# An Investigation of Whisker Growth on Tin Coated Wire and Braid

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**Abstract**
Pure tin is a common finish for copper hook up wire, coaxial cable, ground braid and harness assemblies used on electronic assemblies. Historically there have been fewer reports of whisker growth on tin coated copper wire than on other types of tin coated parts. This paper presents data from humidity- temperature conditioning and electron microscopy inspection of tin coated wire specimens of various size and age. After 4000 hours of 85°C/85%RH conditioning, some of the wires showed tin whisker growth, but the growth was very sparse with near zero density distribution and whisker lengths were typically less than 10 microns. The data indicate very low risk for whisker growth on tin coated copper wire, braid and cable.

Key words: tin coating, tin whisker, wire, braid, cable, intermetallic compound

**Introduction**
Electrodeposited and dipped layers of tin can spontaneously generate hair-like conductive surface growths known as "tin whiskers." Whiskers develop in any environment: ground or vacuum/space, wet or dry, applied power vs. no power. The time period before whiskers start to grow from a tin surface, known as the "incubation period," can vary between minutes and decades.

This paper continues the evaluation of whisker growth on tin-coated wire and cable. Thirteen samples of tin-coated wire and braid, manufactured between 1965 and 2009, from 5 different suppliers, were analyzed by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) to evaluate the material composition, size and density of whiskers. The samples were subjected to JESD201 testing in an attempt to accelerate whisker growth.

**Specifications and Literature Data**
Pure tin is a common coating on bus wire, stranded wire, coaxial cable, and ground braid products. Several commercial and military specifications call out tin coating, including MIL-DTL-17, AA-59551 (superseding QQ-W-343), NEMA-WC27500 (superseding MIL-DTL-27500) and SAE-AS22759 (superseding MIL-W-22759).

Literature data on whisker growth on tin plated wire and cable were reviewed in reference [1]. Analysis of whisker growth on tin coated wire and cable dates back to the 1950s, however, there is no mention of significant whisker growth on these specific types of tin plated product. Several references suggest that there is little to no risk for substantial whisker growth on tin coated wire and cable. In 1992, MIL-STD-1547 ("Electronic Parts, Materials and Processes for Space and Launch Vehicles rev B") was revised to include an exemption for tin plated drawn wire products, such as cables, shielding and ground straps. All other types of tin plated components were prohibited from use on space and launch vehicles. A recent update to this standard (Aerospace Corp. TOR-2006-8583-5236, dated 2006) also allowed for the use of tin-plated wire in high reliability applications.

**Procedures**

**Test Specimens**
A total of nine wires and four braided cables were selected for the investigation. The age, storage conditions and supplier data varied widely. Aluminum specimen holders were fabricated for holding the test specimens to minimize the rigors of handling and to aid in tin whisker inspection/examinations. Figure 1 illustrates some of the test specimens mounted in the specimen holders. Table 1 and Table 2 list the wire and cable basic data.

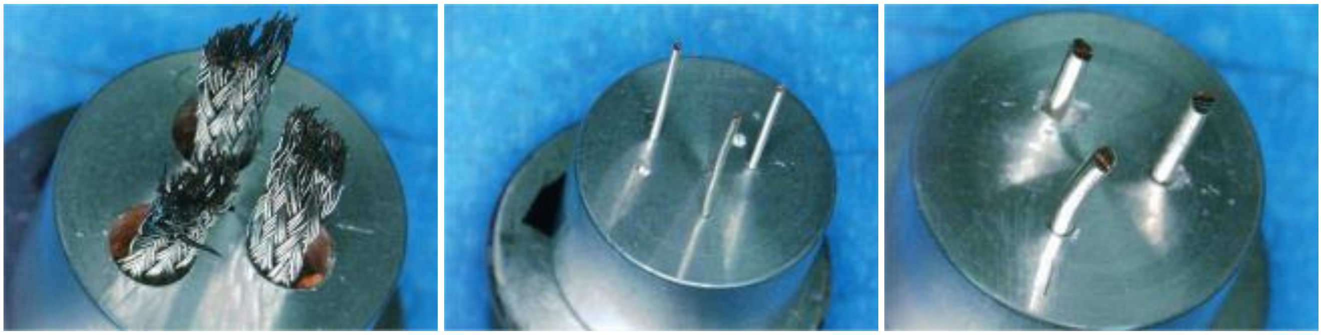

**Figure 1: Examples of Test Specimens in Aluminum Specimen Holders Ready for Inspection**

**Table 1: Investigation Wire Data**

| Sample ID# | Description | Supplier | Location | Year of Manufacture | Storage Conditions | Quantity | Average Diameter (inches) | Length (inches) |
|---|---|---|---|---|---|---|---|---|
| 2 | 22-1-7C Sn coated bus wire | Blake | NGIS Rancho Carmel, CA | 2002 | Uncovered | 1 | 0.0248 | 8.5 |
| 11 | QQ-W-343 type H 16 AWG Sn coated bus wire | Belden | NGAS Redondo Beach, CA | 1966 | Closed Drawer | 1 | 0.0512 | 2.5 |
| 12 | EO8237R QQW343 type H 20 AWG Sn coated bus wire | Victor | NGAS Redondo Beach, CA | 1965 | Closed Drawer | 1 | 0.0325 | 6 |
| 14 | QQW343 type S 24 AWG Sn coated bus wire | Camden | NGAS Redondo Beach, CA | 1982 | Closed Drawer | 1 | 0.0204 | 11.5 |
| 15 | EW-8815 Sn coated bus wire | Victor | NGAS Redondo Beach, CA | 1965 | Closed Drawer | 1 | 0.0322 | 5.125 |
| 19 | EW8812 12 AWG Sn coated bus wire | National | NGAS Redondo Beach, CA | 1966 | Closed Drawer | 1 | 0.0644 | 7.75 |
| 20 | QQW343 Type S 26 AWG Sn coated Cu bus wire | Blake | NGAS Redondo Beach, CA | 1995 | Closed Drawer | 1 | 0.0162 | 7.25 |
| 24 | Electroplated | Blake | Unknown | 2009 | Closed Drawer | 1 | 0.02 | 4.5 |
| 25 | Hot Dipped | Blake | Unknown | 2009 | Closed Drawer | 1 | 0.02 | 4.5 |

**Table 2: Investigation Braided Cable Data**

| Sample I.D. | Supplier | Year of Manufacture | Storage conditions | Braid length (in) | Average braid width (in) | Average braid height (in) | Individual strand quantity | Average diameter (in) | Length (in) |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Cont. Cordage | 2007 | Uncovered | NA | NA | NA | ~100 | 0.0051 | 1 |
| 5 | Belden | 1986 | Uncovered | 4 | 0.1723 | 0.02895 | ~30 | 0.0063 | 1 |
| 21 | Blake | 2003 | Closed drawer | 3.75 | 0.1379 | 0.0443 | ~15 | 0.0062 | 1.25 |
| 22 | Cont. Cordage | 2008 | Closed drawer | 1.75 | 1.075 | 0.1108 | NA | NA | NA |

**JESD201 Conditioning**

The JEDEC JESD201 specification is widely used by the component fabrication industry [2]. The JESD201 specification defines the test conditioning parameters, inspection and tin whisker dimensional acceptability requirements. The JESD201 specification is not universally accepted across the Defense electronics community. Some users consider the results of the testing to only be appropriate for characterizing a specific plating bath or component lot evaluation for tin whisker susceptibility. However, many others in the industry feel that the specification requirements provide an industry-consistent indicator of component fabricator process capability and process consistency. Table 3 illustrates the JESD201 maximum tin whisker length criteria. The specification utilizes three conditioning parameter sets: (1) 4000 hours of ambient (30°C/65RH) conditioning; (2) 1500 thermal cycles (-55°C - +85°C thermal range); (3) 4000 hours of 55°C/85RH high temperature/ high humidity conditioning.

**Table 3: JESD201 Maximum Tin Whisker Length Criteria [1]**

**Table 5a — Technology Acceptance Criteria for Maximum Allowable Tin Whisker Length**

| **Considerations** (Component Type, Lead Pitch or Operating Frequency) | **Maximum Allowable Whisker Length** | | | |
|---|---|---|---|---|
| | **Class 3** | **Class 2** | **Class 1** | **Class 1A** |
| **2 Lead SMD Components** | Pure tin and high tin content alloys are not typically allowed | 40 µm for Temperature/Humidity Storage and High Temperature/Humidity Storage<br>45 µm for Temperature Cycling | 67 µm[1] | 50 µm for Temperature Cycling and High Temperature/Humidity Storage |
| **Multi-Leaded Components** | | | 67 µm[1] | |
| **High Frequency Components[2]** | | | 50 µm | 20 µm for Temperature/Humidity Storage |
| **Components with a minimum lead-to-lead gap >320 µm** | | | 100 µm | 75 µm |

NOTE 1 This spacing accounts for up to 0.05 mm bent leads. The maximum of the 67 µm accounts for adjacent discrete components.

NOTE 2 It is reported that the susceptibility to electrical performance degradation associated with tin whiskers increases with frequency. (RF Components >6 GHz, or Digital Components $T_{rise}$ <59 ps).

## Testing Parameters

A modified JESD201 test parameter matrix was followed for the wire and cable investigation. The following test parameter matrix was used:

- No JESD201 process 'preconditioning' conducted on component test specimens
- Optical and Scanning Electron Microscope (SEM) conducted for each sampling period
- Optical lighting configuration used was in accordance with the NASA Goddard recommendations [3]
- Sampling period consisted of 500 hour intervals
- Specific and random surface areas/regions of each wire/cable was inspected for tin whiskers for each sampling period
- Component conditioning parameters used:
  - High Temperature/Humidity: 4000 hours, 85°C /85% RH, non-condensing environment

Figure 2 illustrates the test chambers used for the conditioning portion of the investigation:

**Figure 2 Conditioning Chambers: High Temperature/Humidity**

**Inspection Criteria**
Optical and scanning electron microscope (SEM) inspection was conducted for each sampling period. A sampling period consisted of 500 hour intervals. An optical lighting configuration was used in accordance with the NASA Goddard recommendations [3] and all surface areas of each test specimen were inspected for tin whiskers. Optical inspection was conducted using magnifications ranging from 10X to 200X and SEM was conducted using magnifications ranging from 100X to 5000X magnification.

**Test Results**
Summaries of each inspection interval are documented in the following sections. It should be noted that the test vehicles were not cleaned during the entire conditioning sequence duration to prevent the accidental removal of tin whiskers. Extraneous debris did accumulate over time making the inspection efforts more difficult.

**Zero Hour Inspection Interval**
Test specimen #2 was the only specimen that had tin whiskers observed at the zero hour inspection interval. The tin whiskers on test specimen #2 were very small with lengths less than 10 um with no measureable area density. Figure 3 illustrates the typical tin whisker found on specimen #2. No tin whiskers were found on the other test specimens during the inspection interval. There was evidence of external debris, scratches, nicks and other handling type indications recorded. Figure 4 illustrates those observations for test specimen #5.

