SUBJECT: Tin Whiskers	MANUFACTURER N/A	PAGE NO.: 1	NO. OF PAGES: 5
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PART NO.: Various	FSC CODE: Various		
REFERENCE: Numerous GIDEP Alerts and Technical Papers			

MESSAGE TO BE TRANSMITTED

Note: An electronic version of this advisory may be obtained in text format via the World Wide Web at ***http://epims.gsfc.nasa.gov*** This site is password protected/restricted access for NASA approved personnel only.

Purpose:

Recent events have prompted the issue of this NASA Parts Advisory to notify and remind the NASA EEE parts community of the potential risks associated with the use of pure tin-plated finishes on electronic components and assemblies. Pure tin finishes are susceptible to the spontaneous growth of single crystal structures known as ***tin whiskers***. Tin whiskers are capable of causing electrical failures ranging from parametric deviations to catastrophic short circuits. Although the tin whisker phenomenon has been documented for decades and is reasonably well understood, it is still a reliability hazard that warrants special attention.

This discussion will not provide a complete explanation of the tin whisker growth mechanism; numerous (often contradictory) publications have attempted this task. The intent is to provide a comprehensive explanation of generally accepted understandings of tin whiskers along with some suggestions for how to reduce the risk of tin whiskers on NASA hardware.

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Potential Risks of Tin Whiskers:

Tin whiskers pose a serious reliability risk to electronic assemblies. Several instances have been reported where tin whiskers have caused system failures. The general risks fall into four categories:

1. Whiskers or parts of whiskers, may break loose and bridge isolated conductors or interfere with optical surfaces
2. In low voltage, high impedance circuits, there may be insufficient current available to fuse the whisker open and a stable short circuit results. Depending on the diameter and length of the whisker, it can take more than 50 milliamps (mA) to fuse one open. More typical is ~10mA
3. At atmospheric pressure, if the available current exceeds the fusing current of the whisker, the circuit only experiences a transient glitch as the whisker opens.
4. ***In space vacuum*** however, a much more destructive phenomenon can occur. If currents of above a few amps are available, the whisker will fuse open but ***the vaporized tin may initiate a plasma that can conduct over 200 amps!*** An adequate supply of tin from the plated surface is necessary to sustain the arc.

GIDEP History:

Numerous GIDEP Alerts and Problem Advisories have been issued that cover specific occurrences of tin whisker related failures, however, none of these mention the plasma arc failure mechanism.

Alert Number	Date	Manufacturer	Product
F3-P-97-01	12/02/96	Potter & Brumfield	Relays
GM-A-93-01	02/05/93	Precision Electronics Components	Potentiometers
S4-P-93-01	10/01/92	Various	Transistors
BA-P-92-01	07/14/92	Various	Diodes, Transistors, Relays
C6-A-91-03	04/01/91	Leach	Relays
8Y-P-90-01	09/01/90	Various	Discrete Semiconductors
F3-A-87-04A	12/01/87	MUPAC	Wire Wrap Panels

This list shows a bias towards relays and other devices typically packaged in metal cans however , any surface plated with pure tin is potentially at risk for tin whisker formation.

Tin-Plated Finishes

The electronics industry has utilized pure plated finishes for decades. Tin forms an excellent protective coating that resists oxidation and corrosion and also provides good solderability. Pure bright tin finishes maintain an aesthetically pleasing shiny surface even when exposed to air and moisture. Tin is also preferred over tin-lead plating because lead in waste streams increases the cost and complexity of disposal. Pure tin plating is a common finish on packages and terminations for Commercial-Off-The-Shelf (COTS) components.

Pure Tin Prohibition in the Military Specification System:

Following a series of tin whisker related failures in the late 1980’s and early 1990’s the U.S. Military sought to eliminate pure tin from its systems. Between 1993 and 1994, language was introduced into most of the MIL EEE part specifications to specifically prohibit the use of pure tin plating. Notable exceptions were the specifications for electromechanical relays. Two of these, MIL-R-6106 and MIL-R-83536, did not prohibit tin on external surfaces until they were converted to performance specifications (PRF) in 1997. A table showing the status for most of the MIL specifications in common spaceflight use is attached.

