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CUPROUS OXIDE WIRING CONTAMINATION (RED PLAGUE) CONTROL PLAN

MEASUREMENT SYSTEM IDENTIFICATION: US Customary Units

Prepared By:

Eric Borrero
Digitally signed by Eric Borrero
Date: 2024.03.04 10:54:18 -05'00'

Eric Borrero
GSFC Workmanship Program Manager
Code 373
NASA Goddard Space Flight Center

Approved By:

TRISTRAM HYDE
Digitally signed by TRISTRAM HYDE
Date: 2024.03.26 12:54:44 -04'00'

Tristram T. Hyde
Chief Engineer
NASA Goddard Space Flight Center

Thomas Mccarthy
Digitally signed by Thomas Mccarthy
Date: 2024.05.09 16:16:03 -04'00'

Thomas V. McCarthy
Director of Engineering and Technology
NASA Goddard Space Flight Center

N/A

Cathleen M. Richardson
Director of Flight Projects
NASA Goddard Space Flight Center

DEIRDRE HEALEY
Digitally signed by DEIRDRE HEALEY
Date: 2024.06.26 16:50:11 -04'00'

Deirdre Healey
Director of Safety and Mission Assurance
NASA Goddard Space Flight Center

David Pierce
Digitally signed by David Pierce
Date: 2024.06.26 12:32:01 -04'00'

David L. Pierce
Director of Wallops Flight Facility
NASA Goddard Space Flight Center

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FOREWORD

This standard is published by NASA's Goddard Space Flight Center (GSFC) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

This standard establishes the set of requirements to impose on wire and cable manufacturing activity at GSFC, and its suppliers, for the prevention and control of cuprous oxide corrosion on silver coated copper wire. Requirements herein are a baseline from which controls may be appended to or subtracted from at the discretion of the applicable project.

Requests for information, corrections, or additions to this standard should be submitted via "Contact GTSP" to the Executive Secretary for the GSFC Technical Standards Program on the GSFC Technical Standards website at http://standards.gsfc.nasa.gov.

Michael Viens

Digitally signed by Michael Viens
Date: 2024.03.26 12:30:08 -04'00'

Michael J. Viens
Technical Standard Program Manager
NASA Goddard Space Flight Center

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1. SCOPE

This standard prescribes the minimum requirements for the control of cuprous oxide corrosion (Red Plague) for silver coated copper wires, cables, and harness assemblies.

1.1 Purpose

The purpose of this standard is to address operations where assembly processes, environmental conditions and contamination may promote the development of Red Plague in silver coated copper wires, cables, and harness assemblies.

1.2 Applicability

This document specifically applies to all internal organizations (e.g., GSFC Divisions) that design, develop, manufacture, test, inspect, rework, repair, refurbish or in any way modify silver coated copper cables, harnesses, and electrical/electronic assemblies for GSFC program and project Flight Hardware.

The lead(Pb)-free and Red Plague (cuprous oxide corrosion) requirements in IPC J-STD-001xS and IPC/WHMA-A-620x-S sections 0.1.5 through 0.1.6 do not apply for the minimum baseline requirements although they may be documented and imposed at the discretion of the GSFC program or project.

Programs and projects that choose to follow the Red Plague Control Plan (RPCP) requirements of the J-STD-001 Space Addendum or IPC/WHMA-A-620 Space Addendum may levy this standard.

This standard may be cited in contract, program, mission assurance requirements, and other Agency documents as a technical requirement. Mandatory requirements are indicated by the word "**shall**." Tailoring of this standard for application to a specific program or project **shall** be approved by the Technical Authority (TA) for that program or project.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text of section 4. The latest issuances of cited documents **shall** be used unless otherwise approved by the assigned TA. The applicable documents are accessible via the NASA Technical Standards System at https://standards.nasa.gov/, directly from the Standards Developing Organizations, or from other document distributors.