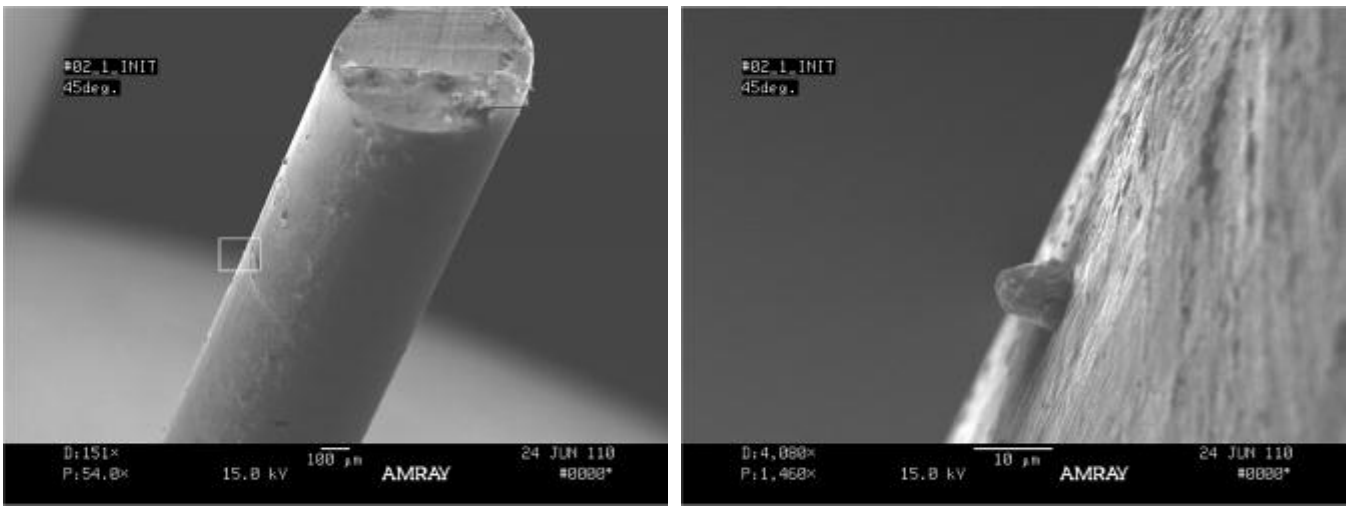

**Figure 3: Typical Tin Whisker Observed on Test Specimen #2 during Zero Hour Inspection Interval**

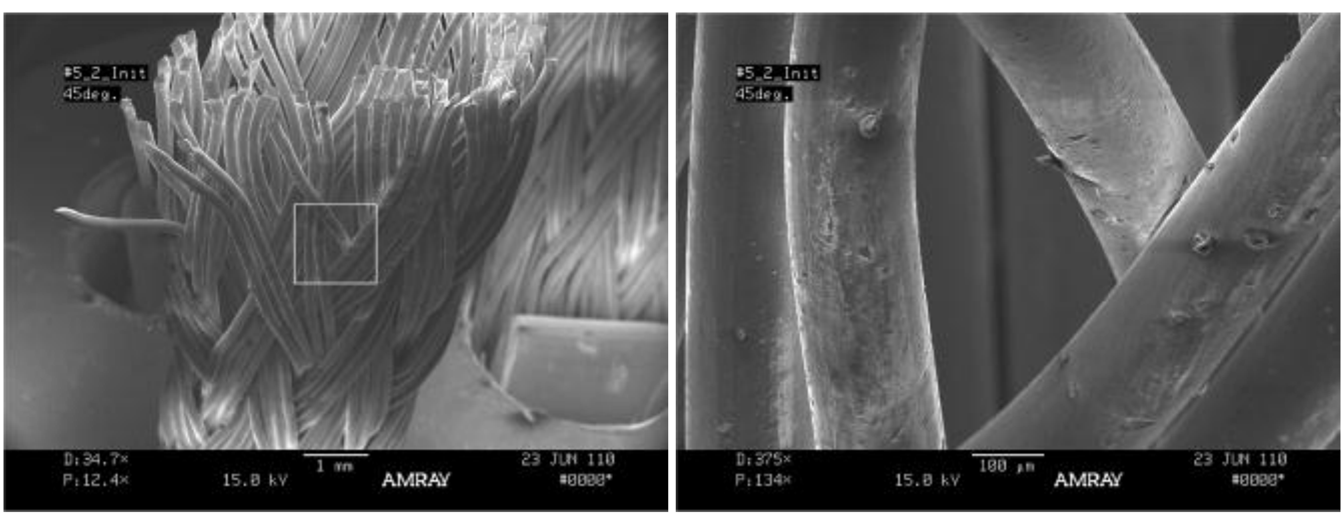

**Figure 4: Typical No Tin Whisker Observation (Test Specimen #5) during Zero Hour Inspection Interval**

**500 Hour Inspection Interval**

The 500 hour inspection interval yielded the documentation of tin whiskers on 3 other test specimens – test specimen's #4, #14 and #15. The tin whiskers observed were very small (10 um or less in length) and were single isolated instances (see Figure 5, Figure 6, Figure 7). The tin whiskers observed on test specimen #2 at the zero hour inspection interval did not appear to grow/change. A single instance of a tin whisker in the 10-20 um length was observed on test specimen #2 (Figure 8).

