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October 2005

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Users of this publication are encouraged to participate in the development of future revisions.

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Handbook and Guide to Supplement J-STD-001

0.1 GENERAL

0.1.1 Scope This Handbook is a companion reference to the J-STD-001 *Requirements for Soldered Electrical and Electronic Assemblies* and is intended to provide supporting information.

Additional detailed information can be found in documents referenced within the Standard (and this Handbook). Users are encouraged to reference those documents to better understand the applicable subject areas.

Although this Handbook uses mandatory terminology (e.g., **shall**, must, etc.), nothing within this Handbook is considered mandatory unless otherwise specified as a mandatory requirement in the contract documentation.

The intent of this Handbook is to capture “how and why” information and give more background for the specification limits and how they were derived. In addition, other supporting information is provided to give a broader understanding of the process considerations needed for the production of acceptable hardware. The target user of this Handbook is a process or manufacturing engineer.

0.1.2 Purpose This Handbook describes materials, methods, and verification criteria that, when applied as recommended or required, will produce quality soldered electrical and electronic assemblies. The intent of this Handbook is to explain the “how-to,” the “why,” and fundamentals for these processes, in addition to implementing control over processes rather than depending on end-item inspection to determine product quality.

The J-STD-001 and the IPC-HDBK-001 do not exclude any acceptable process used to make the electrical connections, as long as the methods used will produce completed solder joints conforming to the acceptability requirements of the Standard.

0.2 FORMAT (Using This Handbook)

This Handbook provides guidance on the J-STD-001E requirements. The clause numbers in this Handbook refer and correspond to the clause numbers in J-STD-001E. However, the information provided in this Handbook is applicable to Users of any previous version of J-STD-001.

The text of J-STD-001E includes a space shuttle symbol where the requirements are different in J-STD-001ES *Space Applications Electronic Hardware Addendum to IPC J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies*, but it has been removed from the text of this Handbook. Although this document will not provide discussion on each of the differences between J-STD-001 and J-STD-001ES, it will provide information on certain topics addressed in J-STD-001ES, i.e., lead-free mitigation, that may need to be considered in a general soldering process. This information will be included in the applicable section of this Handbook and not highlighted in any manner.

A cross reference listing, provided as Appendix C to this Handbook, will assist Users with identifying related paragraphs in previous revisions of J-STD-001. This cross reference listing includes identification of the associated Space Applications Electronic Hardware Addendum paragraphs for revisions E (ES) and D (DS).

Where used verbatim, text that is directly quoted from a standard is italicized. In this Handbook, the word “Standard” refers specifically to J-STD-001 Revision E.

NOTE: References in the text of this Handbook (not text quoted from a Standard) refer only to sections, tables, and figures in this Handbook and will be followed by “of the Standard” unless otherwise noted (see Example 1). If the reference is to a section, table, or figure a designator of the revision being referenced will follow it (see Example 2).

Example 1: For more information on lead trimming, see 5.2.0.5.

Example 2: For more information on surface mount components, see Table 7-2 of the Standard.

All following Clause numbers align to the Clause numbers in published J-STD-001E.

Clause numbers preceded by * are additional content for this Handbook. There is no related Clause in the Standard.

1 GENERAL

1.1 Scope This Standard prescribes practices and requirements for the manufacture of soldered electrical and electronic assemblies. Historically, electronic assembly (soldering) standards contained a more comprehensive tutorial addressing principles and techniques. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001 and IPC-A-610.

1.2 Purpose This Standard describes materials, methods and acceptance criteria for producing soldered electrical and electronic assemblies. The intent of this document is to rely on process control methodology to ensure consistent quality levels during the manufacture of products. It is not the intent of this Standard to exclude any procedure for component placement or for applying flux and solder used to make the electrical connection.

1.3 Classification The User (the individual, organization, company, or agency responsible for the procurement of electrical/electronic hardware, having the authority to define the class of equipment and any variation or restrictions to the requirements of this Standard) and Manufacturer (the individual, organization, or company responsible for the procurement of material and components, as well as all assembly processes and verification operations necessary to ensure full compliance of assemblies to the Standard) must agree on the class to which the product belongs.

It is important to understand that decision about the Class of acceptance criteria is not related to any specific product or product category. The decisions need to be based on criticality of need (continued operation) and the operating environment.

Class 1 General Electronic Products: Includes products suitable for applications where the major requirement is function of the completed assembly.

Class 2 Dedicated Service Electronic Products: Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically the end-use environment would not cause failures.

Class 3 High Performance Electronic Products: Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

1.4 Measurement Units and Applications Table 1-1 is a list of common Metric (SI) prefixes. Engineering drawings or other process documents may not provide measurements in SI units. For those instances where dimensions, temperatures, or other process parameters are provided in English units, conversion formulae are provided in Table 1-2. Non-critical features should be rounded to the first decimal place using standard rounding techniques (use the hundredths value - zero to four rounds down, five to nine rounds up). Critical features should be converted to the appropriate accuracy as required by engineering documentation.

Table 1-1 Metric Prefixes

Prefix	Symbol	Meaning (multiply by)
atto-	a	0.000,000,000,000,000,001
femto-	f	0.000,000,000,000,001
pico-	p	0.000,000,000,001
nano-	n	0.000,000,001
micro-	μ	0.000,001
milli-	m	0.001
centi-	c	0.01
deci-	d	0.1
deka-	D	10
hecto-	H	100
kilo-	K	1,000
mega-	M	1,000,000
giga-	G	1,000,000,000
tera-	T	1,000,000,000,000
peta-	P	1,000,000,000,000,000
exa-	E	1,000,000,000,000,000,000

Table 1-2 Conversion Formulae

Units to be converted	Formula
degrees Fahrenheit (F) to degrees centigrade (C)	$(F-32)/1.8 = C$
inch (in) to centimeter (cm)	$2.54 \times \text{in} = \text{cm}$
inch (in) to millimeter (mm)	$25.4 \times \text{in} = \text{mm}$
mil (.001") to micrometer or micron (μ)	$25.4 \times \text{mils} = \mu$
square inch (in ²) to square centimeter (cm ²)	$6.452 \times \text{in}^2 = \text{cm}^2$
ounce (oz) to gram (g)	$28.35 \times \text{lb} = \text{kg}$
pound (lb) to kilogram (kg)	$0.4536 \times \text{lb} = \text{kg}$
fluid ounce (fl oz) to milliliter (ml)	$29.573 \times \text{fl oz} = \text{ml}$
foot candles (fc) to lumens per square meter (lm/m ²)	$10.76 \times \text{fc} = \text{lm/m}^2$



1.4.1 Verification of Dimensions The dimensions provided in the Standard are targets for a Manufacturer to use in establishing a process control system. It is not the intent of the Standard to require actual measurements for determining compliance to each of the various part mounting, solder fillet dimensions, or other requirements listed. They are provided as reference measurements to be used by the Manufacturer in order to resolve internal process problems.

The Manufacturer should evaluate assemblies that are not clearly rejectable, using 1.4.1 for guidance. Reworking a product simply because it does not exhibit the preferred conditions described in the Standard will not necessarily result in a more reliable product and may actually induce premature failure. Excessive or unnecessary rework can damage parts, the printed wiring substrate, or internal connections of PTHs and vias, not to mention the impact on schedules and profitability. Because of this, the recommended practice is: If the inspector feels the need to evaluate the suspected anomaly from several angles for more than a few seconds, or increase magnification above that listed in the standard, the suspected anomaly should be accepted. After a defect has been identified, magnification may be increased to determine its features.

1.5 Definition of Requirements The figures and tables in the Standard are used to clarify the written requirements. Where the text refers to a table with data the table is providing the requirements, e.g., SMT tables.

It is critical to remember that text always takes precedence over figures. Some figures may show conditions that are not referenced in the text or table. Those figures are not intended to be used for the acceptance or rejection of the product.

1.5.1 Hardware Defects and Process Indicators Hardware defects and process indicators are identified throughout the J-STD-001.

1.5.2 Material and Process Nonconformance This paragraph in the J-STD-001 is intended to ensure that products manufactured with nonconforming materials (i.e., solder, flux) or processes such as soldering temperatures or solder contamination levels outside of the specification limits, would be considered defective. If these nonconforming conditions are present, the product must be identified and evaluated to determine if it is useable.

1.6 General Requirements is adequately defined in the Standard.

1.7 Order of Precedence is adequately defined in the Standard.

1.7.1 Conflict is adequately defined in the Standard.

1.7.2 Clause Reference is adequately defined in the Standard.

1.7.3 Appendices is adequately defined in the Standard.

1.8 Terms and Definitions is adequately defined in the Standard.

1.8.1 Defect is adequately defined in the Standard.

1.8.2 Disposition is adequately defined in the Standard.

1.8.3 Electrical Clearance is adequately defined in the Standard.

1.8.4 High Voltage is adequately defined in the Standard.

1.8.5 Manufacturer (Assembler) is adequately defined in the Standard.

1.8.6 Objective Evidence This is referring to data that supports the existence of or the verity (truth) about a procedure, process or material. The data may have been obtained through observation, measurement, test or other means.

1.8.7 Process Control The philosophy of process control is to establish and control each process involved in the manufacture of a product with an ultimate goal of exacting a 100% acceptable product yield. The process is monitored and adjustments are made to ensure that the process remains in control and that a minimum of defective products is produced.

Process parameters and product output are monitored to provide feedback of performance and assist in identifying the necessary corrective action.

Effective corrective action systems usually begin with documenting the discrepancy and identifying the discrepant hardware. The discrepancy is then evaluated against the process and end product requirements to determine if the product is useable, requires rework, or cannot be used. If the fault is attributable to the Manufacturer's internal processes, corrective action to eliminate the cause is usually prescribed. Where faults are attributable to external causes, such as purchased parts or assemblies, the supplier is usually asked to provide root cause analysis and corrective action. All actions in the corrective action system should be recorded for reference. Trends and overall activity levels are typically monitored to allow management of the procurement and assembly processes.

Continuous improvement means constantly looking for ways to improve the yield of a process and reduce production costs and cycle time. There is a point where the cost of improving the process exceeds the gains of the improvement. Care must be taken to recognize that gains may occur outside of the traditional manufacturing cost environment, such as product life, costs, and customer satisfaction.

Clause 11.3 provides in-depth details on applying process controls.

1.8.8 Process Indicator is adequately defined in the Standard.

1.8.9 Proficiency is adequately defined in the Standard.

1.8.10 Solder Destination Side is adequately defined in the Standard.

1.8.11 Solder Source Side is adequately defined in the Standard.

1.8.12 Supplier is adequately defined in the Standard.

1.8.13 User is adequately defined in the Standard.

1.8.14 Wire Overwrap is adequately defined in the Standard.

1.8.15 Wire Overlap is adequately defined in the Standard.

1.9 Requirements Flowdown This is a critical process control because just as the compatibility between processes within a manufacturing facility can impact the product, any incompatible materials or processes used by a subcontractor can have the same result.

The intent of this paragraph is to ensure when the requirements of the base document are invoked by contract that the prime contractor flows down the same obligations to all their subcontractor and vendors. This clause does not include commercial off-the-shelf items unless it is needed to meet the end item requirements.

The second paragraph deals with parts that are already defined by another specification or requirement that meets or exceeds the requirements of the base document.

The third paragraph is addressing items that are built by the manufacturer and then added to another board (i.e., daughter board onto a motherboard). When this is done, it is recommended that only the daughter board meet the requirement of the base document. The only parts that must meet the requirements of the base document are the solder connections that attach the daughter board to the motherboard when invoked by contract.

1.10 Personnel Proficiency In 1995, IPC responded to member requests for a formal industry traceable training and certification program for electronic assembly acceptance. U.S. Department of Defense (DoD) certification programs, which focused on relatively small users groups, were cancelled. Companies needed a course that would allow them to easily train many workers on the document's requirements. Rather than develop a course internally, companies responded positively and looked forward to IPC's development of the course. IPC worked with a consortium of experienced academia and training companies in the now defunct DoD programs to develop the first program. Credibility of the program was considered paramount and required industry involvement. A committee of industry (user) representatives directed and formally approved

the technical content and another committee (also comprised of industry representatives) established administrative policies and procedures.