2.2 Government Documents

a. NASA-STD 8739.6, Implementation Requirements for NASA Workmanship Standards

b. NASA-STD 8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring
c. NASA-STD 8739.11, EEE Parts Selection, Screening, Qualification & Derating
d. MIL-STD-2073-1E, Method 50, Formula 1
e. MIL-I-8835, Indicator, Humidity, Card, Chemically Impregnated

2.3 Non-Government Documents

a. ASTM B298, Standard Specification for Silver Coated Soft or Annealed Copper Wire
b. ASTM B624, Standard Specification for High-Strength, High-Conductivity Copper-Alloy Wire for Electronic Application
c. ASTM B961, Standard Specification for Silver Coated Copper and Copper Alloy Stranded Conductors for Electronic Space Application
d. IPC J-STD-001, Requirements for Soldered Electrical and Electronic Assemblies
e. IPC J-STD-001xS, Space and Military Applications Electronic Hardware Addendum to IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies
f. IPC/WHMA-A-620, Requirements and Acceptance for Cable and Wire Harness Assemblies
g. IPC/WHMA-A-620xS, Space Applications Electronic Hardware Addendum to IPC/WHMA-A-620, Requirements and Acceptance for Cable and Wire Harness Assemblies
h. SAE-ASM-DTL-23053/4, Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Dual-Wall, Outer Wall Crosslinked

2.4 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in applicable documents or referenced guidance documents.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

ASTM	American Society for Testing Materials
COF_2	Carbonyl Fluoride
ETFE	Ethylene Tetrafluoroethylene (wire insulation material)
GSFC	Goddard Space Flight Center
H_2O	Water
HIC	Humidity Indicator Card
i-HIC	Irreversible Humidity Indicator Card
IPC	Institute for Printed Circuits
O_2	Oxygen
PTFE	Polytetrafluoroetheylene (wire insulation material)
RH	Relative Humidity
RPCP	Red Plague Control Plan

TA	Technical Authority

3.2 Definitions

a. Capping – A process involving the sealing of the cut/exposed ends of the wire/cable with a double-wall (melt-liner) heat shrinkable tubing or preformed end cap, or by dip coating with Red Glyptal Insulating Varnish, to create an environmental barrier to oxygen and moisture contamination.

Figure 1 - Glyptal Sealed Wire End

Figure 2 - Heat Shrink Sealed Wire End

b. Desiccant – A chemically inert media used to absorb moisture from the air within a sealed container or package to induce or sustain a level of dryness (desiccation).

c. Dew Point – The temperature at which a volume of air at a given atmospheric pressure reaches saturation and water vapor precipitates and condenses.

d. Dry Pack – An environmental protection system consisting of activated desiccant material, a Humidity Indicator Card (HIC), and water-vapor-proof packaging (i.e., Moisture Barrier Bag).

e. Glyptal (GLPT) – A general-purpose, red-colored, alkyd-based varnish originally developed as an insulating paint for electrical applications such as environmental sealing of high voltage coils.

f. Irreversible (Maximum) Humidity Indicator Card (i-HIC) – A specially designed paper card/strip containing moisture sensitive chemical indicators that will dissolve and permanently change color when the designated relative humidity (RH) level is exceeded for 24 hours or more. The highest percentage spot containing dissolved solids indicates the maximum humidity reached. An i-HIC is a quality record.

g. Red Plague – The sacrificial corrosion of copper in a galvanic interface comprised of silver and copper, resulting in the formation of red cuprous oxide (Cu2O), and less commonly, black cupric oxide (CuO). Galvanic corrosion is promoted by the presence of moisture (H2O) and oxygen (O2) at an exposed copper-silver interface (i.e., conductor end, pinhole, scratch, nick, etc.).

