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DEPARTMENT OF DEFENSE HANDBOOK

GUIDANCE FOR THE ACQUISITION AND SUSTAINMENT OF SOLDERED DEFENSE ELECTRONIC PRODUCTS

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This is a new handbook that provides guidance to the DoD acquisition community for the procurement of soldered defense electronic products and provides additional information for high consequence of failure defense products. This handbook also provides guidance to the DoD sustainment activities to rework or repair soldered defense products.

3. The DoD Executive Agent for Printed Circuit Board and Interconnect Technology, Commander, NAVSURFWARCENDIV, 300 Highway 361, Crane, IN 47522 developed this handbook.

4. Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard, DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope. This handbook covers soldering technologies for the acquisition and sustainment of soldered defense electronic products. This handbook is for guidance only and cannot be cited as a requirement. The guidance in this handbook is a collection of best practices for soldering defense electronic products.

1.2 Applicability. This handbook applies to the acquisition and sustainment of defense electronic product using the soldering acceptance requirements from DoD-adopted non-Government standards for soldering technologies (see 4.1). This handbook does not apply to the Miniature/Microminiature (2M) Electronic Repair Program, which uses the soldering requirements from NAVAIR 01-1A-23. Other Service numbers for this document are NAVSEA SE004-AK-TRS-010/2M, MARINE CORPS TM 5895-45/1E, and USAF T.O. 00-25-259.

1.3 Classification. DoD uses the IPC classification system to determine acceptance requirements for soldered defense electronic products. This classification system has three product classes:

a. Class 1, General electronic products.

b. Class 2, Dedicated service electronic products.

c. Class 3, High performance and harsh environment electronic products.

In addition, the space and military addendums identify additional acceptance requirements for space and military systems that have a very high consequence of failure and mission-critical functions. See 4.2 for guidance on selecting the proper product class for soldered defense electronic products.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-810 - Environmental Engineering Considerations and Laboratory Tests

(Copies of this document are available online at https://quicksearch.dla.mil.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

EOS/ESD ASSOCIATION, INC.

ANSI/ESD S20.20 - For the Development of an Electrostatic Discharge Control Program for–Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

(Copies of this document are available online at https://www.esda.org/standards.html.)

IPC INTERNATIONAL, INC.

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

IPC-J-STD-001_S - Space Applications Electronic Hardware Addendum to J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC-A-610 - Acceptability of Electronic Assemblies

IPC/WHMA-A-620 - Requirements and Acceptance for Cable and Wire Harness Assemblies

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IPC/WHMA-A-620_S	-	Space and Military Applications Electronic Hardware Addendum to IPC/WHMA-A-620
IPC-1782	-	Standard for Manufacturing and Supply Chain Traceability of Electronic Products
IPC-1791	-	Trusted Electronic Designer, Fabricator and Assembler Requirements
IPC-7711/7721	-	Rework, Modification and Repair of Electronic Assemblies

(Copies of these documents are available online at https://shop.ipc.org/standards.)

SAE INTERNATIONAL

SAE GEIA-STD-0005-1	-	Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
SAE GEIA-STD-0005-2	-	Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems

(Copies of these documents are available online at https://standards.sae.org/.)

3. DEFINITIONS

This section lists the terms needed to understand the information in this handbook. Definitions of other electronic terms not listed are in IPC-T-50 or IPC-J-STD-001.

3.1 Acceleration factors. For a given failure mechanism, the ratio of the time it takes for a certain fraction of the population to fail, following application of one stress or use condition, to the corresponding time at a more severe stress or use condition. (© JEDEC, reproduced from JEP122H with permission by JEDEC.)

3.2 Equivalent. Being the same or higher in effect, requirements, and specifications as the specified standard.

3.3 Mission-critical function. Any function, the compromise of which would degrade system effectiveness in achieving its core mission (DoDI 5200.44).

3.4 Objective evidence. Existing data, usually quantitative, collected by observations, measurements, or tests, that is verifiable and available for review and analysis.

3.5 Operational environment. An environment including all operational requirements and specifications required of the final system, including its platform and packaging. The conditions the system sees during operational use, standby, maintenance, transportation, and storage.

3.6 Pb-free. A solder alloy or surface finish containing less than 0.1 percent by weight lead (Pb) as defined by EU Directive 2002/95/EC and Directive 2011/65/EU.

