DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS CENTER (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE OHIO

MAY 09 2005

MEMORANDUM FOR SEE DISTRIBUTION

FROM: ASC/EN
2530 Loop Road West
Wright-Patterson AFB OH 45433-7101

SUBJECT: Airworthiness Advisory AA-05-01, Lead-Free Solder

1. Operational Safety, Suitability, and Effectiveness (OSS&E) policy gives the Aeronautical Systems Center product-line technical responsibility for air systems. Airworthiness Alerts and Airworthiness Advisories have been established to notify the product-line community about the flight safety issues. Airworthiness Advisories contain guidance and information that describe a new flight safety hazard or condition and provide early warning of potential action.

2. Attached is Airworthiness Advisory AA-05-01, which conveys information pertinent to the use of lead-free solder on United States Air Force aircraft. Please distribute this throughout your organization. For further information on AA-05-01, contact the POCs listed in the advisory. For information on OSS&E policy, the Airworthiness Certification Criteria Control Board, or Airworthiness Alerts and Advisories in general, contact Mr. Alan Owens, ASC/ENSI, (937) 255-1846 or DSN 785-1846.

DENNIS J. CASSETTE, SES
Director, Engineering

Attachment:
AA-05-01

DEPARTMENT OF THE AIR FORCE
Headquarters Aeronautical Systems Center (AFMC)
Engineering Directorate
Wright-Patterson AFB OH 45433-7101

AA-05-01
9 May 2005

AIRWORTHINESS ADVISORY

Lead-Free Solder

PURPOSE:
This Airworthiness Advisory provides information on the trend within the electronics manufacturing community toward the use of lead (Pb)-free solder. To date, no lead-free solders are known to have met the reliability requirements imposed upon military electronics. At the same time, many electronic items being acquired by the United States Air Force (USAF) and Department of Defense (DoD) may already contain lead-free solder due to electronics manufacturers' use of solely lead-free solder.

SCOPE:
This Airworthiness Advisory applies to all USAF aircraft, manned and unmanned, including those operated by the Air National Guard and the USAF Reserve. It also applies to Fielding/ Deployment, Operational Support Activities, Upgrades, and Temporary/Permanent Modifications.

REFERENCED DOCUMENTS:
Galyon, G.T. and Gedney, Ron. "Avoiding Tin Whisker Reliability Problems." *Circuits Assembly – The Journal for Surface Mount and Electronics Assembly,* August 2004, pp. 26-31, http://circuitsassembly.com.

Handwerker, Carol PhD. "Transitioning to Pb-Free Assemblies." *Circuits Assembly – The Journal for Surface Mount and Electronics Assembly*, February 2005.

Livingston, Henry. "GEB-0002: Reducing the Risk of Tin Whisker-Induced Failures in Electronic Equipment," 1 December 2003, http://63.249.145.5/sstc/G12/geb2_paper.pdf.

Norwall, B., "Air Force Links Radar Problems to Growth of Tin Whiskers." *Aviation Week and Space Technology*, June 30 1986, pp. 65-70, http://www.aviationnow.com.

Oresjo, Stig. "Overcoming Lower Wetting Forces of Pb-Free Alloys." *Circuits Assembly – The Journal for Surface Mount and Electronics Assembly*, March 2005, p. 40.

Stratton, Paul. "Nitrogen's Effect on Pb-free Soldering." *Circuits Assembly – The Journal for Surface Mount and Electronics Assembly*, February 2005, pp. 50-51.

Williams, James PhD. "Lead-Free Implications for Barcode Labels." *Circuits Assembly – The Journal for Surface Mount and Electronics Assembly*, February 2004, pp. 58-61.

"DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment." *Official Journal of the European Union*, 13.2.2003, L37/19-L37/23, http://europa.eu.int/eur-lex/en/.