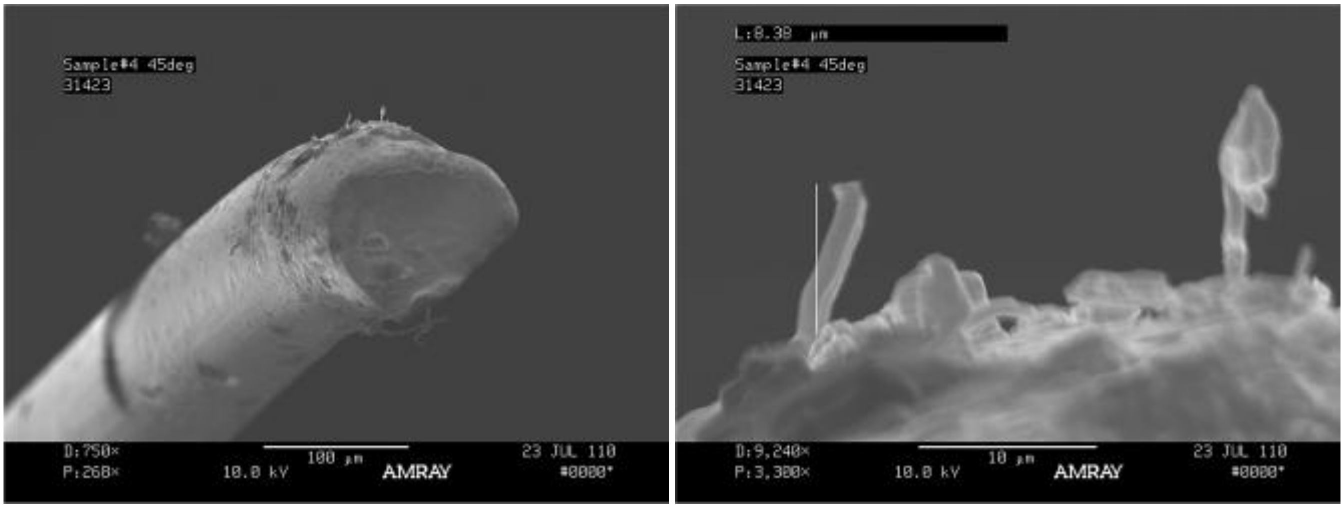


**Figure 5: Typical Tin Whisker Observation (Test Specimen #4) during 500 Hour Inspection Interval**

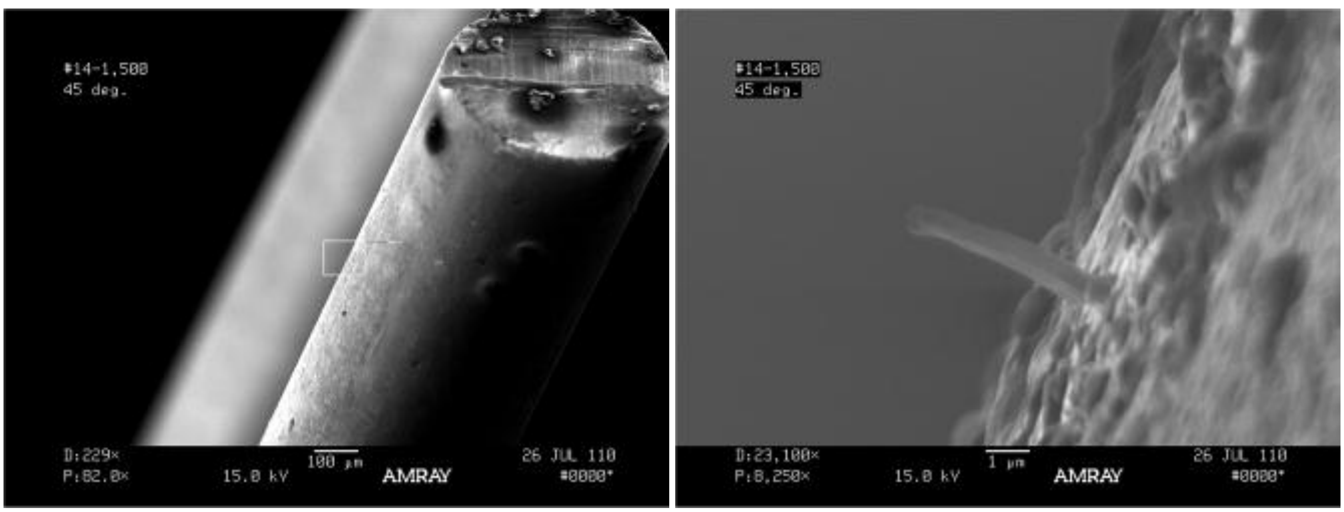


**Figure 6: Typical Tin Whisker Observation (Test Specimen #14) during 500 Hour Inspection Interval**

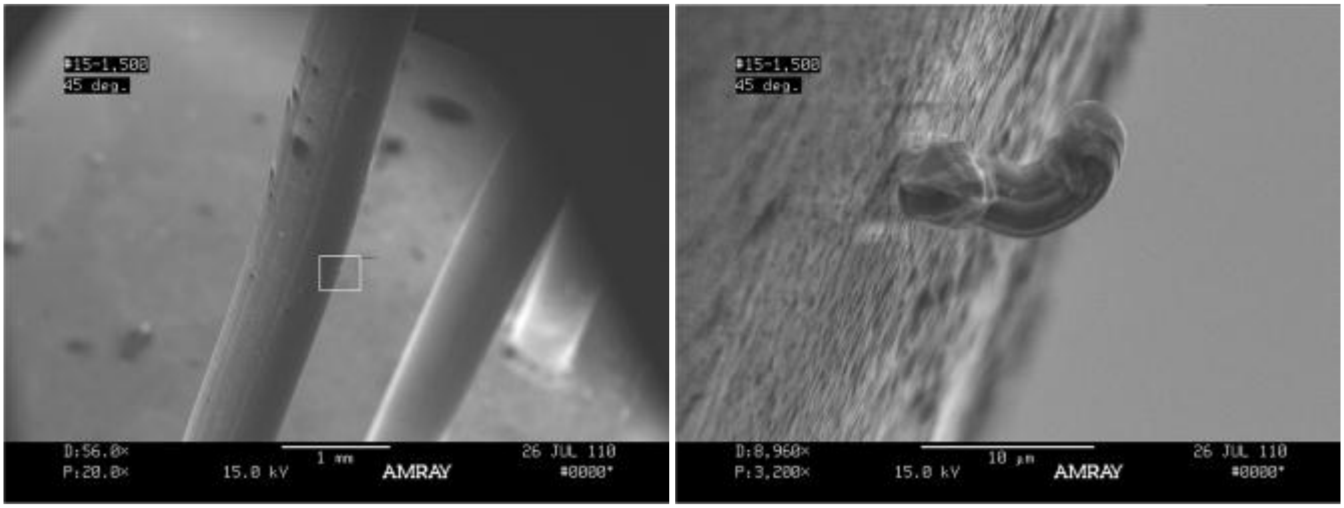


**Figure 7: Typical Tin Whisker Observation (Test Specimen #15) during 500 Hour Inspection Interval**

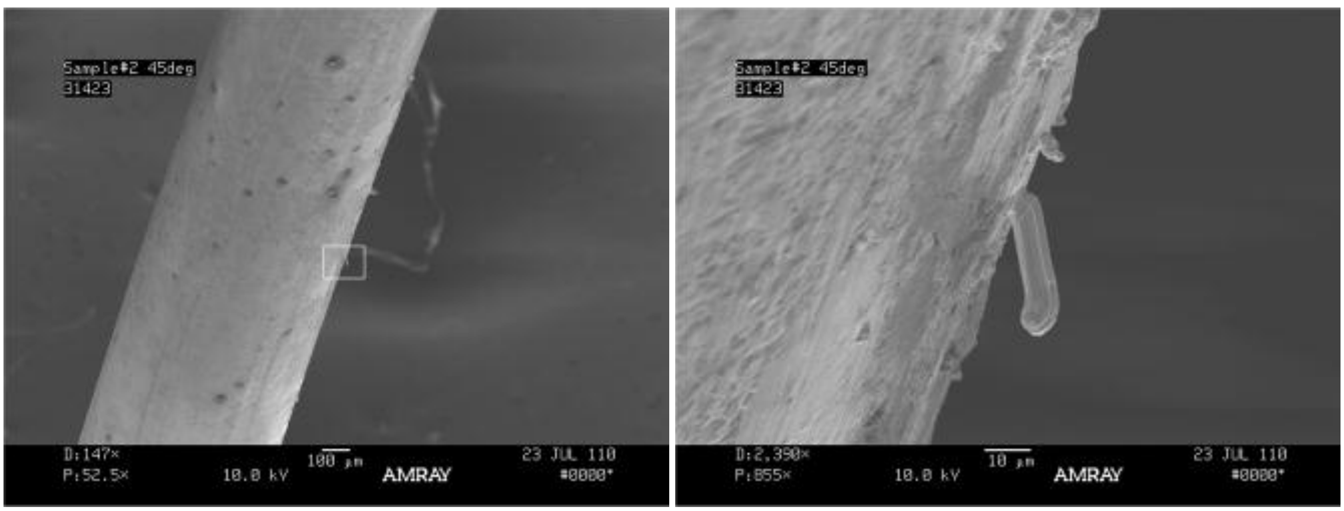


**Figure 8: Typical Tin Whisker Observation (Test Specimen #2) during 500 Hour Inspection Interval**

**1000 Hour Inspection Interval**

The 1000 hour inspection interval observations were a mixed bag of information. The tin whiskers observed on test specimens #4 and #15 had no changes in length or group density. The tin whiskers previously observed on test specimen #2 did not appear to grow/change (Figure 9). Several instances of short, contorted tin whisker clusters were observed on test specimen #14 (Figure 10). Tin whiskers were observed for the first time on test specimen #19. The tin whiskers observed were very small (10 um or less in length) and were in isolated, contorted clusters (Figure 11). No tin whisker occurrences were observed on the other test specimens.

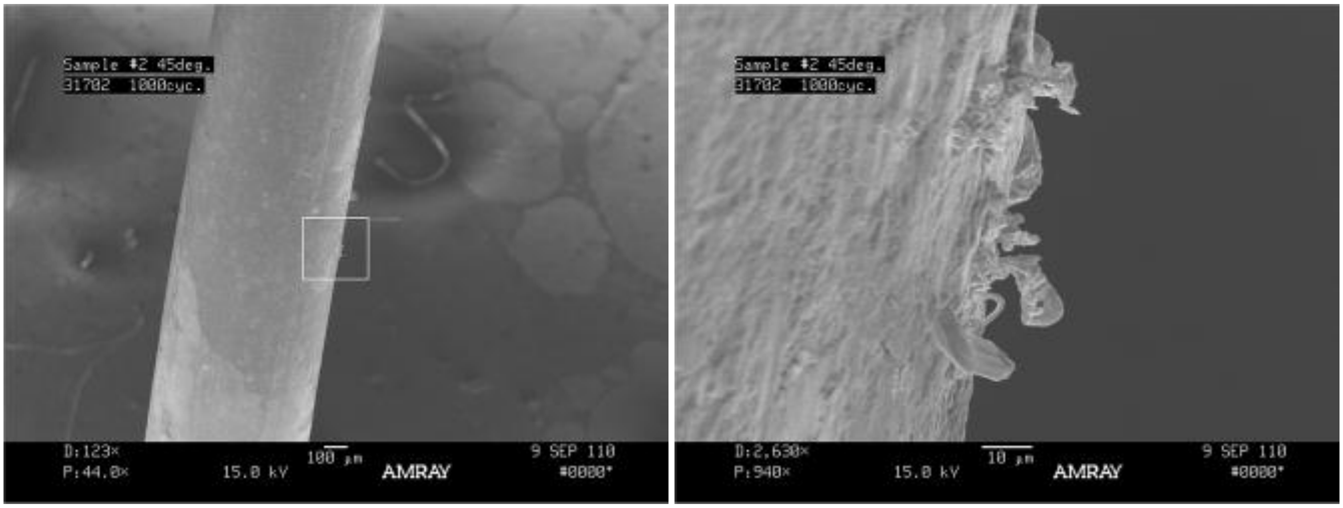


**Figure 9: Typical Tin Whisker Observation (Test Specimen #2) during 1000 Hour Inspection Interval**

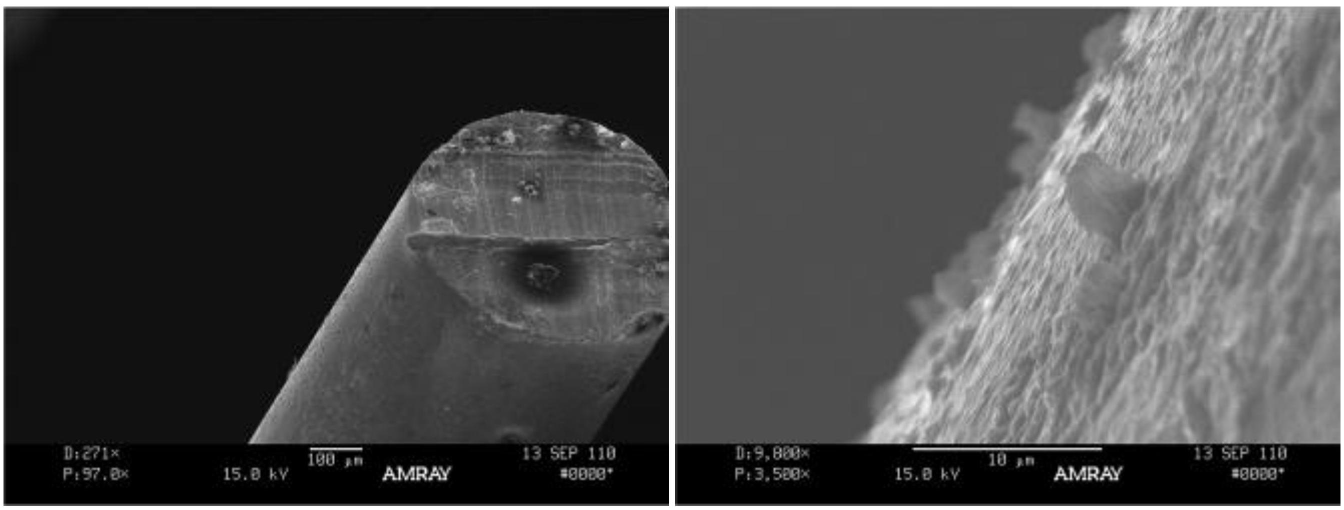


**Figure 10: Typical Tin Whisker Observation (Test Specimen #14) during 1000 Hour Inspection Interval**

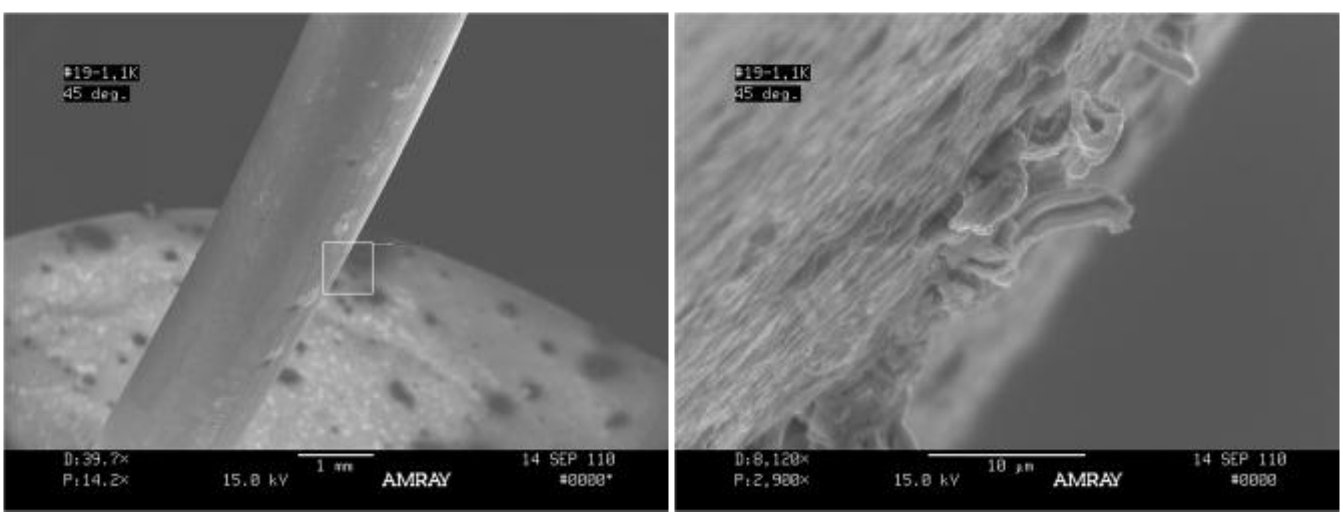


**Figure 11: Typical Tin Whisker Cluster Observation (Test Specimen #19) during 1000 Hour Inspection Interval**

**1500 Hour Inspection Interval**

The 1500 hour inspection interval observations again were a variety of changes. The tin whiskers observed on test specimens #15 and #19 had no changes in length or area density. The tin whisker clusters previously observed on test specimen #2, #4 and #14 at 1000 hours had some density growth with individual cluster groups becoming more populated (Figure 12, Figure 13, Figure 16). Tin whiskers were observed for the first time on test specimen #11 and #12. The tin whiskers observed on both of these test specimens were very small (10 um or less in length) and were isolated with little group density (Figure 14, Figure 15). No tin whisker occurrences were observed on the other test specimens.