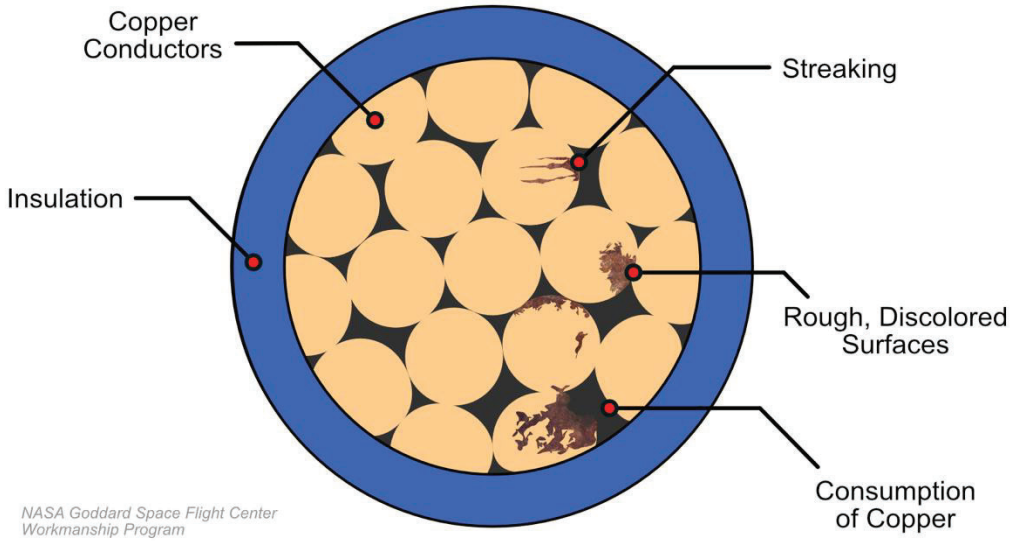

Figure 3 - Cross Section of Wire Afflicted by Red Plague

h. Red Plague Control Plan (RPCP) – A documented set of process controls and material requirements to reduce and mitigate the exposure of silver coated copper conductors to contamination and environmental conditions that promote the development of Red Plague and latent damage.

i. Shelf Life – The length of time during which a material may be stored and remain suitable for use.

j. Stock Wire/Cable/Shield – Wire/Cable/Shielding material which has not been removed from its original packaging or integrated into a cable/harness assembly yet.

k. Use Life – The combined amount of time that a given product has been under assembly, storage before flight, and under test.

4. REQUIREMENTS

4.1 Conductor Strand Material and Coating Requirements

4.1.1 All strands **shall** conform to the applicable American Society for Testing Materials (ASTM) standard(s) for the proper material listed in Table 1.

Table 1 – Silver Coated Copper Conductor Thickness and Specification

Strand Material	Silver Thickness	Application Standard
Annealed copper	1 µm (~40 µin)	ASTM B298
Annealed copper	2 µm (~80 µin)	ASTM B298 ASTM B961
High strength copper alloy	1 µm (~40 µin)	ASTM B298 ASTM B624
High strength copper alloy	2 µm (~80 µin)	ASTM B298 ASTM B624 ASTM B961
Ultra-high strength copper alloy	1 µm (~40 µin)	None

4.1.2 After insulation removal, strands **shall** be free from lumps, kinks, splits, scraped or corroded surfaces, and skin impurities.

4.1.3 Inspection magnification **shall** be per the applicable cable/harness workmanship standard for the assembly.

4.1.4 The silver coating **shall** exhibit a non-porous, smooth, and continuous finish, free from lumps, kinks, splits, scrapes, corrosion, contamination, exposed base metal or coating impurities.

NOTE: Material certification stating compliance to ASTM B961 may be sufficient to meet the above requirement. Material not meeting the Coating and Finish requirements above should be treated as non-compliant material by the applicable processes.

4.2 Procurement Requirements

4.2.1 All stock silver coated copper wire, cable, and piece parts containing silver plated copper wire **shall** be procured in accordance with one of the standards in Table 1, or an alternative standard subject to review and approval by NASA.

4.2.2 All stock silver coated copper wires and cable **shall** be lot traceable to a manufacturer's test report or certificate of compliance.

4.2.3 Silver coated copper wire and cable exceeding 10 years since date of manufacture **shall** be segregated and not be used in harness assemblies or hardware.

4.2.4 Completed cable, harness assemblies, and hardware incorporating silver coated copper conductors with a use life (including storage) exceeding 10 years from the date of assembly **shall** be identified and tracked as a "Limited-Life Item."

NOTE: Surveillance (Functional Test) prior to use is recommended, particularly after long periods of storage. However, functional acceptance testing only verifies that hardware performance has not degraded to a level detectable by the test. As such, the tests cannot be used as "certification" that the tested hardware is corrosion-free – only that the hardware was functional at the time of the test.

NOTE: A Limited Life Analysis should be performed on aging assemblies that contain silver coated copper wire. The analysis should take into consideration the shelf life and use life of the assembly, thermal cycles, mechanical wear, or fatigue, and include refurbishment and maintenance plans.

4.3 Shipping and Storage

Controls for shipping of silver-plated conductors are primarily intended to reduce the likelihood of moisture exposure due to environmental extremes that occur in transit, or other uncontrolled spaces between storage and manufacturing usage of the product. In shipping, sealed containers with desiccant are required. However, extended periods of time in air-tight sealed containers may conflict with controls intended for fluorine outgassing/fluorine attack (white plague), or other corrosion or contamination control requirements. The controls applied to product should be compatible with all materials. See Appendix B.6.

