag film.

5. Flexible printed circuits shall be supported with sulfur and chlorine-free cardstock or other stiff material to prevent damage in shipping.

6. Parts shall not be packaged in bulk quantities (more than one per MBB) without written permission. Bulk packaged printed boards shall be separated with slip sheets that are sulfur and chlorine free (preferred method) or in individual unsealed ESD dissipative/shielding bags. For printed boards with immersion silver finish, slip sheet separators shall be silver-saver paper, with a sheet covering each silver surface.

7. Each moisture barrier bag shall be labeled with supplier's CAGE Code, purchase order number, and the part number, serial number, and date code of each part enclosed.

8. Finished rigid and flexible printed boards supplied to this order that have been left out of dry storage for more than 5 days shall be baked for moisture removal prior to packaging IAW IPC-1601. Within one hour after any baking, parts shall be stored at less than 10% RH, or dry packed in a moisture barrier bag as described herein.

9. For each production lot through lamination, a laminate witness coupon shall be supplied in accordance with IPC-1601. Any samples, including unused IPC-2221 test coupon strips, witness coupons, microsections, and solderability samples shall be packaged as described herein and shipped in the same shipping container as the products they represent.

10. Include a certificate of conformance (C of C) with each order, a serialization sheet detailing the serial numbers for all parts in the delivery, an AS9102 first article inspection report (where applicable), ionic contamination/cleanliness test results, and any other test results required by the drawing or purchase order. If test reports or microsections were supplied with a previous delivery, it shall be noted on the C of C.

11. External packaging shall protect the printed boards from shock and physical damage, and prevent movement during shipping and handling. Sealed bags containing printed boards shall be wrapped in anti-static foam, bubble wrap, or other suitable static dissipative cushioning material. External packaging shall resist tears, punctures, opening of seams or corners, or other breakdown.

Appendix B
Desiccant Required As a Function of Moisture Barrier Bag (MBB) Size

The formula for desiccant provided in IPC J-STD-033 (see 4.2.3) is in SI units, whereas many moisture barrier bags are specified in inches. Table B-1 below includes both square decimeters and square inches for surface area. The amount of desiccant required is rounded up to the nearest commonly available size for desiccant packs.

Desiccant quantities in this table may be adjusted. More desiccant will prolong shelf life beyond one year, or permit the use of MBBs with a higher WVTR than that of the IPC-J-STD-033 standard.

Table B-1 Desiccant Bag Quantities Based on MBB Size

Bag Size (in.)	Area (dm^2)	Area ($in.^2$)	Units	Unit Packs
5 x 7	4.52	70	0.18	2 x 1/6
8 x 10	10.32	160	0.41	3 x 1/6
10x 20	25.81	400	1.02	4 x 1/3
12 x 18	27.87	432	1.11	4 x 1/3
16 x 18	37.16	576	1.47	5 x 1/3
10 x 30	38.71	600	1.54	5 x 1/3
18 x 18	41.81	648	1.66	5 x 1/3
18 x 22	51.10	792	2.03	5 x 1/2
25 x 30	96.77	1500	3.84	8 x 1/2

Assumptions for Table B-1 include the following:

1. Bag area is given in square decimeters and square inches. Surface area includes both sides of the bag.
2. Desiccant is at full capacity, i.e. one unit can absorb at least 2.85 grams of moisture at 20% RH and 25°C.
3. Packing materials inside the bag (dunnage) are assumed to be dry.
4. Required shelf life (storage time) is 12 months minimum at <40°C and 90% RH.
5. Water vapor transmission rate for the moisture barrier bag (WVTR) is assumed to be 0.031 $g/m^2/24$ hours or less (0.002 $g/100\ in^2/24$ hours). Some commonly available bags that meet IPC J-STD-033 requirements specify WVTR of 0.0005 $g/100\ in^2/24$ hours, and therefore the amount of desiccant required would be reduced by a factor of 4.

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Number **2.6.28**	
Subject **Moisture Content and/or Moisture Absorption Rate, (Bulk) Printed Board**	
Date **08/2010**	Revision
Originating Task Group **Board Storage and handling Subcommittee (D-35)**	

IPC-TM-650 TEST METHODS MANUAL

1 Scope Moisture absorption can cause delamination or other damage in printed boards subjected to soldering heat. This test is a process control tool to determine both the bulk moisture content and moisture absorption rate of a printed board. It may be used to determine whether the specimen conforms to the monitoring level of the user's performance specification, to assist in process development, or for process control. This test may not provide accurate analytical results on all specimens, depending on the thickness of the item, the presence of copper layers or other moisture barriers within the structure, or the presence of any volatile compounds other than water. The weight of the specimen is compared before and after a bake operation. The bake is intended to remove most of the water (> 90%) from the sample, and the bake time and temperature specified herein are minimums. To improve test accuracy, or to prevent heat damage, other bake parameters may be as agreed between user and supplier (AABUS).