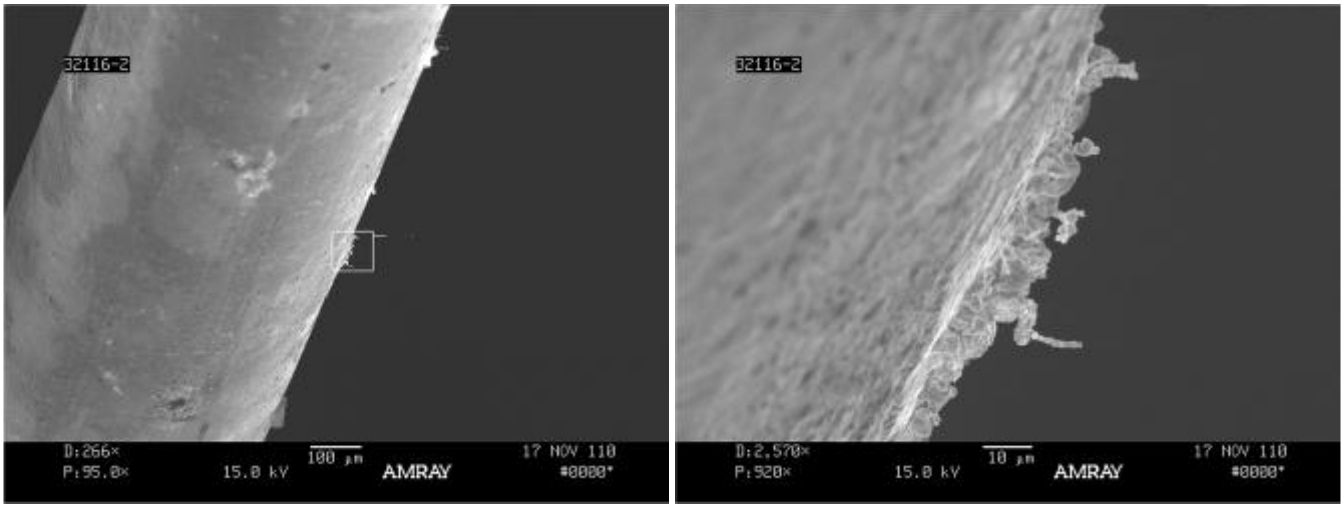


**Figure 12: Typical Tin Whisker Cluster Observation (Test Specimen #2) during 1500 Hour Inspection Interval**

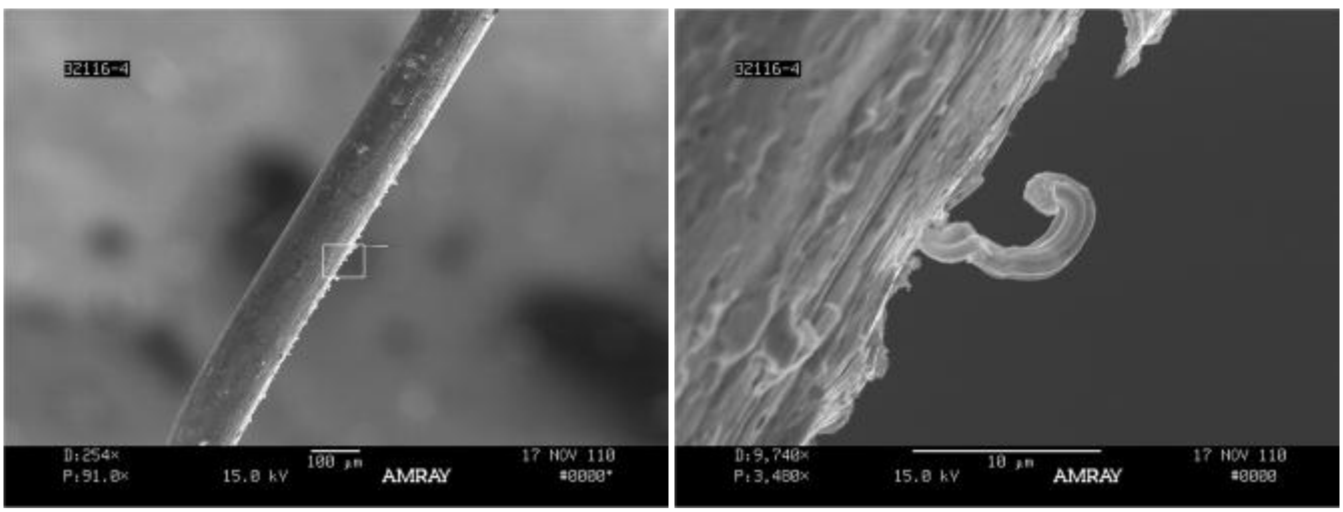


**Figure 13: Typical Tin Whisker Observation (Test Specimen #4) during 1500 Hour Inspection Interval**

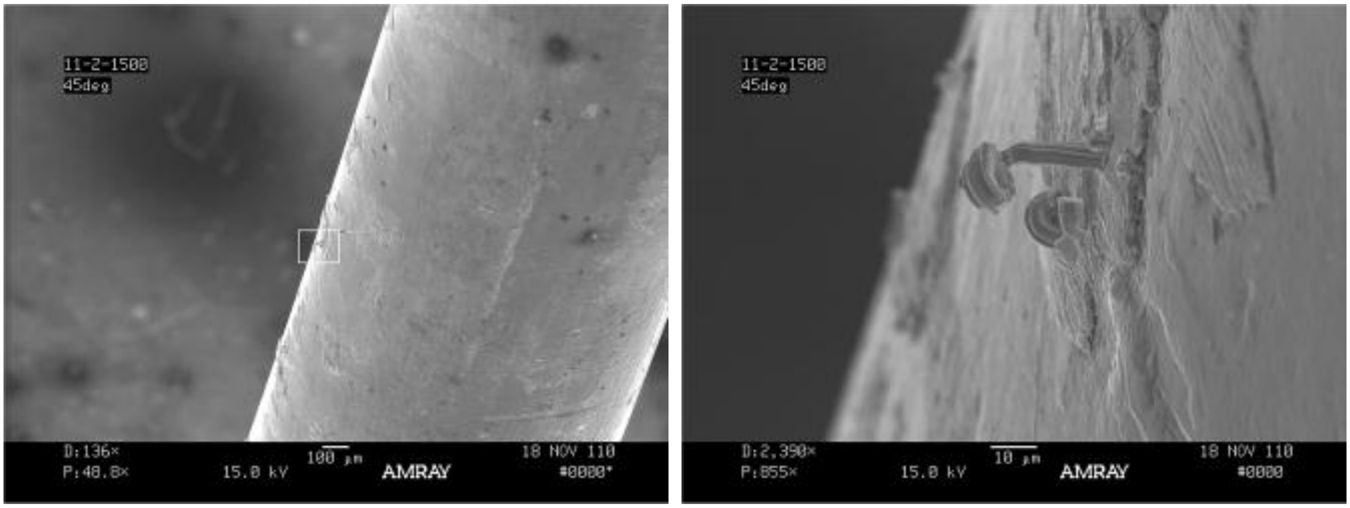


**Figure 14: Typical Tin Whisker Observation (Test Specimen #11) during 1500 Hour Inspection Interval**

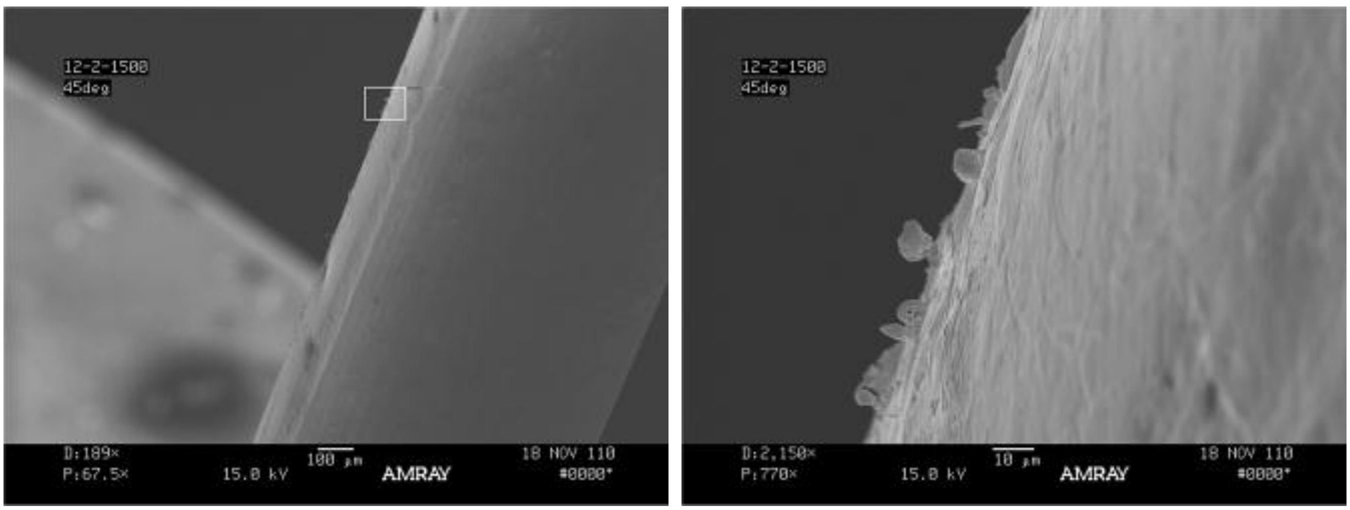


**Figure 15: Typical Tin Whisker Observation (Test Specimen #12) during 1500 Hour Inspection Interval**

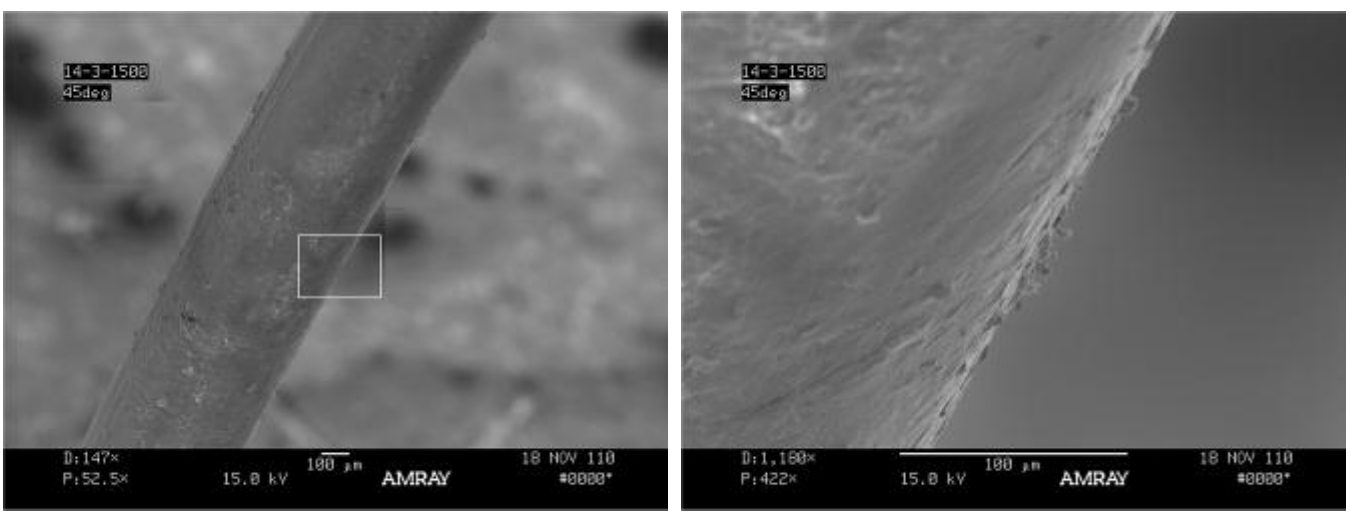


**Figure 16: Typical Tin Whisker Observation (Test Specimen #14) during 1500 Hour Inspection Interval**

**2000 Hour Inspection Interval**

The biggest trend of the 2000 hour inspection interval was the lack of tin whisker growth activity. The tin whiskers observed previously on test specimens # 2, #4, #11, #15, and #19 had no changes in length or group density. A single occurrence of a large, clumpy shaped tin whisker was documented on test specimen #12 (Figure 17). The most interesting observations of this inspection interval were the tin whiskers clusters observed on test specimen #14 were approximately 10 um increased lengths (Figure 18). The tin whiskers were measured in the 10-30 um and were severely contorted. No tin whisker occurrences were observed on the other test specimens.