4.3.1 Silver coated copper wire **shall** be shipped in sealed water-vapor-proof packaging (i.e.- Moisture Barrier Bag, dry pack, etc.), with capped ends, activated desiccant, and an irreversible humidity indicator card (i-HIC).

4.3.2 Wire and cable ends **shall** either be:

a. capped with heat shrinkable endcaps, see Appendix A.2.
b. dipped in insulating electrical varnish for a length of approximately 2.5 cm (1 in), or
c. cut off for a length of approximately 2.5 cm (1 in) before use, if uncapped or unvarnished.

4.3.3 The minimum quantity of desiccant to be used **shall** be based on the protective package's interior exposed surface area, in accordance with MIL-STD-2073-1E, Method 50, Formula 1.

4.3.4 The maximum humidity exposure measurements **shall** be recorded using an Irreversible Humidity Indicator Card that can measure 70% RH or lower, or a combination of Irreversible / Reversible humidity indicator that can measure 70% or lower.

NOTE: Many humidity indicator cards are available. The ability to verify that the wire or cable was not subjected to a 70% RH environment in transit or storage is critical.

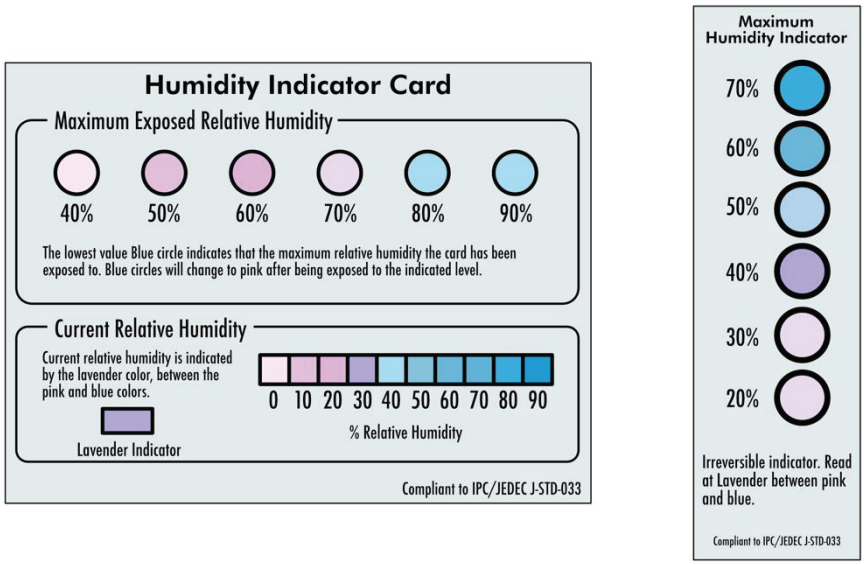

Figure 4 - Humidity Indicator Cards

4.3.5 Wire and cable **shall not** be stored in direct contact with paper materials or wood (e.g., boxes, spools).

NOTE: Paper and wooden packing materials are comprised of fibers and pulp which may flake off or offgas and deposit onto the cable assembly as a contaminant. Wire and cable should not be procured attached to wooden spools. If humidity indicator cards are required to be in contact with the cable assembly, they should be placed in a ventilated bag.

4.3.6 Silver coated copper wire and cable **shall** be protected to reduce and control exposure to environmental conditions and contamination that promote the development of cuprous / cupric oxide corrosion (Red Plague). Protective measures including but not limited to nitrogen dry box, environmentally controlled storage facility, clean room, or a container meeting the shipping and storage requirements in 4.3.

4.4 Assembly

4.4.1 Primary and shield conductors **shall** be visually inspected for mechanical damage and Red Plague prior to installation to a cable/harness assembly.

4.4.2 All silver coated wire **shall** be stored and processed in an environment where the temperature does not reach dew point, and the RH is maintained <70%.

NOTE: Caution should be taken to ensure wire and cable have reached thermal equilibrium with the assembly environment prior to removal from the protective packaging. This is to reduce the risk of condensation formation.

4.4.3 Aqueous solvents (water-based) and automated cleaning systems of any kind **shall not** be used on assemblies containing silver coated wire.