A good training program reinforces both discrimination and workmanship skills—see it, hear it, read it, write it and apply it. These programs include a critical element not available from online, video or computer-based training—full interaction with a knowledgeable, credible instructor to immediately resolve comprehension issues. While no IPC document requires participation in an IPC training program to use the Standard, customers frequently require that vendors have completed a certification program to ensure their products have gone through rigorous quality control. Use of industry traceable training also greatly facilitates ISO certification that has become important in international trading.

The impact of formal training like IPC Training and Certification Programs on the electronics manufacturing industry cannot be overestimated. Literally hundreds of thousands of people involved in the production of circuit boards and assemblies have benefited significantly from these programs. Major OEMs and EMS companies have become leaders in the program, with impressive results.

Electronics assembly has always involved a large component of manual work, such as hand soldering and rework and repair techniques. Even at present, much of an assembly's quality and reliability is dependent upon the ability and consistency of skilled operators.

1.11 Acceptance Requirements is adequately defined in the Standard.

1.12 General Assembly Requirements is adequately defined in the Standard.

1.13 Miscellaneous Requirements is adequately defined in the Standard.

1.13.1 Health and Safety is adequately defined in the Standard.

1.13.2 Procedures for Specialized Technologies is adequately defined in the Standard.

2 APPLICABLE DOCUMENTS

This clause in the Standard provides a summary of documents that are referenced. These documents are constantly being revised, new documents developed, and others made obsolete.

The extent that referenced documents are requirements depends on the wording of the reference in the Standard.

Following is a listing of documents referenced in this Handbook that are in addition to those listed in the Standard.

2.1 EIA¹

GEIA-STD-0005-1 Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder

GEIA-STD-0005-2 Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems

GEIA-HB-0005-1 Program Management/Systems Engineering Guidelines for Managing the Transition to Lead-Free Electronics

GEIA-HB-0005-2 Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder and Finishes

GEIA-STD-0006 Requirements for Using Solder Dip to Replace the Finish on Electronic Piece Parts

2.2 IPC²

IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies

IPC-1601 Printed Board Handling and Storage Guidelines

IPC-7525 Stencil Design Guidelines

1. www.eia.org

2. www.ipc.org

2.3 Electrostatic Discharge Association³

ESD TR 20.20 ESD Handbook

3 MATERIAL, COMPONENTS, AND EQUIPMENT REQUIREMENTS

3.1 Materials Selected materials in combination with the equipment establish a baseline process; therefore a material and process validation of the initially selected materials and equipment should be performed.

The manufacturer of a product must evaluate internal manufacturing processes, as well as those of subcontractors or suppliers. This is done in order to determine how the materials and processes used to create the product will interact with each other at each step in the manufacturing process, as well as storage and its end use environment. The material and process compatibility evaluation must consider such things as the expected manufacturing process(es), including temperature limits and rates of change; chemistry of fluxes, solvents, parts, and coatings; and coefficients of thermal expansion.

Re-evaluation to this requirement should be performed and documented whenever major elements of proven processes are changed. This is another area where proper communication between manufacturers and their subcontractors or suppliers is critical. Any change by a subcontractor (e.g., plating alloys, solder mask materials, cleaning methods, etc.) should be communicated to the manufacturer to ensure that the proposed changes will not have a detrimental impact on subsequent processes or acceptability of the product.

Samples of process changes:

Major Process Changes

- Fabrication houses
- Laminates (FR-4 to CEM-1)
- Metallization (HASL tin-lead to palladium flash)
- Solder masks (dry film to an LPI)
- Fluxes, type and/or formulation (RMA to water soluble)
- Cleaning, method and/or chemistry (Freon TMS to aqueous saponifier)

Minor Process Changes

- Bake or cure cycles
- Minor process variations in fabrication
- Change from a 6% solids flux to a 2% flux of the same formulation
- Equipment or tooling where the output satisfies the requirements of the Standard (lead bending dies or wire strippers)

NOTE: The previous lists attempt to separate changes into major and minor categories for guidance, but the reader must use caution. Depending upon the combination of processes and materials, what might be a minor change for one supplier could be considered a major change to another.

Objective evidence of this compatibility evaluation **shall** be maintained and available for review. The manufacturer's process procedures or its user's requirements determine the format for the objective evidence and for how long it will be maintained.

In previous versions of J-STD-001 there was an appendix with guidance on material and process compatibility. This guidance has been updated and is now available as IPC-9202.

3.2 Solder This clause covers many of the materials considerations of the items used in electronics manufacture. Such information is useful when trying to understand the materials in use and their properties. Later clauses cover how these materials are used or processed.

Solder, an alloy used for joining metals, solidifies below 430 °C. It is generally accepted that the joining of metals above 430 °C is referred to as brazing. The most common alloy is tin and lead. Other alloys used in soldering include tin-silver, tin-antimony, tin-zinc, and indium-based solders. The melting point of the solder depends on the metals in the alloy and the

3. www.esda.org

percentage of each. Solder alloys, which change directly from liquid to solid and solid to liquid without any intermediate plastic states, are eutectic solders. The various solder types and their compositions and melting points can be found in J-STD-006.

Tin/lead solders used for electronics soldering are typically eutectic or near eutectic alloys. The eutectic composition, as shown in Figure 3-1(B), shows the tin/lead eutectic at 63% tin by weight and 37% lead by weight and is referred to as Sn63Pb37. In this diagram, the area above line A-B-C is always liquid (this line being referred to as the liquidus), and the area below line A-D-E-C is always solid (this line being the solidus). The area between these two lines is a mixture of solid and liquid phases, often referred to as the “pasty” region. The selection of the near eutectic condition is to promote rapid solidification of the solder connection, which minimizes grain growth during solidification, yielding a “shinier” solder joint.

Another common alloy used in electronics soldering is 60% tin/40% lead, referred to as Sn60Pb40. This alloy is often preferred in commercial applications due to its lower cost and similar properties to Sn63Pb37. The trade-off between Sn60Pb40 and Sn63Pb37 is the longer solidification time when the solder solidification process passes through the “pasty” region in Figure 3-1. This can result in duller appearing (although no less reliable) solder joints and an increased occurrence of disturbed solder connections (which move during solidification, resulting in a rough surface and dewetting).

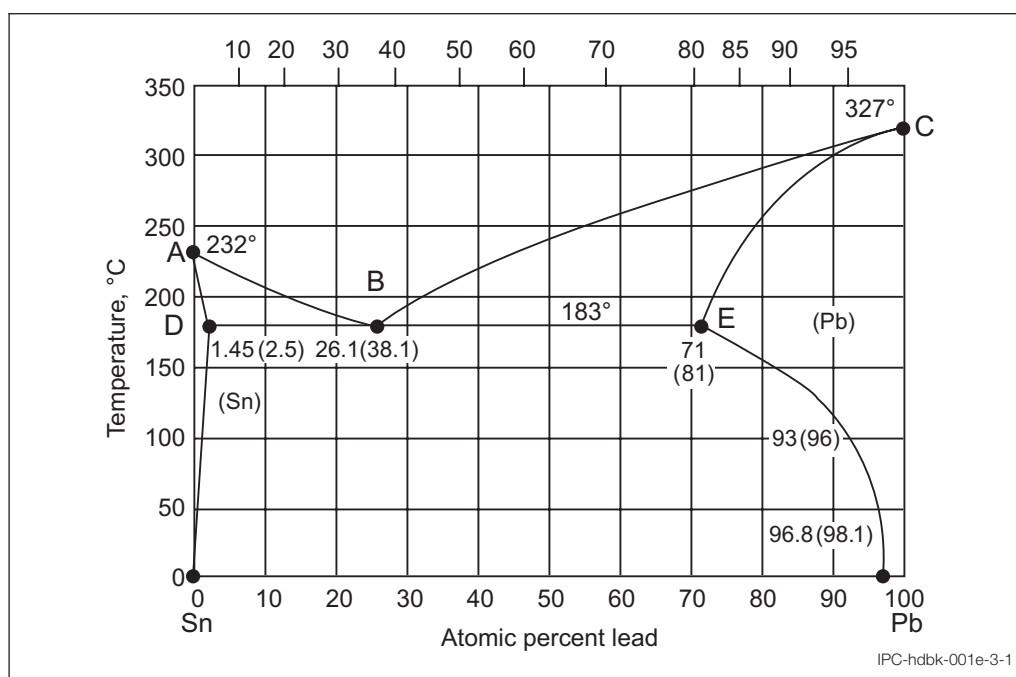


Figure 3-1 Phase Diagram for Eutectic Solder

The metallurgy of solder is a mixture of tin-rich crystals, referred to as the β phase, with a composition of 97.5% tin/2.5% lead and lead rich crystals, referred to as the alpha α phase, with a composition of 19% tin/81% lead. The as-cooled appearance of the eutectic solder microstructure is seen in Figure 3-2 and Figure 3-3 as a two phase structure containing a dispersion of darker platelets, being the lead-rich α phase, mixed in with larger crystals of the tin-rich β phase.

NOTE: When viewing solder using a Scanning Electron Microscope (SEM), the solder matrix appears like a photographic negative of the optical appearance due to the relationship between apparent “brightness” in an SEM view and atomic weight.

A number of diffusion reactions, which can occur while the solder is molten, as well as after solidification, can affect solder morphology. These reactions change the appearance of the solder microstructure and can be summarized as:

Leaching – The dissolution of substrate metallization(s) into the molten solder during soldering.

Coarsening – A solid state diffusion reaction which causes the individual phases to coalesce in order to reduce total free energy of the system by minimizing the interfacial area of the separate phases. The solder joints will appear “dull.” Either temperature or applied stress/plastic deformation can drive this process.

Aging – The growth of intermetallic layers between the bulk solder and the substrate or component, which is driven primarily by time and temperature.

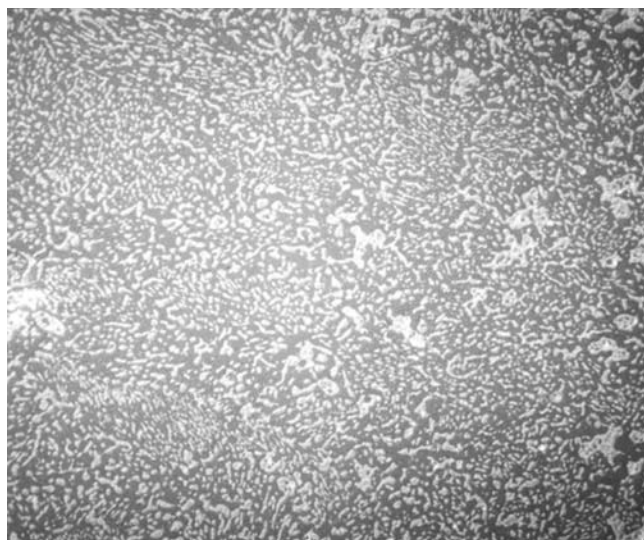


Figure 3-2 Eutectic Solder Microstructure

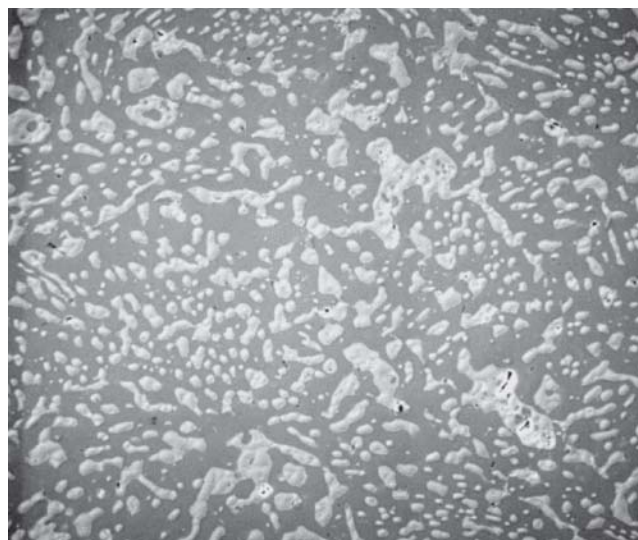


Figure 3-3 Eutectic Solder Microstructure

Physical Properties of Solder Alloys The properties of these solder alloys are sensitive to temperature, strain rate, cyclic loading frequency, and grain size. A listing of common physical properties of solder is given in Table 3-1.