3.7 Producing activity. A public or private sector entity that manufactures, reworks, or repairs soldered defense electronic products.

3.8 Reliability. The probability that a component, device, or assembly will function properly for a definite period of time under the influence of specific environmental and operational conditions. (© 2022 IPC International, Inc. Reprinted from IPC-T-50N with permission.)

3.9 SAC305. Solder with 3.0 percent by weight silver (Ag), 0.5 percent by weight copper (Cu) with the balance tin (Sn).

3.10 SnPb. Solder with a composition of 60 to 63 percent by weight tin (Sn) and 37 to 40 percent by weight lead (Pb).

3.11 Solder. A metal alloy with a melting temperature that is below 427 °C (800 °F). (© 2022 IPC International, Inc. Reprinted from IPC-T-50N with permission.)

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3.12 Solder interconnect. A low-impedance solder connection between the terminals of packaged electronic devices and metal lands on a printed board intended to complete electrical circuits required for the intended electrical function.

3.13 Technical data. Recorded information, regardless of the form or method of the recording, of a scientific or technical nature. Technical data includes applicable engineering data, drawings, specifications, and standards.

3.14 Tin whiskers. Tin whiskers are electrically conductive, long crystals that grow from tin-rich surface finishes due to stresses within the tin finish arising from internal or external sources. Tin whiskers can range in length from a few micrometers to millimeters and have been documented to cause failure in electronic products.

4. ACQUISITION GUIDANCE

This section has the contractual actions the contracting activity should take to ensure soldered defense electronic products meet their performance, safety, and reliability requirements.

4.1 Standards for soldering technologies. The DoD uses several non-Government standards that have the acceptance requirements for a broad range of performance, safety, and reliability requirements and operational environments for the acquisition and sustainment of soldered defense electronic products. These standards are:

a. *IPC-J-STD-001*. A DoD-adopted standard that describes materials, methods, and acceptance requirements for producing soldered electrical and electronic assemblies. IPC-J-STD-001 can be specified in the contract as a standalone document or used in conjunction with IPC-A-610 or IPC/WHMA-A-620 or both (see 4.1.1).

b. *IPC-J-STD-001_S*. A DoD-adopted addendum to IPC-J-STD-001 that supplements or replaces specifically identified requirements of IPC J-STD-001 for soldered electrical and electronic products that must survive the vibration and thermal cyclic environments of space and military applications. This addendum is not a standalone document. Per IPC, the base document must be the same revision as the addendum such as IPC-J-STD-001H and IPC-J-STD-001HS. Where requirements are not supplemented or replaced by this addendum, the class 3 requirements of IPC-J-STD-001 apply.

c. *IPC-A-610*. A DoD-adopted standard that provides the visual acceptance requirements for the manufacture of electrical and electronic assemblies. IPC-A-610 has requirements outside the scope of IPC-J-STD-001 defining mechanical and other workmanship requirements. IPC-A-610 can be specified in the contract as a standalone document or used in conjunction with IPC-J-STD-001 or IPC/WHMA-A-620 or both (see 4.1.1).

d. *IPC/WHMA-A-620*. This standard describes materials, methods, tests, and acceptability requirements for producing crimped, mechanically secured, or soldered interconnections and the related assembly activities associated with cable and harness assemblies. IPC/WHMA-A-620 can be specified in the contract as a standalone document or used in conjunction with IPC-A-610 or IPC-J-STD-001 or both (see 4.1.1).

e. *IPC/WHMA-A-620_S*. An addendum to IPC/WHMA-A-620 that supplements or replaces specifically identified requirements of IPC/WHMA-A-620 for cables and wire harnesses that must survive the vibration and thermal cyclic environments of space and military applications. This addendum is not a standalone document. Per IPC, the base document must be the same revision as the addendum such as IPC/WHMA-A-620D and IPC/WHMA-A-620DS. Where requirements are not supplemented or replaced by this addendum, the class 3 requirements of IPC/WHMA-A-620 apply.

For defense products having mission critical functions (see 3.3) and high consequence of failure, the contracting activity should consider citing IPC-J-STD-001_S in the contract with IPC-J-STD-001 and, if applicable, IPC/WHMA-A-620 with IPC/WHMA-A-620_S to include the additional acceptance requirements. There is no space addendum for IPC-A-610.