4.4.4 Completed cable, harness assemblies, and hardware incorporating silver coated copper conductors **shall** be identified as containing silver plated copper and include date of assembly with the packaging and associated traceability documents. See 4.2.4.

APPENDIX A – Industry Baseline Document References

Specifications used for materials described herein are located below. These specifications are commonly used industry-wide baselines for environmentally sealed dry packaging and are not a requirement for compliance to this document.

A.1 Water-Vapor-Proof Packaging – MIL-STD-2073-1, Method 51

A.2 Moisture Barrier Bags – MIL-PRF-81705 (Type 1)

A.3 Desiccant – MIL-D-3464 (Type II)

A.4 SAE-ASM-DTL-23053/4 – Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Dual-Wall, Outer Wall Crosslinked

A.5 MIL-I-8835A – Indicator, Humidity, Card, Chemically Impregnated

A.6 IPC/JEDEC J-STD-033 – Handling, Packaging, Shipping and Use of Moisture, Reflow, and Process Sensitive Devices

APPENDIX B – Technical Background

B.1 Technical Background

Red Plague develops in an exposed copper silver interface when a galvanic cell forms between the copper base metal and silver coating promoted by moisture (liquid/condensing H_2O) and oxygen (O_2). Exposed conductor ends (crimp terminations), poor plating quality (pin hole, porosity, thin coating), mechanical damage, corrosion, and wicking of flux or solvent under the Polytetrafluoroethylene (PTFE) jacket are some of the initiating factors in the development of Red Plague. Once initiated, the sacrificial corrosion of the copper base conductor can continue indefinitely in the presence of moisture and O_2. The color of the corrosion by-products may vary depending on the amount of oxygen available but is commonly noted as a red/reddish-brown discoloration on the silver coating surface, hence the term “Red Plague”. The following are some of the main contributors to the development of Red Plague in silver coated copper wires"

B.2 Mechanical Damage

One of the primary initiators of the Red Plague is the mechanical damage during the manufacturing, resulting in damage of the silver coating. The damage to the coating exposes the copper-silver interface to atmospheric moisture and O_2. Other sources of mechanical damage include improper assembly and installation practices such as excessive flexing and improper bend radius. Silver coatings on stranded wire are particularly susceptible to mechanical damage due to microscopic movement between the strands when bent, moved, or otherwise subjected to vibration.

B.3 Environmental conditions

A galvanic cell must form between the copper base metal and silver coating in the presence of liquid or condensing water (H_2O) and O_2. Protection from high humidity levels and other contaminants such as flux, aqueous solvents and other cleaning systems is considered the greatest significant mitigation against Red Plague.

B.4 High Temperature

Though the upper continuous operating temperature rating of most silver coated wiring is +200 °C (+392 °F), exposure to temperature approaching +200 °C (+392 °F) or higher, induces migration of the copper base metal through the silver coating which may reduce the coating thickness resulting in creation of porosity sites for cuprous oxide corrosion to occur. This effect takes place typically only in long duration operation (100’s of hours) at temperature beyond the wire’s continuous rating, or where the wiring is exposed to excessive heat during test or high accelerated burn-in.

NOTE: Short term transient temperatures in excess of 200°C, such as those experienced during solder reflow, are not a contributor to Red Plague.

B.5 Chemical Attack

Exposure to chemicals present in the environment (oxygen, sulfur compounds, salt, etc.) may result in corrosion and corrosion by-products that attack and compromise the mechanical integrity of the silver coating. Common "green" packaging materials such as paper wrapping materials, rubber bands, wooden crates, and cardboard boxes, often contain and offgas small amounts of sulfur. Exposure to condensing and corrosive atmospheres such as coastal launch facilities also pose a significant risk.

B.6 White Plague

Fluorine attack, also known as ‘white plague’, can develop in fluoropolymer-insulated wires and cables when carbonyl fluoride (COF_2), an extremely reactive compound, is released. The following materials are known insulation materials which release COF_2, and must have sufficient ventilation in storage:

- Polytetrafluoroethylene (PTFE)
- Ethylene Tetrafluoroethylene (ETFE)
- Tetrafluoroethylene (TFE)
- Perfluoroalkoxy (PFA)
- Cross-Linked Modified Ethylene Tetrafluoroethylene (XL-ETFE)

This may require wire/cable with insulation of this type to be stored in a nitrogen purged dry box environment, or an open-air environment where humidity is controlled.