Table 3-1 Common Physical Property Values for Eutectic or Near Eutectic Tin/Lead Solder

Physical Property (Alloy)	Value
Surface Tension (Sn60Pb40)	0.41 J/m ² @ 250 °C in air
Elasticity - (Sn63Pb37)	32 x 10 ³ N/mm ² @ 25 °C
Viscosity - (Sn63Pb37 & Sn60Pb40))	2 centipoise (N·s/m ²)
Density (Sn63Pb37)	8400 kg/m ³ @ 20 °C
(Sn63Pb37)	8000 kg/m ³ @ 250 °C
(Sn60Pb40)	8500 kg/m ³ @ 20 °C
Coefficient of Thermal Expansion (Sn63Pb37)	24.5 x 10 ⁻⁶ /K
Heat of fusion (Sn60Pb40)	4600 J/kg
Specific heat (Sn60Pb40)	176 J/(kg·K)
Electrical Resistivity (Sn60Pb40)	0.17 milliohm·m @ 25 °C 0.32 milliohm·m @ 100 °C
Thermal Conductivity (Sn60Pb40)	51 J/(m·s·K) @ 25 °C 49 J/(m·s·K) @ 100 °C
Thermal Diffusivity (Sn63Pb37)	3.4 * 10 ⁻⁵ m ² /s

3.2.1 Lead-Free Solder Lead Free Solder alloys less than 0.1% lead by weight not listed by J-STD-006 may be used when such use is agreed upon by the manufacturer and the user.

Environmental legislation has had an enormous impact on the solder alloys used for electronics assembly. The European Union Restriction of Hazardous Substances (RoHS) directive officially went into effect on July 1, 2006 but a significant portion of the electronics supply chain began a wide variety of transition actions in the years prior to that implementation deadline in an effort to understand material issues and fabrication concerns. The RoHS directive contained a requirement that the maximum concentration of lead in a solder alloy was 0.1% which effectively resulted in the extinction of lead bearing solder alloys except for specialized applications. The electronics industry has initially focused on one non-lead solder alloy family, Tin (Sn)/ Silver (Ag)/ Copper (Cu) - (SAC), for a variety of criteria which includes (but not limited to) cost, metallurgical complexity, melting point, surface tension, availability and process-ability. Three solder alloys - SAC405, SAC305, and SAC105 - have received the most industry attention. Further industry resources have been expended in the characterization of Tin (Sn)/ Copper (Cu) “modified” solder alloys such as Sn/Cu/Ni/Ge or Sn/Cu/Ni/Bi. The rationale for considering the Sn/Cu “modified solder alloys is improvements in drop shock properties, lower copper dissolution properties and alloy cost. Table 3-2 illustrates a variety of lead-free solder alloys and their elemental compositions. Table 3-3 lists a variety of lead-free solder alloys and their melting temperatures.



Documents

Document Sharing Hub

Table 3-2 Lead-Free Solder Alloys
(from G. Henshall et al, "iNEMI Pb-Free Alloy Alternatives Project Report: State of the Industry" SMTAI 2008 Conference Proceedings)

Alloys	Investigators	Reference
Sn4.0Ag0.05Cu (SAC405)	Pandher (Cookson), H. Kim & D. Kim (Intel), Kobayashi (Nippon Steel), Darveaux (Amkor/ASU)	ECTC 2007
Sn3.0Ag0.55Cu (SAC305)	Pandher (Cookson), Syed (Amkor), Kobayashi (Nippon Steel), Darveaux (Amkor/ASU)	ECTC 2007
Sn1.0Ag0.5Cu (SAC105)	Pandher (Cookson), H. Kim & D. Kim (Intel), Kobayashi (Nippon Steel)	ECTC 2007
Sn0.3Ag0.7Cu+Bi (SACX0307)	Pandher (Cookson)	ECTC 2007
Sn0.3Ag0.7Cu+Bi+Ni+Cr	Pandher (Cookson)	ECTC 2007
SAC305+0.05Ni+0.5In	Syed (Amkor)	ECTC 2007
SAC255+0.5Co	Syed (Amkor)	ECTC 2007
SAC107+0.5Ge	Syed (Amkor)	ECTC 2007
SAC125+0.05-0.5Ni (LF35)	Syed (Amkor), D. Kim (Intel), Kobayashi (Nippon Steel), Darveaux (Amkor/ASU)	ECTC 2007
SAC101+0.02Ni+0.05In	Syed (Amkor)	ECTC 2007
Sn-3.5Ag	Cavasin (AMD), Darveaux (Amkor/ASU)	ECTC 2007
Sn-3.5Ag+0.05-0.25La	Pel & Qu (Ga Tech)	ECTC 2007
Sn-0.7Cu	Darveaux (Amkor/ASU)	ECTC 2007
Sn0-4Ag0.5Cu+Al+Ni	Huang (Indium)	ECTC 2007
Sn0.7Cu0.05Ni+Ge (SN1000)	Sweatman, Miyaoka, Seki, Suenaga, Nislumura (Nihon Superior)	ICS&R Toronto 2008

Table 3-3 Lead-Free Solder Alloys and Their Melting Temperatures

Composition (Percent)					Solidus (°C)	Liquidus (°C)
Sn	Ag	Cu	Bi	Sb		
95.5	3.8	0.7			217	220
95.5	4.0	0.5			217	225
95.5	3.9	0.6			217	225
96.5	4.7	1.7			217	244
91.8	3.4		4.8		211	213
96.5	3.5				221 ¹	
99.3		0.7			227 ¹	
99				1	232	235
97				3	232	238
95				5	235	240
65	25			10	233 ²	

Note 1. Eutectic composition

Note 2. Melting point

The use of lead-free solder alloys result in the soldering process engineer having to address two primary issues due to the differences from the traditional tin/lead solder alloys: (1) solder alloy initial melting point; (2) solder alloy solidification characteristics. The traditional tin/lead solders have melting points beginning at 183 °C. The melting point of the SAC solder alloy family is 217 °C, 34 °C higher. This increase in solder alloy temperature causes a domino effect as the soldering flux, the printed wiring laminate, the components and the soldering process equipment must all be compatible for the higher temperature. Several industry studies have shown that a small increase in the amount of flux contained in a solder wire core, as shown in Figure 3-4, can be beneficial due to the increased soldering process temperatures caused by the lead-free solder alloy melting point.



Figure 3-4 Solder Wire Core Flux Comparison

Secondly, relatively few of the lead-free soldering alloys have eutectic alloys as described in clause 3.2. A eutectic solder alloy solidification behavior of changing from a liquid to a solid at a specific temperature provides

engineer a number of process control advantages in comparison to the non-eutectic solidification behavior of changing from a liquid + solid to a solid.

Caution should be exercised in selecting a lead-free solder alloy for a soldering process as these new alloys constitute a change in the form/fit/function of an electronic assembly. The diverse compositional ranges of the lead-free solder alloys combine with product functional requirements and product use environment interactions, results in a wide range of solder alloy thermal and mechanical characteristic responses. Figure 3-5 illustrates how a sampling of lead-free solder alloys compares to the traditional tin/lead solder alloys in fracture toughness testing. Figure 3-6 shows a similar response for drop shock testing.

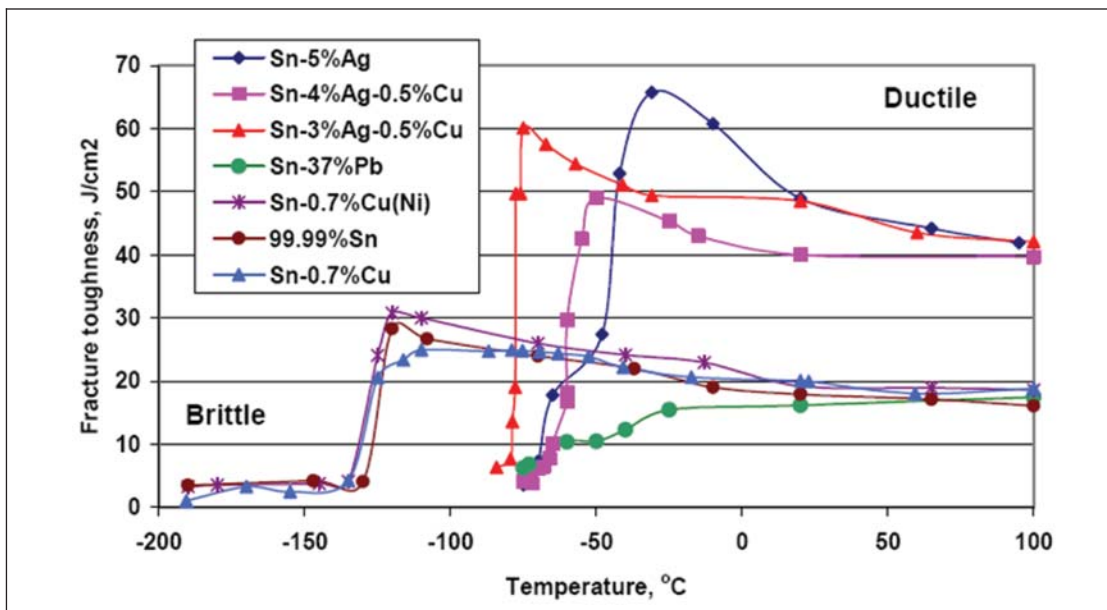


Figure 3-5 Solder Alloy Fracture Toughness Testing Results (Graph from P. Ratchev et al, "A Study of Ductile to Brittle Fracture Transition Temperatures in Bulk Pbfree Solder Alloys," EMPC 2005, Brugge, Belgium)

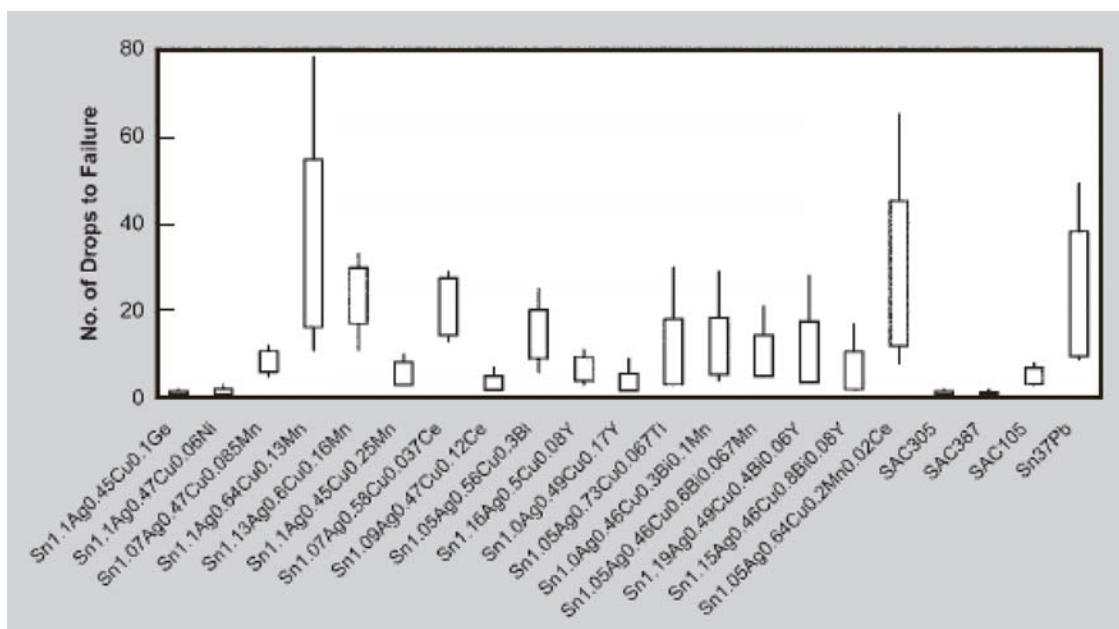


Figure 3-6 Solder Alloy Drop Shock Testing Results (Graph from Lee et al, July JOM 2007)

Lead-Free Soldering: Process Considerations

Background The use of conventional tin-lead (Sn/Pb) solder in circuit board manufacturing is under ever-increasing political scrutiny due to environmental issues and new regulations concerning lead, such as the Waste Electrical and Electronic Equipment (WEEE) and the RoHS Directives in Europe. In response to this, global commercial electronics manufacturers are initiating efforts to transition to lead-free assembly. Tin/lead soldering processes and lead-free soldering process are similar in many respects; however, there are a number of significant differences that need to be addressed insure product integrity.