Government Electronics and Information Technology Association (GEIA) policy letter. Subject: "GEIA Position Regarding RoHS." Signed by Christopher J. Denhamm III, Vice President, Standards and Technology, http://www.geia.org.

IPC-1066, "Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices." January 2005, http://www.ipc.org/TOC/IPC-1066.pdf

IPC/EIA J-STD-006A. "Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications." May 2001. http://www.electronics.ca/standards/materials/IPC-J-STD-006A.html.

MIL-PRF-19500; Semiconductor Devices, General Specification for

MIL-PRF-38534; Hybrid Microcircuits, General Specification for

MIL-PRF-38535; Integrated Circuits (Microcircuits) Manufacturing, General Specification for

MIL-PRF-39014; Capacitor, Fixed, Ceramic Dielectric, General Specification for

MIL-PRF-39016; Relays, Electromagnetic, Established Reliability, General Specification for

MIL-PRF-55182; Resistors, Fixed, Film, General Specification for

MIL-PRF-55342; Resistors, Chip, Fixed, Film, General Specification For

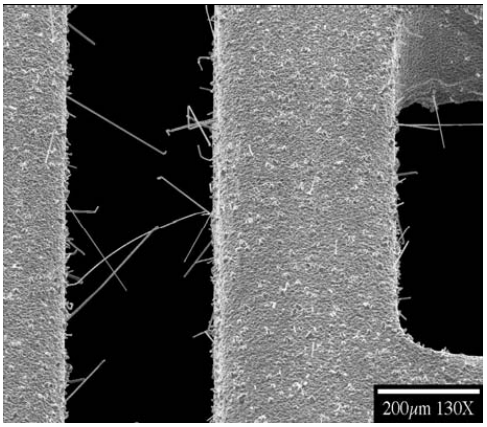
MIL-PRF-55365; Capacitor, Fixed, Electrolytic (Tantalum), Chip, General Specification For

NASA Pure Tin Plating Prohibition Policy statement. NASA Electronic Parts and Packaging Program (NEPP) Web page, http://nepp.nasa.gov/npsl/Prohibited/tin_prohibition.htm.

NASA PARTS ADVISORY NA-044. Subject: "Tin Whiskers." Originator: Michael J. Sampson, NASA Goddard Space Flight Center, Component Technologies and Radiation Effects Branch, 10/23/98, NEPP Web page.

NASA PARTS ADVISORY NA-044A. Subject: "Tin Whiskers." Contact: Michael J. Sampson, NASA Goddard Space Flight Center, Component Technologies and Radiation Effects Branch, 12/17/98, NEPP Web page.

BACKGROUND:
In the past, pure tin (Sn) was used to solder electronic components. In fact, "pure tin [was] commonly used in the electronics industry because of its corrosion resistance and ease in soldering" (Norwall, p. 65). Over time, it was discovered that use of pure tin in electronic components could create "tin whiskers." Tin whiskers are single crystals which emerge from tin-finished surfaces. They are "needle-like protrusions, or whiskers, capable of causing electrical shorting in tightly spaced electronic circuitry" (Galyon and Gedney, p. 26).



[1] The USAF became intimately aware of the needle-like protrusions when whiskers, "one fortieth the diameter of a human hair," caused "intermittent performance problems" in the radar used on the F-15 (Norwall, p. 65). Because of these "intermittent performance problems" the F-15 community directed the use of leaded solder instead of pure tin solder for all its hybrid circuits. This direction was taken since leaded solder had been shown to slow (if not prevent) the growth of tin whiskers. Use of leaded solder during the electronics manufacturing process has resulted in many consecutive incident-free years. However, leaded solder may become obsolete in the electronics industry. Consequently, the USAF will have to re-approach the issue of tin whiskers, and will have to address the reliability of electronics as lead-free manufacturing and repair become standardized.

It should be emphasized that the tin whisker problem is widespread—it is by no means an experience exclusive to the USAF. The NASA NEPP Web page indicates at least three reports of incidents in which a tin whisker-induced short circuit caused complete failure of a commercial satellite. If sufficient current is available, a tin whisker short circuit in vacuum can fuse open, but the resulting vaporized tin may provide for formation of high-conduction plasma. If current is low, the whisker may not fuse and a short circuit may be continuous.[2] NASA's policy states, "Pure tin plating is prohibited as a final finish on EEE parts and associated hardware." NASA Parts Advisories NA-044 and NA-044A address this topic and contain extensive lists of specifications, a large number of which prohibit pure tin; many specify a minimum inclusion of 3% lead content. The Defense Logistics Agency[3] has provided a sample list of defense specifications which preclude the use of pure tin: for Monolithic microcircuits, MIL-PRF-38535 Para A.3.5.6.3; Hybrid microcircuits, MIL-PRF-38534 Para E.4.2.7; Semiconductors, MIL-PRF-19500 Para H.4.1; Film resistors, MIL-PRF-55182 Para 3.5.3.4; Chip film resistors, MIL-PRF-55342 Para 3.5.3; Chip tantalum capacitors, MIL-PRF-55365 Para 3.5.2.3; Ceramic capacitors, MIL-PRF-39014 Para 3.5.1.1; and Relays, MIL-PRF-39016 Para 3.4.1.a.[4] Unfortunately, while the tin whisker crystalline structure is widely known, there is no generally-accepted model for the mechanism of whisker formation.

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[1] Photo courtesy of Mr. Peter Bush, State University New York at Buffalo
[2] NASA Parts Selection List Web page
[3] http://www.dscc.dla.mil/offices/sourcing_and_qualification/offices.asp
[4] These documents are available at http://assist.daps.dla.mil/online/start/.

"The electronics industry is just beginning a conversion to lead-free processes and products to comply with the European Union's Reduction of Hazardous Substances (RoHS) Directives" (Galyon and Gedney, p. 26). Driving the conversion to lead-free solder is the RoHS statement that only lead-free solder be allowed within electronics sold in the States of the European Union. Although there is no domestic regulation that directs US electronics manufacturers to convert to lead-free solder, in order to sell their products overseas they too will have to comply with the directive by its implementation date of 1 July 2006.

The conversion to lead-free solder is affecting the USAF due to its increasing reliance on commercial companies for its electronic equipment requirements. The impact will become greater as more US companies transition from leaded solder to lead-free solder.

DISCUSSION:

The USAF and DoD have come to rely on the unique characteristics of leaded solder. Leaded solder has a reputation as a very reliable substance for the production of electronic equipment and has been shown to reduce the phenomenon of "tin whiskers." "Tin whiskers can pose a serious reliability risk to electronic assemblies that have a pure tin finish."[5] In addition, leaded solder has demonstrated itself durable during adverse conditions, proving it suitable for the military's unique electronic equipment requirements. Now that the electronics industry is moving toward the use of lead-free solder, the DoD must cope with this trend. The difficulty in moving toward suitable lead-free solder replacements is compounded by the fact that the consumer electronics items, which form the bulk of many companies' production, are often projected for significantly shorter useful lives than the lifespans targeted for military equipment. The solder products which are adequate for the shorter term may not always be sufficient to support desired military lifetimes.

To date, no lead-free solder has matched the qualities found within leaded solder. The Joint Council on Aging Aircraft, through the Aging Aircraft Squadron, is currently conducting reliability testing of three lead-free alloys already being used within the commercial industry. While test results will not result in qualification of a specific lead-free alloy substitute, they will provide baseline information to be used in the development of transition strategies for implementing lead-free solder alloys into aerospace electronics applications. The results for these tests are expected in early 2006. In the meantime, it is important to note that "there is no pending US legislation mandating lead-free electronic products, and should such legislation arise, military, aerospace and medical equipment manufacturers would likely be exempt" (Livingston, p. 1).

It should be noted that there are potential complications with any move toward use of substitute materials for SnPb solder. The various alloys have different melting points, which means that the temperatures which must be reached for lead-free solder melting are often higher than those for SnPb solder. The results of elevated temperatures may include damage to circuit components, insulations, and plastic parts, as well as warping or delamination of circuit cards (Stratton, p. 50). In addition, the higher temperatures may result in problems with retention of barcode labels needed to track parts information (Williams, pp. 58-61). It is important that flux

[5] (Livingston, p. 1).

materials be chosen appropriately for the solder used. Some solder and flux formulations produce oxides which are more difficult to clean (Williams, p. 58). Wetting properties of different materials vary, increasing the likelihood of defects (Oresjo, p. 40); work has been done toward use of nitrogen to improve results (Stratton, p. 50). There is no one, simple and absolute substitution for SnPb formulations, and the need for backward and forward compatibility must be addressed (Handwerker, p. 1).

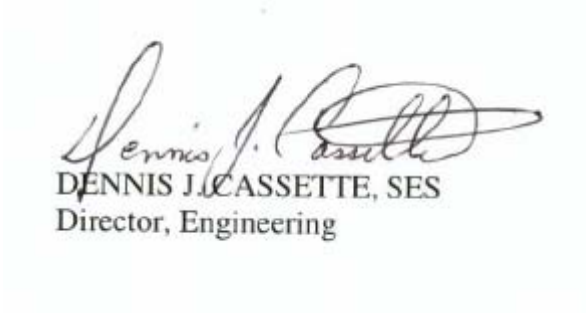
Even with a probable exemption, the "Department of Defense and NASA believe that the use, and therefore the risk, of tin finish on electronic components will increase because: 1) commercial industry has stated the initiative to eliminate lead from electronics, 2) defense and aerospace industry trends show increasing usage of commercial components, and 3) continuing reductions in circuit geometry and power means that even small whiskers may cause catastrophic failures" (Livingston, p. 1).

GUIDANCE/RECOMMENDATIONS:

The safety of USAF equipment must not be sacrificed in the transition to lead-free solder practices. Though there are many alternative solder alloys available to replace traditional tin-lead, none of them has passed the reliability testing required of aerospace-quality hardware. A common replacement for tin-lead solder is pure tin—material with known reliability problems due to tin "whiskering." Until such time that a suitable, reliable, lead-free solder replacement is identified, all program managers should ensure their electronic equipment suppliers continue to provide items which meet all performance, compatibility, and reliability requirements. Failure to do so could adversely affect the reliability of weapons systems. This standpoint has also been adopted by the GEIA, and is shared by NASA's prohibition of pure tin as a final finish on electrical, electronic, and electromechanical (EEE) parts.[6] Further, Joint Industry Standard IPC/EIA J-STD-006A, "Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications," (adopted for use by the Department of Defense) states in Appendix A, Table A-1: "Sn99.9 is included in this standard for use in replenishing tin in wave soldering baths and is NOT suitable for use as a stand-alone solder because of potential performance and reliability problems." To preclude the inadvertent or unknown acceptance of parts with lead-free solder, incorporation of industry standard IPC-1066, "Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices," into purchasing/repair requirements is recommended. As lead-free components enter the marketplace, experience has shown lead content markings are not always correct. Specifically, some components may be marked as containing lead but actually be found to be lead free, so further testing/inspection of incoming items may be warranted.

[6] NEPP Web page

POINTS OF CONTACT:
Contact the ASC/AFRL Engineering Standards Group, ASC/ENOI, at (937) 255-6295 or DSN 785-6295 for additional information. Technical questions on the subject of this advisory should be directed to Mr. Richard Hricko, ASC/AAA, (937) 255-7210; Capt Andrew Clewett, ASC/VFE, (937) 694-6739; or Mr. Raymond Schlegelmilch, ASC/ENFA, (937) 255-5078.



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