A Brief Description Of Tin Whiskers:

- Whiskers are elongated single crystals of pure tin that have been reported to grow to more than 4mm (160 mils) in length and from 0.3 to 10μm in diameter (typically ~1 μm).
- Whiskers grow spontaneously without an applied electric field or moisture (unlike dendrites) and independent of atmospheric pressure (they grow in vacuum).
- They may be straight, kinked, hooked or forked and some are reported to be hollow. Their outer surfaces are usually grooved.
- Whisker growth may begin soon after plating or may take years to initiate.

Tin Whisker Growth Mechanism:

The mechanism(s) by which tin whiskers grow has been studied for many years. However, a single accepted explanation of this mechanism has not been established but there are some commonly agreed factors involved in tin whisker formation. Tin whisker growth is primarily attributed to stresses in the tin plating. These stresses may be from many sources including:

- Residual stresses in the tin resulting from the plating process. Electrodeposited finishes are most susceptible due to the high current densities involved in the plating process.
- Compressive stresses such as those introduced by torquing of a nut or a screw
- Bending or stretching of the surface after plating
- Scratches or nicks in the plating introduced by handling
- Coefficient of Thermal Expansion mismatches between the plating material and substrate
- The change in lattice spacing that occurs from the formation of intermetallic compounds such as those between copper and tin.
- Whiskers appear to grow more readily at temperatures approaching 50°C. Lower and higher temperatures do not prevent growth until temperatures approaching 150°C are reached.
- Bright tin finishes (shiny) seem to be worse than matte finishes due to some influence of the organic compounds used as brighteners.

Suggestions for Reducing the Risk of Tin Whiskers:

At this time, the only sure way of avoiding tin whiskers is not to use pure tin plating. Utilize procurement specifications that have clear restrictions against the use of pure tin plating. Most (but not all, see attachment) of the commonly used military specifications currently have prohibitions against pure tin plating. Studies have shown that alloying tin with a second metal reduces the propensity for whisker growth. Alloys of tin and lead are acceptable where the alloy contains a minimum of 3% lead by weight.

Pure tin-plated parts in stock should either be replaced with parts plated with something other than pure tin, hot solder dipped, or sent to a plating house to have the tin plating stripped and replaced with a tin based alloy containing at least 3% lead. Stripping and replating is a recommended approach and is a service offered by some of the original part manufacturers.

If the procurement of pure tin-plated parts is unavoidable it is suggested that the user arrange to either have them stripped and replated or hot solder dipped as described above, prior to installation.

Other treatments such as conformal coating and foam encapsulation appear to be beneficial but the limitations are not understood. It has been reported that tin whiskers can grow through conformal coating. It has also been demonstrated experimentally that conformal coating can restrict the availability of tin sufficiently to prevent plasma formation. However, such factors as the minimum thickness of coating necessary to prevent whisker growth or plasma formation have not been determined. Similarly, it has been shown that foam can prevent sustained arcing but the effects of foam type, foam density, pore size etc. have not been evaluated.

It has been reported that reflowing or “fusing” pure tin plating is an effective means to prevent whisker formation. Again, the limitations of this approach have not been identified; the effect could be time dependent, affected by the substrate, the environment, or by any number of other potential variables. It is known that scratches or impacts to pure tin finishes can become sites for prolific whisker growth, so handling could easily compromise the effectiveness of reflow. Therefore, reflow is not a recommended method to prevent whisker formation.

This is preliminary information. Studies and evaluations are planned to address the critical open questions, so as to provide more detailed suggestions in the future.

For Further Information:

Additional information is available at:
http://misspiggy.gsfc.nasa.gov/whisker/

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Attachment to NASA Parts Advisory NA-044

Current Specification Status with Respect to Pure Tin for Commonly used EEE Part (Military) Specifications

This attachment has been prepared to provide additional guidance in support of **NASA Parts Advisory NA-044** dated 10/23/98. The table below includes a listing of EEE part procurement specifications (Military and NASA) that are commonly used for spaceflight part procurements.