Mixed Metallurgy The implementation of the European RoHS Directive has initiated an electronics industry materials evolution. Printed wiring board laminate suppliers, component fabricators, and printed wiring assembly operations are engaged in numerous investigations to determine what lead-free (Pb free) material choices best fit their needs. The complexities of Pb free soldering process implementation insures a transition period in which Pb free and tin/lead solder finishes will be present on printed wiring assemblies. The use of lead-free components in a tin/lead soldering process is not a new topic for the electronics industry. Texas Instruments introduced a nickel/palladium/gold component surface finish in 1990 and the electronics industry has successfully processed that finish with few issues. The introduction of lead-free finishes such as tin, gold, silver and bismuth requires due diligence by the soldering process engineer to insure that any potential incompatibilities, such as gold embrittlement, are addressed. Figure 3-7 illustrates the incompatibility of a lead free bismuth solder alloy with a tin/lead component finish. The reduction in solder joint thermal cycle fatigue life is clearly evident for a tin/lead surface finish and a tin/copper surface finish with a SnAgCuBi solder alloy.

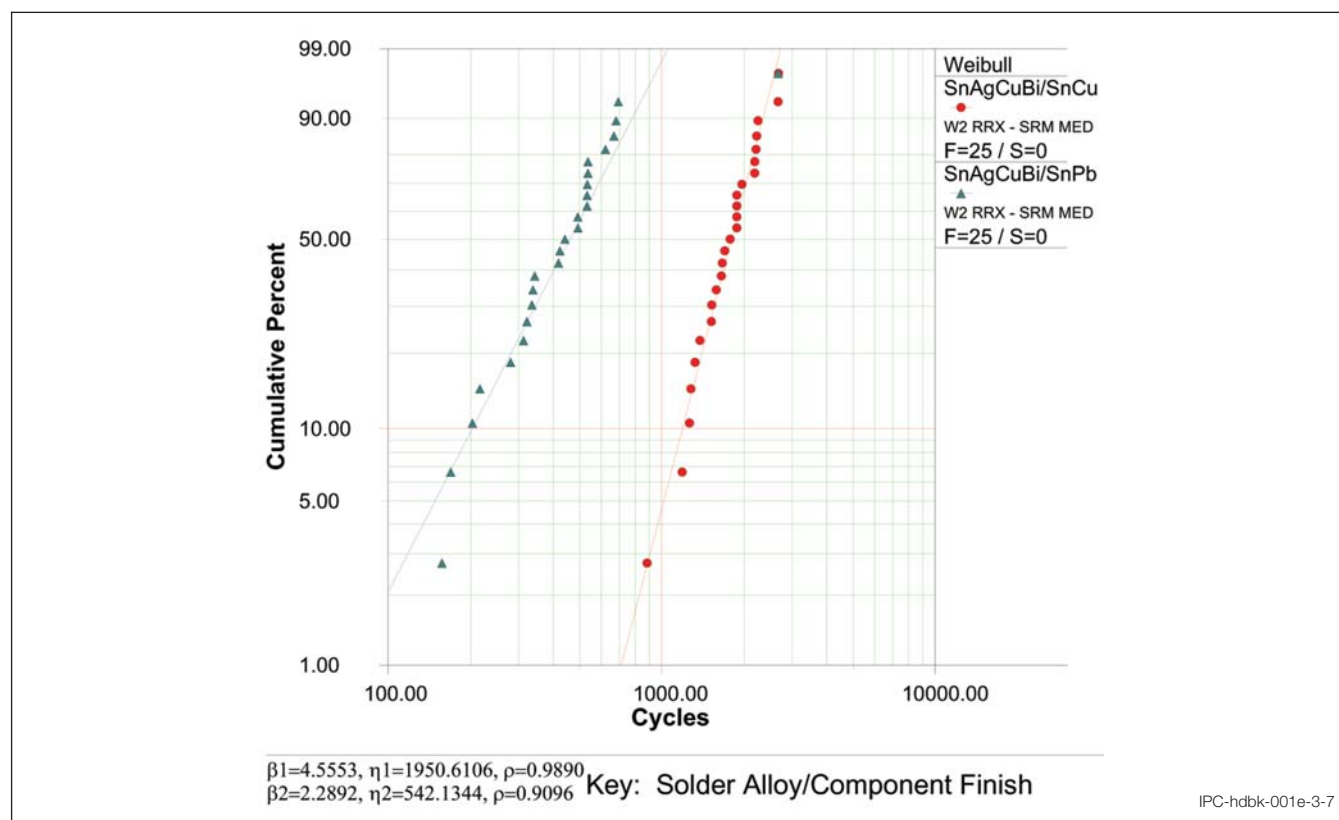


Figure 3-7 Lead-Free Solder Alloy/Component Surface Finish Incompatibility Example (D. Hillman and R. Wilcoxon, "JCAA/JG-PP Lead-free Solder Testing for High Reliability Applications: -55 °C to +125 °C Thermal Cycle Testing" SMTAI Conference, 2006)

A second mixed metallurgy topic of concern is the soldering of area array component styles such as ball grid arrays (BGAs), chip scale packages (CSPs), and flip chips (FCs). The contribution of the solder ball metallurgy to the overall solder joint volume for an area array package is significantly greater than for standard surface mount package technologies. Combine the solder ball contribution to the higher melting point of a lead-free solder alloy and the resulting solder joint has the potential for the creation of a non-uniform solder joint microstructure or an incomplete solder joint reflow. Figure 3-8 illustrates these two effects.

Temperature Compatibility The introduction of lead-free soldering processes has resulted in an increase in soldering process temperatures. The using of SAC solder alloy family increases the soldering process temperature from 235 °C to 260 °C.

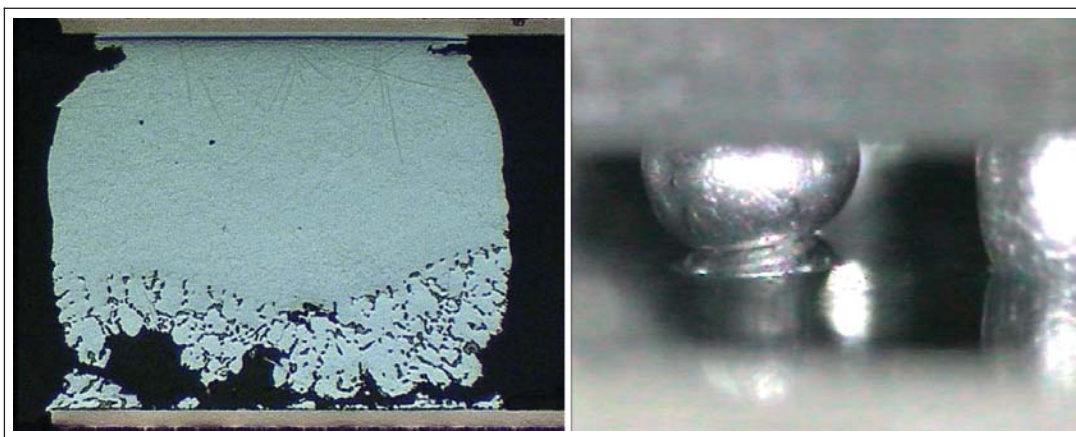


Figure 3-8 left: Non-uniform Solder Joint Microstructure, right: Incomplete Solder Joint Reflow (Head-on-Pillow) (Photo courtesy Rockwell-Collins, used by permission)

(Sn63Pb37 solder alloy) to 217 °C, a 34 °C increase without accounting for the thermal thieving effects of the printed wiring laminate! A review of the component and laminate temperature compatibility is necessary. Laminate materials will delaminate and warp if they can not withstand the lead-free soldering process temperatures. A components moisture sensitivity level (MSL) is a function of temperature and some component materials will degrade if exposed to lead-free soldering processes. Figure 3-9 illustrates component incompatibility examples.

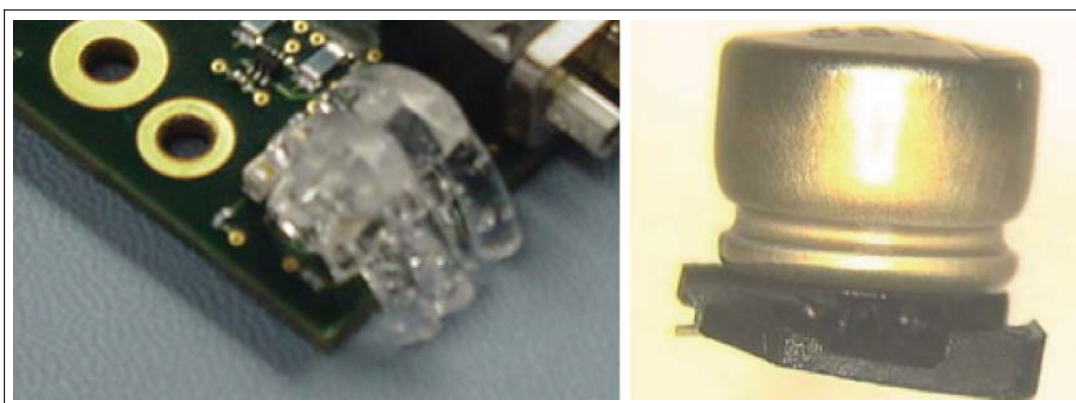


Figure 3-9 Component Degradation Due to Lead-free Soldering Process Incompatibility (Courtesy of Rockwell Collins (left) and National Physical Laboratory (right))

Soldering Process Equipment Compatibility The tin content of lead-free soldering alloys is significantly greater than the traditional eutectic tin/lead solder alloys. Molten tin is an aggressive element in terms of the dissolution and erosion of other metals. The implementation of lead-free soldering processes requires a review of lead-free solder alloy compatibility with any process equipment that will come in contact with the molten alloys. Wave solder pots and static solder pots are two primary areas of concern. Figure 3-10 illustrates the attack of wave solder process equipment by a lead-free solder alloy.

Copper Dissolution Concerns The discussion of molten lead-free solder alloy damage of soldering process equipment also has lead-free soldering process implications. The dissolution of copper plating on surface mount pads and in plated thru holes is significantly increased for lead-free soldering processes. Figure 3-11 shows the accumulative effect of



Figure 3-10 Lead-free Solder Alloy Attack of Wave Solder Equipment ("Pb-free Technology and the Necessary Changes in Soldering Process and Machine Technology," H. Schlessmann, APEX 2002 Conference Proceedings)

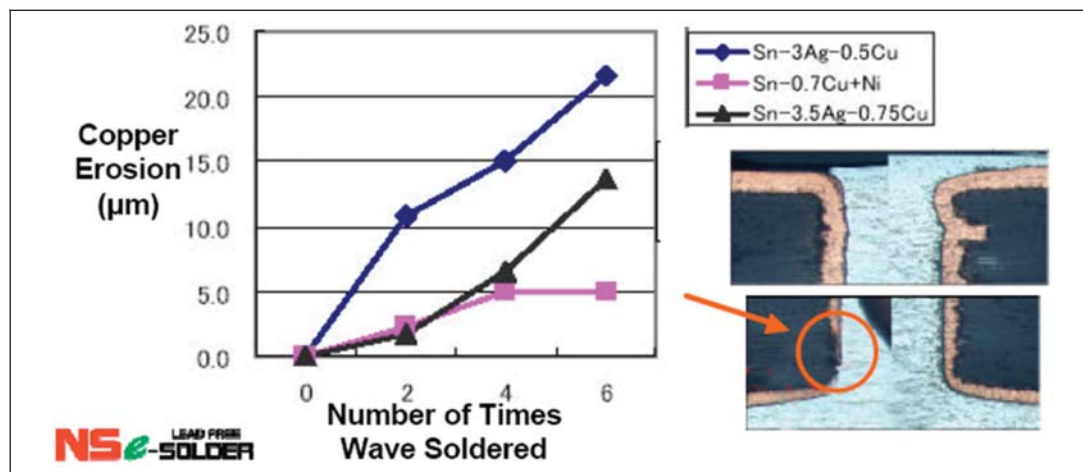


Figure 3-11 Copper Erosion Due to Lead-Free Soldering Processes (Courtesy of Nihon Superior)

repeated soldering process exposures for various lead-free soldering alloys. The copper dissolution issue is of critical importance for plated thru hole rework processes, especially those utilizing mini-wave or selective solder equipment.