2 Applicable Documents

IPC-QL-653 Certification of Facilities that Inspect/Test Printed Boards, Components and Materials

3 Test Specimens

This test may be applied to actual printed boards. If the item is too large to be weighed easily, a representative sample or coupon may be used. The sample may be sectioned from a larger printed board or assembly (e.g., a scrapped item), provided that the sample represents the features and construction of the whole. The sample should be sized based on the mass capacity and physical dimensions of the analytical balance. If a coupon is used, it must include features and construction similar to the item that it represents, including similar content and distribution of copper, and must have been subjected to the identical processing environments and conditions. It should be realized that the use of a representative coupon excised from a larger printed board may result in exposed laminate edges that will result in a slightly different absorption rate than the actual printed board.

4 Apparatus

4.1 Circulating air oven capable of maintaining a uniform temperature of 105 +5 °C/-0 °C (221 +9 °F/-0 °F). Nitrogen atmosphere (inert) or vacuum is not required, but will promote drying and improve accuracy of the test.

4.2 Analytical balance capable of determining the test sample/coupon weight in grams to 4 places of accuracy (X.XXXX) is required. Precautions **shall** be taken to ensure that the analytical balance test location is not compromised by vibration or air drafts. If the test samples are functional printed circuit boards with embedded active devices, ESD requirements appropriate to handling these circuit boards **shall** be followed. The analytical balance **shall** be calibrated in accordance with IPC-QL-653.

4.3 Tweezers, tongs or equivalent **shall** be used to handle the test sample/coupons to prevent handling contamination. The tweezers **shall** be cleaned prior to each test sample/coupon weighing session.

4.4 Gloves **shall** be used when handling the test samples/coupons to prevent handling contamination. The gloves **shall not** contribute any contamination material on the test samples/coupons.

5 Procedure

5.1 Initial Weighing The weight of the test sample/coupon **shall** be determined to the nearest 0.0001g and recorded.

5.2 Bake The test sample/coupon **shall** be baked for 24 hours at 105 +5 °C/-0 °C (221 + 9 °F/-0 °F), unless AABUS.

Note: The intent of this bake is to remove at least 90% of the moisture from the sample. Printed boards that are very thick, have solid copper planes, or that are especially saturated with moisture (which may be bound deep within inner layers) may require longer bake times and/or higher temperatures.

5.3 Post-Bake Weighing An extremely rigid post bake weighing regimen must be strictly followed to accurately determine the test sample/coupon absorption rate. The analytical balance measurement station **shall** be organized to prevent any interruption of the post bake weighing process.

Procedure:

1. The test sample/coupon **shall** be removed from the circulating oven and transferred immediately (within 2 minutes) to the analytical balance measurement location.

2. Each test sample/coupon **shall** be placed on the analytical balance and allowed to dwell for 15 seconds, and then the sample/coupon weight **shall** be recorded to the nearest 0.0001 g. Note that the sample/coupon weight will not settle completely.

These measurements characterize the bulk moisture content of the test samples. If the moisture absorption rate is desired, continue with process steps 3 through 5:

3. Measure and record ambient temperature and relative humidity at the analytical balance measurement station.

4. The test sample/coupons **shall** remain at the analytical balance measurement station for 15 minutes +1/-0 minutes and procedure steps 2-3 **shall** be repeated.

5. Repeat step 4, taking measurements at 15 minute intervals, for at least 4 hours.

Note: The ambient temperature and humidity, the frequency with which ambient conditions are recorded, the measurement intervals between weighings and the number of weighings may be adjusted AABUS.

5.4 Calculations Calculate the bulk moisture content using the following equation:

$$\text{Moisture Content (\%)} = \frac{\text{(Initial Weight)} - \text{(Post-Bake Weight)}}{\text{(Post-Bake Weight)}} \times 100$$

Calculate the moisture absorption rate by plotting the bulk moisture content versus time using the data recorded in Procedure steps 3 through 5 of 5.3.

Note: Metals do not absorb moisture, and metal content in the specimen will affect the accuracy of this determination. If copper or other metals are likely to exceed 20% of the weight of the specimen, this weight should be determined or estimated, and subtracted from both the Initial Weight and the Post-Bake Weight in the formula above. This correction factor **shall** be AABUS.

5.5 Report Report the bulk moisture content or moisture absorption rate for the sample/coupon.