The table provides:

- Date of the most current specification revision
- Brief explanation of the current "Pure Tin Prohibition Status" within the specification
- Date and revision of the specification when the prohibition language was added (if at all)
- Brief comments regarding the risk associated with the given specification

Based on the information provided, users can roughly determine the timeframe (lot date code) when the manufacturer was restricted from producing pure tin plated components. However, the exact date when a given manufacturer's product ceased to include pure tin has not been determined.

Notes:

1) The attachment does not cover ALL EEE part procurement specifications being used in spaceflight programs. This list only encompasses the more commonly used specifications within NASA. Numerous contractor-specific Source Control Drawings (SCD) are also in use which may or may not prohibit the use of pure tin plating. Many of these SCDs are based upon the equivalent or similar military specification for that commodity. The specific language in each SCD should be reviewed to determine if pure tin plating is restricted.
2) This table covers the Base specification requirements only. In some instances, the detail specification sheet (slash sheet) or MS drawing may limit the plating finish to specific materials; thereby possibly prohibiting the use of pure tin. Therefore, a review of the slash sheets may be required to determine if pure tin plating is restricted.
3) Based on experience, the following commodities appear to be the ones most at risk for whisker formation. Particular attention to these commodity types is suggested:

    - Relays
    - Connectors
    - Filters
    - Bus Wire

4) The complexity of some commodities such as connectors, wire and cable has made the completion of the table in those commodity sections difficult. Updates to this table will be provided at a later date and will be made accessible via the homepage:
http://misspiggy.gsfc.nasa.gov/whisker

Current Specification Status with Respect to Pure Tin for Commonly used EEE Part (Military) Specifications

Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
Capacitors				
MIL-PRF-20 (Ceramic)	05/06/93 Rev H Am 2	Pure tin is allowed on terminals	N/A	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-123 (Ceramic)	07/06/98 Rev B Am 5	Pure tin is allowed on chip capacitor terminations only	N/A	Termination “W” allows pure tin or tin-lead terminations
MIL-PRF-23269 (Glass)	08/06/93 Rev E Am 1	No pure tin allowed. Minimum of 3% lead.	08/06/93 Rev E Am 1	
MIL-PRF-39003 (Tantalum)	05/22/98 Rev H Am 4	No pure tin allowed. Minimum of 3% lead.	08/06/93 Rev H Am 2	
MIL-PRF-39006 (Tantalum)	07/07/98 Rev E Am 1	No pure tin allowed on terminals. However, spec does not prevent tin plated cases.	12/24/93 Rev D Am 1	Not likely to be a problem. Most, if not all designs, use tantalum cases that are sleeved. Tantalum cases are not likely to be plated.
MIL-PRF-39014 (Ceramic)	09/16/97 Rev F	No pure tin allowed. Minimum of 3% lead.	11/23/93 Rev E Am 4	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-49467 (Ceramic)	07/15/98 Rev A Am 2	No pure tin allowed. Minimum of 3% lead.	05/19/97 Rev A	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-49470 (Ceramic)	07/15/98 Am 1	No pure tin allowed. Minimum of 3% lead.	11/19/97 Base	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-55365 (Tantalum)	04/13/98 Rev D Am 1	No pure tin allowed. Minimum of 3% lead.	08/02/93 Rev C Am 4	

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
MIL-PRF-55681 (Ceramic)	06/29/98 Rev E Am 1	Pure tin is allowed	N/A	A precautionary note exists in spec as of 07/3/94. However, this does not prohibit pure tin. Termination "W" allows pure tin or tin-lead terminations.
MIL-PRF-83421 (Film)	12/30/93 Rev B Am 3	No pure tin allowed. Minimum of 3% lead.	07/04/93 Rev B Am 2	
MIL-PRF-87217 (Film)	02/23/94 Am 4	Pure tin is not expressly disallowed. See MIL-PRF-83421.	N/A	Parts are made as MIL-PRF-83421 so they should be covered by the same prohibition
Connectors and Accessories				
MSFC 40M38277		To Be Determined		Information not available at time of Advisory release
MSFC 40M38298		To Be Determined		Information not available at time of Advisory release
MSFC 40M39569		To Be Determined		Information not available at time of Advisory release
GSFC S-311-P-4	09/05/91 Rev D	No Pure tin allowed.		
GSFC S-311-P-10	09/21/92 Rev D	No Pure tin allowed.		
GSFC S-311-P-718	09/05/91 Base Rev	To Be Determined		Information not available at time of Advisory release
MIL-C-5015		To Be Determined		Information not available at time of Advisory release
MIL-C-24308	11/12/97 Rev D Am 2	Pure tin is allowed on some styles		Class H connectors are likely to be pure tin plated. However, most NASA programs do not recommend use of Class H parts.