Lead-Free Finishes: Mitigation Strategies Several mitigation strategies currently exist within industry which can be used to minimize the risk of tin-whisker growth and subsequent problems. Until the growth mechanism for tin whiskers is fully understood and there is an accepted test method for tin whiskers propensity, there is currently no one known mitigation strategy that can be used to completely eliminate the risk of tin whisker growth. However, there are several mitigation strategies used in industry today that have been proven to reduce the risk of tin whisker growth. GEIA-STD-0005-2, “Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems,” provides detailed information on how to assess the level of risk associated with a particular product group and provides mitigation strategies which correspond to the level of mitigation required. These mitigation techniques focus primarily on processes that can be utilized after the component has been manufactured and subsequently assembled to the board. Mitigation strategies which can be used earlier in the design process such as; procuring parts that do not have a pure tin finish, board layout, spacing and plating options are discussed in GEIA-STD-0005-2, but are not discussed in this document.

Following is a short summary of a few commonly used industry mitigation strategies discussed in the GEIA-STD-0005-2:

1. Conformal Coating

If components with lead-free solder finishes must be used, government and industry subject matter experts strongly encourage utilizing conformal coating as a mitigation strategy. Conformal coat reduces the risk of a tin whisker failure by slowing down the growth of the tin whisker and/or containing whisker growth within the coating. However, depending on the type of coating and coating thickness, tin whiskers have been found to grow through conformal coatings. While most known coatings eventually allow growth through the coating over time there is no known case of a tin whisker re-entering or puncturing back into and penetrating the coating on an adjacent surface. However, this fact does not eliminate the possibility that two whiskers from adjacent surfaces couldn't still intersect in free space and thereby create a short circuit condition. Coating materials and processes should be carefully reviewed to ensure their compatibility with the hardware design and application. For spray-on conformal coatings, the effectiveness of the mitigation depends on how well the coating is applied at various angles to avoid shadowing from high profile components. Conformal coating is difficult, if not impossible, to get underneath components with under-mounted connections, such as BTCs, BGAs, CSPs and PGAs. Also, coefficient of thermal expansion (CTE) mismatches become a serious concern when coatings are applied underneath components. For a conformal coating to be an effective lead-free mitigation strategy, the quality and thickness of the conformal coat must be controlled. Testing has shown acrylic conformal coatings are the least effective in mitigating tin whisker growth. Urethane coatings generally tend to retard whisker growth better than acrylic, but tests have also shown whiskers break through urethane coatings as well, but usually at a slower rate. Experiments and tests indicates paraxyllylene coatings provide the most effective coverage due to its vacuum deposition process and is more effective than other coatings in mitigating tin whisker growth. Unfortunately there is a perceived upfront cost increase and level of difficulty associated when utilizing this type of coating and therefore a lot of push back from industry against using it. However, the argument can be made that the increased cost of applying and reworking this type of coating can be offset with its resulting performance over time and the resulting savings incurred over the life of a system utilizing this type of coating. Additionally, new coatings such as Atomic Layer Deposition (ALD) and others are routinely being developed and evaluated for their effectiveness concerning tin whisker mitigation.

2. *Embedment/Encapsulation*

In order for an embedment or encapsulation material to be an effective tin whisker mitigation, the material should fully wet and cover all surfaces of the components and areas specified for coverage. The cured material should be compatible with the hardware and product environment and should not adversely affect hardware performance or reliability. Other issues, such as CTE mismatch between the encapsulant and the surface, to which it is bound, should be addressed before using this form of mitigation. Rework may also be impossible when employing this type of mitigation, depending on the specific application.

3. *Solder Dip Tin-Finished Surfaces*

Hot solder dipping of tin-finished leads and surfaces using a Sn-Pb based solder will help reduce whisker formation by relieving stress in the tin. It is important to note that solder dipping for mitigation purposes is different from traditional solder dipping because the lead must be coated over its entire length, right up to the package interface. The solder dipping process exposes components to higher temperatures than they would see during normal assembly processes, which could reduce the reliability of the component. To avoid these reliability issues, the solder dip process must be qualified and carefully controlled. This can be accomplished by using Scanning Acoustical Microscopy (SAM) before and after dipping along with other analytical techniques. Components with glass to metal seals can be damaged through thermal shock during the dipping process and it is recommended these parts not be solder dipped if possible.

4. *Pb Over-Plating*

Pb over-plating involves plating Pb on the surface of the tin and then baking the component to promote complete inter-diffusion of the Pb through the tin. This method is probably the most suitable for use on small chip-style passive devices. Additional guidance and technical information on lead-free mitigation strategies can be found in the following documents and are an excellent resource for developing and implementing lead-free control plans.

- GEIA-STD-0005-1, Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
- GEIA-STD-0005-2, Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems
- GEIA-HB-0005-1, Program Management/Systems Engineering Guidelines for Managing the Transition to Lead-Free Electronics
- GEIA-HB-0005-2, Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder and Finishes
- GEIA-STD-0006, Requirements for Using Solder Dip to Replace the Finish on Electronic Piece Parts

3.2.2 Solder Purity Maintenance Testing of a solder bath is a preventative measure. It is easier to test the solder bath and correct the composition than to disposition non-conforming hardware.

Testing Frequency How often the solder is tested is up to the individual user. To establish a baseline, the solder pot should be tested at a set frequency (i.e., monthly) established by the user, based on production levels, etc. Based on these results and how much product is being assembled using the solder pot, the frequency of testing can then be increased or decreased appropriately. Another option, once a baseline history has been established, is to replace the solder bath periodically rather than test and replenish it.

A summary of the recommended levels of solder impurities for eutectic (Sn63Pb37) and near eutectic (Sn60Pb40) solder and their effects is shown in Table 3-4. If an alternative alloy is used, the user must develop a table comparable to Table 3-4 with the guidance from the solder supplier.

Contamination Sources Some materials that may be found in solder baths, some of the reasons they are there, and issues to be aware of are outlined below. In small amounts, these materials are acceptable, but in higher levels, these materials are considered contaminants. It is noted that the addition of a certain amount of bismuth, nickel, and copper to the eutectic tin-lead solder alloy improves the wetting ability of the solder, whereas the addition of cadmium and zinc decreases the wetting power of the eutectic solders.

Copper Copper has negligible solubility in both tin and lead. Two intermetallic compounds: Cu₃Sn and Cu₆Sn₅, are formed between copper and tin. As the copper content of the molten solder increases, higher temperatures are needed to overcome sluggishness and grittiness of the liquid metal. This increases the rate of solution of additional copper from the surfaces to be soldered, rapidly degrading the soldering conditions.

Gold The solubility of gold in tin-lead at room temperature is negligible. Several intermetallic compounds are formed between tin (Au₆Sn, AuSn, AuSn₂ and AuSn₄) and lead (Au₂Pb and AuPb₂). Unless the soldering is rapidly completed

Table 3-4 Levels of Allowable Solder Impurities for Sn60Pb40 and Sn63Pb37 Solders (Weight %)¹

Material	Preconditioning (Lead/Wire Tinning)	Assembly soldering (Pot, Wave, etc.)	Effect on solder joint if maximum allowable level is exceeded during usage
Copper (Cu)	0.750%	0.300% ²	Solder begins "sticking" to insulation materials, above 0.3% viscosity increases and solder becomes gritty.
Gold (Au)	0.500%	0.200% ²	Solder becomes sluggish and grainy; above 4% solder becomes brittle.
Cadmium (Cd)	0.010%	0.005% ²	Oxidation rate increases, above 0.15% area of spread decreased by 25%.
Zinc (Zn)	0.008%	0.005% ²	Finish becomes dull, dewetting, oxidation rate increases.
Aluminum (Al)	0.008%	0.006% ²	Solder becomes sluggish, frosty and porous; oxidation rate increases.
Antimony (Sb)	0.500%	0.500%	Increased dewetting.
Iron (Fe) ³	0.020%	0.020%	Forms FeSn ₂ which is unsolderable.
Arsenic (As)	0.030%	0.030%	Grainy/pitted appearance, edge dewetting and reduction in area-of-spread.
Bismuth (Bi)	0.250%	0.250%	Dulling of surface, may reduce ability of solder to wet brass & steel.
Silver (Ag)	0.750%	0.100%	Solder surface finish becomes gritty.
Nickel (Ni) ³	0.025%	0.010%	Blisters, formation of hard insoluble compounds.

Note 1. Data from J-STD-006, for Class 3 (critical) use solders.

Note 2. The total of copper, gold cadmium, zinc, and aluminum **shall not** exceed 0.4%.

Note 3. The solubility of these materials in solder at temperatures <260 °C is very low and problems only arise as a result of prolonged exposure.

the gold intermetallics will rise to the surface of the connection, causing an extremely dull gray, grainy surface. Above 0.340% gold contamination in the solder pot may cause embrittlement of the solder connection.

Cadmium The solubility of cadmium in both tin and lead is negligible. There is an intermetallic phase at elevated temperature. Cadmium surfaces can deteriorate rapidly and cause spotty connections with poor adhesion (poor wetting). Practically speaking, this problem does not often surface.

Cadmium is considered the plating of choice for resistance to salt-laden environments, but there are concerns with some of the carcinogenic properties of the materials in the cadmium plating process. Cadmium wastes also constitute hazardous materials with all of the attendant environmental regulations. The cadmium metal, itself, is not carcinogenic.

The most common source for cadmium metals being transferred to solder baths is the back shells on connectors, which are often cadmium plated to increase environmental resistance.

Zinc Zinc has little solid solubility in tin and none in lead. No intermetallic compounds are formed with either tin or lead. Zinc is detrimental to the solder alloy. As little as 0.005% of zinc is reported to cause a lack of adhesion, grittiness, and susceptibility to grain boundary weakening.

Aluminum Aluminum does not have any solid solubility in either tin or lead at room temperatures, and only a small amount of aluminum is dissolved in liquid tin at an elevated temperature. Aluminum in molten solder usually causes sluggishness in the melt, with a considerable amount of grittiness and lack of adhesion. Very little aluminum is used in electronic soldering because of the large galvanic potential present between aluminum and the tin-lead alloy (1.53V). Aluminum surfaces that must be exposed to molten solder, even for a short time, should be hard anodized.

Antimony The solubility of antimony in tin at room temperature is about 6-8%, while little antimony is dissolved in lead at room temperature. In some specifications, the presence of 0.2-0.5% antimony is mandatory to retard the transformation of tin into its gray state (tin-pest). Excessive antimony may cause a spread reduction in lead termination.

Iron Iron has some solubility in tin at elevated temperatures, forming two intermetallic compounds, FeSn and FeSn₂, manifesting themselves as needle-shaped crystals. The presence of iron in solder is detrimental and causes grittiness.

Arsenic No solubility of arsenic in either tin or lead has been observed. Two intermetallic compounds: Sn₃As₂ and SnAs, appear as a long needle in the microstructure. Arsenic may cause poor wetting.

Bismuth At room temperature, bismuth has solubility in lead of up to 18% and solubility in tin of about 1%. A concentration of less than 0.25% will cause a reduction in the working temperature. Bismuth causes a gray appearance.