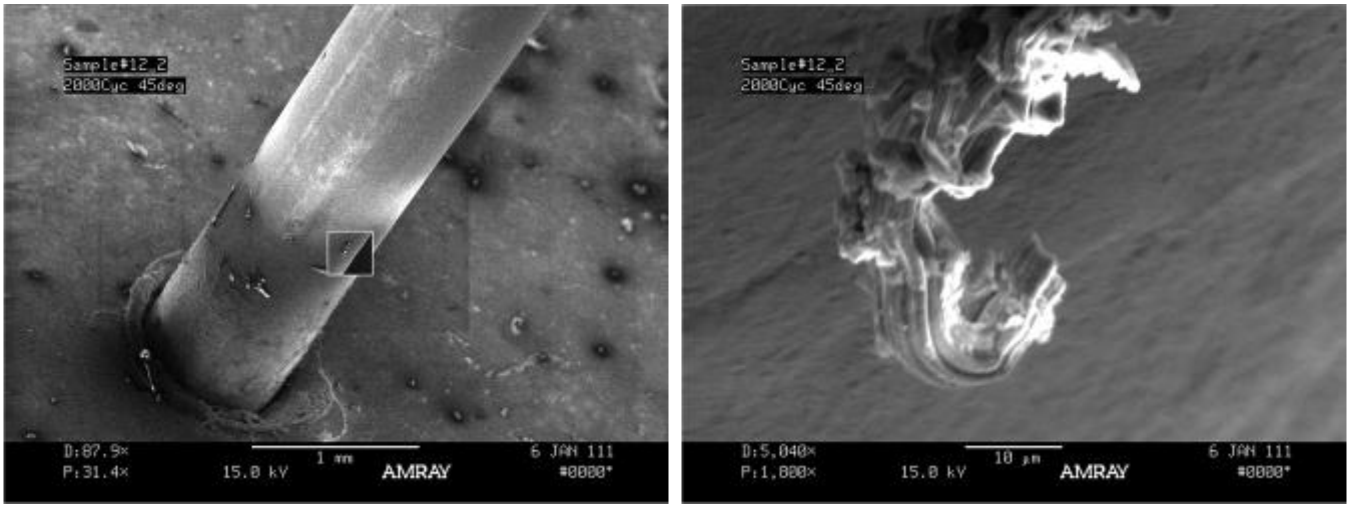


**Figure 17: Large Tin Whisker Observation (Test Specimen #12) during 2000 Hour Inspection Interval**

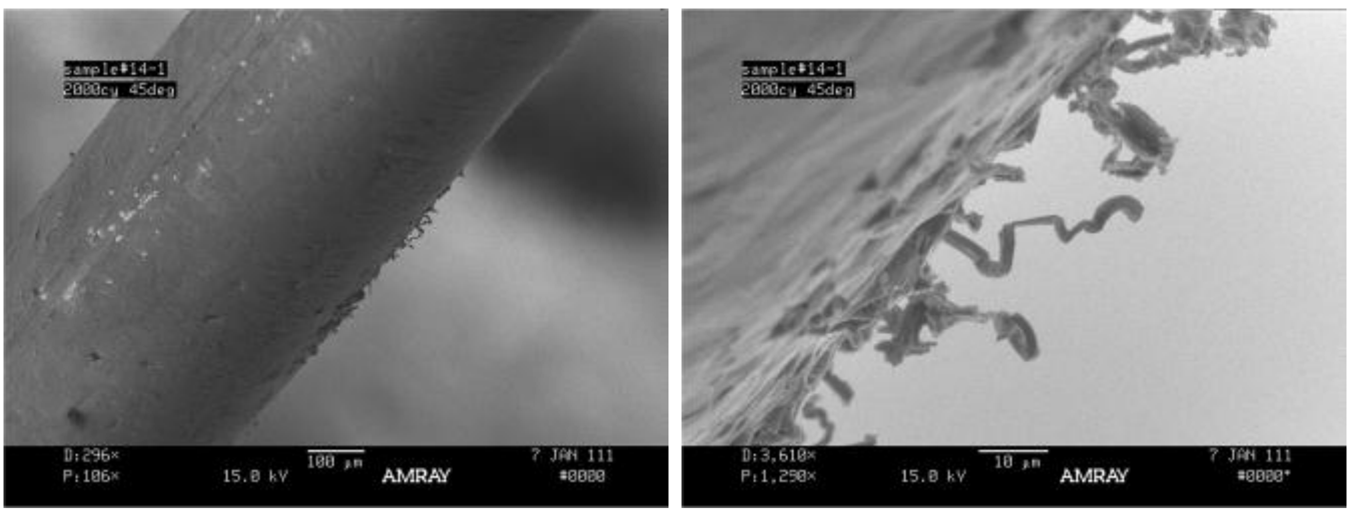


**Figure 18: Tin Whisker Observation (Test Specimen #14) during 2000 Hour Inspection Interval**

**2500 Hour Inspection Interval**

The biggest trend of the 2500 hour inspection interval was the complete stagnation of tin whisker growth activity. No changes in the tin whisker previously observed on test specimens or any occurrences were observed on the other test specimens that had yet to register a tin whisker observation.

**3000 Hour Inspection Interval**

The 3000 hour inspection interval observations documented only one test specimen change from the previous 2500 inspection interval observations as tin whisker growth remained unchanged. The tin whiskers documented on specimen #11 at the 1500 hour inspection interval began to form small cluster groups in a similar fashion as observed on test specimens #2 and #4 at earlier inspection intervals. Figure 19 illustrates the tin whisker clusters observed on test specimen #11 during the inspection.

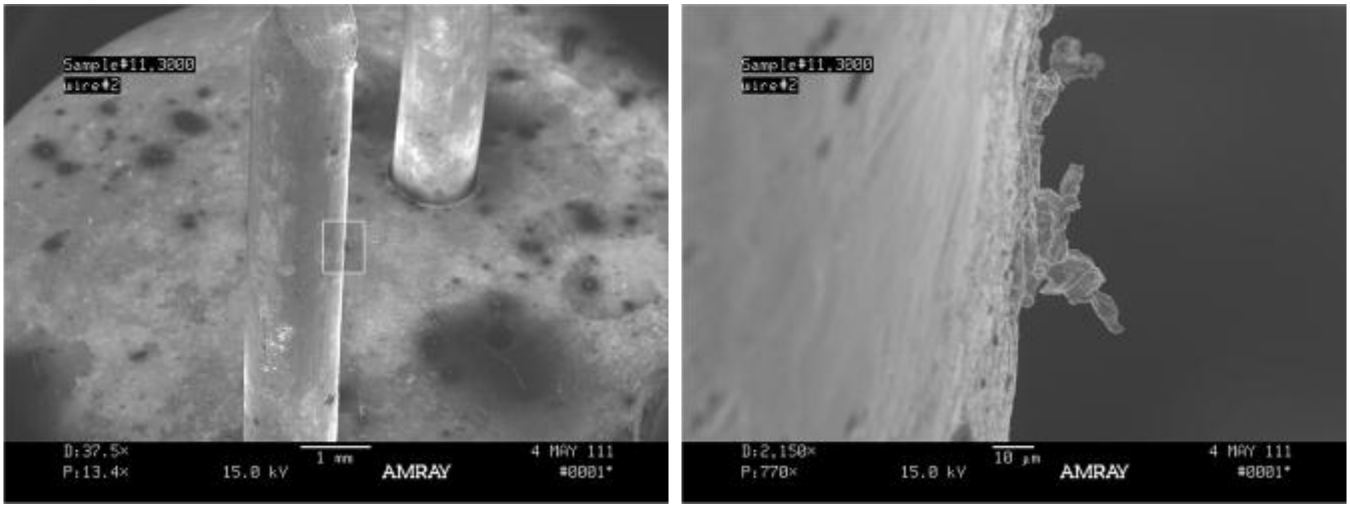


**Figure 19: Tin Whisker Cluster Observation (Test Specimen #11) during 3000 Hour Inspection Interval**

**3500 Hour Inspection Interval**

The 3500 hour inspection interval was not conducted due to SEM equipment issues. The time duration between the completion of a 500 hour conditioning interval and the initiation of the subsequent 500 hour inspection interval had been maintained up to this point of the investigation. The amount of time required to complete an inspection interval was three-four weeks.  It was decided that it would be better to skip the 3500 hour inspection internal rather than introduce a new exposure variable especially with only one final inspection interval (4000 hours) remaining in the test.

**4000 Hour Inspection Interval**

The 4000 hour inspection interval observations documented no changes in the test specimen tin whisker growth activity as they remained unchanged. Test specimen #14 was observed to have severe surface morphology changes occurring which was not observed on any other test specimens (Figure 20). The authors initially suspected that the surface morphology change might be an indication of tin pest but in-depth SEM analysis of the test specimen #14 revealed that that plating was delaminating/flaking from the wire surface.

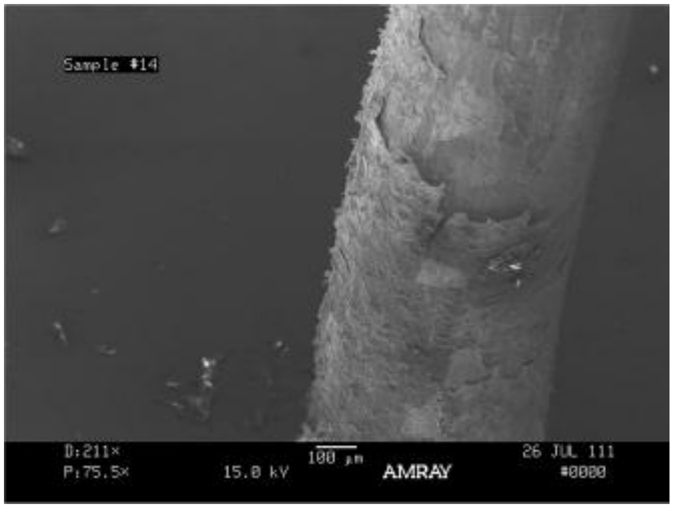


**Figure 20: Severe Surface Morphology Change Observation (Test Specimen #14) during 4000 Hour Inspection Interval**

**Discussion**

A rigorous investigation of these wires and cables conducted in 2009 included SEM and metallographic analysis found no tin whisker instances on any of the samples despite a wide variety of factors: 10 suppliers, up to 44 years of age, and uncontrolled handling/storage procedures [1]. The current investigation was able to cause minor tin whisker initiation and growth using a high temperature/high humidity conditioning methodology. The tin whiskers produced during the 4000 hours of conditioning can be characterized as follows.

- Morphology: single crystal, isolated, many instances of severely contorted
- Length: small, typically less than 10 um in length, with some isolated instances of 10-30 um lengths being observed
- Density: some instances of small, isolated tin whisker converting to small isolated cluster groups
- Growth: random, non-linear, erratic, in a large number of test specimens nonexistent

Table 4 illustrates a tin whisker activity summary over the 4000 hours of conditioning for the test specimens used in the test. Of the 13 test specimens included in the investigation, only test specimen #14 was documented to have some segment of continuous tin whisker activity.

**Table 4: Investigation Tin Whisker Initiation/Growth Activity During Testing**

| Sample ID# | Description | Year of Manufacture | Sample Inspection Interval (hours) | | | | | | | | Max Whisker Length Observed (um) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 4000 | |
| 2 | 22-1-7C Sn coated bus wire | 2002 | Yes | No | No | Yes | No | No | No | No | 20 |
| 11 | QQ-W-343 type H 16 AWG Sn coated bus wire | 1966 | No | No | No | Yes | No | No | Yes | No | 25 |
| 12 | EO8237R QQW343 type H 20 AWG Sn coated bus wire | 1965 | No | No | No | Yes | No | No | No | No | 10 |
| 14 | QQW343 type S 24 AWG Sn coated bus wire | 1982 | No | Yes | Yes | Yes | Yes | No | No | No | 30 |
| 15 | EW-8815 Sn coated bus wire | 1965 | No | Yes | No | No | No | No | No | No | 13 |
| 19 | EW8812 12 AWG Sn coated bus wire | 1966 | No | No | Yes | No | No | No | No | No | 10 |
| 20 | QQW343 Type S 26 AWG Sn coated Cu bus wire | 1995 | No | No | No | No | No | No | No | No | 0 |
| 24 | Electroplated | 2009 | No | No | No | No | No | No | No | No | 0 |
| 25 | Hot Dipped | 2009 | No | No | No | No | No | No | No | No | 0 |
| 4 | QQB575R36T0500 Sn coated 1/2" braid | 2007 | No | Yes | No | Yes | No | No | No | No | 15 |
| 5 | 1188 Sn coated 1/8" braid | 1986 | No | No | No | No | No | No | No | No | 0 |
| 21 | C260796-001 QQB575 Sn coated Cu 1/8" braid | 2003 | No | No | No | No | No | No | No | No | 0 |
| 22 | QQB575R30T1000 Sn coated Cu 1" Braid | 2008 | No | No | No | No | No | No | No | No | 0 |

**Key - Green indicates no tin whisker activity, Red indicates tin whisker activity**

There was no apparent correlation between tin whisker activity and the thickness of the tin coating or intermetallic compound thickness. Three of the 9 wire samples, and 3 of 4 braid samples, showed no tin whiskers after the inspection. Five out of 5 samples manufactured before 1982 showed whisker activity. Two out of 8 samples manufactured after 1982 showed whisker activity. None of the tin whiskers observed exceeded 30 um in length which is below the JESD201 maximum tin whisker length 40 um value for Class 2 high temperature/high humidity conditioning. The typical tin whisker length measured for all samples when tin whiskers were observed was 10um.

## Conclusions

The tin whiskers observed and documented on a small sample size of wire and cable specimens, subjected to the high temperature/high humidity conditioning, were characterized as low risk potential for causing product issues.

Whisker suppression in tin electroplated wires is most likely due to a combination of relatively thin plating, geometry (no sharp edges) and post-plating processing operations that may relieve stresses in the tin layer. None of these three factors appear to be a cure-all for whisker growth, but the combination of factors appears to be effective in suppressing whisker growth. In hot tin dipped and electroplated wires with thin (type S) tin coating, whisker suppression is likely enhanced due to copper-tin intermetallic compound growth that consumes the tin layer a short time after manufacture.

It can be concluded that electrodeposited and redrawn tin plated wire, braid and cable products can be used on high reliability hardware with no further steps necessary to mitigate tin whisker growth.

## Acknowledgements

The authors would like to thank Brian Smith, Rockwell Collins, for SEM fixture assistance.

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1. T. Lesniewski, “Assessment of Whisker Growth from Tin Coated Wire and Cable”, 2009 SMTAI Conference, pg 619-627.
2. JEDEC Standard, JESD201, “Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes”, March 2006.
3. Web Site: http://nepp.nasa.gov/WHISKER/experiment/exp2/index.html#current.

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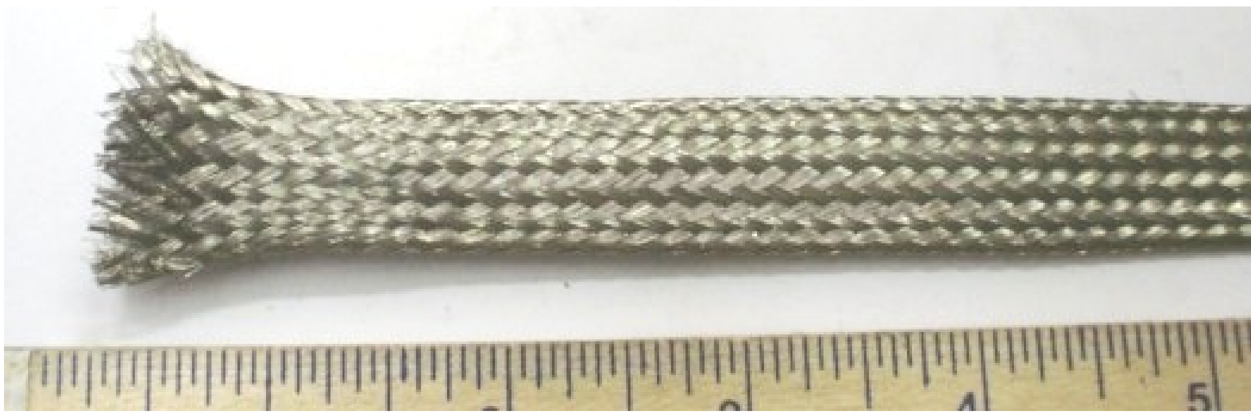
# Objective

**“What is the risk for whisker growth on tin-coated wire and braid?”**



- Previous study looked at room temperature aging of tin wire and braid; **no whiskers.**
- This paper continues the evaluation.
- Thirteen wire and braid samples were subjected to JESD201 testing to accelerate whisker growth.
- Samples were analyzed by SEM and EDX to determine size and density of whiskers.

# Nine wire samples

| Sample ID# | Description | Supplier | Location | Year of Manufacture | Storage Conditions | Quantity | Average Diameter (inches) | Length (inches) |
|---|---|---|---|---|---|---|---|---|
| 2 | 22-1-7C Sn coated bus wire | Blake | NGIS Rancho Carmel, CA | 2002 | Uncovered | 1 | 0.0248 | 8.5 |
| 11 | QQ-W-343 type H 16 AWG Sn coated bus wire | Belden | NGAS Redondo Beach, CA | 1966 | Closed Drawer | 1 | 0.0512 | 2.5 |
| 12 | EO8237R QQW343 type H 20 AWG Sn coated bus wire | Victor | NGAS Redondo Beach, CA | 1965 | Closed Drawer | 1 | 0.0325 | 6 |
| 14 | QQW343 type S 24 AWG Sn coated bus wire | Camden | NGAS Redondo Beach, CA | 1982 | Closed Drawer | 1 | 0.0204 | 11.5 |
| 15 | EW-8815 Sn coated bus wire | Victor | NGAS Redondo Beach, CA | 1965 | Closed Drawer | 1 | 0.0322 | 5.125 |
| 19 | EW8812 12 AWG Sn coated bus wire | National | NGAS Redondo Beach, CA | 1966 | Closed Drawer | 1 | 0.0644 | 7.75 |
| 20 | QQW343 Type S 26 AWG Sn coated Cu bus wire | Blake | NGAS Redondo Beach, CA | 1995 | Closed Drawer | 1 | 0.0162 | 7.25 |
| 24 | Electroplated | Blake | Unknown | 2009 | Closed Drawer | 1 | 0.02 | 4.5 |
| 25 | Hot Dipped | Blake | Unknown | 2009 | Closed Drawer | 1 | 0.02 | 4.5 |

# Four braid samples

| Sample I.D. | Supplier | Year of Manuf | Storage conditions | Braid length (in) | Avg braid width (in) | Avg braid height (in) | Strand quantity | Avg dia (in) | Length (in) |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Cont. Cordage | 2007 | Uncovered | NA | NA | NA | ~100 | 0.0051 | 1 |
| 5 | Belden | 1986 | Uncovered | 4 | 0.1723 | 0.02895 | ~30 | 0.0063 | 1 |
| 21 | Blake | 2003 | Closed drawer | 3.75 | 0.1379 | 0.0443 | ~15 | 0.0062 | 1.25 |
| 22 | Cont. Cordage | 2008 | Closed drawer | 1.75 | 1.075 | 0.1108 | NA | NA | NA |

# Test Conditions

A modified JESD201 test parameter matrix was used:

• No JESD201 process ‘preconditioning’ conducted on component test specimens

• High Temperature/Humidity: 4000 hours, 85°C /85% RH, non-condensing environment

• Sampling period: every 500 hours

• Optical (10X to 200X) and SEM (100X to 5000X) inspection was conducted for each sampling period

• Optical lighting configuration in accordance with NASA Goddard recommendations

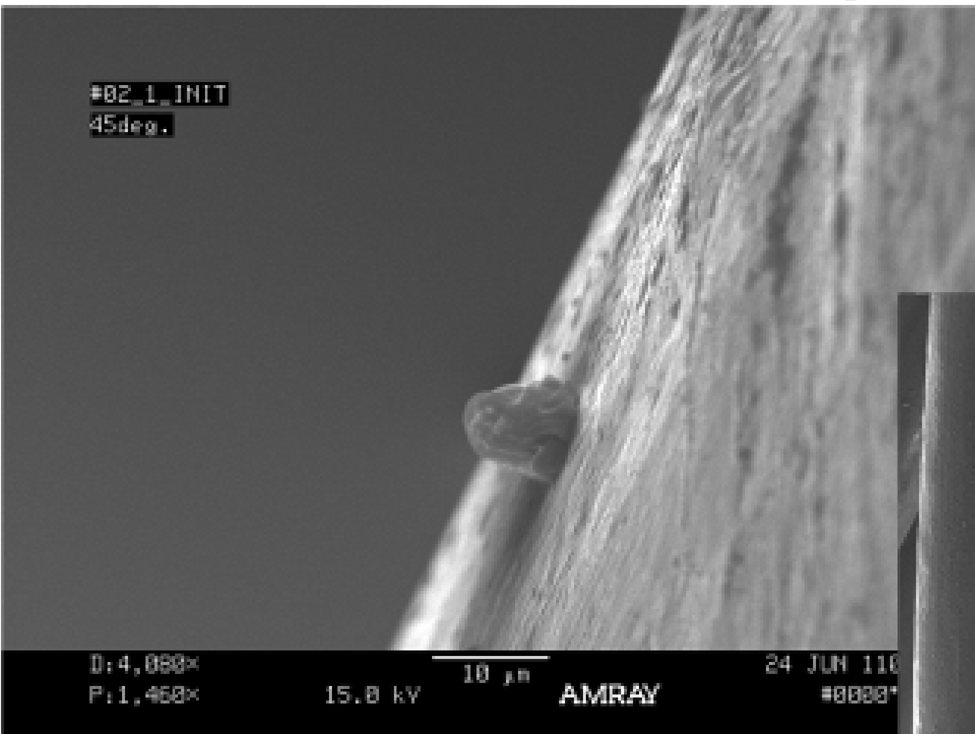
• Specific and random surface areas/regions of each wire/cable was inspected for tin whiskers for each sampling period