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
MIL-C-26482		To Be Determined		Information not available at time of Advisory release
MIL-C-83513	04/22/97 Rev D	Pure tin is allowed		Information not available at time of Advisory release
MIL-C-83517	07/07/98 Am 4	To Be Determined		Information not available at time of Advisory release
MIL-C-38999	04/06/90 Rev J	The current unreleased draft includes a pure tin prohibition with 3% lead minimum.		Past revisions allow pure tin
MIL-C-39012	08/25/95 Rev D Am 1	To Be Determined		Information not available at time of Advisory release
MIL-C-39029		To Be Determined		Information not available at time of Advisory release
MIL-C-55302		To Be Determined		Information not available at time of Advisory release
MIL-C-85049		To Be Determined		Information not available at time of Advisory release
Crystals				
MIL-O-55310	03/25/98 Rev D	No pure tin allowed. Minimum of 3% lead.	03/15/94 Rev C	
Discrete Semiconductors (Diodes/Transistors)				
MIL-S-19500	09/08/97 Rev K Am 1	No pure tin allowed. Minimum of 3% lead.	04/15/94 Rev J	

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
Filters				
MIL-PRF-15733	11/15/96 Rev G Am.5	No pure tin allowed. Minimum of 3% lead.	12/31/93 Rev G Am 4	
MIL-PRF-28861	09/11/98 Rev B Am.4	No pure tin allowed. Minimum of 3% lead.	01/31/94 Rev B	
Fuses				
MIL-F-23419 (Fuses)	06/12/98 Rev E Am 3	No pure tin allowed. Minimum of 3% lead.	06/01/94 Rev E Am 1	
MIL-PRF-39019 (Circuit Breakers)	08/27/97 Rev D	Pure tin is allowed		
Inductors				
MIL-C-39010	08/27/97 Rev E	No pure tin allowed. Minimum of 3% lead.	01/04/94 Rev D	
MIL-C-83446	10/03/94 Rev B Am 4	No pure tin allowed. Minimum of 3% lead.	10/03/94 Rev B Am 4	
MIL-STD-981	02/10/94 Rev B	Solder is not allowed to be pure tin. However, no min lead content is specified	02/10/94 Rev B	

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
Microcircuits				
MIL-M-38510	08/27/93 Rev J Not. 1	Pure tin is allowed.		
MIL-PRF-38534	09/12/96 Rev C Am 1	No pure tin allowed on terminations. Minimum of 2% lead. No language about package plating restrictions	08/23/95 Rev C	
MIL-PRF-38535	12/01/97 Rev E	No pure tin allowed.	03/14/95 Rev C	
Relays				
GSFC S-311-P-2(06)	03/16/92	Inactivated. Last rev allowed pure tin. Superseded by S-311-P-754.	N/A	
GSFC S-311-P-754	09/25/98 Rev D	No pure tin allowed. Minimum of 3% lead.	09/25/98 Rev D	
MIL-PRF-6106	12/01/97 Rev K	No pure tin allowed. Minimum of 3% lead.	12/01/97 Rev K	
MIL-PRF-39016	06/30/98 Rev E Am 2	No pure tin allowed. Minimum of 3% lead.	07/18/94 Rev E	
MIL-PRF-83536	12/19/97 Rev A Am 1	No pure tin allowed. Minimum of 3% lead.	03/21/97 Rev A	

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
Resistors				
GSFC S-311-P-672	04/06/98 Rev E	To Be Determined		Information not available at time of Advisory release
GSFC S-311-P-683	07/02/96 Rev A	To Be Determined		Information not available at time of Advisory release
GSFC S-311-P-742	12/26/95 Rev C	To Be Determined		Information not available at time of Advisory release
GSFC S-311-P-813	03/09/98 Rev B	To Be Determined		Information not available at time of Advisory release
MIL-PRF-39005 (Wirewound)	03/16/98 Rev E Am 1	No pure tin allowed. Minimum of 3% lead.	07/01/93 Rev D Am 2	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-39007 (Wirewound)	07/03/97 Rev H	No pure tin allowed. Minimum of 3% lead.	03/23/93 Rev G Am 1	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-39008 (Carbon Comp.)	04/11/97 Rev C Not.1 Inactivated	No pure tin allowed. Minimum of 3% lead.	05/05/93 Rev C Am 1	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-39009 (Wirewound)	07/03/97 Rev D	A “Note” in Section 6 “prohibits” pure tin but does not specify a min lead content. Terminals require minimum of 40% lead.	01/27/94 Rev C Am 1	
MIL-PRF-39015 (Variable)	06/09/98 Rev D Am 1	No pure tin allowed. Minimum of 3% lead.	04/27/93 Rev C Am 2	
MIL-PRF-39017 (Film)	05/19/97 Rev F	No pure tin allowed. Minimum of 3% lead.	07/01/93 Rev E Am 2	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use

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MIL-PRF-55182 (Film)	09/17/98 Rev G Am 3	No pure tin allowed. Minimum of 3% lead.	08/11/93 Rev F Am 2	Packaging is non-metallic. Not likely to be a concern since most spaceflight programs solder dip terminals prior to use
MIL-PRF-55342 (Film)	09/17/98 Rev G Am 1	No pure tin allowed. Minimum of 3% lead.	05/10/93 Rev E Am 2	
MIL-PRF-83401 (Network)	03/18/96 Rev G	No pure tin allowed. Minimum of 3% lead.	06/11/93 Rev F Am 3	
MIL-PRF-914 (Network)	12/19/97 Rev A Am 1	No pure tin allowed. Minimum of 3% lead.		
Thermistors				
MIL-T-23648	06/15/98 Rev D Am 1	No pure tin allowed. Minimum of 3% lead.	04/15/93 Rev C Am 1	
GSFC S-311-P-18	05/12/95 Rev G	Pure tin is allowed	N/A	
Transformers				
MIL-T-27	06/06/94 Rev E Am 2	Pure tin is allowed		
MIL-STD-981	02/10/94 Rev B	Solder is not allowed to be pure tin. However, no min lead content is specified	02/10/94 Rev B	

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Specification Number	Current Specification Revision Date	Current Pure Tin Prohibition Status	Specification Revision When Pure Tin Prohibition Introduced	Comment
Wire and Cable				
S-311-P-13	06/07/96 Rev B	To Be Determined		Information not available at time of Advisory release
MIL-C-17	01/08/96 Rev G Am 3	To Be Determined		Information not available at time of Advisory release
J-W-1177	10/16/96 Rev B Not. 1	To Be Determined		Information not available at time of Advisory release
MIL-W-5086	12/07/79 Rev C Am 1	To Be Determined		Information not available at time of Advisory release
MIL-W-22759	05/07/91 Rev E Am 1	Pure tin plating is allowed on some styles including (but not limited to) /16, /18, /32, /34	N/A	Pure tin coated wire is recommended for solder applications only. Tin whisker growth is only a risk in areas where the insulation has been removed and the wire has not been coated with solder.
MIL-W-81381	09/08/87 Rev A Not. 1	To Be Determined		Information not available at time of Advisory release
QQ-W-343 (Bus Wire)	04/18/97 Rev G	Pure tin is allowed	N/A	Not likely to be a concern if tin plated bus wire is solder dipped/coated prior to use with solder containing a minimum of 3% lead. Ex. Part number that is pure tin plated: QQW343H(xx)S1T Where T= tin plated
MIL-C-27500	12/10/97 Rev H	To Be Determined		Information not available at time of Advisory release