Silver There is no solid solubility in either tin or lead, but tin and silver form the intermetallics Ag₆Sn and Ag₃Sn. When silver content rises over 2.0%, the silver-tin intermetallics will segregate upon cooling.

Nickel Nickel shows no solubility in either tin or lead. Intermetallics formed with tin are Ni₃Sn, Ni₅Sn₂, and Ni₇Sn₄.

Solder Pot Contamination Copper, iron, gold, and nickel may be found in solder baths as a result of lead clippings, PCB pieces, or components falling into solder baths. In addition to these known causes of contamination, there are other ways that contaminants can get into the solder pot, such as a piece of jewelry falling into the solder pot.

Effect of Contamination on Solder Process Contamination can have adverse effects on the soldering process. It can result in brittle or grainy joints and lower the reliability of the product.

Resolving Contamination Problems If there are contamination problems, several options are available. By removing calculated amounts of contaminated solder and adding amounts of “virgin” solder to the solder bath, the relative level of contamination will be reduced. This can also be done if all of the contaminants are within limits as a process control measure.

If the user needs to add a large amount of “virgin” solder to the solder pot to bring the contamination limits to acceptable limits, the user may want to consider replacing the entire solder bath.

Reducing pot temperature will allow some contaminants to come out of the solution. This can happen through solidification of impurities or the creation of immiscible liquids. Either way provides relatively easy removal of the contamination.

In addition, if the solder bath is exceeding the limits, the possible cause of the contamination should be investigated:

- Has the solder bath been heavily used?
- Was there a one-time isolated incident that might explain the condition?

If the contamination is above the acceptable levels, increasing the frequency of analysis should also be considered.

Tin Depletion A product of wave soldering is the formation of dross on the static portion of the wave solder pot. The dross is primarily composed of solder, encapsulated by tin oxide. Additionally, a fine, black powder, which is found in tin oxide, will often form near the impeller shaft. It should be noted that this formation of tin oxides gradually diminishes the tin available in the solder and the tin level needs to be frequently monitored and the tin replaced.

Shown below are two formulas for determining the amount of tin to be added to a solder pot to adjust the tin content. Two cases are shown, depending on whether or not the amount of solder in the pot remains constant or not.

Case 1: Solder pot mass constant. (i.e., solder is removed and replaced by new solder/tin)

$$M_{T_A} = \frac{M_P (Sn\%_D - Sn\%_C)}{(Sn\%_A - Sn\%_C)} \quad \text{Eq. 3-1}$$

Case 2: Solder pot mass increases with added solder or tin.

$$M_{T_A} = \frac{M_P (Sn\%_D - Sn\%_C)}{(Sn\%_A - Sn\%_D)} \quad \text{Eq. 3-2}$$

Where:

M_{T_A} = The mass of tin to be added to the solder pot.

M_P = The mass of solder pot (prior to addition).

$Sn\%_D$ = The tin content desired in the solder pot (% by weight).

$Sn\%_C$ = The tin content currently in solder pot (% by weight).

$Sn\%_A$ = The tin content in solder or tin bar used for addition (e.g., 100 for pure tin bar).

3.3 Flux Soldering flux provides the environment in which molten solder must work; it changes the surface by removing and preventing contamination. Fluxing is only a part of the total soldering operation, but the choice of the proper flux and the correct use of that flux can directly determine the reliability of the completed assembly. Solder is not glue and does not simply fill up a gap between parts or stick to a surface. Molten solder will only flow out and bond to a clean surface, the flux must prepare the surface by providing a clean metal contact.

When solder is melted on a tarnished or oxidized surface, the internal, cohesive forces in the solder cause it to pull into a ball, much as water balls up on a waxed surface. Only when the surface is clean (free from oxide and dirt) will the bonding forces between the solder and metallic surface overcome the solder cohesive force and flow out over the surface.

Techniques such as mechanical abrasion, soldering with ultrasonics, using reducing gases such as hydrogen, using inert gases such as nitrogen or soldering in a vacuum, have all been effective means for preparing the surfaces for solder. However, the use of soldering flux is preferred, because of easy application, low cost, and reliability.

A material will only flow freely over a surface if in doing so, the total free energy of the system is reduced. In the case of soldering, the free energy of a clean surface is higher than a dirty one, making it more likely to promote solder flow.

The major purposes of a flux are:

1. **Chemical** – Reduces the oxides from the surface to be soldered and protects this surface (by covering it) from reoxidation.
2. **Thermal** – Assists in heat transfer from the heat source to the item being soldered (especially critical for hand and pulse soldering).
3. **Physical** – Transports the oxides and other reaction products away from the area being soldered.

In use, fluxes have two general criteria:

1. **Flux Activity** – The ability of the flux to reduce oxides and protect the surfaces from reoxidizing.
2. **Flux Corrosivity** – The impact of the flux residues on the long-term reliability of the assembly or device being soldered.

These two criteria typically oppose one another, as active fluxes tend to be highly corrosive, and fluxes that are not corrosive over the long term are also generally not very active in the short term. Obviously, one method of overcoming this problem is to remove the flux residue using some cleaning method. There is always some potential for residue remaining (due to operator error or inadequate processing); therefore, extremely active fluxes are rarely used in electronics.

For the fluxes to be useful, it is necessary that these materials be evaluated for corrosivity and insulation resistance of the residue when exposed to life cycle type environments. It has been noted that in many cases, “No Clean” fluxes are not compatible with cleaning attempts or even other “No Clean” fluxes. The impact of materials used in subsequent processes (fluxes, solvents, and conformal coatings) needs to be evaluated in combination with the flux and soldering process under evaluation.

The following lists the requirements for choosing the correct soldering flux:

- Must remove oxide and penetrate films.
- Must be thermally stable.
- Prevent oxidation at soldering temperatures.
- Lower interfacial surface tension.
- Be easily displaced by the molten solder.
- Be non-injurious to components.
- Be easily removed, if desired.
- Not affect performance if left on assembly.

Flux should at the very least remove oxide. The secondary task of flux is to prevent oxidation of the surfaces during heating and to promote wetting and spreading of the solder by lowering the surface tension. Reducing oxidation is the only type of “cleaning” that a flux is designed to do. Too often the flux is expected to remove other types of contamination such as oil, grease, dirt and fingerprints.

Especially with the very low solids content fluxes, heat stability is a critical factor as the thin film of flux has to withstand whatever part of the entire heating process required.

3.3.0.1 Choosing the Proper Flux Sometimes the scientific approach is totally neglected and there are attempts to try every flux made, hoping to find that one magic formula which accomplishes the ideal soldered connection. The proper method to approach any soldering application, whether the heating is done with an iron, pot, flame, wave solder machine or air reflow is to consider the entire soldering system.

The temperature and types of heating methods, time of soldering, and the condition of the surfaces being soldered all determine the type of flux which must be used. The amount of oxide reduction required by a flux determines the strength or activity necessary, and therefore, the type of flux.

The solderability of plated metal coatings is affected also by the bath purity and processing conditions. The nature of the oxide coating is dependent not only on the metal selected, but also on the environmental and thermal history.

3.3.0.2 Flux Types There are basically only two types of fluxes: organic and inorganic. Each of these types has many variations. Fluxes of all types are available as liquids, pastes, or in cored wire solder. When using a cored solder in conjunction with a liquid flux, it is good practice to use similar compatible fluxes so that removal of the residues is a simple matter.

With very few exceptions, fluxes are acids. Acids reduce oxides on metals. The acids can be water soluble, such as the inorganic and most organic fluxes, or non-water soluble, such as rosin or certain other carboxylic acids, or only solvent soluble, such as the SA type fluxes.

The IPC J-STD-004 Requirements for Soldering Fluxes specification defines the industry classification system used distinguish the different flux chemistries available for industry use. Table 3-5 lists the flux classifications.

Table 3-5 Flux Identification System¹

Materials of Composition ²	Flux/Flux Residue Activity Levels	% Halide ³ (by weight)	Flux Type ³	Flux Designator
Rosin (RO)	Low	0.0%	L0	ROL0
		<0.5%	L1	ROL1
	Moderate	0.0%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	0.0%	H0	ROH0
		>2.0%	H1	ROH1
Resin (RE)	Low	0.0%	L0	REL0
		<0.5%	L1	REL1
	Moderate	0.0%	M0	REM0
		0.5-2.0%	M1	REM1
	High	0.0%	H0	REH0
		>2.0%	H1	REH1
Organic (OR)	Low	0.0%	L0	ORL0
		<0.5%	L1	ORL1
	Moderate	0.0%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	0.0%	H0	ORH0
		>2.0%	H1	ORH1
Inorganic (IN)	Low	0.0%	L0	INL0
		<0.5%	L1	INL1
	Moderate	0.0%	M0	INM0
		0.5-2.0%	M1	INM1
	High	0.0%	H0	INH0
		>2.0%	H1	INH1

Note 1. Fluxes are available in S (Solid), P (Paste/Cream) or L (Liquid) forms.

Note 2. See J-STD-004 for comparisons of RO, RE, OR and IN composition classes and L, M and H activity levels with the traditional classes such as R, RMA, RA, water soluble and low solids "no-clean."

Note 3. The 0 and 1 indicate absence (<0.05% by weight in flux solids) and presence of halides, respectively. See J-STD-004 for flux type nomenclature.

The historic flux classifications of R, RMA, and RA have been replaced by a class system that provides a more detailed characterization of the flux material in terms of base chemistry, flux activity level, and halide content. The following chapter clauses provide further detail of the different base flux chemistries.

3.3.0.2.1 Rosin/Resin Fluxes (RO or RE classification) The mildest fluxes are those derived from rosin. Rosin is a mixture of resin acids which occur naturally in the oleoresin or sap of pine trees. The resin acids are three-ring, isomeric monocarboxylic acids with a hydrophenanthrene nucleus. Consisting of primarily abietic, pimaric acids and other similar acids; rosin was long acclaimed as the best flux for electronics soldering because of its neutral insulating nature at room temperature.

Rosin itself is a rather poor flux, since its oxide reduction ability is minimal. The use of rosin as a flux requires careful control over temperature. Rosin begins to melt at about 70 °C, but does not react with copper oxide until 100 °C forming copper abietate. This green, soapy reaction product often has been mistaken for corrosion, but is actually an insulating flux residue.

about 260 °C rosin begins to decompose and form reducing gases to function at peak fluxing ability. Too high a temperature (exceeding 340 °C) will rapidly render rosin inactive and cause polymerization, leaving a residue that is difficult to remove.

Due to the minimal oxide reduction character of pure rosin, most fluxes contain activation additives that leave residues with the neutral properties of plain rosin. The first step came nearly 60 years ago when organic acids and organic acid chloride derivatives were added to the rosin to improve the fluxing action. Other activating agents, such as amine hydrohalides, have been used successfully in fluxes for decades.

Problems arise only with today's electronics. When only flux cored wire solder was being used, all of the activated rosin flux was heated to soldering temperature, which resulted in an effective decomposition of the organic activators, leaving a relatively inert residue. With the introduction of automated methods for soldering printed board assemblies came the increased use of liquid activated rosin fluxes. IPC J-STD-004 details specific tests for distinguishing between the various types of rosin fluxes.

Activated rosin/resin fluxes in an unheated condition can dissolve several hundred angstroms of copper in a temperature humidity test. The amount of activating agent used in the activated rosin fluxes is usually less than one percent but this can cause electrical problems if the operating temperature of the solder assembly exceeds 70 °C, the point where rosin begins to melt. To avoid the potential problems which may arise when using activated fluxes, flux technology then developed along several different paths.

Even with the understanding that activated rosin fluxes have the potential to cause electrical conductivity problems at elevated temperatures, or corrosion problems if only the rosin portion is removed, the majority of companies using rosin flux still prefer activated rosin flux. Many millions of electronic assemblies since 1950 have been soldered using this most popular of flux types. The reason was simple, i.e., printed boards and component parts were not always solderable enough for milder fluxes to produce reliably soldered connections.