4.1.1 Using multiple soldering standards. IPC-J-STD-001, IPC-A-610, and IPC/WHMA-A-620 may be used in conjunction with each other. However, these standards do have some overlapping requirements. So, if the contracting activity chooses to cite any combination of IPC-J-STD-001, IPC-A-610, or IPC/WHMA-A-620, the contract should specify the order of precedence between these standards. When the contract cites only one of these standards, the acceptance requirements from the others do not apply.

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If the contracting activity chooses to cite both IPC-J-STD-001 and IPC-A-610 in the contract, the revisions of both standards should be the same, for example, IPC-J-STD-001H and IPC-A-610H. The likelihood of the acceptance requirements conflicting increases when using different revisions. The IPC task groups for these standards are diligent in their efforts to have the acceptance requirements track each other, but occasionally conflicts may occur. The current revision of IPC/WHMA-A-620 differs in revision letter from the current revisions of IPC-J-STD-001 and IPC-A-610. The revisions of IPC-J-STD-001 and IPC-J-STD-001_S do track each other, but developing the addendums lags the base document by about 6 months.

IPC has a revision cycle policy of 3 years for each standard. Between the major revisions, IPC may issue an amendment to make corrections and minor changes. An amendment may change the acceptance requirements. Check https://shop.ipc.org/standards to find the latest revision, amendment, or both.

Using non-Government soldering standards other than those listed requires due diligence by the contracting activity to ensure the other standard meets all applicable performance, safety, and reliability requirements of soldered defense electronic products.

4.1.2 Order of precedence. DoD contracts should specify the order of precedence. The order of precedence should be:

a. The contract.
b. The technical data.
c. The specified soldering addendums, if applicable (see 4.1).
d. The specified soldering standards (see 4.1).
e. The referenced documents from these standards.

Requirements in a higher-ranked document supersede those in lower-ranked documents. For example, the technical data may add to or change the acceptance requirements from IPC-J-STD-001. When conflicts occur, the higher-ranked document takes precedence. The figures in IPC standards and addendums help with interpreting the written acceptance requirements, but the text takes precedence.

4.1.3 Electrostatic discharge (ESD). Producing activities (see 3.6) should have an ESD control program in accordance with ANSI/ESD S20.20 or an equivalent standard approved by the contracting activity. The ESD control program should cover:

a. Training.
b. Product qualification.
c. Compliance verification.
d. Grounding and equipotential bonding systems.
e. Personnel grounding.
f. ESD protected area (EPA) requirements.
g. Packaging systems.
h. Marking.

Guidance for establishing an effective ESD control program is in ESD TR20.20. Compliance verification guidance and test procedures are in ESD TR53-01.

4.2 Specifying the product class. The contracting activity specifies the product class or classes in contracts for manufacture, rework, and repair of soldered defense electronic products. This may not apply to commercial-off-the-shelf (COTS) products as the configuration is usually outside the control of the acquiring program. The classification system described in 1.3 establishes the acceptance requirements of soldering technologies for electronic products. Failure to specify the proper product class may have an adverse effect on the performance and reliability of defense electronic products when the specified class is too low or may result in an unnecessary increase in cost when the specified class is too high. Use these guidelines to specify the proper product class:

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a. Class 1 is not suitable for defense electronic products. The reliability requirements of soldering technologies in class 1 are too low for use in defense electronic products.

b. Class 2 is suitable for defense electronic products with operational environments that are mostly benign, characterized by temperatures near ambient and low or no vibration or shock environments. Class 2 products do not have mission-critical functions as defined in 3.3. Failures in class 2 products are unlikely to jeopardize mission success, have a low consequence of failure, and have no safety implications. In these cases, the contracting activity should cite class 2 for soldered electronic products.

c. Class 3 is suitable for defense electronic products with operational environments that are severe, characterized by temperature extremes and high vibration or shock environments. Class 3 products have mission-critical functions as defined in 3.3. Failures in class 3 products will likely jeopardize mission success, have a moderate to high consequence of failure, and may have safety implications. In these cases, the contracting activity should specify class 3 for soldered electronic products.