# Zero Hour Inspection Interval

- Test specimen 2 was the only specimen that had tin whiskers
  - less than 10 um long with no measureable area density
- No tin whiskers were found on the other test specimens
- There was evidence of external debris, scratches and nicks

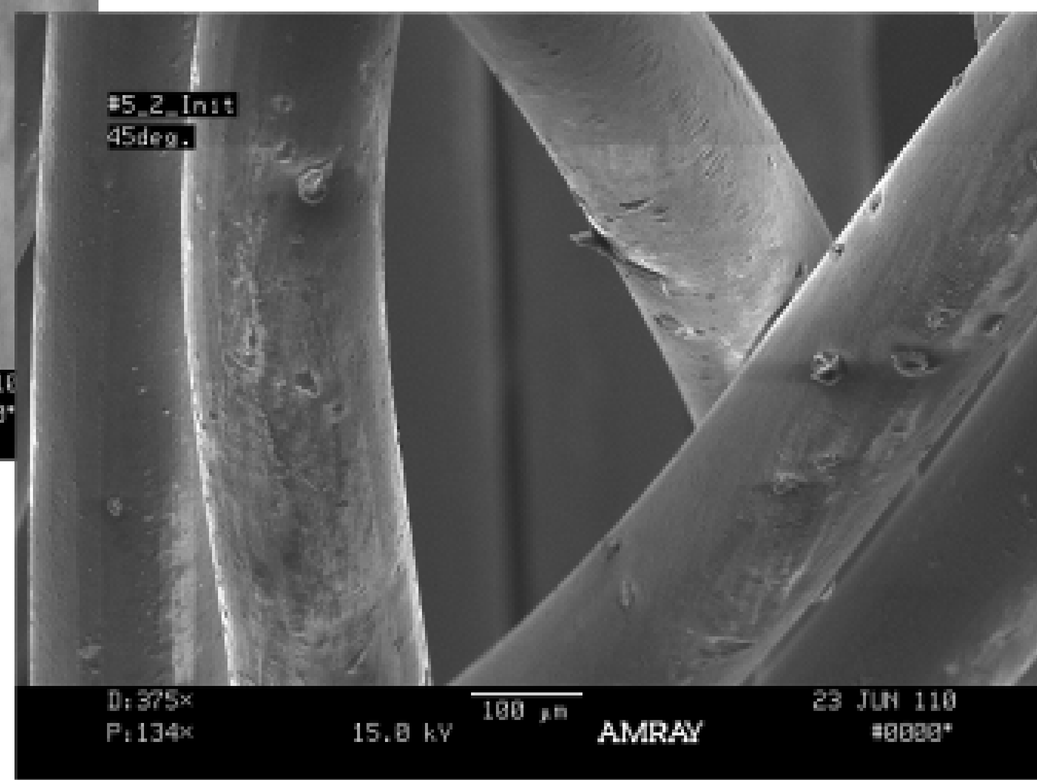
One specimen out of 13 shows whiskers

# Zero Hour Inspection Interval




wire

braid

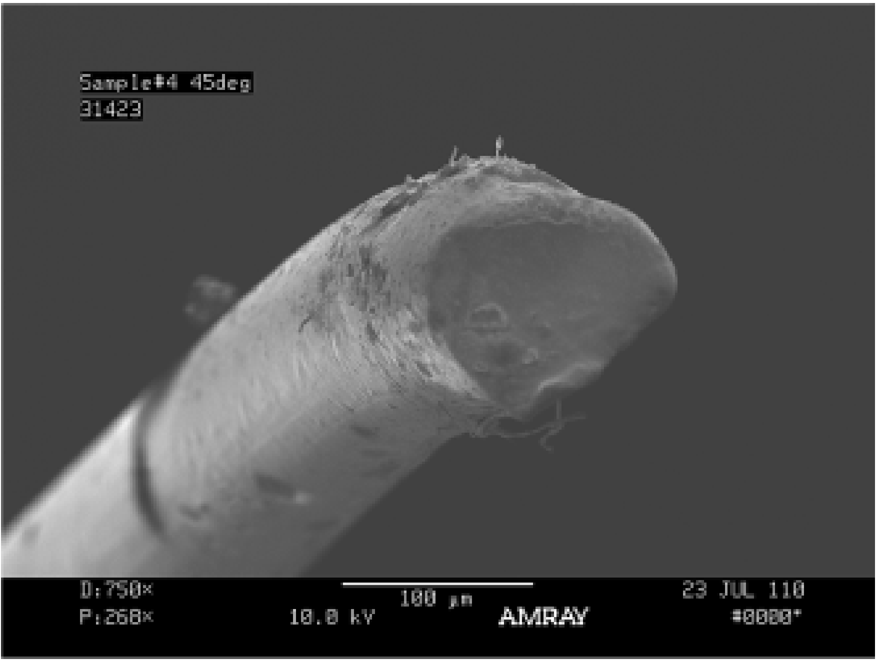


# 500$^{th}$ Hour Inspection Interval

- Tin whiskers observed on 3 other test specimens: 4,14 & 15.
  - very small (10 um or less in length)
  - single isolated instances
- Whiskers on specimen 2 did not appear to grow/change; a single instance of a 10-20 um long whisker was observed on specimen 2

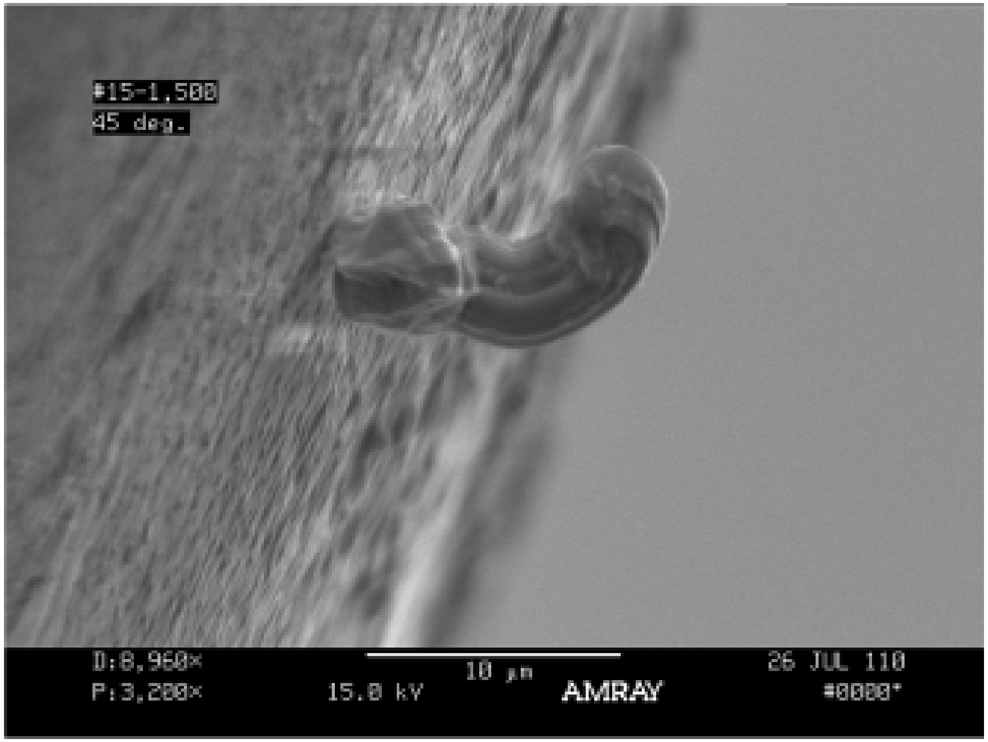
4 specimens out of 13 show whiskers

# 500th Hour Inspection Interval




15 um whisker on Specimen 4

10 um whisker on specimen 15

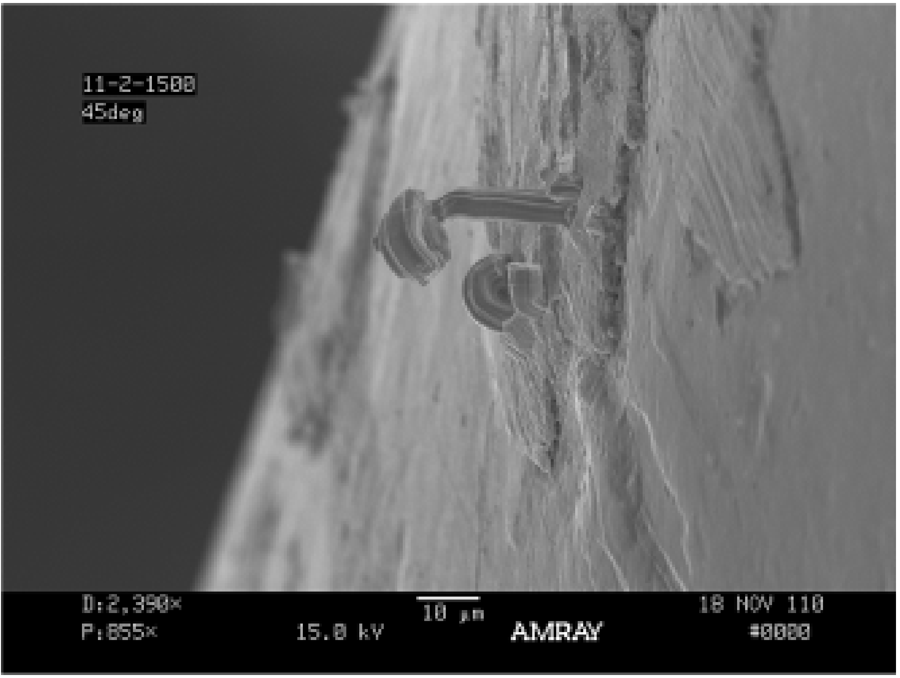


# 1500th Hour Inspection Interval

- New whiskers on specimens 11 & 12
  - Less than 10 um long
  - Isolated with little group density
- No change in length or area density to specimens 15 & 19
- Whisker clusters previously observed on test specimens 2, 4 & 14 had density growth with individual cluster groups becoming more populated

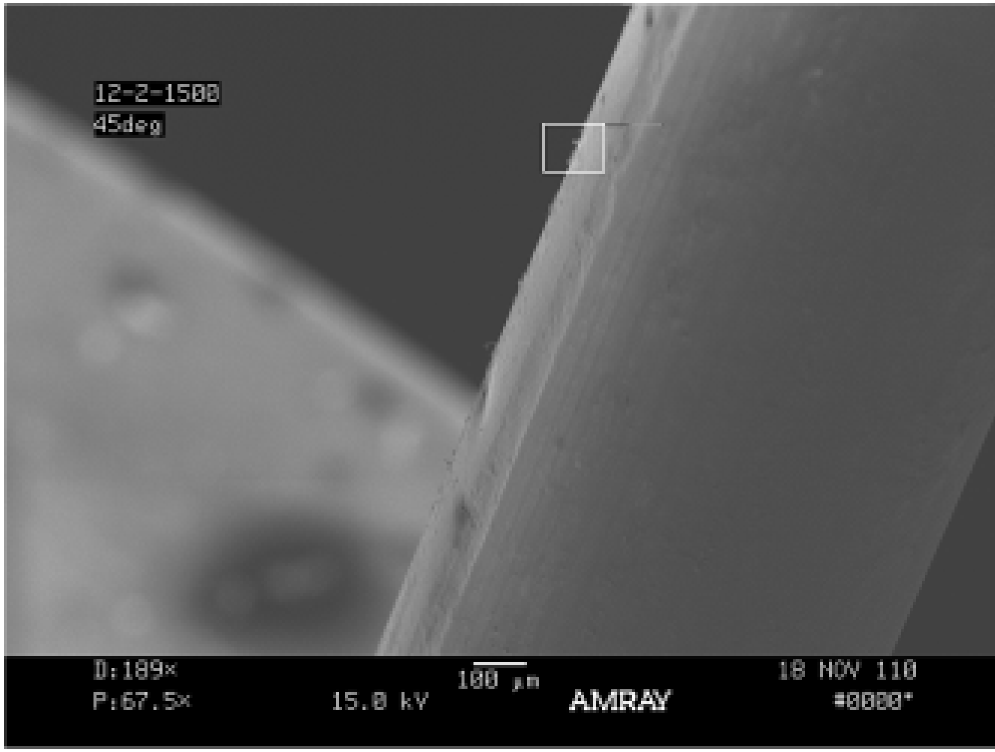
7 specimens out of 13 show whiskers

# 1500th Hour Inspection Interval




15 um whisker on specimen 11

Small cluster on specimen 12



# 2500th Hour Inspection Interval

- Complete stagnation of tin whisker growth activity.
- No changes in the tin whisker length or density

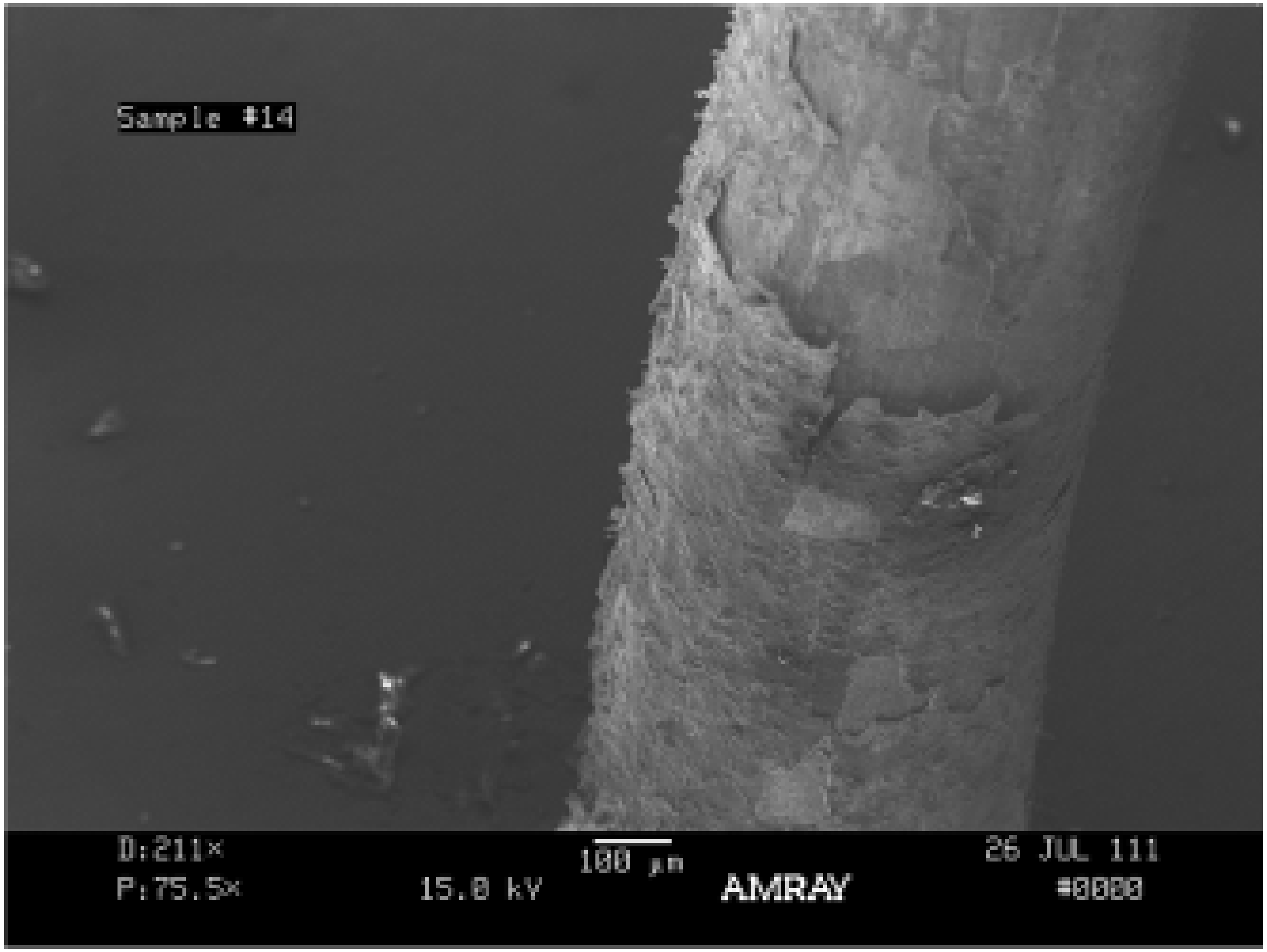
No change in whisker growth

# 4000th Hour Inspection Interval

- No changes in tin whisker growth activity
- Specimen 14 had surface morphology changes not observed on other test specimens
  - Initially suspected to be an indication of tin pest
  - In-depth SEM analysis revealed delaminating/flaking of plating from the wire surface.

No change in whisker growth

# 4000th Hour Inspection Interval




Degradation of plating on specimen 14

APEX EXPO 2012 IPC

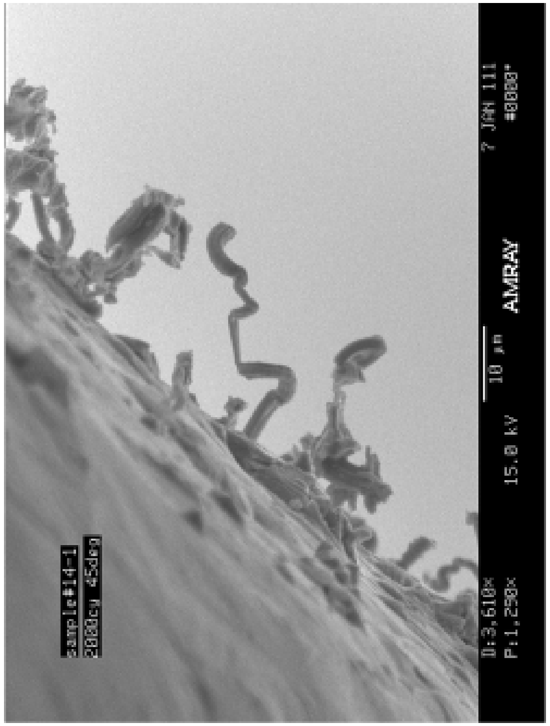
# Summary of Results

| Sample ID# | Description | Year of Manufacture | Sample Inspection Interval (hours) | | | | | | | | Max Whisker Length Observed (um) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 4000 | |
| 2 | 22-1-7C Sn coated bus wire | 2002 | Yes | No | No | Yes | No | No | No | No | 20 |
| 11 | QQ-W-343 type H 16 AWG Sn coated bus wire | 1966 | No | No | No | Yes | No | No | Yes | No | 25 |
| 12 | EO8237R QQW343 type H 20 AWG Sn coated bus wire | 1965 | No | No | No | Yes | No | No | No | No | 10 |
| 14 | QQW343 type S 24 AWG Sn coated bus wire | 1982 | No | Yes | Yes | Yes | Yes | No | No | No | 30 |
| 15 | EW-8815 Sn coated bus wire | 1965 | No | Yes | No | No | No | No | No | No | 13 |
| 19 | EW8812 12 AWG Sn coated bus wire | 1966 | No | No | Yes | No | No | No | No | No | 10 |
| 20 | QQW343 Type S 26 AWG Sn coated Cu bus wire | 1995 | No | No | No | No | No | No | No | No | 0 |
| 24 | Electroplated | 2009 | No | No | No | No | No | No | No | No | 0 |
| 25 | Hot Dipped | 2009 | No | No | No | No | No | No | No | No | 0 |
| 4 | QQB575R36T0500 Sn coated 1/2" braid | 2007 | No | Yes | No | Yes | No | No | No | No | 15 |
| 5 | 1188 Sn coated 1/8" braid | 1986 | No | No | No | No | No | No | No | No | 0 |
| 21 | C260796-001 QQB575 Sn coated Cu 1/8" braid | 2003 | No | No | No | No | No | No | No | No | 0 |
| 22 | QQB575R30T1000 Sn coated Cu 1" Braid | 2008 | No | No | No | No | No | No | No | No | 0 |

**Key - Green indicates no tin whisker activity, Red indicates tin whisker activity**

# Discussion

- High humidity / temperature conditioning induced minor tin whisker initiation and growth
- The tin whiskers produced during the 4000 hours of conditioning can be characterized as follows.
  - Morphology: single crystal, isolated, many instances of severely contorted
  - Length: small, typically less than 10 um in length, with some isolated instances of 10-30 um lengths being observed
  - Density: some instances of small, isolated tin whisker converting to small isolated cluster groups
  - Growth: random, non-linear, erratic, in a large number of test specimens nonexistent



# Discussion

- There was no apparent correlation between tin whisker activity and the thickness of the tin coating or intermetallic compound thickness.
- 3 of the 9 wire samples, and 3 of 4 braid samples, showed no tin whiskers after the inspection.
- 5 out of 5 samples manufactured before 1982 showed whisker activity.
- 2 out of 8 samples manufactured after 1982 showed whisker activity.
- None of the tin whiskers observed exceeded 30 um in length which is below the JESD201 maximum tin whisker length value (40 um) for Class 2 high temperature/high humidity conditioning.
- On tin/braid samples with tin whiskers, the typical tin whisker length measured was 10um.

# Conclusions

- Tin whiskers grown on a small sample size of wire and cable specimens during high temperature/high humidity conditioning were characterized as low risk potential for causing product issues.
- Whisker suppression in tin electroplated wires is most likely due to a combination of
  - relatively thin plating
  - geometry (no sharp edges)
  - post-plating processing operations that may relieve stresses in the tin layer.
- None of these three factors appear to be a cure-all for whisker growth, but the combination of factors appears to be effective in suppressing whisker growth.

- It can be concluded that electrodeposited and redrawn tin plated wire, braid and cable products can be used on high reliability hardware with no further steps necessary to mitigate tin whisker growth.