The good insulating property of the rosin residue protected the circuitry from the environment. When necessary, because of high voltage requirements or when the assembly would operate at higher than room temperature, the rosin and activator residue can be removed with solvents containing alcohol or with water saponifier (detergent) cleaning. The objective is reliable soldering without knowing the solderability of parts, and the necessary removal of residue afterwards.

3.3.0.2.2 No Clean Fluxes There are four factors resulting in the development and use of very low residue fluxes. First, there was a natural progression of the activated rosin fluxes to lower solids. This was driven by the desire to have less residue remaining, whether or not it was removed. Concurrently, as the solids content was being reduced, the electrical requirements on the printed board assembly were becoming more stringent, and fully activated fluxes with lower rosin content were leaving deleterious residues.

The second factor leading to the development of "no clean" fluxes was the improved solderability of printed boards and components, somewhat driven by the introduction of improved solderability test equipment. With the advent of statistical process controls in component production and more "just-in-time" deliveries, the need for chloride (or bromide) activated fluxes diminished.

The third factor was economics; it costs a lot of money to remove flux residue. Solvents and cleaning equipment are expensive. Disposal of waste solvent is expensive. Surface mounted components trap flux residue which is very difficult to remove. So, the activated rosin fluxes may not be completely removed and could possibly cause electrical problems depending on the flux used and degree of removal.

The fourth factor was environmental. With revelations that chlorinated solvents are affecting the protective ozone layer in the upper atmosphere, and with a greater awareness of the toxicity of solvents, there is increased interest in fluxes which can be left on the printed board assembly. At the same time, automation often requires electrical testing with "bed-of-nails" probes, so minimal residue was a requirement.

This type of flux can be rosin based and is activated mainly with non-water soluble organic acids. The solids content was in the 2-5% range and is now more in the lower end of this range. Some fluxes which are still noncorrosive and non-conductive do not contain rosin. It is most important to have excellent solderability of the parts being soldered since such a mild flux has a very low level of activity. Much test data is available from the flux Manufacturers on the corrosion and electrical insulation resistance of the residue. It should be noted that the term "no clean" fluxes is an industry process descriptive term and does not necessarily reflect the flux chemistry character - IPC J-STD-004 provides the appropriate flux identification and characterization.

3.3.0.2.3 Organic Fluxes (OR classification) Though this type of flux has been used for several decades, only in the 1980s did the general use of organic flux dramatically increase.

The organic water soluble fluxes are complex mixtures of organic acids, halide salts of organic acids and amines, wetting agents and solvents. All this salt has an effect on the insulation resistance of porous printed boards, such as paper-base phenolic. Glass/epoxy printed boards have been used successfully with or without plated-through holes. The assembly must be designed for water removal of the flux residue.

Any areas where flux can be trapped should be avoided, such as stranded wiring, porous components, open relays or transformers.

One of the most dangerous properties of these organic fluxes is the ability of the residue to absorb water from the environment, greatly increasing its quantity and mobility. There is no such thing as self-neutralizing flux since neutralization requires heating to soldering temperature—a feat which is never completely accomplished.

The advantages for organic water soluble fluxes center on efficiency and ease of cleaning. Since the organic fluxes are very active, very little pre-cleaning is necessary, except to remove oil and dirt other than oxide. Reliability is greatly increased with the decrease in expensive rework. The time and temperature of the soldering process can be reduced since less heat is required to activate the flux. Post cleaning in a water solution also removes other ionic residues which may be on the printed board assembly from previous handling during processing.

This advantage of cleaning with water can also be a disadvantage. The very active fluxes contain hydrochloric acid which can attack copper and lead resulting in rinse water which can be an environmental problem. The solderability of assemblies has improved to the point where milder organic fluxes can be used. Either neutral pH or halide-free fluxes are available to avoid the dissolution of metal in the rinse water. Soldering activity is reduced, but so also is the attack on metals, laminates, and solder mask.

3.3.0.2.4 Inorganic Fluxes (IN classification) These flux materials find very limited use for electrical connections, this type of flux consists of metal chloride salts, primarily zinc and stannous chlorides.

The strongest fluxes, the so-called stainless steel fluxes, usually contain a considerable amount of hydrochloric or phosphoric acids. These fluxes are highly corrosive and not completely removable with a water rinse. Unfortunately, most companies that have been in existence from at least 1990 have stories of corrosive soldering paste (zinc chloride in petroleum jelly) turning up on the assembly line brought in by someone experiencing difficulties using the milder fluxes. The results can be disastrous, although “everything solders great!”

3.3.1 Flux Application

3.4 Solder Paste Solder paste is a suspension of pre-alloyed solder powder particles in a flux vehicle to which special agents have been added to enable the solder powder to remain in stable suspension. Solder pastes are non-Newtonian fluids (comprised of more than one phase) and are also thixotropic (a material that viscosity decreases asymptotically over time under constant shear). The materials used to control viscosity and the thixotropic nature of the solder paste are generally proprietary.

Most solder pastes contain 75-92 mass percent of solder metal (equivalent to approximately 24-45 percent by volume). The agents which are added to prevent the separation of the metal from the light flux vehicle also provide certain rheological properties which are necessary for the methods of application.

Solder paste, as a convenient mixture of solder and flux, is used to join metals in a wide variety of applications: anything from automobile fuel tanks, copper tubing, and sheet metal, to electronic devices, hybrid microcircuits, and surface mounted component soldering.

What resulted in the increased importance in the use of solder pastes in the electronics industry is the ability to apply small quantities accurately to those areas where solder joints need to be formed. Also, the inherent tackiness of the paste enables components and hybrids to be temporarily connected to the board during the handling processes up to the time of the melting of the alloy to form the joint.

3.4.1 Solder Powder The solder powder used to make the solder paste should be controlled to give a consistent material. The mixture of the flux and thixotropic control materials are referred to as the “flux binder.”

Occasionally, solder powders are mixed such that the “bulk” composition is a common solder (e.g., Sn63Pb37) but is in fact a mix of particles of other compositions. An example of this is the solder powder sometimes used for leaded SMD soldering, which is Sn63Pb37 when analyzed in bulk, but is in fact a mix of pure tin and Sn10Pb90 powders. The composition of the solder powder is controlled to give a consistent material.

used to slow the reflow of the joint during vapor phase soldering, thus reducing the number of open solder connections sometimes produced. Although the melting points of both materials are above the typical vapor phase reflow temperature of 215 °C, solder reflow is accomplished initially by solid state diffusion between the individual particles, creating a meltable alloy at the interface. In this manner, complete reflow is achieved.

Atomizing liquid solder in an inert atmosphere generally forms the particles. The shape distribution of the resulting powder is determined during the atomization phase, as sieving the material through a mesh doesn't necessarily eliminate elongated particles. This distribution is a function of the skill and processes used by the powder Manufacturer, details of which are generally proprietary. The powder production process also impacts particle size.

3.4.2 Particle Shape Effects The shape of the solder powder affects a number of paste characteristics.

- Oxide formation on the surface of the powder. The larger the surface-to-volume ratio, the larger the amount of oxides formed on the solder paste. These oxides will inhibit reflow, increase the formation of solder balls, and subsequently reduce the overall volume of solder in the joint compared to the amount of solder printed (the difference being the amount of solder loss through solder ball formation).
- Large variations in particle size and shape. This will increase both the wear on the dispensing equipment (e.g., stencil, screen, or syringe) and the probability of small openings becoming blocked by solder particle "log jams."

A certain degree of non-uniformity of solder shape has been shown to increase the ability of the solder paste to resist solder paste "slump" during heating. In modern solder pastes, however, the "binder" controls slump. The uniformity of shape (spherical) is generally taken as one of the measures of the overall quality of the solder powder.

3.4.3 Solder Particle Size Effects Solder particle sizes are a result of the solder powder process combined with post process sorting of the powder using mesh screens to sort the powder by size. Typically, solder powder sizes are categorized by a mesh value, which indicates whether the powder in question passed through the screen (-) or is retained on top of the screen (+). This value sign will precede the mesh value. A summary of common mesh sizes used for solder powders is shown in Table 3-6.

Table 3-6 Mesh Size vs. Particle Size for Solder Powders Used in Solder Paste

Mesh Size	Particle Sizes (mm)
-325	Less than 45 mm
-270	Less than 55 mm
-200	Less than 75 mm
-200, +325	Between 45 mm and 75 mm

The choice of appropriate solder paste size is a tradeoff between the ease with which the solder paste can be printed, stenciled, or dispensed vs. the amount of solder balling. Solder balling increases with decreasing particle size due to the increased ratio (surface area/volume) of the powders and the fact that the smaller particles are more apt to be washed away from the main deposition of solder paste. These isolated solder particles (fines) are unable to coalesce into the main solder joint and are subsequently washed away during post solder cleaning. Requiring both an upper and lower boundary for particle size (e.g., - 200, +325) may reduce fines.

3.4.3 Oxide Content in Solder Paste Oxides are formed by the exposure of the solder powder to air either during the powder fabrication or the addition of the binder materials. Solder powders typically contain some oxides, but new manufacturing techniques have made it possible to fabricate the solder paste (from powder through mixing with the binder) with an oxide content <0.03% by weight. When the oxide content increases to above 0.15% by weight, solder balling may result, especially with less active (ROL0/ROL1) fluxes. Solder oxides are less dense than solder (typically 6500 kg/m³) and will float to the surface of the molten solder.

Two quick qualitative tests for oxide content are:

- Reflow a small amount of paste on a substrate (typically 200 microns thick, with a 5.5 mm diameter) and look for the presence of solder balls. The size and number of solder balls are an indication of oxide content.
- Reflow about 10g of solder paste under a reflow fluid (typically peanut oil) at 215 °C. Allow to cool under the oil, then remove and examine. The oxides will float to the surface and appear as a bumpy/dull area on the top surface of the solder "button."

3.4.4 Metals Content Typically, the metals content of solder pastes is expressed as a percentage by weight. For most electronics applications, the solder paste used is 80 - 95% metal by weight. As the solder paste metal content decreases, the viscosity of the paste typically becomes more dependent on thixotropic control materials. These materials typically have

effectiveness with increasing temperature; therefore, pastes with lower metal contents have an increased tendency toward slump. Typical metal contents as a function of paste application method are shown in Table 3-7.

Table 3-7 Recommended Viscosities of Solder Pastes (@25 °C; 1 Pa·s = 1000 centipoise)

Application Method	Metal Content (% by weight)	Viscosity (Pa*)
Stencil Print	90%	600-1000
Screen Print	85%-90%	400-700
Syringe Dispenser	80%-85%	200-450
Pin Transfer	75%	50-250

3.4.5 Paste Viscosity The viscosity of the solder paste is highly dependent on:

- Temperature: in curves of viscosity vs. temperature, breaks in the curve can be caused by a phase change in the binder material.
- Applied shear stress.
- The “work history” of the solder paste: a result of the fact that as a solder paste is exposed to shear stresses, the viscosity drops and doesn’t recover immediately.
- The shear velocity at which the viscosity is measured.

A demonstration of these effects is shown in Table 3-8.

Table 3-8 Effects of Parameters on Viscosity (Shear rate is 1.5/sec unless otherwise noted)

Parameter	Change	Viscosity Change (Pa)
Particle Size	1-45 mm to 40-80 mm	From 250 to 390
Metal Content	86% to 90% (mass)	From 280 to 400
Temperature	From 18 °C to 28 °C	From 320 to 220
Shear Rate	From 0.1/sec to 50/sec	From 2000 to 50

As a result, all of the preceding items must be tightly controlled in order to get repeatable results between various test sites. Two types of viscosity measurement equipment are typically used for solder pastes: a rotating concentric cylinder method and a rotating helipath with a paddle.

In each case, it is essential to ensure that the solder paste stabilizes at a specified temperature (23 °C - 25 °C) prior to measurement. Any mixing done in order to prepare the sample (e.g., moving a sample from one container to the test container) should be controlled and/or done well before the measurement is taken. Typically eight to 24 hours are needed to allow for a sample of solder paste to achieve a stable and uniform temperature. This would also be adequate time to allow for any “mixing” effects to subside.

