

IPC-HDBK-001H

2021 - January

Handbook and Guide to Supplement J-STD-001

Supersedes IPC-HDBK-001F

February 2016

An international standard developed by IPC



BUILD ELECTRONICS BETTER



Documents

Document Sharing Hub

The Principles of Standardization

In May 1995 the IPC's Technical Activities Executive Committee (TAEC) adopted Principles of Standardization as a guiding principle of IPC's standardization efforts.

Standards Should:

- Show relationship to Design for Manufacturability (DFM) and Design for the Environment (DFE)
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

Standards Should Not:

- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

Notice

IPC Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of IPC from manufacturing or selling products not conforming to such Standards and Publication, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than IPC members, whether the standard is to be used either domestically or internationally.

Recommended Standards and Publications are adopted by IPC without regard to whether their adoption may involve patents on articles, materials, or processes. By such action, IPC does not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Recommended Standard or Publication. Users are also wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

IPC Position Statement on Specification Revision Change

It is the position of IPC's Technical Activities Executive Committee that the use and implementation of IPC publications is voluntary and is part of a relationship entered into by customer and supplier. When an IPC publication is updated and a new revision is published, it is the opinion of the TAEC that the use of the new revision as part of an existing relationship is not automatic unless required by the contract. The TAEC recommends the use of the latest revision. Adopted October 6, 1998

Why is there a charge for this document?

Your purchase of this document contributes to the ongoing development of new and updated industry standards and publications. Standards allow manufacturers, customers, and suppliers to understand one another better. Standards allow manufacturers greater efficiencies when they can set up their processes to meet industry standards, allowing them to offer their customers lower costs.

IPC spends hundreds of thousands of dollars annually to support IPC's volunteers in the standards and publications development process. There are many rounds of drafts sent out for review and the committees spend hundreds of hours in review and development. IPC's staff attends and participates in committee activities, typesets and circulates document drafts, and follows all necessary procedures to qualify for ANSI approval.

IPC's membership dues have been kept low to allow as many companies as possible to participate. Therefore, the standards and publications revenue is necessary to complement dues revenue. The price schedule offers a 50% discount to IPC members. If your company buys IPC standards and publications, why not take advantage of this and the many other benefits of IPC membership as well? For more information on membership in IPC, please visit www.ipc.org or call 847/597-2809.

Thank you for your continued support.



IPC-HDBK-001H

Handbook and Guide to Supplement J-STD-001

Developed by the IPC-HDBK-001 Task Group (5-22F) of the Assembly and Joining Committee (5-20) of IPC

Supersedes:

IPC-HDBK-001F - February 2016
IPC-HDBK-001E - February 2012
IPC-HDBK-001 w/Amendments
1 & 2 - October 2005
IPC-HDBK-001 w/Amendment 1 -
December 2000
IPC-HDBK-001 - March 1998

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

Contact:

IPC
3000 Lakeside Drive, Suite 105N
Bannockburn, Illinois
60015-1249
Tel 847 615.7100
Fax 847 615.7105

This Page Intentionally Left Blank

Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. While the principal members of the IPC-HDBK-001 Task Group (5-22F) of the Assembly and Joining Committee (5-20) are shown below, it is not possible to include all of those who assisted in the evolution of this handbook. To each of them, the members of IPC extend their gratitude.

Assembly and Joining Committee	IPC-HDBK-001 Task Group	Technical Liaison of the IPC Board of Directors
Chair Dan Foster Missile Defense Agency	Co-Chairs John Mastorides Honeywell Aerospace	Bob Neves Microtek (Changzhou) Laboratories
Vice Chair Karen Tellefsen MacDermid Alpha Electronics Solutions	Scott Meyer Collins Aerospace Vice Chair Miguel Dominguez Continental Temic SA de CV	

Members of IPC-HDBK-001 Task Group

Kathy Johnston	Irene Romero, Delta Group Electronics Inc.	Kim Souva, Kearfott Corporation
Mary Muller	Lowell Sherman, DLA Land and Maritime	Sue Powers-Hartman, Killdeer Mountain Manufacturing, Inc.
Ross Dillman, ACI Technologies, Inc.	Murilo Levy Casotti, Embraer SA	Jasbir Bath, Koki Solder America
Constantino Gonzalez, ACME Training & Consulting	Leo Lambert, EPTAC Corporation	Augustin Stan, L&G Advice Serv SRL
Sean S. Keating, Amphenol Ltd (UK)	Helena Pasquito, EPTAC Corporation	Shelley Holt, L3Harris Communications
Bob Potysman, ATRON Group LLC	Eric Camden, Foresite, Inc.	Kevin Kusiak, Lockheed Martin Corporation
Joseph Kane, BAE Systems	Terry Munson, Foresite, Inc.	Grayson Cook, Lockheed Martin Missiles & Fire Control
Kelly Kovalovsky, BAE Systems	Graham Naisbitt, Gen3 Systems Limited	Joshua Hudson, Lockheed Martin Missiles & Fire Control
Agnieszka Ozarowski, BAE Systems	Francesco Di Maio, GESTLABS S.r.l.	Kyle Johnson, Lockheed Martin Missiles & Fire Control
Brian Parlman, BAE Systems	Lalith Bandara, GPV Lanka (Pvt) Ltd.	Vijay Kumar, Lockheed Martin Missiles & Fire Control
Jonathon Vermillion, Ball Aerospace & Technologies Corp.	John Mastorides, Honeywell Aerospace	Brian Llewellyn, Lockheed Martin Missiles & Fire Control
Gerald Bogert, Bechtel Plant Machinery, Inc.	Christina Rutherford, Honeywell Aerospace	Owen Reid, Lockheed Martin Missiles & Fire Control
James Barnhart, BEST Inc.	Richard Rumas, Honeywell Canada	Ann Marie Tully, Lockheed Martin Missiles & Fire Control
Norman Mier, BEST Inc.	Jennie Hwang, H-Technologies Group	Pamela Petcosky, Lockheed Martin Mission Systems & Training
David Adams, Collins Aerospace	John Waryold, HumiSeal Division of Chase Corporation	Linda Woody, LWC Consulting
David Hillman, Collins Aerospace	Jeffrey Lee, iST - Integrated Service Technology	Jason Fullerton, MacDermid Alpha Electronics Solutions
Scott Meyer, Collins Aerospace	Toshiyasu Takei, Japan Unix Co., Ltd.	Matt Garrett, Microsemi
Douglas Pauls, Collins Aerospace	Jose Delgado, Jet Propulsion Laboratory	
Dan White, Collins Aerospace		
Ivan Roman, Continental Automotive		
Miguel Dominguez, Continental Temic SA de CV		
Jose Servin Olivares, Continental Temic SA de CV		
Symon Franklin, Custom Interconnect Ltd		

Ernst Eggelaar, Microtronic
Daniel Foster, Missile Defense Agency
Edward Rios, Motorola Solutions
Robert Cooke, NASA Johnson Space Center
James Blanche, NASA Marshall Space Flight Center
Charles Gamble, NASA Marshall Space Flight Center
Garry McGuire, NASA Marshall Space Flight Center
William May, Naval Surface Warfare Ctr
Daniel McCormick, Naval Surface Warfare Ctr
Joseph Sherfick, Naval Surface Warfare Ctr
Nicholas Walton, Naval Surface Warfare Ctr
Randy McNutt, Northrop Grumman Aerospace Systems
Patrick Phillips, Northrop Grumman Innovation Systems

Mahendra Gandhi, Northrop Grumman Space Systems
Bruce Hughes, Nvidia Corporation
Ken Moore, Omni Training Corp.
Gustavo Arredondo, PARA TECH Parylene Services
Richard Kraszewski, Plexus Corp.
Steven Corkery, Raytheon Company
James Daggett, Raytheon Company
Roger Miedico, Raytheon Company
James Saunders, Raytheon Company
Fonda Wu, Raytheon Company
Lance Brack, Raytheon Missile Systems
George Millman, Raytheon Missile Systems
Paula Jackson, Raytheon UK
Michael Carano, RBP Chemical Technology, Inc.
Rama Murthy PBV, Research Centre Imarat, DRDO, Ministry of Defence

Gary Latta, SAIC
Neil Johnson, Solve Direct Electronics
Benjamin Piepgrass, Southwest Research Institute
Robert Fornefeld, STI Electronics, Inc.
Patricia Scott, STI Electronics, Inc.
Lynda Pelley, Teledyne Dalsa
James Parke, The Aerospace Corporation
Gaston Hidalgo, Toyota Motor North America
Ingrid Swenson, TTM Technologies, Inc.
Paul Zutter, U.S. Army Aviation & Missile Command
Dave Harrell, Viasat Inc.
Bud Bowen, Winchester Interconnect
Zhiman Chen, Zhuzhou CRRC Times Electric Co., LTD.
Zhe (Jacky) Liu, ZTE Corporation

Table of Contents

0.1 GENERAL	1	1.11 Acceptance Requirements	10
0.1.1 Scope	1	1.12.0 Product Assurance	10
0.1.2 Purpose	1	1.12 Inspection Methodology	10
	1	1.12.1 Process Verification Inspection	10
1.0 GENERAL	3	1.12.2 Visual Inspection	10
1.1 Scope	3	1.13 Facilities	11
1.2 Purpose	3	1.13.1 Environmental Controls	11
1.3 Classification	3	1.13.2 Field Assembly Operations	12
1.4 Measurement Units and Applications	3	1.13.3 Health and Safety	12
1.4.1 Verification of Dimensions	4	1.14 Electrostatic Discharge (ESD)	12
1.5 Definition of Requirements	4	2.0 APPLICABLE DOCUMENTS	13
1.5.1 Hardware Defects and Process Indicators	5	2.1 EIA	13
1.5.2 Material and Process Nonconformance	5	2.2 IPC	13
1.5.3 Procedures for Specialized Technologies	5	2.3 Electrostatic Discharge Association	14
1.6 Process Control Requirements	5	2.4 SAE	14
1.6.1 Opportunities Determination	6	3.0 MATERIAL, COMPONENTS, AND EQUIPMENT REQUIREMENTS	15
1.6.2 Statistical Process Control	6	3.1 Materials	15
1.7 Order of Precedence	6	3.2 Solder	16
1.7.1 Appendices	6	3.2.1 Solder – Pb-free	20
1.8 Terms and Definitions	6	3.2.2 Solder Purity Maintenance	26
1.8.1 Circumferential Solder Separation (Area Void of Solder)	6	3.3 Flux	29
1.8.2 Diameter	7	3.3.1 Flux Application	32
1.8.3 Disposition	7	3.4 Adhesives	32
1.8.4 Electrical Clearance	7	3.5 Chemical Strippers	33
1.8.5 Engineering Documentation	7	3.6 Components	33
1.8.6 FOD (Foreign Object Debris)	7	3.6.1 Component and Seal Damage	33
1.8.7 High Voltage	7	3.6.2 Coating Meniscus	33
1.8.8 Manufacturer (Assembler)	7	3.7 Tools and Equipment	33
1.8.9 Objective Evidence	7	3.7.1 Solder Transfer	35
1.8.10 Process Control	7	4.0 GENERAL SOLDERING AND ASSEMBLY REQUIREMENTS	37
1.8.11 Proficiency	8	4.1 Solderability	37
1.8.12 Solder Destination Side	8	4.2 Solderability Maintenance	37
1.8.13 Solder Source Side	8	4.3 Removal of Component Surface Finishes	37
1.8.14 Solder Void	8	4.3.1 Gold Removal	37
1.8.15 Supplier	8	4.3.2 Other Metallic Surface Finishes Removal	38
1.8.16 Tempered Leads	8	4.4 Thermal Protection	38
1.8.17 User	8	4.5 Rework of Nonsolderable Parts	39
1.8.18 Wire Overwrap	8	4.6 Preprocessing Cleanliness Requirements	39
1.8.19 Wire Overlap	8	4.7 General Part Mounting Requirements	39
1.9 Requirements Flowdown	9	4.7.1 General Requirements	39
1.10 Personnel Proficiency	9	4.7.2 Lead Deformation Limits	39
1.10.1 X-ray Specific Personnel Proficiency	9		

4.8	Hole Obstruction	40	5.4.8	Series Connected	64
4.9	Metal-Cased Component Isolation	40	5.5	Soldering to Terminals	64
4.10	Adhesive Coverage Limits	40	5.5.1	Bifurcated Terminals	64
4.11	Mounting of Parts on Parts (Stacking of Components)	40	5.5.2	Slotted Terminal	64
4.12	Connectors and Contact Areas	40	5.5.3	Cup and Hollow Cylindrical Terminals – Soldering	64
4.13	Handling of Parts	40	5.6	Jumper Wires	66
4.13.1	Preheating	41	5.6.1	Insulation	67
4.13.2	Controlled Cooling	41	5.6.2	Wire Routing	67
4.13.3	Drying/Degassing	42	5.6.3	Wire Staking	67
4.13.4	Holding Devices and Materials	42	5.6.4	Unpopulated Land or Via – Lap Soldered	68
4.14	Machine Soldering	42	5.6.5	Supported Holes	68
4.14.1	Nonreflow Soldering	42	5.6.6	SMT	68
4.14.2	Reflow Soldering	44			
4.14.3	Selective Soldering	53	6.0	THROUGH-HOLE MOUNTING AND TERMINATIONS	71
4.15	Solder Connection	54	6.1	Through-Hole Terminations – General	71
4.15.1	Exposed Surfaces	54	6.1.1	Lead Forming	74
4.15.2	Solder Connection Anomalies	55	6.1.2	Termination Requirements	75
4.15.3	Partially Visible or Hidden Solder Connections	56	6.1.3	Lead Trimming	76
4.16	Heat Shrinkable Soldering Devices	56	6.1.4	Interfacial Connections	77
4.17	Threaded Fasteners	56	6.2	Supported Holes	77
4.18	Torque	56	6.2.1	Solder Application	77
5.0	WIRES AND TERMINAL CONNECTIONS	57	6.2.2	Through-Hole Component Lead Soldering	78
5.1	Wire and Cable Preparation	57	6.2.3	Coating Meniscus in Solder	78
5.1.1	Insulation Damage	58	6.3	Unsupported Holes	78
5.1.2	Strand Damage	58	6.3.1	Lead Termination Requirements for Unsupported Holes	78
5.1.3	Tinning of Stranded Wire – Forming	58	7.0	SURFACE MOUNTING OF COMPONENTS	79
5.2	Solder Terminals	59	7.1	Surface Mount Device Lead	79
5.3	Bifurcated, Turret and Slotted Terminal Installation	59	7.1.1	Plastic Components	79
5.3.1	Shank Damage	59	7.1.2	Forming	79
5.3.2	Flange Damage	60	7.1.3	Unintentional Bending	80
5.3.3	Flared Flange Angles	60	7.1.4	Flat Pack Parallelism	80
5.3.4	Terminal Mounting – Mechanical	60	7.1.5	Surface Mount Device Lead Bends	80
5.3.5	Terminal Mounting – Electrical	60	7.1.6	Flattened Leads	80
5.3.6	Terminal Mounting – Soldering	61	7.1.7	Parts Not Configured for Surface Mounting ...	80
5.4	Mounting to Terminals	61	7.2	Leaded Component Body Clearance	81
5.4.1	General Requirements	61	7.2.1	Axial-Leaded Components	81
5.4.2	Turret and Straight Pin Terminals	62	7.3	Parts Configured for Butt/I Lead Mounting ...	81
5.4.3	Bifurcated Terminals	62	7.4	Installation of Surface Mount Components	81
5.4.4	Slotted Terminals	63	7.5	Soldering Requirements	81
5.4.5	Hook Terminals	63	7.5.1	Misaligned Components	81
5.4.6	Pierced or Perforated Terminals	63	7.5.2	Unspecified and Special Requirements	82
5.4.7	Cup and Hollow Cylindrical Terminals – Placement	63	7.5.3	Bottom Only Chip Component Terminations	82

7.5.4	Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s)	82	8.9	Frequently Asked Questions on Cleanliness ...	93
7.5.5	Cylindrical End Cap Terminations	82	8.9.1	Question: Why would an assembler choose to clean a “no-clean” flux?	93
7.5.6	Castellated Terminations	83	8.9.2	Question: How do I know that the area under a low standoff component, e.g., BGA, is clean?	96
7.5.7	Flat Gull Wing Leads	83	8.9.3	Question: Can flux residues flow or relocate?	96
7.5.8	Round or Flattened (Coined) Gull Wing Leads	83	8.9.4	Question: How does hand cleaning or topical cleaning impact overall cleanliness? ...	96
7.5.9	J Lead Terminations	83	8.9.5	Question: Can you explain what electro- chemical failures are?	96
7.5.10	Butt/I Terminations	84	8.9.6	Question: Will wearing gloves make it easier to meet the ionic requirements of J-STD-001?	97
7.5.11	Flat Lug Leads	84	8.9.7	Question: I know ionic residues are related to electrochemical failures, but do they have other negative impacts?	97
7.5.12	Tall Profile Components Having Bottom Only Terminations	84	8.9.8	Question: What IPC resources are avail- able to assist in understanding this complex issue?	98
7.5.13	Inward Formed L-Shaped Ribbon Leads	84			
7.5.14	Surface Mount Area Array Packages	85	9.0	PRINTED BOARD REQUIREMENTS	99
7.5.15	Bottom Termination Components (BTC)	85	9.1	Printed Board Damage	99
7.5.16	Components with Bottom Thermal Plane Terminations (D-Pak)	85	9.1.1	Blistering/Delamination	99
7.5.17	Flattened Post Terminations	85	9.1.2	Weave Exposure/Cut Fibers	99
7.5.18	P-Style Terminations	85	9.1.3	Haloing	99
7.5.19	Vertical Cylindrical Cans with Outward L-Shaped Lead Terminations	86	9.1.4	Edge Delamination	99
7.5.20	Wrapped Terminals	86	9.1.5	Land/Conductor Separation	99
7.5.21	Flexible and Rigid-Flex Printed Circuitry with Flat Unformed Leads	86	9.1.6	Land/Conductor Reduction in Size	99
7.6	Specialized SMT Terminations	86	9.1.7	Flexible Circuitry Delamination	99
8.0	CLEANING AND RESIDUE REQUIREMENTS	87	9.1.8	Flexible Circuitry Damage	99
8.0.1	Process Residues and Their Impact on Product Reliability	87	9.1.9	Burns	100
8.0.2	Historical Perspective on Cleaning and Cleaning Processes	88	9.1.10	Non-Soldered Edge Contacts	100
8.0.3	Magnification and Visual Inspection for Cleanliness	88	9.1.11	Measles	100
8.1	Qualified Manufacturing Process	90	9.1.12	Crazing	100
8.1.1	Cleaning Designator	90	9.2	Marking	100
8.2	Ionic Process Monitoring	90	9.3	Bow and Twist (Warpage)	100
8.2.1	Sampling Plan	92	9.4	Depanelization	100
8.2.2	Control Limits	92	10.0	COATING, ENCAPSULATION AND STAKING (ADHESIVE)	101
8.2.3	Exceeding the Control Limits	92	10.0.1	Conformal Coating General	101
8.3	Re-qualification Requirements	92	10.0.2	Conformal Coating Adhesion	101
8.3.1	Level 1 – Major Changes Requiring Validation	92	10.0.3	Substrate Preparation	102
8.3.2	Level 2 – Minor Changes with Supporting Objective Evidence	92	10.1	Conformal Coatings	105
8.4	Foreign Object Debris (FOD)	93	10.1.1	Materials	105
8.5	Visible Residues	93	10.1.2	Masking	108
8.6	Non-ionic Residues	93	10.1.3	Application	109
8.7	Ultrasonic Cleaning Processes	93	10.1.4	Thickness	110
8.8	Guidance Documents	93	10.1.5	Uniformity	110



10.1.6	Bubbles and Voids	110	Figure 3-9	Component Degradation Due to Pb-Free Soldering Process Incompatibility	25
10.1.7	Delamination	110	Figure 3-10	Pb-Free Solder Alloy Attack of Wave Solder Equipment	25
10.1.8	Foreign Objects Debris	111	Figure 3-11	Copper Erosion Due to Pb-Free Soldering Processes	25
10.1.9	Other Visual Conditions	111	Figure 3-12	Coating Meniscus on a Lead	33
10.1.10	Inspection	111	Figure 4-1	Thermal Shunt	39
10.1.11	Rework or Touchup	111	Figure 4-2	Component Bridging	40
10.2	Encapsulation	112	Figure 5-1	Compound Wire Stripper	57
10.2.1	Application	113	Figure 5-2	Stripped Wire	57
10.2.2	Performance Requirements	113	Figure 5-3	Insulation Thickness	58
10.2.3	Rework of Encapsulant Material	113	Figure 5-4	Antiwicking Tool	59
10.2.4	Encapsulant Inspection	113	Figure 5-5	Flange Damage	60
10.3	Staking	113	Figure 5-6	Flare Angles	60
10.3.1	Staking – Application	113	Figure 5-7	Terminal Mounting – Mechanical	60
10.3.2	Staking – Adhesive	114	Figure 5-8	Terminal Mounting	60
10.3.3	Staking (Inspection)	114	Figure 5-9	Stress Relief	61
11.0	WITNESS (TORQUE/ANTI-TAMPERING) STRIPE	115	Figure 5-10	Wire Wrap	61
12.0	REWORK AND REPAIR	117	Figure 5-11	Wire Wrap Around Terminal Post	61
12.1	Rework	117	Figure 5-12	Continuous Runs	62
12.2	Repair	117	Figure 5-13	Wire and Lead Wrap Around	62
12.3	Post Rework/Repair Cleaning	117	Figure 5-14	Side Route Connections and Wrap on Bifurcated Terminal	63
APPENDIX GUIDE		119	Figure 5-15	Bifurcated Terminal Top and Bottom Route Connection	63
APPENDIX A	Guidelines for Soldering Tools and Equipment	121	Figure 5-16	Slotted Terminal	63
APPENDIX B	Minimum Electrical Clearance – Electrical Conductor Spacing	122	Figure 5-17	Hook Terminal Connections	63
APPENDIX C	J-STD-001 Guidance on Objective Evidence of Material Compatibility	123	Figure 5-18	Pierced or Perforated Terminal Wire Placement	64
APPENDIX D	X-Ray Guidelines	125	Figure 5-19	Solder Depression	64
APPENDIX E	Cross Reference Listing by Revision	127	Figure 5-20	Cup and Hollow Cylindrical Terminals – Vertical Fill of Solder	65
ACRONYM INDEX		137	Figure 5-21	Jumper Wires	69
Figures			Figure 6-1	Component Lead Stress Relief Examples	71
Figure 3-1	Phase Diagram for Eutectic Solder	17	Figure 6-2	Side Mounting	71
Figure 3-2	Eutectic Solder Microstructure	17	Figure 6-3	Vertical Mounting of Freestanding Components	72
Figure 3-3	Eutectic Solder Microstructure	17	Figure 6-4	Mounting of Components with Dual Non-Axial Leads	72
Figure 3-4	Solder Wire Core Flux Comparison	22	Figure 6-5	Typical Configuration of Components with Dual Non-Axial Leads	72
Figure 3-5	Solder Alloy Fracture Toughness Testing Results	22	Figure 6-6	End Mounting	73
Figure 3-6	Solder Alloy Drop Shock Testing Results	23	Figure 6-7	Mounting with Feet on Standoffs	73
Figure 3-7	Pb-Free Solder Alloy/Component Surface Finish Incompatibility Example	24	Figure 6-8	Non-Resilient Footed Standoffs	73
Figure 3-8	left: Non-Uniform Solder Joint Microstructure, right: Incomplete Solder Joint Reflow (Head-on-Pillow)	24	Figure 6-9	Lead Forming Forces	74
			Figure 6-10	Lead Bends	75
			Figure 6-11	Through-Hole Mounting Methods	76
			Figure 6-12	Via Fill	77
			Figure 7-1	Surface Mount Device Lead Forming	79
			Figure 7-2	DIP Lead Forming	80
			Figure 7-3	Surface Mounted and Butt/Joint Mounted	81

Figure 8-1	Burned Printed Board	87	Table 3-8	Pb-Free Solder Alloys	31
Figure 8-2	Dendrites	87	Table 3-9	Flux Identification System (from J-STD-004B w/Amendment 1)	32
Figure 8-3	Solder Mask Surface Appearance	89	Table 4-1	Baking Times and Temperatures (Bare/Unpopulated Printed Board)	42
Figure 8-4	White Residue	89	Table 4-2	Common Screen Parameters	46
Figure 8-5	Frosted Solder Appearance	89	Table 4-3	Common Screening Problems and Solutions ...	46
Figure 8-6	Average Tin Whisker Density (D. Hillman, IPC/SMTA Cleaning and Conformal Coating Conference, 2010)	97	Table 4-4	Physical Properties of Vapor Phase Reflow Fluids	48
Figure 8-7	Average Tin Whisker Density (P. Snugovsky IPC/SMTA Cleaning and Conformal Coating Conference, 2010)	98	Table 4-5	Advantages and Disadvantages of Vapor Phase Soldering	48
Figure 10-1	Cure Windows of Primer Cure	103	Table 4-6	Thermal Data for Electronic Materials	49
Figure 10-2	Conditions that Influence the Extent of Primer Cure	104	Table 4-7	Problems and Solutions in Vapor Phase Soldering	50
Figure 10-3	Influence of Temperature and Humidity	104	Table 4-8	IR Radiation	51
Figure 10-4	Conformal Coating Family Trees	106	Table 4-9	Advantage and Disadvantages of IR Soldering	51
Tables					
Table 1-1	Metric Prefixes	4	Table 4-10	Characteristics of Infrared Sources for SMT Soldering	51
Table 1-2	Conversion Formulae	4	Table 5-1	Allowable Strand Damage	58
Table 3-1	Common Physical Property Values for Eutectic or Near Eutectic Tin/Lead Solder	18	Table 6-1	Component to Land Clearance	71
Table 3-2	Mesh Size vs. Particle Size for Solder Powders Used in Solder Paste	19	Table 6-2	Components with Spacers	74
Table 3-3	Recommended Viscosities of Solder Pastes	20	Table 6-3	Lead Bend Radius	75
Table 3-4	Effects of Parameters on Viscosity (Shear rate is 1.5/sec unless otherwise noted)	20	Table 6-4	Protrusion of Leads in Supported Holes	76
Table 3-5	Test Requirements for Flux Classifications (from J-STD-004B w/Amendment 1)	21	Table 6-5	Protrusion of Leads in Unsupported Holes	76
Table 3-6	Pb-Free Solder Alloys and Their Melting Temperatures	21	Table 8-1	IPC Rhino Team	90
Table 3-7	Maximum Limits of Solder Bath Contaminant	27	Table 8-2	Flux Identification	94
			Table 10-1	Preferred Conformal Coating Removal Methods	112

This Page Intentionally Left Blank

Handbook and Guide to Supplement J-STD-001

Δ 0.1 GENERAL

Δ 0.1.1 Scope This Handbook is a companion reference to the J-STD-001 (standard) 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 this document is 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 to produce acceptable hardware.

NOTE: The revision of this Handbook was revised in an attempt to align with the base document/standard at the same revision. Please check for the latest revision or for any amendment(s) that may include changes that could alter explanations for how and why, or more detailed discussions on criteria.

Δ 0.1.2 Purpose The 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 the 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, if the methods used will produce completed solder joints conforming to the acceptability requirements of the standard.

Δ 0.2 FORMAT (Using This Handbook)

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

Although this document will not provide discussion on each of the differences between J-STD-001H and the two addendums J-STD-001HS and J-STD-001HA/IPC-A-610HA, it may provide information on certain topics addressed in addendums, e.g., Pb-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 E 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 and Military Applications Electronic Hardware Addendum paragraphs for revisions F, G and H. A cross-reference to the associated Automotive Addendum paragraphs is not included in this revision.

Information concerning the appendices in J-STD-001 is either addressed in the body of this Handbook or covered more thoroughly in another document. An appendices guide is included at the end of 13 Rework and Repair that links the topics discussed in the appendices of J-STD-001 to the appropriate supplemental information.

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 H.

NOTE: References in the text of this Handbook (not text quoted from a standard) referring only to Sections, Tables, and Figures in this Handbook will be annotated accordingly, see Example 1. If the reference is to a Section, Table, or Figure in the standard, it will be followed by “of the standard,” 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.

Endnotes are included in some sections to acknowledge references included in that section. Acronyms are used throughout this Handbook and are defined in an Acronym Index at the end of this Handbook.

All following Section numbers align to the Section numbers in the published J-STD-00H.

Section numbering that is unique to the Handbook, i.e., not part of this standard – examples 8.0.1 - 8.0.4 – are part of this Handbook, but not part of the standard Section numbers preceded by are additional content for this Handbook. There is no related Section in the standard.

1.0 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. This standard does not provide comprehensive tutorials on principals and techniques, but it may direct the reader to other documents that may. For a more complete understanding of the J-STD-001H recommendations and requirements, the standard suggests using this document and IPC-A-610H.

As stated in 1.5.3 Procedures for Specialized Technologies, it is an industry consensus document, meaning that additions, deletions and modifications to the standard are made and agreed upon via consensus vote by the standards Development Committee responsible for that document. The standards Development Committee is made up of User and Manufacturer representatives from across the industry. IPC provides a Staff Liaison.

The standard content is dependent upon industry submissions of requests for change. At the back of each standard there is a standard Improvement Form and instruction on how to submit the form. Whenever possible these criteria should be submitted to the IPC Technical Committee/standards Development Committee to be considered for inclusion in upcoming revisions of this standard.

As materials, products and processes evolve in our industry, it is expected that there will be submissions requesting improvements or addition of new criteria related to new technologies and/or component configurations and possible changes to material requirements as chemistries evolve. All submissions should be accompanied by supporting data. Submissions are reviewed, discussed, evaluated and dispositioned via consensus vote at standard Development Committee meetings, which anyone can attend. (Contact IPC for more information on standards Development Committees)

1.2 Purpose *This standard prescribes material requirements, process requirements, and acceptability requirements for the manufacture of soldered electrical and electronic assemblies. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001, IPC-AJ-820 and IPC-A-610. Standards may be updated at any time, including with the addition of amendments. The use of an amendment or a newer revision is not automatically required.*

As described in 1.1 Scope of this Handbook, there is a process in place for submitting requests for changes to the standard.

1.3 Classification The User (the individual, organization, company, contractually designated authority or agency responsible for the procurement or design 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/Harsh Environment 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.

This section discusses use of the standard and establishment of Product Classes. It also provides a list of design and fabrication specifications that these requirements are meant to align with or support. When a Contract invokes this standard on a product, any product feature not addressed with requirements in this standard should be identified by the Manufacturer if not already identified by the User. Acceptability requirements for those features should be established, documented, and agreed upon.

1.4 Measurement Units and Applications Table 1-1 in this Handbook 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 measurements

temperatures, or other process parameters are provided in English units, conversion formulae are provided in Table 1-2 in this Handbook. 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.

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 for reference purposes (to disposition borderline conditions), or in order to resolve internal process problems.

The Manufacturer should evaluate assemblies that are not clearly rejectable, using 1.4.1 Verification of Dimensions 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 plated through-holes and vias, not to mention the impact on schedules and profitability.

Clarification for rounding values was adding to the standard revision G as follows, *round all observed or calculated values “to the nearest unit” in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of ASTM Practice E29. For example, specifications of 2.5 mm max, 2.50 mm max, or 2.500 mm max, round the measured value to the nearest 0.1 mm, 0.01 mm, or 0.001 mm, respectively, and then compare to the specification number cited.*

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. If a condition is not clearly rejectable, it should be accepted. After a defect has been identified, magnification may be increased to determine its features.

1.5 Definition of Requirements The user needs to be aware that some of the content within the standard is recommendations only, and they are typically based on industry best practice. This content will contain wording other than “**shall**” or “**shall not**.” When there is a statement that uses “Should” for example, that is a recommendation and not a requirement. 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. The standard contains requirements for three Classes of requirements, as identified in 1.3.

For this reason, each requirement has beside it a designation which informs the user of this standard what the disposition should be for each specific class of product (1, 2, and 3). The requirements can be different for each Product Class. The User first must know to which Product Class their product is being built and accepted. When they read a requirement in the standard, the user should only be looking at the designation for their applicable Product Class, and ignoring the others.

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 in) 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)	$10.76 \times \text{fc} = \text{lm/m}^2$

As an Example: Let us assume your product is Class 2 and we are looking at the requirement in 3.8.2.

3.8.2 Coating Meniscus *Component coating meniscus **shall not** [N1D2D3] be trimmed.*

The “**shall**” means there is a requirement. Then look for the Class 2 requirement, next to it, in the brackets. For each Product Class there is a letter followed by the class number.

“N” means there is No **requirement** established for that Class

“A” means the condition is Acceptable for the Class

“P” means the condition is a Process Indicator for that Class, which means it is acceptable but should be monitored to see if the process can be improved to produce a better result, closer to the acceptable condition.

A “D” in front of the Product Class number means that the condition is a defect for that Product Class.

The 3.8.2 requirement states that the component meniscus that can extend from the body of a component, down the lead, **shall not** be trimmed. The designator inside the bracket for Class 2 is “D” (D2). That means that for Class 2 it is a defect. Classes 1 and 3 have their own designators, which may or may not be the same. In this case, Class 3 is also a defect if the meniscus is trimmed. If the meniscus is trimmed on Class 1 product, the designator inside the brackets is “N,” which means there are no criteria established, so there are no criteria to reject the condition, and it would be acceptable unless separate criteria were established by the manufacturer or their user.

1.5.1 Hardware Defects and Process Indicators Hardware defects and process indicators are identified throughout J-STD-001. This paragraph defines both “Defect” and “Process Indicator.” The main difference is that defects must be documented and dispositioned. Process indicators are NOT defects but typically are an indication that something in your process has shifted. Process indicators are not the same as “Acceptable” and should be monitored in order to identify trends that may require process changes or hardware anomalies that require additional analysis. There are several options for implementing a process indicator monitoring system. Common methods include adding the Process Indicators listed in the standard to the company defect documentation system with a separate Process Indicator code or identifier so they can be documented and monitored separately from defects while still using common defect tracking systems. Other companies use separate tracking tools for the Process Indicators.

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. As an example, 3.3 Flux states that type H or M fluxes **shall not** be used for tinning of stranded wires, for all three Product Classes. If it is determined after the product has been built that either one of these fluxes was used to tin stranded wire, it would be a material nonconformance, as well as a violation of 3.3 Flux. Tests that simulate the product life expectancy and environments should be performed so that the resulting data may be used to support the disposition. This is particularly important to support a use-as-is disposition. 3 Flux and Appendix C of the standard must also be considered when determining material and process nonconformance based on material/process compatibility testing and/or verifications required by standard, the class of products being manufactured and any applicable contract requirements.

1.5.3 Procedures for Specialized Technologies Technologies improve and change on a regular basis. New technologies emerge as well. In order for the standard to keep up with these technologies, IPC and the industry standard committee must rely on Users, Suppliers, and Manufacturers to provide proposed criteria and supporting data to the IPC for consideration of addition to the standard. There is a standard Improvement Form at the back of the standard, which should be used for this purpose.

1.5.3.1 Manufacture of Devices Incorporating Magnetic Windings Is adequately defined in the standard.

1.5.3.2 High Frequency Applications Is adequately defined in the standard.

1.5.3.3 High Voltage Applications Is adequately defined in the standard.

1.6 Process Control Requirements The philosophy of process control is to establish and control each process involved in the manufacture of a product with the ultimate goal of obtaining a 100% acceptable product yield. The process parameters and production output are monitored, and adjustments are made to ensure the process remains within the established control limits. Monitoring yield results provides performance feedback data used to reduce or eliminate the production of defective product and identify the necessary corrective action to reduce variation in the process.

The corrective action should include a global assessment of whether the noted condition could impact other products than the product on which the noted condition was detected.

Process control must be a documented system, available for review, that meets the intent of IPC-9191, SAE - EIA-557, or some other User-approved system.

The process control plan should include or reference documentation that contains the following:

- Proper training of personnel with responsibilities in development, implementation, and utilization of process control and statistical methods that are commensurate with their responsibilities.
- Quantitative methodologies with objective evidence to demonstrate that the process is capable and in control.
- Improvement strategies to define initial process control limits and methodologies, which should lead to continuous process improvement and subsequent defect reduction.
- Defined criteria within the process control plan for switching to or from sample-based inspections.
- The occurrence of a defect(s) in a sample inspection can prompt 100% inspection of the lot for that defect condition in accordance with the process control plan.
- Monitoring systems to identify and correct the occurrence of process indicators. This also applies to out of control processes and discrepant assemblies.
- Documented audit plans to monitor process characteristics.

Effective Corrective Action Systems Usually begins 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. Practically speaking, 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.

1.6.1 Opportunities Determination Is adequately defined in the standard.

1.6.2 Statistical Process Control Is adequately defined in the standard.

1.7 Order of Precedence The Order of Precedence should look like this:

Contract

User approved assembly drawings and documentation

J-STD-001

Documents cited within the J-STD-001

Assembly drawings and documentation that are NOT User approved

Δ **1.7.0.1 Clause References** When the document refers to a "Section" it is referring to the beginning of a subject section. 1.7 is a Section. Any other paragraphs that begin with 1.7 are subordinate sections. 1.8 would be the next Section.

1.7.1 Appendices At the back of the standard, there are four Appendices. This Section clarifies for the user of the standard that the Appendices do not contain requirements unless the contract, assembly drawing(s), documentation or purchase order identifies them as being required.

1.8 Terms and Definitions Terms and Definitions used in the standard, other than those found in 1.8 Terms and Definitions, should align with IPC-T-50, Terms and Definitions. J-STD-001 and IPC-T-50 revision dates may not align, which could affect whether or not a new term is defined in the IPC-T-50.

1.8.1 Circumferential Solder Separation (Area Void of Solder) Is adequately defined in the standard.



1.8.2 Diameter

1.8.2.1 Conductor Diameter The conductor diameter is the outside diameter of wire, either stranded or solid, without the insulation.

1.8.2.2 Wire Diameter The wire diameter is the outside diameter of wire, either stranded or solid, including insulation if present.

1.8.3 Disposition Defines how a defect should be treated once it has been identified as a defect. It lists four possible dispositions. The standard does not limit the disposition to only those four examples provided.

1.8.4 Electrical Clearance This section defines electrical clearance and gives examples of what noncommon conductors might be. The standard does not identify one specific distance as the minimum electrical clearance requirement that must be met.

1.8.5 Engineering Documentation Is adequately defined in the standard.

1.8.6 FOD (Foreign Object Debris) FOD (Foreign Object Debris) is adequately defined in the standard, also reference 8.4 Foreign Object Debris (FOD).

1.8.7 High Voltage The definition does not specify what is considered “high voltage,” but points out that it can be different based on design and application. It is important to note that an assembler or inspector typically has no way of knowing if high voltage processing and/or criteria need to be applied unless the drawing or documentation specifies it.

1.8.8 Manufacturer (Assembler) As seen in the standard, “Manufacturer” could mean an individual, company, or organization. Ultimately the Manufacturer could be any of these that are responsible for the assembly process and verification of compliance to the requirements of the standard.

1.8.9 Objective Evidence This definition is referring to data that supports the existence of or the verity (truth) about a procedure, process, material, inspection or test result. The data may have been obtained through observation, measurement, test or other means. There are several instances cited in the standard where objective evidence would be required. Personnel Proficiency, Solder, Flux Application, Removal of Component Surface Finishes, SMT Area Array Packages, Bottom Termination Components, Conformal Coating Materials, and Statistical Process Control sections all have some reference or requirement referencing the need for objective evidence. Objective evidence is also mentioned in the Appendices at the end of the standard. Revision G of the standard added several examples of objective evidence to include:

- a. Work instructions.
- b. Procedures and records required by the quality management system.
- c. Chemical and physical test data.
- d. Reliability calculations based on recognized industry reliability standards.
- e. Manufacturer data sheets/reports, known acceptable record of performance by selected suppliers.
- f. External and/or internal audit reports.
- g. Test/inspection reports including actual measured values.
- h. Training records.
- i. Soldering temperature versus time profiles.
- j. Technical basis for changes in materials and/or processes. As an example, see Appendix C.k. Historical data.
- l. Competency Matrix (skills checklist).

1.8.10 Process Control Product quality is dependent on 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 achieving a 100% acceptable product yield. The process is monitored, and adjustments are made to ensure that the process remains in control and that minimal defective products are produced. Process parameters and product output are monitored to provide feedback of performance and assist in identifying the necessary corrective action.

Manual/nonautomated processes inject variations, which are not as repeatable as an automated process and therefore are much more difficult to control. Results of manual processes employing the same equipment, such as a soldering iron, with the same setting, soldering the same materials, may produce different results. Manual processes are operator dependent. Outfitting operators with the same tools to control a process may yield little, or no change. The way a tool is used is operator dependent. With a soldering iron, for example, how, where, and with how much pressure a soldering iron tip is placed on a connection to be soldered are all individual factors which contribute to the resulting solder connection. How fast an operator feeds the wire solder and the diameter of that solder are also factors, as is the application of external liquid flux. Outfitting an assembly area with the same soldering tool cannot remove the human factor and may or may not help to control the process and yield better process results. Additional hands-on training when tools are changed may help reduce variation in results.

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 benefits from 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.

J-STD-001H 1.6 Process Control Requirements provides in-depth details on applying process controls.

1.8.11 Proficiency The standard requires proficiency for anyone performing tasks or verifications (inspections) of requirements in accordance with the standard. Additional detail relating to personnel proficiency is found in 1.10 Personnel Proficiency.

1.8.12 Solder Destination Side When soldering a plated through-hole, the solder is applied on one side of the assembly and flows through the hole to form a solder fillet on the opposite side of the assembly. Which side of an assembly is the solder destination side depends on where the solder is applied. The side where the solder is applied is NOT the destination side. The side that the solder flows onto after it goes through the plated through-hole IS the solder destination side.

1.8.13 Solder Source Side When soldering a plated through-hole the solder is applied on one side of the assembly and flows through the hole towards the opposite side of the assembly. Which side of an assembly is the solder source side depends on where the solder is applied. The side where the solder is applied IS the solder source side.

1.8.14 Solder Void Is adequately defined in the standard.

1.8.15 Supplier The Supplier as stated in the standard is the individual, organization or company that provides parts and or materials to the individual, organization or company that is manufacturing the product.

1.8.16 Tempered Leads Is adequately defined in the standard.

1.8.17 User The User is defined in the standard as the individual, organization, company, contractually designated authority, or agency responsible for the procurement or design of electrical/electronic hardware, and having the authority to define the class of equipment and any variation or restrictions to the requirements of this standard, i.e., the originator/ custodian of the contract detailing these requirements. The User may also be the Manufacturer.

1.8.18 Wire Overwrap An overwrap is wrapped around a terminal for more than 360 degrees and remains in contact with the terminal or post. This would not be a defective condition unless the maximum degree of wrap was designated.

1.8.19 Wire Overlap This definition is in reference to a wire overlapping itself when wrapped on a terminal. It is not in reference to wires that overlap each other in any other application, such as inside a heat shrinkable soldering device. An overlap occurs when a wire is wrapped around a terminal for more than 360 degrees, and at any point with the wire

area the wire is not in contact with the post and crosses over itself. This would be a defective condition for two of the three Product Classes, unless specifically allowed via approved design or documentation.

1.9 Requirements Flowdown When a User requires that their product be manufactured to the requirements of the standard and specifies the Product Class, they expect to receive exactly that. When the prime manufacturer outsources a portion of the manufacturing process, it is critical that those same requirements are placed upon the subcontractor and any of their subcontractors that are contracted to build or supply portions of the end item. This is a critical process to control. 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 that when the requirements of the base document are invoked by contract that the prime contractor flows down the same obligations to all of their subcontractors and vendors. This section does not include commercial off-the-shelf items unless they are required to meet the end item requirements.

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

The third paragraph addresses items that are procured with the intent of attaching them to your assembly. An example would be procurement of a daughter board to be attached to a motherboard that was manufactured to requirements of this standard. It is recommended that the procured daughter board also meet the same acceptability requirements. The only parts that must meet the requirements of the base document are the solder connections that attach the daughter board to the motherboard.

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) cancelled their certification programs, which focused on relatively small user groups. 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 requested IPC 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. The IPC training and certifications program is revision specific due to content changes as the base document is revised. The process for developing the training program remains the same. A committee of industry (user) representatives directs and formally approves the technical content.

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 Certification 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, which has become important in international trading. Any training program that is based on the requirements of the standard, but it is created by a source other than the IPC Industry Committee, is considered a Qualification training program. Operators should be issued a qualification to the requirements, or an internal Company certification that qualifies them to the requirements of the standard. Operators completing those training programs may be qualified to the requirements, but they are not Industry Certified to the standard requirements. Only the industry-created and approved IPC Training program can issue a true IPC Certification to the requirements of this standard. The distinction between being qualified to the standard and Certified to the standard is critical to the integrity of the training program. We must distinguish between the two. To some customers this is an important distinction because of the credibility and high standards the industry approved IPC Training program is held to.

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.

1.10.1 X-ray Specific Personnel Proficiency is adequately defined in the standard.

1.11 Acceptance Requirements is adequately defined in the standard.

1.12.0 Product Assurance Quality cannot be inspected into a product. It must be manufactured-in and this can only be realized by establishing, maintaining, and continuously improving the manufacturing processes by implementing an effective process control methodology. Continuous process improvement is also one of the key principles of a high-level Quality Management System (QMS), such as ISO 9001.

1.12 Inspection Methodology The intent of inspection is to verify the product meets customer requirements. How products are inspected can be as important as the product itself.

There is no one right answer for “how” to inspect finished product. Typically, the inspection procedure will use a combination of process verification, visual inspection, magnification aids, lighting, and sampling inspection to verify product meets requirements. This collective effort is the inspection methodology.

1.12.1 Process Verification Inspection Process verification evaluates the operations used to produce the product. These operations include the practices, methods, procedures and written inspection plans used by the people doing the work. Without process control and verification, product variability could occur, resulting in noncompliant product. A process control plan is recommended to identify the methods and materials used in the soldering process, see 1.6 Process Control Requirements.

Process verification should consist of the following:

1. Surveillance or auditing of each operation in the control plan verifies all of the activities required to produce the end-product. By auditing the process, we can see the interactions between the various operations needed to make the process work.
2. Verification of the output of each process operation ensures compliance of the product to the established acceptance criteria. Verification can be achieved by various means such as but not limited to: “Go-No Go Gauges;” GD&T (geometric dimensioning and tolerance) measurements; and visual inspection.

1.12.2 Visual Inspection A finished assembly may be required to be 100% visually examined to ensure acceptance criteria has been met. Visual inspection should be performed with adequate illumination using the applicable magnification aid(s).

Conformal coating, staking and encapsulation tend to hide or distort the appearance of solder connections. Solder and cleaning inspections must be completed before the application of coating materials to ensure inspection is unimpeded.

When visual inspection cannot be applied, x-ray or other non-destructive means or inspections may be utilized to determine acceptability such as hole fill or BGA voiding.

1.12.2.1 Lighting The intent of this requirement is to ensure that the work surface is properly illuminated to facilitate component identification, reduce assembly errors, establish a uniform level of illumination between workstations, and to reduce operator fatigue.

The illumination level was reduced to a “should” recommendation in the base document after concern was raised that requiring a minimum illumination level would be cost prohibitive for some assembly houses, because even if they currently met the illumination level of 1,000 lux they would be required to verify the illumination level if it was a requirement.

The illumination level was elevated to a mandatory requirement in the Space Addendum.

A note was added to advise Users that the color of the light is useful in assisting the operator in discerning materials and contaminants with increased clarity. Metals such as copper and Alloy 42 look the same at color temperatures under 3000 K, however, under higher color temperatures (4500 to 5000 K are best), these metals have very different appearance.

An illumination level of 1,000 lux at the work surface is the accepted practice for the minimum level of illumination in which operators and inspectors should be expected to perform their tasks. 1,000 lux is approximately equivalent to 93 foot-candles when measured using a photographic light meter.

Storage cabinets/shelving, workbench risers, test equipment, and personnel frequently obscure light from overhead fixtures. Even without obstacles, overhead (ceiling mounted) lighting rarely supplies the necessary illumination and will not meet the specification without supplemental lighting installed directly above the workstation. Before placing a light meter on the surface to be measured, the workstation should be set up the same as it will be for production with personnel in place. This will assure that the value indicated on the light meter reflects actual working conditions.

Lamps with a combination of a light fixture and a magnifying lens are often used because they not only provide illumination but are a useful assembly and inspection tool as well. Light sources should be selected to prevent shadows on items being inspected.

1.12.2.2 Magnification Aids The magnification power for visual inspection is identified in Table 1-2 for solder connections, Table 1-3 for wires and wire connections, and Table 1-4 for other criteria.

The magnification power requirement is based on the size of the land width or wire to be inspected, as identified in Tables 1-2 and 1-3, and assemblies with mixed sizes (land or wire) can be completely inspected at the greater magnification power.

If the presence of a defect cannot be determined at the prescribed inspection power, the item is acceptable.

- This describes acceptance protocol directing the inspector to verify the correct magnification power was selected to inspect the item. If visual inspection of the item, using the correct magnification power meets all acceptance criteria, then the item is acceptable.
- Additionally, this means that if one cannot determine non-compliance to specific criteria e.g., plated through hole minimum vertical barrel fill, minimum adhesive staking, bonding height, maximum side overhang for a gull wing device at the defined inspection magnification prescribed herein, then the condition in question is acceptable, and no further action is required.
- Further 1.4.1 Verification of Dimensions states actual measurements are not required, except for referee purposes. This means the training, experience and visual observation of the inspector is sufficient to identify non conformance for percentages or dimensions.

The referee magnification power is intended for use only after a defect has been determined but is not completely identifiable at the inspection power.

- This describes the application of “referee” power to increase the magnification to the specified maximum amount per Tables 1-2 or 1-3.
- Increasing the magnification to “referee” levels is intended to assist in determining additional information related to details of the defect, i.e., assisting in determination of actual measurement parameters, contamination preventing proper wetting, insufficient solder flow preventing acceptable barrel fill, alignment or deformation causing excessive side overhang, etc.

The use of referee magnification may also exonerate a “defect.” This means that once viewed at the referee magnification it becomes evident that the “defect” in fact meets all the required acceptance criteria, therefore is acceptable and should be treated as such.

Mixed Land or Wire Widths When hardware contains multiple land widths and requires different magnification powers, the higher inspection magnification power may be used for inspecting the entire assembly.

Eye Tests An eye test may be required to ensure operator visual acuity. Eye testing may be required by contract or may be standard operating practices for manufacturers.

Lighting Lighting is defined in 1.12.2.1 Lighting of the standard. Adequate lighting requirements are necessary to reduce shadows, and to aid in the inspection process. The light range identified is approximately equivalent to day light reducing yellow tinting.

1.13 Facilities A facility’s environment can have a substantial impact on the output of a production line. A few considerations are:

- Environmental factors can impair the proper function of solder, solder pastes, fluxes, and conformal coating resulting in significant rework.
- Humidity can have a substantial impact on electrostatic charge generation, solder, solder pastes, fluxes, and conformal coating performance and many other process parameters
- Eating, drinking and the use of tobacco products, including the use of e-cigarettes, in the workplace have the potential to:
 - Subject personnel to possible health risks through the inhalation or ingestion of toxic chemicals or materials.
 - Contaminate the work area and surfaces to be processed, i.e., reducing solderability, adhesion of coatings, etc.

1.13.1 Environmental Controls The intent of this Section is to ensure that the assembly area is isolated from external process or environmental conditions that may damage or degrade printed circuit boards, electronic assemblies and components, or adversely impact the solder assembly processes or overall product quality.

A positive pressure air conditioning system ensures that the uncontrolled external environment (humidity, temperature, air drafts, air pollution, contaminating chemicals, etc.) does not enter the soldering facility.

1.13.1.1 Temperature and Humidity The limits given in this Section have been accepted as the minimum-maximum range for temperature and humidity in which most solder pastes, fluxes, conformal coatings or other solvents will perform as expected while maintaining considerations for control of electrostatic charges and operator comfort. Process control procedures should include modified limits where special materials or processes dictate.

Enhanced ESD control procedures may be required if humidity levels drop below 30% RH or if ESD Class 0 components are being used. Examples of additional controls may include the use of air ionizers, ESD smocks, continuous monitoring or more frequent checks of non-continuous monitors.

1.13.1.1.1 Temperature For Operator comfort and solderability maintenance, the temperature should be maintained between 18° C [64° F] and 30° C [86° F].

1.13.1.1.2 Humidity Controlling the range (lower and upper limits) of humidity in the assembly area allow soldering (including solderability maintenance) and assembly materials, e.g., conformal coating, to function correctly in the process, based on vendor recommendations or documented evidence of process performance. For operator comfort the relative humidity should not exceed 70%.

1.13.2 Field Assembly Operations The intent of this requirement is to ensure that the effects of exposure to uncontrolled environmental conditions during field assembly operations are understood and mitigated to ensure reliable solder joints and to minimize the introduction of defects in Class 3 products.

1.13.3 Health and Safety Health and safety are paramount. Occupational Safety and Health Administration (OSHA) regulations and any other local or governmental regulations are put in place to ensure the health and safety of workers. Access to those regulations should be available to everyone. It is good practice to flow applicable cautions into company rules and regulations or even into the manufacturing documentation when it is related to a process that will be performed, or when there will be a known exposure. Think of personal safety first and always wear required personal protective equipment.

1.14 Electrostatic Discharge (ESD) Anyone involved in the assembly or handling of electronic hardware must be aware of and mitigate the potential for latent and/or immediate damage to sensitive electrical/electronic components by ESD. The Manufacturer must have a documented ESD control program that provides sufficient protection at the sensitivity level of the most electrostatic discharge sensitive (ESDS) device(s) used in the product. This documentation must be available for review by the User.

ANSI/ESD-S20.20 (or equivalent) and ESD-TR20.20 ESD Handbook provide valuable information on establishing an ESD control program and proper handling and storage procedures, as well as how to set up and maintain an ESD-safe facility.

The most important aspect of any ESD control program is that both the personnel handling ESD sensitive parts or assemblies and the product must be at the same electrical potential. ESD sensitive product outside protective packaging in an ESD Protected Area (EPA) should be connected to ground. Personnel grounded by wrist straps or heel straps, without the product being connected to ground, may not provide the equipotential balance to preclude ESD damage. For example, applying conformal coating while the assembly is resting on an insulating tray will not provide the required equipotential balance. Nonessential insulators should be removed from the EPA. Insulating materials necessary to the work being performed, such as an instrument case, paper or cardboard, computer mouse, chemical containers and similar items should be placed away from ESD sensitive product.

2.0 APPLICABLE DOCUMENTS

This section 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

EIA-557 Statistical Process Control 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-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-STD-0006 Requirements for Using Robotic Hot Solder Dip to Replace the Finish on Electronic Piece Parts

2.2 IPC²

IPC-TR-580 Cleaning and Cleanliness Test Program Phase 1 Test Results

IPC-TR-581 IPC Phase III Controlled Atmosphere Soldering Study

IPC-TR-582 Cleaning and Cleanliness Testing Program Test Results for: Phase 3 - Low Solids Fluxes and Pastes Processed in Ambient Air

IPC-TR-583 An In-Depth Look at Ionic Cleanliness Testing

IPC-WP-019 An Overview on Global Change in Ionic Cleanliness Requirements

IPC-WP-113 Guidance for the Development and Implementation of a Red Plague Control Plan (RPCP)

IPC-WP-114 Guidance for the Development and Implementation of a White Plague Control Plan (WPCP)

IPC-HDBK-830 Guidelines for Design, Selection and Application of Conformal Coatings

IPC-TP-1043 Cleaning and Cleanliness Test Program, Phase 3, Water Soluble Fluxes, Part 1: B-24, Interactions of Water Soluble Fluxes with Printed Wiring Board Substrates/Metallizations

IPC-TP-1044 Cleaning and Cleanliness Test Program, Phase 3, Water Soluble Fluxes, Part 2: B-36, Comparison to Phase 1 Rosin Benchmark

IPC-TR-587 Conformal Coating Material and Application “State of the Industry” Assessment Report

IPC-1602 Standard for Printed Board Handling and Storage

IPC-7093 Design and Assembly Process Implementation for Bottom Termination Components

IPC-7095 Design and Assembly Process Implementation for BGAs

IPC-7525 Stencil Design Guidelines

IPC-9111 Troubleshooting for Printed Board Assembly Processes

1. www.eia.org

2. www.ipc.org

2.3 Electrostatic Discharge Association³

ESD TR 20.20 ESD Handbook

2.4 SAE⁴

SAE AR6415 Use of Pb-Free Ball Grid Array Component Soldered Using SnPb Solder

3. www.esda.org

4. www.sae.org

3.0 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 processes, 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 (note this is a requirement for Class 3). 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.

J-STD-001 8.0 Cleaning and Residue Requirements, contains additional information about Major changes requiring validation and Minor changes with supporting objective evidence.

In addition to validation of major changes, minor changes require validation with objective evidence that the changes are not detrimental to the product.

Samples of process changes:

Major Process Changes

- Fabrication houses
- Changes in manufacturing suppliers (materials and process/products)
- Printed Board fabrication processes
- Laminates (FR-4 to CEM-1)
- Metallization (HASL SnPb to Pd flash)
- Solder masks, e.g., dry film to an LPI
- Fluxes or flux-bearing materials, e.g., flux, solder paste, paste flux, cored wire solder, including type and/or formulation, e.g., ROL0 to ROL1; ROL0 to ORL0; RMA to water soluble
- Cleaning, method and/or chemistry, e.g. solvents, aqueous detergents, topical cleaners, change from Freon TMS to aqueous saponifier
- Geographic change in manufacturing location

Minor Process Changes

- Bake or cure cycles
- Minor process variations in fabrication including:
 - Changes in cleaning parameters:
 - Increase in belt speed (in-line cleaning systems)
 - Decrease in cycle time (batch systems)
 - Decrease in pressures or flow rates
 - Decrease in wash or rinse temperatures
 - Process parameters variations that are outside of equipment and/or chemistry manufactures recommendations
 - Changes in reflow, wave solder or selective solder recipes beyond the recommended process windows established by the equipment, flux, or paste manufactures.
- 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)
- Changes within a manufacturing location.



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.

J-STD-001 Appendix C has guidance on material and process compatibility. This guidance has been updated and is now available as IPC-9202. In addition, IPC-CH-65 6 Process Development and Verification contains additional guidance for material compatibility testing and includes sample test plan guidelines and test method considerations.

3.2 Solder This section 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 sections cover how these materials are used or processed.

Soldering is defined as the joining of two metals using a filler material with a maximum melting temperature of 450 °C [840 °F]. Electronics soldering processes are typically in the range of 100 °C - 300 °C [212 °F - 572 °F]. Brazing is defined as the joining of two metals using a filler material with a minimum melting temperature of 450 °C [840 °F]. The most common solder alloys are SnPb and SAC-based materials. Other alloys used in soldering are SnAg, SnSb, SnZn, SnBi and In-based solders. The melting point of the solder depends on the metals in the alloy and the percentage of each. Solder alloys, which change directly from liquid to solid and solid to liquid without any intermediate plastic/pasty states, are eutectic solders. The various solder types and their compositions and melting points can be found in J-STD-006.

SnPb solders used for electronics soldering are typically eutectic or near eutectic alloys. The eutectic composition, as shown in Figure 3-1(B), shows the SnPb eutectic at 63% tin by weight and 37% Pb 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% Sn/40% Pb, 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).

The metallurgy of solder is a mixture of tin-rich crystals, referred to as the beta (β) phase, with a composition of 97.5% Sn/2.5% Pb and Pb-rich crystals, referred to as the alpha (α) phase, with a composition of 19% Sn/81% Pb. 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 Pb-rich α phase, mixed in with larger crystals of the Sn-rich β phase.

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.

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.

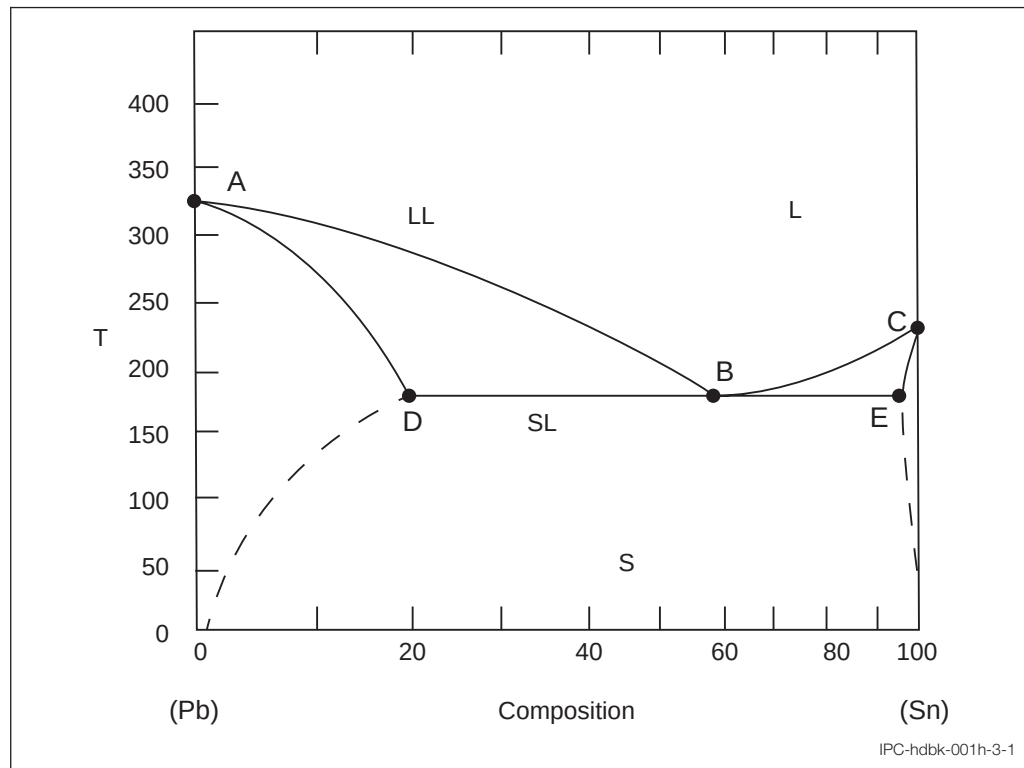


Figure 3-1 Phase Diagram for Eutectic Solder

L. Liquid

S. Solid

T. Temperature/ °C

LL. Liquidus Line

SL. Solidus Line

Composition. Composition in/wt% Sn

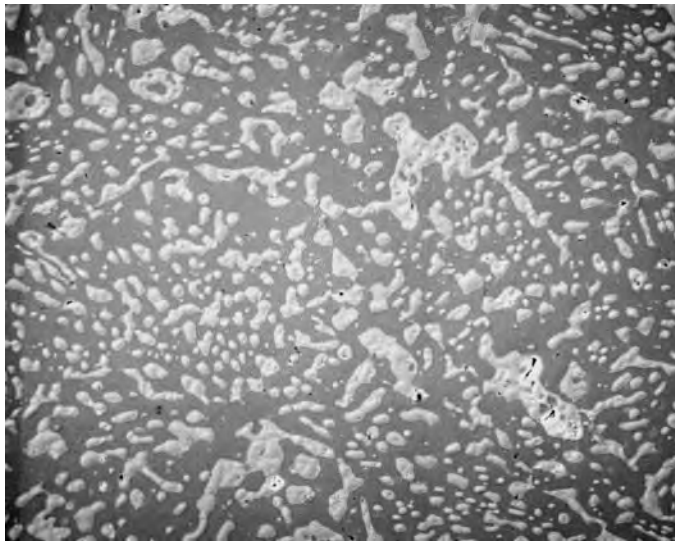


Figure 3-2 Eutectic Solder Microstructure

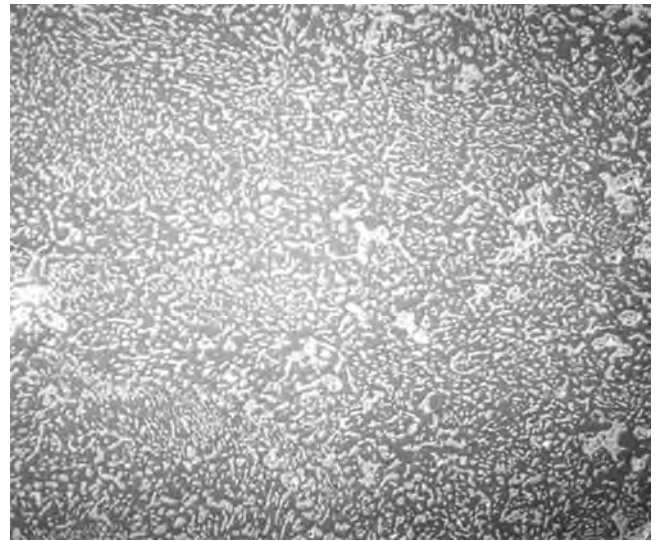


Figure 3-3 Eutectic Solder Microstructure

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) (Sn63Pb37) (Sn60Pb40)	8400 kg/m ³ @ 20 °C 8000 kg/m ³ @ 250 °C 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 x 10 ⁻⁵ m ² /s

Δ **3.2.0.1 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.
- Placement can be automated, eliminating the need for manual assembly, inspection and touchup.
- Inaccessible soldered joints can be made.

Disadvantages of using solder preforms include:

- Solder preforms are sometimes viewed as a custom made, non-stock part because of small quantities, limited geometries, and minimum sources of supply.
- Short run quantities of special shapes may preclude recouping tooling costs.

Selection of solder preforms includes considerations of the solder alloy. In the case of preforms containing flux, 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 Flux, 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 4.16 Heat Shrinkable Soldering Devices.

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. 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.

Δ **3.2.0.2 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 pastes 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.

Δ 3.2.0.2.1 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. This mixture is 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.

Δ 3.2.0.2.2 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 can be formed on the solder paste. These oxides will inhibit reflow and increase the formation of solder balls (which can lead to a reduction in overall volume of solder in the completed joint).
- 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.”

Δ 3.2.0.2.3 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 3-2.

Table 3-2 Mesh Size vs. Particle Size for Solder Powders Used in Solder Paste

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

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. The smaller the particle size the more likely solder balling is to occur. Large number of solder balls is referred to as solder fines, and depending on size, may be washed away during the post solder cleaning process. Requiring both an upper and lower boundary for particle size, e.g., -200, +325, may reduce solder fines.

Δ 3.2.0.2.4 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 (ROLO /ROL1) fluxes. Solder oxides are less dense than solder (typically 6500 kg/m³) and will float to the surface of the molten solder.

A qualitative test for oxide content is to 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, see IPC-TM-650 2.4.43.

Δ 3.2.0.2.5 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 lose 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 3-3.

Table 3-3 Recommended Viscosities of Solder Pastes

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

Note 1. At 25 °C, 1 Pa·s = 1000 centipoise.

Δ **3.2.0.2.6 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 does not recover immediately.
- The shear velocity at which the viscosity is measured.

A demonstration of these effects is shown in Table 3-4.

Table 3-4 Effects of Parameters on Viscosity (Shear rate is 1.5/sec unless otherwise noted)

Parameter	Change	Viscosity Change (Pa)
Particle Size	1-45 μm to 40-80 μm	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, 3 to 4 hours are needed for a sample of solder paste to reach room temperature after refrigeration between 0 °C and 10 °C.

Δ **3.2.0.2.7 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 spacing.

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.

3.2.1 Solder – Pb-free Solder alloys less than 0.1% Pb 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 Pb in a solder alloy was 0.1% which effectively resulted in the extinction of Pb-bearing solder alloys except for specialized applications. The electronics industry has initially focused on one non-Pb 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 3-5 illustrates a variety of Pb-free solder alloys and their elemental compositions. Table 3-6 lists a variety of Pb-free solder alloys and their melting temperatures.

Table 3-5 Test Requirements for Flux Classifications (from J-STD-004B w/Amendment 1)

NOTE: The reference in Note 1 is from J-STD-004B w/ Amendment 1.

Flux Type	Copper Mirror	Corrosion	Quantitative Halide ¹	Conditions for Passing 100 M SIR Requirements ²	Conditions for Passing ECM Requirements
			(Cl-,Br-,F-,I-) (by weight)		
L0	No evidence of mirror breakthrough	No evidence of corrosion	<0.05% ³	No-clean state	No-clean state
L1			≥0.05 and <0.5%		
M0	Breakthrough in less than 50% of test area	Minor corrosion acceptable	<0.05% ³	Cleaned or No-clean state ⁴	Cleaned or No-clean state ⁴
M1			≥0.5 and <2.0%		
H0	Breakthrough in more than 50% of test area	Major corrosion acceptable	<0.05% ³	Cleaned	Cleaned
H1			>2.0%		

1. This method determines the amount of halide present (see Appendix B-10).

2. If a printed circuit board is assembled using a no-clean flux and it is subsequently cleaned, the user should verify the SIR and ECM values after cleaning. J-STD-001 may be used for process characterization.

3. Fluxes with halide measuring <0.05% by weight in flux solids may be known as halide-free. If the M0 or M1 flux passes SIR when cleaned, but fails when not cleaned, this flux **shall** always be cleaned.

4. Fluxes that are not meant to be removed require testing only in the no-clean state.

Table 3-6 Pb-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 Pb-free solder alloys result in the Soldering Process Engineer having to address two primary issues due to the differences from the traditional SnPb solder alloys: (1) solder alloy initial melting point; (2) solder alloy solidification characteristics. The traditional SnPb solders have melting points beginning at 183 °C [361 °F]. The melting point of the SAC solder alloy family is 217 °C [423 °F], 34 °C [93 °F] 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 Pb-free solder alloy melting point.



Figure 3-4 Solder Wire Core Flux Comparison

Secondly, relatively few of the Pb-free soldering alloys have eutectic alloys as described in 3.2 Solder. A eutectic solder alloy solidification behavior of changing from a liquid to a solid at a specific temperature provides the Soldering Process 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 Pb-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 Pb-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 Pb-free solder alloys compares to the traditional SnPb solder alloys in fracture toughness testing. Figure 3-6 shows a similar response for drop shock testing.

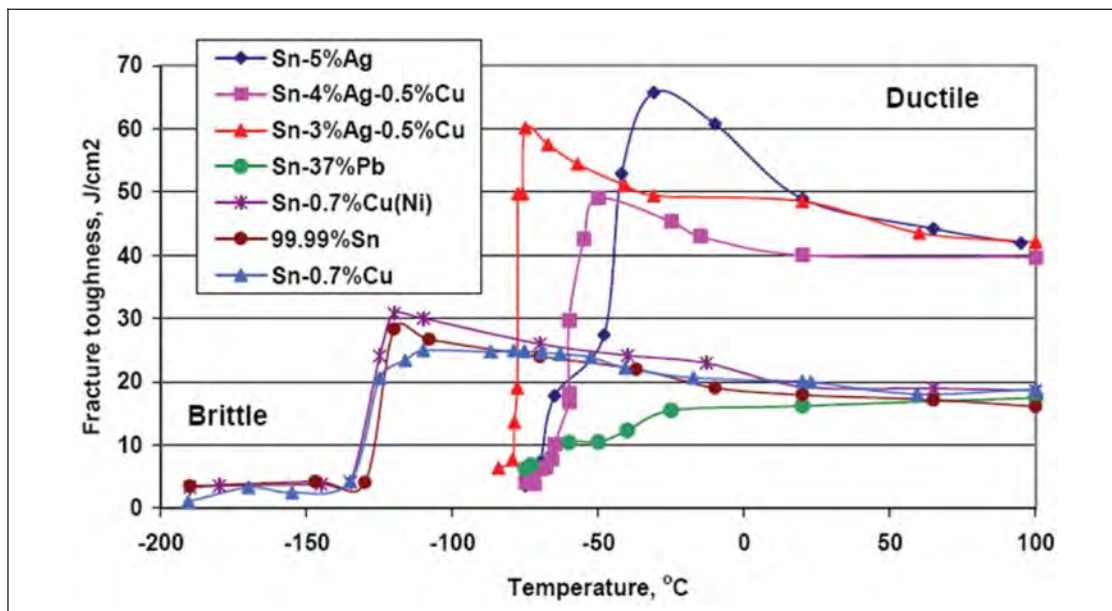


Figure 3-5 Solder Alloy Fracture Toughness Testing Results (Graph from P. Ratchev et al, "A Study of Ductile to Brittle Fracture Transition Temperatures in Bulk Pbfree Solder Alloys," EMPC 2005, Brugge, Belgium)

Pb-Free Soldering: Process Considerations

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

Mixed Metallurgy The implementation of the European Restriction of Hazardous Substances (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 Pb-free material choices best fit their needs. The complexities of Pb-free soldering process implementation ensures a transition period in which Pb-free and SnPb solder finishes will be present on printed wiring assemblies. The use of Pb-free components in a SnPb soldering process is not a new topic for the electronics industry. Pb-free NiPdAu component finishes have been used successfully since the 1990s. The introduction of Pb-free finishes such as Sn, Au, Ag and Bi 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

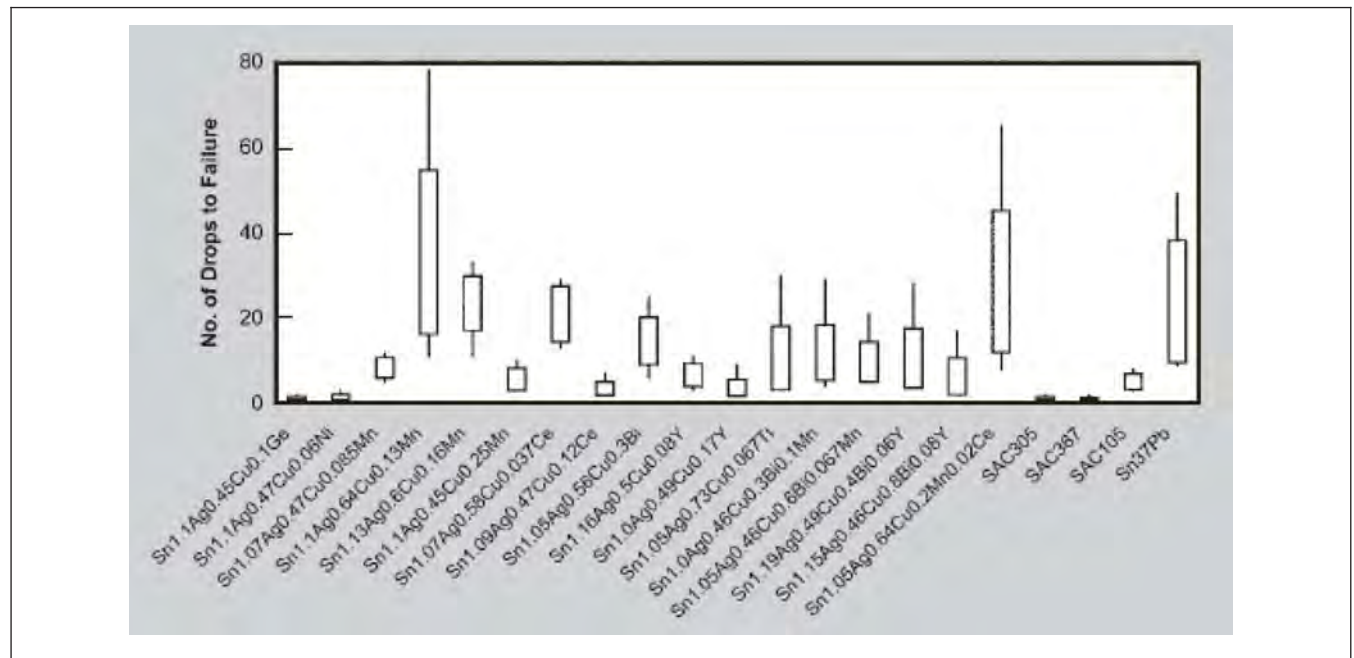


Figure 3-6 Solder Alloy Drop Shock Testing Results (Graph from Lee et al, July JOM 2007)

incompatibility of a Pb-free alloy containing bismuth solder with a SnPb component finish. Compared with a SnCu surface finish, the reduction in solder joint thermal cycle fatigue life is clearly evident for a SnPb surface finish and a SnCu surface finish with a SnAgCuBi solder alloy.

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 Pb-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 Pb-free soldering processes has resulted in an increase in soldering process temperatures. The usage of SAC solder alloy family increases the melting temperature. As an example, SAC 305 melts at 217 °C [423 °F], a 34 °C [93 °F] increase without accounting for the thermal thinning 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 cannot withstand the Pb-free soldering process temperatures. A components moisture sensitivity level (MSL) is a function of temperature and some component materials will degrade if exposed to Pb-free soldering processes. Figure 3-9 illustrates component incompatibility examples.

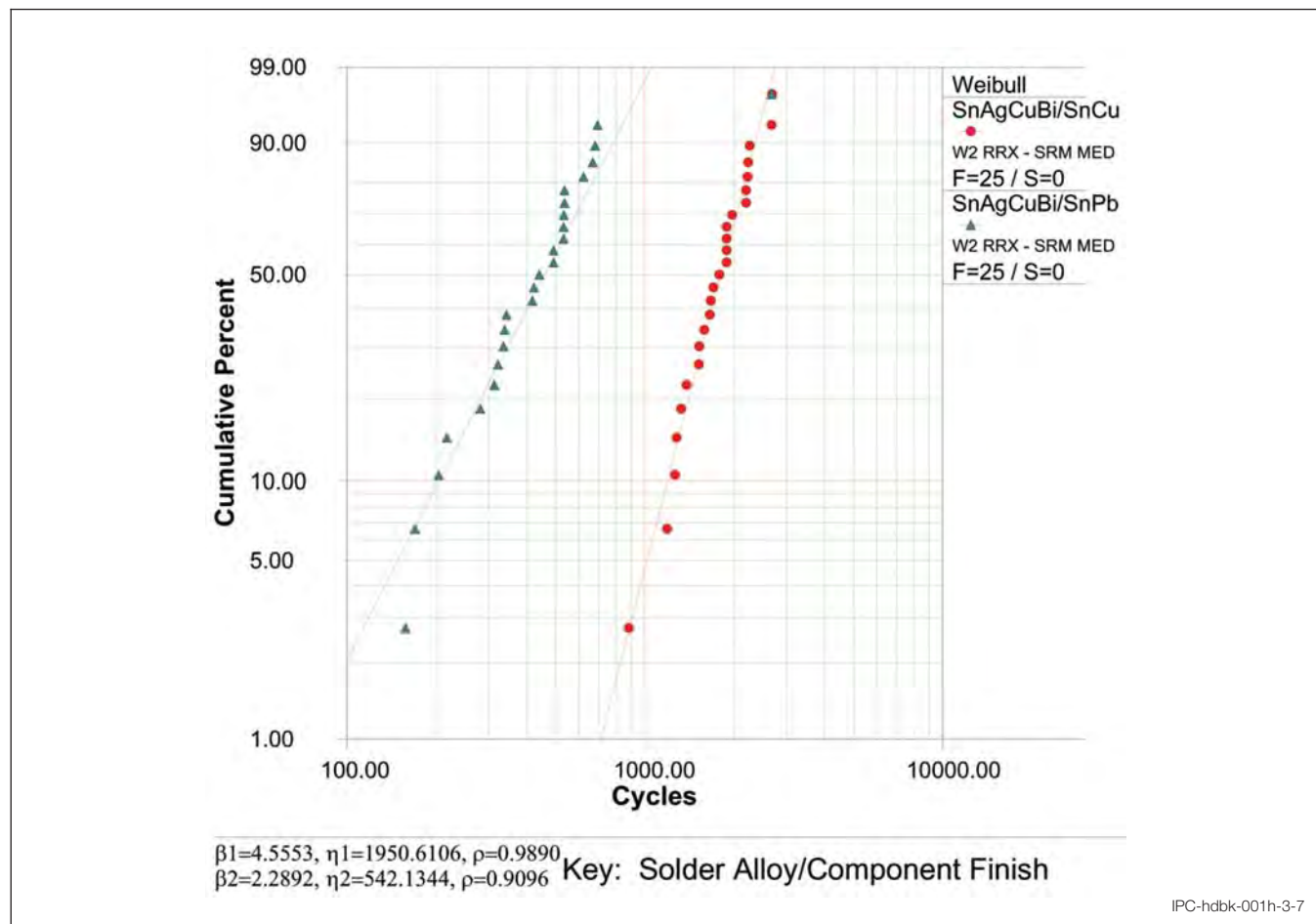


Figure 3-7 Pb-Free Solder Alloy/Component Surface Finish Incompatibility Example (D. Hillman and R. Wilcoxon, "JCAA/JG-PP Lead-free Solder Testing for High Reliability Applications: -55 °C to +125 °C Thermal Cycle Testing" SMTAI Conference, 2006)

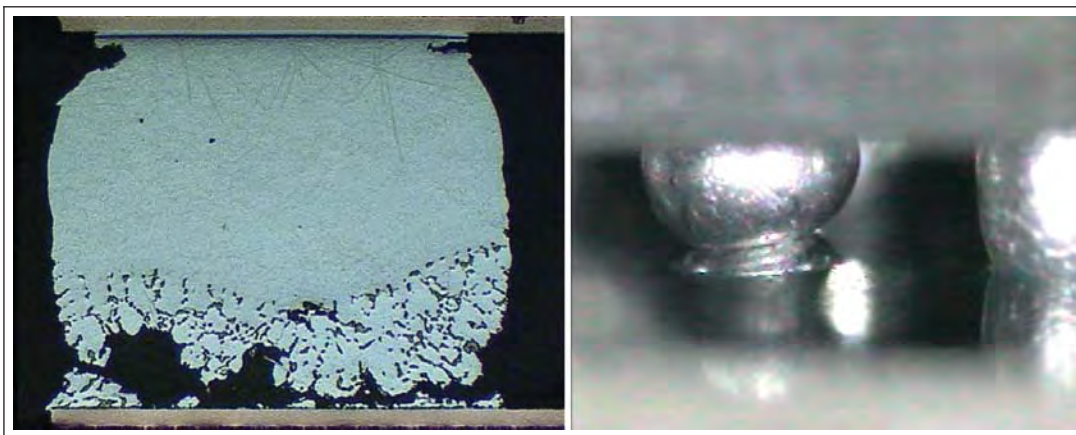


Figure 3-8 left: Non-Uniform Solder Joint Microstructure, right: Incomplete Solder Joint Reflow (Head-on-Pillow) (Photo courtesy Rockwell-Collins, used by permission)

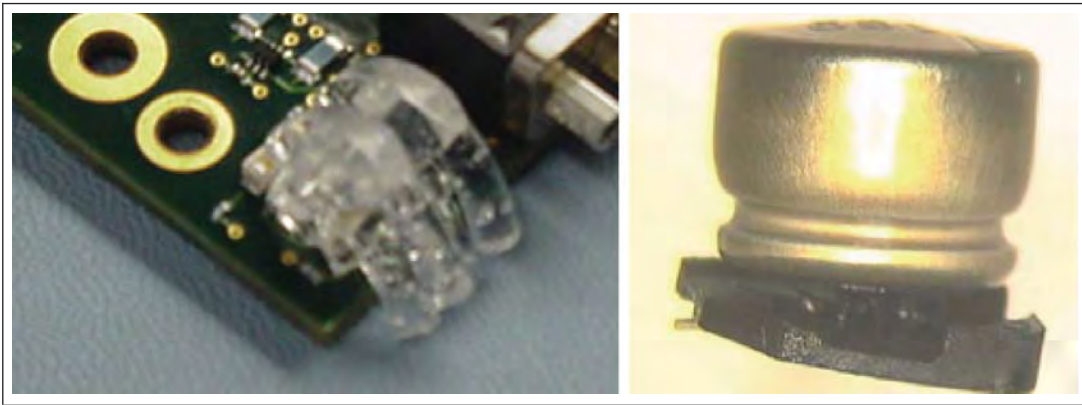


Figure 3-9 Component Degradation Due to Pb-Free Soldering Process Incompatibility (Courtesy of Rockwell Collins (left) and National Physical Laboratory (right))

Soldering Process Equipment Compatibility The tin content of Pb-free soldering alloys is significantly **greater** than the traditional eutectic SnPb solder alloys. Molten tin is an aggressive element in terms of the dissolution and erosion of other metals. The implementation of Pb-free soldering processes requires a review of Pb-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 Pb-free solder alloy.

See SAE ARP6415 for a review of known impacts, issues and processes for the use of Pb-free BGAs.

Copper Dissolution Concerns The discussion of molten Pb-free solder alloy damage of soldering process equipment also has Pb-free soldering process implications. The dissolution of copper plating on surface mount pads and in plated through-holes is significantly increased for Pb-free soldering processes. Figure 3-11 shows the accumulative effect of repeated soldering process exposures for various Pb-free soldering alloys. The copper dissolution issue is of critical importance for plated through-hole rework processes, especially those utilizing mini-wave or selective solder equipment.



Figure 3-10 Pb-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)

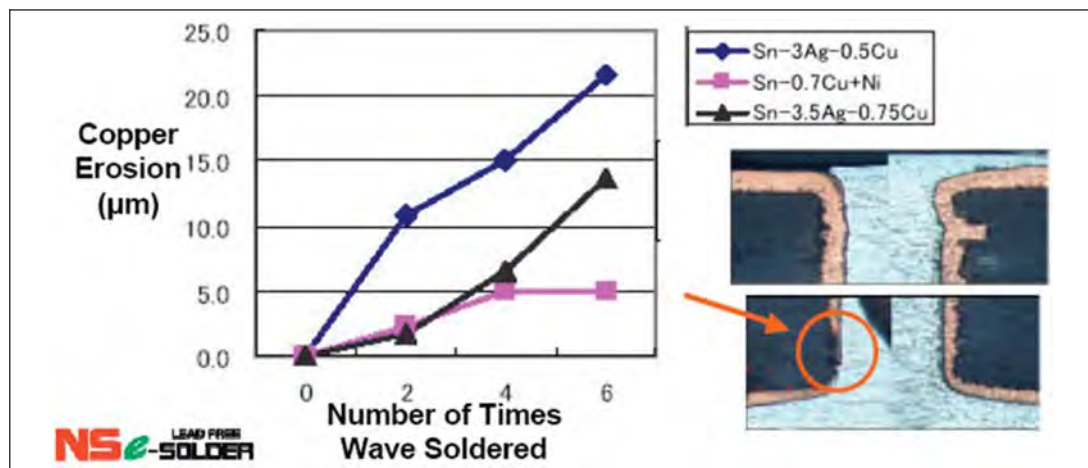


Figure 3-11 Copper Erosion Due to Pb-Free Soldering Processes (Courtesy of Nihon Superior)

Pb-Free Finishes: Mitigation Strategies 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 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 Pb-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 Pb-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 indicate Para-xylylene 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.

See IPC-TR-587 for additional information on a study of major conformal coating types, coating application techniques, and coating cure technologies characterizing the final film thickness on common component surfaces.

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 Sn-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 operations.
4. **Pb Over-Plating** – Pb over-plating involves plating Pb on the surface of the tin and then baking the component to promote complete interdiffusion 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 Pb-free mitigation strategies can be found in the following documents and are an excellent resource for developing and implementing Pb-free control plans.

See GEIA-STD-0005-1, GEIA-STD-0005-2, GEIA-HB-0005-1, GEIA-HB-0005-2 and GEIA-STD-0006.

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 maximum recommended levels of solder impurities for SnPb eutectic (Sn63Pb37) and near eutectic (Sn60Pb40) and Pb-free (SAC305) solder and their effects is shown in Table 3-7. If an alternative alloy is used, the user must develop a table comparable to Table 3-7 with the guidance from the solder supplier.

Table 3-7 Maximum Limits of Solder Bath Contaminant

Contaminant	Preconditioning Maximum Contaminant Weight Percentage Limit SnPb Alloys	Assembly Maximum Contaminant Weight Percentage Limit SnPb Alloys	Preconditioning and Assembly Maximum Contaminant Weight Percentage Limit SAC305 Pb-Free Alloys	Effect on solder joint if maximum allowable level is exceeded during usage
Copper (Cu)	0.75	0.3	1.1, Note 2	Solder begins "sticking" to insulation materials, above 0.3% viscosity increases, and solder becomes gritty.
Gold (Au)	0.5	0.2	0.2	Solder becomes sluggish and grainy. Excessive gold can cause solder embrittlement, see Gold (Au) in this section.
Cadmium (Cd)	0.01	0.005	0.005	Oxidation rate increases, above 0.15% area of spread decreased by 25%.
Zinc (Zn)	0.008	0.005	0.005	Finish becomes dull, dewetting, oxidation rate increases.
Aluminum (Al)	0.008	0.006	0.006	Solder becomes sluggish, frosty and porous; oxidation rate increases.
Antimony (Sb)	0.5	0.5	0.2	Increased dewetting.
Iron (Fe)	0.02	0.02	0.02	Forms FeSn ₂ which is unsolderable.
Arsenic (As)	0.03	0.03	0.03	Grainy/pitted appearance, edge dewetting and reduction in area-of-spread.
Bismuth (Bi)	0.25	0.25	0.25	Dulling of surface, may reduce ability of solder to wet brass and steel.
Silver (Ag), Note 1	0.75	0.1	Note 3	Solder surface finish becomes gritty.
Nickel (Ni)	0.025	0.01	0.05	Blisters, formation of hard insoluble compounds.
Lead (Pb)	N/A	N/A	0.1	
Total of Copper (Cu), Gold (Au), Cadmium (Cd), Zinc (Zn), Aluminum (Al) Contaminants	N/A	0.4	N/A	

Note 1. Not applicable for Sn62Pb36Ag2: limits to be 1.75% to 2.25%.

Note 2. A maximum copper limit of 1.0% may be specified as agreed between Manufacturer and User. Printed boards that are characterized as thick and thermally demanding may have potential plated through-hole fill and/or solder joint defects due to the impact of copper on solder flow characteristics.

Note 3. SAC305 silver content limits to be 2.5% - 3.5%. Alloys with different nominal silver content have different limits that may be applied as agreed between Manufacturer and User. Consult the alloy supplier for guidance.

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 SnPb 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 (Cu) Copper has negligible solubility in both tin and Pb. 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 (Au) The solubility of gold in SnPb at room temperature is negligible. Several intermetallic compounds are formed between Sn (Au_6Sn , AuSn , AuSn_2 and AuSn_4) and Pb (Au_2Pb and AuPb_2). Unless the soldering is rapidly completed, the Au intermetallics will rise to the surface of the connection, causing an extremely dull gray, grainy surface. Above 3% Au contamination in the solder pot may cause embrittlement of the solder connection.

Cadmium (Cd) The solubility of cadmium in both Sn and Pb 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 (Zn) Zinc has little solid solubility in tin and none in Pb. No intermetallic compounds are formed with either tin or Pb. 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 (Al) Aluminum does not have any solid solubility in either tin or Pb 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 Al and the SnPb alloy (1.53V). Aluminum surfaces that must be exposed to molten solder, even for a short time, should be hard anodized.

Antimony (Sb) The solubility of antimony in tin at room temperature is about 6-8%, while little antimony is dissolved in Pb 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 (Sn-pest). Excessive antimony may cause a spread reduction in Pb termination.

Iron (Fe) Iron has some solubility in tin at elevated temperatures, forming two intermetallic compounds, FeSn and FeSn_2 , manifesting themselves as needle-shaped crystals. The presence of iron in solder is detrimental and causes grittiness.

Arsenic (As) No solubility of arsenic in either Sn or Pb has been observed. Two intermetallic compounds, Sn_3As_2 and SnAs , appear as a long needle in the microstructure. Arsenic may cause poor wetting.

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

Silver (Ag) There is no solid solubility in either Sn or Pb, but Sn and Ag form the intermetallics Ag_6Sn and Ag_3Sn . When Ag content rises over 2.0%, the AgSn intermetallics will segregate upon cooling.

Nickel (Ni) Nickel shows no solubility in either Sn or Pb. Intermetallics formed with Sn are Ni_3Sn , Ni_3Sn_2 , and Ni_3Sn_4 .

Solder Pot Contamination Copper, iron, gold, and nickel may be found in solder baths as a result of lead clippings, printed board 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.

3.2.2.1 Solder Pot Purity and Maintenance Dross and burnt flux must be removed from the surface of the molten solder to ensure the dross does not contaminate the items being tinned.

3.3 Flux Unless otherwise specified on the design or assembly drawing or instructed by the User, the fluxes referenced by this document **shall** conform to IPC J-STD-004.

Flux shall [N1D2D3] conform to flux activity levels L0 and L1 of flux materials rosin (RO), resin (RE), or organic (OR), except ORL1 shall not [N1D2D3] be used for no-clean soldering.

Class 2 in this revision imposes the same flux activity levels as Class 3. L0 and L1 flux level is specified because they are low flux activity and present a reduced risk of corrosion and damage to the finished assembly. OR based fluxes have an increased tendency for creep corrosion (Xu, C., Smetana, J., Franey, G., Guerra, G., Fleming, D., Reents, W., Willie, D., Xiaodong, J., *Creep Corrosion of PWB Finishes: Its Cause and Prevention, presented at IPC APEXEXPO 2008*). L1 has a higher halide content but has <0.5% versus <0.05% for L0.

Soldering flux provides the environment in which molten solder must work; it prepares the surface to be soldered by removing contamination and preventing oxidation. 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. Flux facilitates the surface preparation 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 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 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 reducing 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.

Δ 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 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.

Δ 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. Flux within flux-cored solder wire and external flux must be compatible. 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 RA (rosin activated) type fluxes. IPC J-STD-004 defines the industry classification system used to distinguish the different flux chemistries available for industry use (See Tables 3-8 and 3-9 in this Handbook and J-STD-004B w/Amendment 1, paragraph 3.3.1.2.2).

Table 3-8 Pb-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

The historic flux classifications of R (rosin), RMA (rosin mildly activated), and RA (rosin activated) 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 sections provide further detail of the different base flux chemistries.

Δ 3.3.0.2.1 "No Clean" Fluxes These fluxes are used to eliminate the cleaning processes or cleaning itself. Flux materials in some combination with cleaning processes and/or material may not be compatible. 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.

Δ 3.3.0.2.2 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 mono-carboxylic 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.

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.

Δ 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 organics acids and amines, wetting agents and solvents. All this salt has an effect on the insulation resistance of porous printed boards, such as paper-based 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.

Table 3-9 Flux Identification System (from J-STD-004B w/Amendment 1)
NOTE: The references in Note 1 and Note 2 are from J-STD-004B w/Amendment 1.

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. Halide measuring <0.05% by weight in flux solids may be known as halide-free. This method determines the amount of halide present (see Appendix B-10).

Note 2. The 0 and 1 indicate the absence or presence of halides, respectively. See paragraph 3.3.1.2.2 for flux type nomenclature.

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 Pb 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.

Δ 3.3.0.2.4 Inorganic Fluxes (IN Classification) These flux materials find very limited use for electrical connections, as 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.

3.3.1 Flux Application All fluxes applied to a single assembly must be compatible. This implies that the flux used in solder paste, wave solder and rework material must be compatible from a chemical and cleaning process standpoint. Objective evidence is explained in Appendix C of the standard.

3.4 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. Curing of the adhesive material is to be performed as defined by the Manufacturer and can typically include thermally activated, ultraviolet (UV) light cured, two-part epoxies and ambient cured. Adhesive 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.

The location of the adhesive prior to and after curing should not degrade the ability of solder to form an acceptable interconnection. 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.

3.5 Chemical Strippers Chemical stripping is appropriate for solid, single conductor wire only. Chemical stripping of small gauge (<28 AWG) is used to prevent stretching of the wire and to prevent surface damage caused by mechanical stripping. 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.

3.6 Components Is adequately defined in the standard.

3.6.1 Component and Seal Damage Typically component specification limits for allowable component and seal damage are not readily available on the production floor. Engineering should provide guidelines of component specification requirements for commonly occurring anomalies to component bodies and seals. This guidance can be in the form of visual images and written guidelines clearly detailing acceptable and defective limits of damage for specific components.

3.6.2 Coating Meniscus The coating meniscus should never be trimmed as such would violate the integrity of the component body. If trimmed post-solder, the coating meniscus is typically trimmed so the connection technically complies with the requirement that the component body not enter a solder connection. This is a very short-sighted approach to the problem and should not be done. Trimming the meniscus from the component may violate the lead-to-body seal of the component and allow processing materials/solvents to enter the component cavity and cause corrosion of the component's electrical elements.

On a lead with a coating meniscus the first 1 mm [0.040 in] (dimension "C" below) of the lead adjacent to the meniscus should be considered nonsolderable due to outgassing and contamination propagated from the meniscus coating during its curing, see Figure 3-12.

The component should be mounted with a space between the meniscus and the surface of the printed board. Temporary spacers may be positioned under the component to space the body above the board during the soldering process and can be removed following soldering. Permanent spacers may be used when allowed by the drawing.

3.7 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 temperature control and

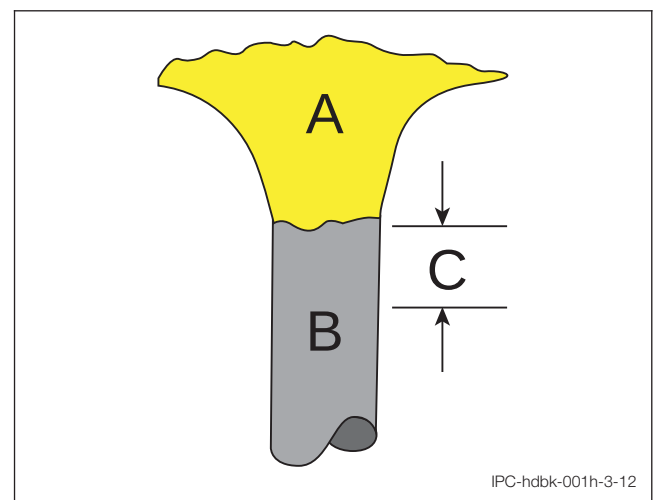


Figure 3-12 Coating Meniscus on a Lead

A Meniscus
B Lead
C Lead Adjacent to the Meniscus

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 ensuring 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 printed board.

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 printed board 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 board 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:

- Using the lowest operating temperature that produces an acceptable solder connection.
- Avoiding physical damage to the plating surface from excessive pressure when soldering.

- Avoiding using the tip as a prying tool.
- Minimizing idle time with a hot tip resting in the holder.

Pb-free Concerns When processing requires the use of Lead-Free (Pb-free) alloys, the soldering systems, especially tips, should not be used to process Pb alloy solders to avoid cross contamination. Segregation of soldering equipment for Pb-free processes includes tips, sponges, tip cleaning tools, wire solder and solder paste, wave soldering systems and any supporting tooling that cannot be effectively cleaned of all residual solder.

Hand soldering equipment used for Pb-free soldering is no different than equipment used for traditional SnPb soldering. The same equipment can be used for either application requiring only a tip change to prevent cross-contamination of alloys and adjustment of the tip temperature. Once a tip is used for Pb-free soldering, it should not be used with other solder alloys.

Tip life can be substantially reduced with Pb-free solders. Higher operating temperature will cause the tip to oxidize faster for any solder. Additionally, Pb-free tin-based alloys () interact more aggressively with the iron-based plating finish on the tips causing the iron to leach into the Pb-free alloys eroding the plating finish. Manufacturers have introduced tips with increased iron plating thickness for tips used in Pb-free processing. Any soldering tip that shows plating cracks, wear areas, or exposed copper core material must be discarded.

Δ 3.7.1 Solder Transfer Transferring molten solder to the junction of two surfaces that will be connected using a soldering process is a bad habit for operators to use. It is easy to do when you apply an amount of solder to the hot soldering iron tip, and then transport it to the connection. Activation of Flux is completed at the soldering iron tip, therefore, there is no flux to activate the joining surfaces. There is inadequate heating of the connection potentially resulting in poor wetting of component lead or substrate land surfaces. It is very important to heat the connecting surfaces (Lead and the land) to be soldered before the application of solder. Proper processes for creating solder connections, including formation of a heat bridge prior to applying the solder, are addressed in solder training courses and should include advice of not using a Solder Transfer process.