d. In special cases where failures in defense electronic products cannot be tolerated, the performance and reliability requirements of soldering technologies may exceed class 3. The additional requirements are in IPC-J-STD-001_S and, if applicable, IPC/WHMA-A-620_S. Special case is suitable for defense electronic products with operational environments that have extreme temperature, vibration, or shock environments. Special case products have mission-critical functions as defined in 3.3. Failures in these products will jeopardize mission success, have a very high consequence of failure, and may have safety implications leading to loss of life. In these cases, the contracting activity should specify both IPC-J-STD-001 class 3 and IPC-J-STD-001_S for soldered electronic products and, if applicable, IPC/WHMA-A-620 with IPC/WHMA-A-620_S for cable harnesses.

4.3 Accepting soldered defense products. All soldered defense products should meet the requirements in the contract and the technical data and the applicable acceptance requirements from the specified soldering standards (see 4.1.2 for order of precedence).

4.3.1 Defective products. Defects may have an adverse effect on the performance, safety, or reliability of the defense product in its operational environment over its service life. A defective soldered defense product does not meet one or more of the applicable acceptance requirements from the specified soldering standards (see 4.1). Producing activities should use IPC-7711/7721 as a guide for rework and repair processes and procedures of defective products.

4.3.1.1 Dispositioning defective and non-conforming soldered products. The contract should list the requirements for dispositioning defective and non-conforming products. A defect or non-conformance may have an adverse effect on the performance, safety, or reliability of the defense product in its operational environment. A defective soldered defense product does not meet one or more of the applicable acceptance requirements from the specified soldering standards (see 4.1). Once identified as defective, the contractor should document and disposition defects based on contract requirements.

Defects can be reworked, scrapped, returned to supplier, used as-is, or repaired. Rework restores complete conformity of the defective soldered defense products to the technical data while repair restores performance, safety, and reliability without achieving complete conformity to the technical data. The definitions for scrap, return to supplier, or use as-is are self-evident. Typically, the contractor has discretion over rework, scrap, and return to supplier dispositions, while the contractor can use as-is or repair defects only after receiving approval from the contracting activity.

4.3.2 Material and process non-conformance. Material and process non-conformance occurs when the producing activity uses materials or processes not in the material and processes baseline (see 4.5), when a process falls out of tolerance, or with an unauthorized material or processes change. Material and process non-conformance often does not result in an obvious change in appearance but may have an adverse effect on the performance, safety, or reliability of the defense product in its operational environment. See 4.3.1.1 for dispositioning non-conforming soldered products.

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4.3.3 Acceptance requirements not specified. In most cases, the soldering standards in 4.1 list the requirements for deciding if a soldered defense product is acceptable. Component configurations not listed in either standard are beyond the scope of those standards and this handbook. Use of these component configurations requires agreement between the contracting activity and producing activities before implementation. This agreement should include the acceptance requirements. The Contracting Officer should approve the new acceptance requirements before producing activities use them.

4.4 Using COTS electronic products. Before implementing COTS products solutions, programs should consider the risks of using COTS products in defense systems. Soldering processes, materials, and controls used in COTS products may be unspecified and not suitable for the operational environment or expected service life of the soldered electronic products in question. COTS products built in the last 10 years are likely to use lead-free (Pb-free) materials. Furthermore, suppliers may make configuration changes to COTS products without notification throughout the product's service life that may result in performance or reliability degradation. Programs need to evaluate and understand the risks of COTS products in order to make informed decisions regarding their use in defense systems and to ensure the performance, safety, and reliability of these systems. Producing activities should use a COTS management plan in accordance with EIA933 or an equivalent approved standard to manage COTS implementation. See 4.7 for additional information on using Pb-free materials.

4.5 Requiring a material and process baseline. Producing activities should have controlled materials, bills of materials, and processes they intend to use for making, reworking, and repairing soldered defense products in an established baseline. Producing activities can use any soldering method, process, or procedure whose output meets all the applicable acceptance requirements from the specified soldering standards (see 4.1). See IPC-HDBK-001 for information on soldering methods, processes, and procedures. This baseline is critical for ensuring configuration control, managing change, and finding non-conformance.

4.5.1 Using IPC-1782 as guidance. The contracting activity can use IPC-1782 as a guide and a source of requirements for a material and process baseline. IPC found that, without a uniform traceability standard, finding root causes for quality and reliability issues wasted resources. According to IPC, the lack of a traceability standard also made it difficult to create and effectively administer contracts. IPC-1782 divides traceability into four levels of rigor from level 1—basic to level 4—comprehensive. The first three levels correspond to IPC's three product classes—class 1, class 2, and class 3—defined in 1.3. Level 4 is for aerospace, defense, and medical. If the contracting activity is using IPC-1782, the contract should specify the level of traceability for material, M1 through M4, and the level of traceability for process, P1 through P4. If the contract cites IPC-J-STD-001_S or IPC/WHMA-A-620_S, the contracting activity should consider specifying level 4 (M4/P4) for traceability in the contract. Most likely, level 4 would be a cost driver. See IPC-1782 for more information on traceability levels.

4.5.2 Compatible materials. Producing activities should select compatible materials, including solders, component termination finishes, and printed board materials, including surface finishes, equipment, and processes to make, rework, or repair soldered defense products that will meet the applicable acceptance requirements from the specified soldering standards (see 4.1).

4.5.2.1 Solder. Solder alloys should be in accordance with the technical data. If the technical data does not specify solder alloys, producing activities should use solder alloys meeting the applicable requirements from IPC-J-STD-006 or an equivalent standard approved by the contracting activity. In addition, producing activities should not use Pb-free solders in defense products unless the contracting activity has approved a lead-free control plan (LFCP) authorizing its use (see 4.7.1).

4.5.2.2 Flux. Both external flux and flux-cored solder used to make, rework, or repair soldered defense products should be in accordance with the technical data. If the technical data does not specify flux, producing activities should use flux meeting the applicable requirements from IPC-J-STD-004 or an equivalent standard approved by the contracting activity. In addition, producing activities should ensure external flux and flux-cored solder are compatible in both the cleaning process and selected chemistry.

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4.5.2.3 Solder paste. Solder paste used to make, rework, or repair soldered defense products should be in accordance with the technical data. If the technical data does not specify the solder paste, producing activities should use solder paste meeting the applicable requirements from IPC-J-STD-005 or an equivalent standard approved by the contracting activity. Solder paste chemistry and particle size selection should be compatible with the assembly process.

4.5.2.4 Silver-coated copper wire. The contract should include a requirement for a red plague control plan (RPCP) when the producing activity plans to use silver-coated copper wire or cable in defense products. An RPCP lists the controls and processes needed to reduce and control exposure to environmental conditions and contamination that promote the development of cuprous oxide corrosion, also known as red plague. Guidance for an RPCP is in IPC-WP-113, which includes an RPCP template. For applications with service life (including storage time) exceeding 10 years, 80-microinch silver coating provides more suitable protection from red plague than typical 40-microinch wire. Producing activities should submit the RPCP to the contracting activity for review and approval before using silver-coated copper wire and cable.

4.5.2.5 Printed boards and flexible circuitry. A producing activity should be a trusted supplier in accordance with IPC-1791 for the design, fabrication, and assembly of printed boards and flexible circuitry. Printed boards and flexible circuitry materials used to make soldered defense products should be in accordance with the technical data. If the technical data does not specify printed boards and flexible circuitry materials, producing activities should use printed boards and flexible circuitry designed and made in accordance with MIL-PRF-31032 or the IPC series of printed board design standards, such as IPC-2221, IPC series of printed board fabrication standards, such as IPC-6011, and IPC-A-600 for acceptability of printed boards. In addition, if the technical data does not specify solderability requirements, producing activities should use printed board surface finishes meeting the applicable solderability requirements from IPC-J-STD-003 or an equivalent standard approved by the contracting activity. See IPC-AJ-820 or IPC-HDBK-001 for more information on maintaining solderability.

In some cases, tailored improvements of the IPC standards are needed particularly for etchback and copper thickness. The IPC printed board fabrication standards allow for specifying effective etchback to provide a durable via for most military applications, but it must be specified on the drawing for the board. The IPC fabrication standards also control copper thickness by an average thickness requirement that allows for insufficient copper to meet most military applications, so drawings should specify a minimum thickness (e.g., >0.001 to 0.0015 inch depending on the application stresses).

4.5.2.6 Components. Wires and component terminations should meet the solderability requirements in the technical data. If the technical data does not specify solderability requirements, producing activities should use wires and component terminations meeting the applicable solderability requirements from IPC-J-STD-002 or an equivalent standard approved by the contracting activity. See IPC-AJ-820 or IPC-HDBK-001 for more information on maintaining solderability.

Wires and component terminations with pure tin finishes should follow requirements in SAE GEIA-STD-0005-2. Components with gold finishes should be evaluated for gold embrittlement. Mixed alloy soldering of Pb-free ball grid arrays and tin-lead (SnPb) solder interconnects should be evaluated for mixing of the alloys (see SAE ARP6415).

4.5.2.7 Conformal coatings. Conformal coating materials used to coat soldered defense products should be in accordance with the technical data. If the technical data does not specify conformal coating materials, producing activities should use conformal coatings meeting the applicable requirements from IPC-CC-830 or an equivalent standard approved by the contracting activity. Producing activities should not use expired shelf-life conformal coatings in defense products unless the contracting activity approves or if such use is part of the material and process baseline. IPC-J-STD-001 or IPC-A-610 should be followed for acceptability of the coated product. When using conformal coating as a tin whisker mitigation for pure tin-plated components, follow requirements in SAE GEIA-STD-0005-2.

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4.5.3 Soldering processes. This handbook does not advocate any solder process. Producing activities should develop and maintain operating procedures describing the soldering process and the proper operation of the automatic soldering machine and associated equipment. Producing activities should also ensure that the cleanliness of soldered defense products built with these processes meets the applicable cleanliness requirements from IPC-J-STD-001 after soldering. See IPC-WP-019 for guidance on the elements and requirements from IPC-J-STD-001 regarding residues.

4.5.4 Changing the material and process baseline. Changing to materials and processes different from the established material and process baseline may be a configuration change due to the potential adverse effect on the performance, safety, or reliability of the soldered defense products.

4.6 Reliability. Reliability of solder interconnections should be determined. To assess the reliability of a defense system in its operational environment, the test methods should include conditions and durations to evaluate major potential failure mechanisms for the materials and construction of the soldered defense product. For solder interconnections, this assessment should include fatigue crack propagation and the formation of brittle intermetallic phases or voids. Some aspects of reliability to consider are durability under thermal cycling, vibration, and shock; the effect of thermal aging; and effects of installation process temperatures. More guidance and examples for planning and conducting tests and for analyzing and using results are in SAE GEIA-HB-0005-2 and IPC-9701. Failure analysis by metallographic examination or composition analysis is critical for interpreting results from these tests. MIL-STD-810 provides vibration and shock conditions and identifies the test methods for evaluating the reliability of soldered defense electronic products.

Specification of the life expectancy of a assembly is a fundamental requirement for assessing the assembly's reliability. In addition, the life-cycle loads under which the assembly is required to operate also needs to be specified. Finally, the criteria for failure are needed so that the loss of function can be gaged.

4.6.1 Use case. The conditions under which the equipment with solder interconnections will be used should be characterized sufficiently to conduct a reliability assessment. For solder, temperature cycles, mechanical loads (including bending), torsion, and vibration—both harmonic and random—should be considered. For mechanical loading conditions, loading rates and the temperature of the structures are also important considerations. In addition, storage time and conditions before use or in between uses can have an impact. The electrical current that solder will be required to carry also needs to be determined.

4.6.2 Tests. Physical tests should be carried out to demonstrate that the solder interconnections survive the loading conditions defined by the expected use case to which the solder interconnections will be subjected. For each test, the acceleration factors (see 3.1) for the solder interconnections should be defined. Acceleration factors are dependent on the material, construction, and test conditions. The application of the acceleration factors to the test results should be used to establish the life expectancy as well as the reliability of the solder interconnections for the use case. Failure mechanisms should be identified and should be part of a reliability report.

4.7 Using Pb-free materials. The commercial electronics industry has transitioned from SnPb to Pb-free materials to comply with the European Union's Restriction of Hazardous Substances (RoHS) Directive. While RoHS does not apply to electronic products in defense systems, the transition to Pb-free materials affects manufacturers of defense systems because of their considerable reliance on commercial suppliers for components and COTS products, the majority of which are now Pb-free. This conversion of the commercial supply chain to Pb-free materials requires DoD to be diligent in ensuring that the performance, safety, and reliability of electronic products do not suffer adverse effects throughout the service life. When using Pb-free materials, producing activities should:

a. Ensure all components are compatible with the reflow temperatures required for the Pb-free solder alloy selected.

b. Be aware that the appearances of non-eutectic Pb-free solder interconnections will differ from eutectic SnPb solder interconnections, which may require retraining operators and inspectors. The primary difference between the solder interconnections using SnPb alloys and Pb-free alloys is the visual appearance of the solder. All other solder fillet acceptance requirements are the same. While Pb-free and SnPb connections may have similar appearance, Pb-free alloys are more likely to have surface roughness (grainy or dull) or different wetting contact angles.

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c. Account for aging behavior during any testing intended to demonstrate the long-term reliability of Pb-free solder alloys. The mechanical properties of Pb-free solder alloys vary significantly with aging in a manner very different from SnPb alloys. See SAE GEIA-STD-0005-3 for testing requirements.

d. Use Pb-free solder alloys only when unambiguously specified in the technical data (see 3.7) and all associated process and maintenance documents.

4.7.1 Requiring an LFCP. DoD does not exclude the use of any solder alloys or any solderable surface finishes for component terminations or printed boards. However, some Pb-free materials can adversely affect the performance, safety, and reliability of electronic products when compared with traditional SnPb materials; therefore, programs should not allow the use of Pb-free materials without implementing a Pb-free risk management approach, such as an LFCP in accordance with SAE GEIA-STD-0005-1 or an equivalent standard approved by the contracting activity. The risk management approach should have objective evidence confirming that performance and reliability specifications of electronic products are met when using Pb-free materials. Risk management should address part selection, assembly processes, COTS products, component reprocessing to add lead, and tin whisker mitigations. Contracting activities can use DI-MGMT-81772 to require programs to develop and manage an LFCP.

4.7.2 Designing products with Pb-free materials. When the LFCP authorizes Pb-free materials, design engineers should use IPC/PERM-2901 as a supplemental guide for designing defense products with Pb-free materials. IPC/PERM-2901 helps to develop Pb-free electronic designs meeting the performance, safety, and reliability requirements for defense products. Pb-free risks and issues covered by IPC/PERM-2901 include Pb-free solders and solder interconnections, tin whisker mitigations, printed board defects, and product qualification. IPC/PERM-2901 is not an all-inclusive design guide for electronics, as it only covers the differences between Pb-free electronic design and the traditional SnPb designs. Design engineers will need other reference material to create a complete electronic design package.

4.7.3 Tin whisker mitigations. Tin whiskers (see 3.8) can cause electrical shorts resulting in premature failures. Tin whisker mitigations should be in accordance with SAE GEIA-STD-0005-2 or an equivalent standard approved by the contracting activity. The contracting activity should specify the tin whisker control level—1, 2A, 2B, 2C, or 3—in the contract or the technical data. Using hot solder dip as a tin whisker risk mitigation should be in accordance with SAE GEIA-STD-0006 or an-approved equivalent standard approved by the contracting activity. See SAE GEIA-HB-0005-1 and SAE GEIA-HB-0005-2 for more information on Pb-free materials and Pb-free risk management.

4.8 Packaging soldered products. The contract should reference MIL-STD-2073-1 for military packaging requirements, including ESD packaging requirements, and the red plague packaging requirements in an RPCP if applicable (see 4.5.2.4).

4.9 Avoiding counterfeit materials. Most of the components and supplies used within the scope of this handbook are subject to counterfeiting. Contractors and subcontractors at all tiers should be aware and buy critical and high-risk components and supplies that are in-production or stocked from the original component manufacturer, their authorized suppliers, or other suppliers who buy such components and supplies exclusively from the original component manufacturer or their authorized suppliers.

4.9.1 Addressing counterfeit avoidance in the contract. The contracting activity should consider invoking Defense Federal Acquisition Regulation Supplement (DFARS) subpart 246.870. This clause identifies contractor mitigation requirements, such as supplier selection, inspection, test, traceability, containment, reporting, disposition, training, obsolescence management, and flow-down. While this DFARS clause covers electronic components, most of the other materials used within the scope of this handbook are also subject to counterfeiting and should be mitigated using similar methods.

4.9.2 Additional information regarding counterfeit components. Several industry standards have guidance in establishing these requirements. These include SAE International standards AS5553, AS6081, AS6171, and AS6174. The first three documents apply only to electronic parts, while the last document applies to mechanical parts and materials. NAVSO P-7000 has more information about managing risk associated with counterfeit components and supplies in defense products. NAVSO P-7000 is available via a search for “P-7000” at https://www.secnav.navy.mil/rda/DASN-P.

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4.10 Flowing-down requirements to subcontractors. The contract should flow-down the applicable acceptance requirements from the specified soldering standards including product class, ESD requirements, the LFCP including tin whisker mitigations tin whisker control level, a COTS management plan, and counterfeit requirements to subcontractors at all tiers providing supplies for the acquisition of soldered defense products. Procuring activities can use a parts, materials, and processes (PM&P) management plan per MIL-STD-3018 for these data requirements.

5. SUSTAINMENT GUIDANCE

This section has the guidance for reworking and repairing soldered defense electronic products to ensure these products meet their performance, safety, and reliability requirements. Rework restores complete conformity of the defective soldered defense products to the technical data while repair restores performance, safety, and reliability without achieving complete conformity to the technical data. For procurements during the sustainment phase of the product's life cycle, use the acquisition guidance in section 4.

5.1 Standards for reworking and repairing soldered defense electronic products. The technical data should identify the soldering standards used to manufacture the soldered defense electronic product. If the technical data are not available or do not specify the soldering standards, activities should use their locally required soldering standards. If no soldering standards are specified, activities should use IPC-J-STD-001 or IPC-A-610 (see 4.1). In addition, activities should use IPC-7711/7721 as a guide for rework and repair processes and procedures.

5.2 Electrostatic discharge. Sustainment activities should have an ESD control program in accordance with ANSI/ESD S20.20 (see 4.1.3).

5.3 Identifying the product class. The technical data should identify the product class (see 4.2). If the technical data are not available or do not identify the product class, use class 3 as most soldered defense products fall into this classification.

5.4 Accepting reworked or repaired soldered defense products. All reworked or repaired soldered defense products should meet the requirements in the technical data. If the technical data are not available, activities should use their locally required soldering standards, IPC-J-STD-001, or IPC-A-610 for the acceptance requirements (see 4.3).

5.5 Using COTS electronic products. Unless the technical data are available, rework and repair of COTS electronic products is beyond the scope of this handbook (see 4.4).

5.6 Using compatible materials. Activities should select compatible materials, equipment, and processes to ensure soldered defense products will meet the applicable requirements from IPC-J-STD-001 or IPC-A-610 after rework and repair (see 4.5.2).

5.7 Using Pb-free materials. Unless otherwise specified in the technical data, do not use Pb-free materials to rework or repair soldered defense electronic products (see 4.7).

5.8 Packaging soldered products. Use MIL-STD-2073-1 for military packaging requirements, including ESD packaging requirements, and the red plague packaging requirements in a RPCP if applicable (see 4.5.2.4).

5.9 Avoiding counterfeit materials. Activities at all tiers should buy critical and high-risk components and supplies that are in-production or stocked from the original component manufacturer, their authorized suppliers, or other suppliers who buy such components and materials exclusively from the original component manufacturer or their authorized suppliers (see 4.9).

6. NOTES

6.1 Intended use. This handbook provides guidance for the acquisition and sustainment of soldered defense electronic products. Meeting the applicable acceptance requirements from IPC-J-STD-001, IPC-A-610, or IPC/WHMA-A-620 ensures the soldered defense products meet their performance, safety, and reliability requirements.

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6.2 Subject term (key word) listing.

Lead-free

Lead-free control plan (LFCP)

Pb-free

Soldering

Tin whiskers

Tin-lead

CONCLUDING MATERIAL

Custodians:
Army – AV
Navy – SH
Air Force – 20

Review activities:
Army – CR, MI
Navy – AS, CH
Air Force – 24, 85
DLA – CC, DH

Civil agencies:
NASA

Industry associations:
IPC International
SAE International
USPAE

Preparing activity:
Navy – SH
(Project SOLD-2020-002)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.

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