As viscosity changes with velocity, a measure of viscosity at 2 or more points in the paste’s operating range (as determined from squeegee print speed) is the most informative. This information can be used to develop a VSI, which can be used to characterize solder pastes for printability. It has been suggested that a VSI of 3-6 is acceptable, with VSIs as high as 8 being available and providing superior printability.

3.4.6 Determination of Correct Paste Volume The use of solder paste allows for a unique control of the volume of solder deposited for a given solder joint. In this fashion, the volume of solder deposited can be tailored to reduce defects and compensate for other restraints (e.g., need for common thickness of a stencil or pad-to-pad spacings).

Models for determining the volume of solder paste required for a specific solder joint vary from simple geometric models to more complex functions, which take into account such features as surface tension, solder density, gravity, and wetting angle. In general, the geometric models perform well enough for most purposes and are readily adaptable to spreadsheet type “what if” models.

Items that the model will need to take into effect are:

- Lead shape (including lead-to-lead coplanarity and potential spacing of lead from pad).
- Proposed solder fillet shape.
- Solder volume required for acceptable fillet.

- Solder already present in the form of pretinned pads and leads.
- Variability in lead and pad dimensions.

It should be stressed that this model is only an approximation based on nominal conditions. Allowances should be made for normal and expected process variations.

3.5 Solder Preforms Solder can be manufactured into specific, preformed shapes for use in automated assembly and soldering applications, or when precise amounts of solder and flux are required. Solder preforms are stamped from flat ribbon, formed from wire, cast from melted metal, or made with compacted powdered solder.

Advantages of using solder preforms include:

- Precise amounts of solder and flux for each solder joint.
- Soldering not dependent on an operator's judgment.
- Placement can be automated, eliminating the need for manual assembly, inspection and touchup.
- Inaccessible soldered joints can be made.
- Highly skilled operators are not required.

Disadvantages of using solder preforms include:

- As a manufactured part, the price per unit weight of solder is higher for solder preforms.
- Short run quantities of special shapes may preclude recouping tooling costs.
- Solder preforms are sometimes viewed as a custom made, non-stock part because of small quantities, limited geometries, and minimum sources of supply.

Selection of solder preforms includes considerations of the solder alloy, a determination of the proper flux and percentage required and choosing dimensions which deliver the correct amount of solder to the solder joint.

Solder preforms should meet the same requirements for solder and flux. Flux solvents used in solder preforms should not be harmful to the work piece or solder connection and should be easily removed after the soldering operation. If solder preforms are used in surface mount applications, the ability of the fluxes and other constituents to be cleaned from under the part is an important factor in the selection of the flux and the cleaning system.

Solder preforms may contain flux in some form. The fluxes in the creams, pastes, and preforms are under the same restrictions as the liquid fluxes outlined in 3.3 (i.e., L0 or L1 activity, RO, RE, OR bases). Not all solder preforms contain flux.

When a solder preform contains flux that is totally encapsulated, it is called a heat-shrinkable, controlled solder device, which is covered in 4.19. When the flux is either absent or non-encapsulated, devices can be categorized into the following types:

- **Solder Tapes** – These controlled soldering devices are used to deliver the correct amount of solder to multiple wire or lead terminations, typically on center spacing of 0.38 mm - 1.27 mm. They prevent solder bridging and provide lead alignment for chip carriers, flexible printed circuits, and edge connectors during solder reflow. The solder tape device consists of a strip of solder and a slotted, high-temperature polymer tape with a pressure-sensitive adhesive on one surface.
- **Solder Columns** – These controlled soldering devices are used to provide leadless ceramic chip carriers with conductive mounting columns consisting of a copper helix and solder. The mounting columns serve as compliant, conductive interfaces between the chip carrier and the board. They also alleviate the stress resulting from the different coefficients of thermal expansion of IC packages and circuits boards.

The installation procedure for non-encapsulated devices may be generalized into the steps listed below. Details such as lead preparation, fixturing, and heating techniques will vary with the applications and should be specified on the appropriate assembly documents.

1. If necessary, pre-tin leads to meet solderability requirements.
2. Position the controlled soldering device as specified in the applicable installation instructions.
3. Position the item to be terminated as directed in the applicable installation instructions.
4. Apply heat until the solder melts and flows enough to form a fillet along the soldered interface.
5. Allow the assembly to cool undisturbed until the solder has solidified.
6. Inspect termination for conformance to the applicable criteria.

3.6 Adhesives Several types of adhesives are used in the fabrication of electronic products and provide an electrical, thermal or mechanical function depending on the adhesive properties of each formulation. Selection of an appropriate adhesive should identify the securing properties required, the application and curing method, and the service life of the material in the intended environment. The application and use of adhesives cannot degrade the performance of the components or inhibit the ability of the soldering process to form an acceptable interconnection between the land pattern and the device termination surfaces. Formulations of applicable adhesives are available with specific characteristics and curing methods including thermally activated, ultraviolet (UV) light cured, two-part epoxies and ambient cured. Applications exist for temporary adhesives intended to remain in place until a process operation is completed and the material can then be removed as directed by the Manufacturer. Specific components that require a staking adhesive to minimize vibration should be identified and the adhesive requirements, volume and placement locations defined. The attachment of surface mount devices prior to the soldering process is the most common application for adhesives in electronic assemblies.

When an adhesive is required for securing surface mount components, the material is applied directly to the surface of the circuit card and the surface mount component is subsequently placed into the adhesive material and processed through a curing cycle to bond the component to the surface. The application methods most widely used to deposit the adhesive material in the designated component locations are:

- **Stencil or Screen Printing** – a hard stencil or screen mesh template is fabricated matching the location for deposit of the adhesive. Using either an automated or manual method, the adhesive material is pushed through the aperture openings in the stencil or screen mesh. Stencil printing typically provides better deposition control of the volume of adhesive applied over screen mesh printing.
- **Pneumatic Dispensing** – an automated process using air pressure to dispense a controlled volume of adhesive onto the printed circuit board surface via a dispensing needle nozzle at a designated x-y coordinate location.
- **Pin Transfer** – an automated process utilizing tooling to hold small diameter pins to transfer adhesive material from a receptacle cup to a designated x - y location. Physical size of the deposited adhesive dots is determined by the diameter of the transfer pins used.

The location of the adhesive prior to and after curing **shall not** degrade the ability of solder to form an acceptable interconnection and the adhesive must be cured completely. Curing of the adhesive material is to be performed as defined by the Manufacturer, typically accomplished for surface mount attachment using a thermal cycle to activate the material and secure the components.

The selection of adhesive materials should consider all subsequent processing of the soldered assembly, i.e., cleaning processes, additional thermal cycles for soldering other devices, or any electrical, environmental or mechanical testing, so as not to degrade the attachment characteristics.

3.7 Chemical Strippers Chemical stripping is appropriate for solid, single conductor wire only. Chemical strippers vary in their strength of aggressiveness in removing both the organic insulation and the metallization of the wire surface. Removal of organic insulation from solid conductors using a chemical stripping process is an alternative to mechanical stripping on small gauge (≤ 28 AWG) conductors to prevent stretching of the wire and also can be used for the stripping of enamel coated solid wire to prevent surface damage caused by mechanical stripping. The chemical stripping process is an efficient method for complete removal of the insulation, resulting in an exposed, clean, solderable conductor surface.

When the chemical stripping process is completed, it is necessary to totally remove/neutralize the stripping agent per the Manufacturer's recommendation. Stripping chemical left on the conductor surface or allowed to wick under the remaining insulation will continue to attack both the insulation and wire surface creating a long term reliability concern.

The chemical stripping chemistry must be selected and processed in a documented manner that does not degrade (i.e., oxidize) the surface of the conductor inhibiting solderability. The stripping agent and process selected for chemical insulation removal should be repeatable. Precautions should be taken relative to health and safety concerns as directed by the Manufacturer of the chemistry used.

If a chemical stripping agent is applied for removal of conformal coating, the surface must be neutralized and cleaned after the conformal coating has been removed, resulting in a solderable surface for subsequent operations.

Temporary maskant materials, applied to protect specific surface areas during production activities, must be completely removed after processing, leaving no detrimental residue or degradation to solderable surfaces.

3.8 Components is adequately defined in the Standard.

3.8.1 Component and Seal Damage is adequately defined in the Standard.

3.8.2 Coating Meniscus is adequately defined in the Standard.

3.9 Soldering Tools and Equipment Appendix A of the Standard addresses the criteria for selection of hand soldering systems identifying the requirements for temperature control, tip to ground resistance, and system capability to provide controlled and sustainable heat to the connection area. Appendix A also addresses machine soldering system criteria for preheating of assemblies, temperature control and utilization of documented process controls. Specific hand solder system or machine solder system product details from the Manufacturer should be reviewed prior to purchase of equipment insuring production needs are met and component integrity is preserved during processing.

NOTE: The following will focus on hand soldering tools and associated information.

Regardless of the soldering iron type being used, successful hand soldering depends on the following conditions:

- Thermal contact is maintained between the soldering tip and the item to be soldered.
- Tip size and shape is thermally matched to the component.
- Tip is to be clean and free of oxides with an intact plating finish.
- The operator's technique creates a thermal "bridge" of molten solder between the tinned tip of the soldering iron and the item to be soldered.
- Flux (typically from cored solder wire or applied liquid flux) is allowed to flow over the area to be soldered in advance of the molten solder, increasing the ability of the surface to accept solder (wetting) and providing a thermal transfer medium to aid in heating.
- Solder volume (amount) is controlled to form an acceptable solder connection.
- Contact time of the tip to the area to be soldered is controlled to create an acceptable solder connection without inducing thermal damage to the component or PCB.

A hand soldering tool can be defined by reducing it to its simplest terms: a heating source and a soldering tip. The heating source (element) provides heat to the tip, and the tip transfers heat from the element to the area and component being soldered. The amount of heat required is determined by the thermal mass of the component and the thermal mass of the laminate material. The mass and physical shapes of the soldering tip are considered when selecting an appropriate tip for a specific solder operation. Many variations of tip design are available to accomplish acceptable solder connections.

Control of the systems heat source (element) is provided by internal sensor technology designed to monitor and provide a constant temperature at the tip, matching the thermal demands of the solder connection being formed. Sensor technology varies from each Manufacturer, with each design focusing on temperature stability, rapid thermal recovery time, low tip resistance to ground, and no risk of ESD damage to electronic products being soldered. IPC-TM-650 defines various test methods that can be used to evaluate soldering system performance using a common test protocol.

The physical configuration of the PCB laminate structure, which includes the number of circuit trace layers, ground planes and quantity of interconnect locations, will affect the amount of heat required from the heating element. The thermal load of the location to be soldered may require the use of an external auxiliary heat source to elevate the entire assembly to a temperature close to the required reflow point to minimize the risk of laminate damage due to prolonged tip contact time.

Soldering iron tips are typically created by shaping a core material from a copper alloy mixture and applying a plated finish, typically iron, to provide maximum thermal transfer via the copper alloy and surface finish stability with resistance to oxidation. As the plated surface deteriorates or wears over time, oxidation of the exposed copper base layer decreases the ability of the tip to transfer the needed heat during soldering, ultimately resulting in the need to replace the tip. Tip selection, specifically the length, physical shape and thermal mass, should primarily be capable of providing rapid transfer of heat to the solder connection being formed without thermal damage to the component or PCB surface area. Minimizing the contact dwell time of the heated tip to the solder connection is accomplished by controlling the tip size and shape.

Raising the tip operating temperature significantly above the solder melt temperature to reduce contact dwell time by inducing rapid heat transfer to the connection point can cause thermal damage and poor quality solder connections. Modern heating element sensor technology and low mass tip designs have established the performance required to utilize the tip as a thermal transfer vehicle rather than a thermal storage medium.

When a tip becomes excessively oxidized (plating breakdown) or contaminated with flux residues or other foreign matter, the ability of the tip to transfer heat is greatly reduced. Tips should be kept clean and coated (tinned) with clean solder at all times to reduce oxidation. Replace or recondition tips in accordance with the tip Manufacturer's instructions. Tip life can be maximized by: