ENVIRONMENTAL EXPOSURE OF JG-PP/JCAA TEST PWAS

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Background:

The Joint Group of Pollution Prevention (JG-PP), partnered with the Joint Council on Aging Aircraft (JCAA) initiated the JG-PP / JCAA Lead Free Soldering Program. This project's goal is to generate critical reliability data on circuit cards manufactured and reworked with Lead Free and Tin Lead (SnPb) solders for military and space applications. In 2004, the program manufactured hardware with various electronic packages with Lead Free solders. Environmental Stress Screening testing was performed, based on MIL-STD 883. Members of the JG-PP / JCAA Lead Free Project Team include NASA, International Trade Bridge, American Competitiveness Institute, Rockwell Collins, Raytheon, Boeing, and BAE Systems.

The American Competitiveness Institute was assigned the task to perform Salt Atmosphere and Humidity Exposure Tests. The objective was to determine if Tin Silver Copper (SnAgCu) Lead Free solder joints reliability was equivalent to or better than Tin Lead (SnPb) solder joints.

Test Methods:
The samples were kept sealed in their original packaging or in a dry box prior to any exposure testing.

Board #	Description of board (Reflow Solder Alloy / Wave Solder Alloy)	Exposure testing
38	SnPb / SnPb	Humidity Exposure
39	SnPb / SnPb	Humidity Exposure
40	SnPb / SnPb	Humidity Exposure
107	SnAgCu / SnAgCu	Humidity Exposure
108	SnAgCu / SnAgCu	Humidity Exposure
109	SnAgCu / SnAgCu	Humidity Exposure
146	SnAgCuBi / SnCu	Humidity Exposure
147	SnAgCuBi / SnCu	Humidity Exposure
148	SnAgCuBi / SnCu	Humidity Exposure
35	SnPb / SnPb	Salt Atmosphere Exposure
36	SnPb / SnPb	Salt Atmosphere Exposure
37	SnPb / SnPb	Salt Atmosphere Exposure
104	SnAgCu / SnAgCu	Salt Atmosphere Exposure
105	SnAgCu / SnAgCu	Salt Atmosphere Exposure
106	SnAgCu / SnAgCu	Salt Atmosphere Exposure
143	SnAgCuBi / SnCu	Salt Atmosphere Exposure
144	SnAgCuBi / SnCu	Salt Atmosphere Exposure
145	SnAgCuBi / SnCu	Salt Atmosphere Exposure

Table 1. Description of samples tested and corresponding board number.

Humidity Exposure
The PWAs specified in Table 1 were exposed to 30°C and 95% RH for five 48-hour cycles per MIL-STD-810F Method 507.4. ACU utilized a Blue M FRP-09C temperature humidity chamber. The PWAs were tested for continuity prior to and after exposure as per instructions from the customer (Figures 1 & 2.). All 55 components were tested.

Salt Fog Exposure
The PWAs specified in Table 1 were exposed to a 48 hour Salt Spray Atmosphere as per ASTM B117 and the agreement with the customer. ACI used an Engelhard Environmental Chamber to perform the test. Given the number of samples it was necessary to do two sets of exposures with board types being intermingled. The PWAs were tested for continuity prior to and after exposure as per instructions from the customer (Figures 1 & 2.). All 55 components were tested.

Failure analysis performed for both tests utilized a Phoenix X-Ray PCB Analyzer 160 unit.

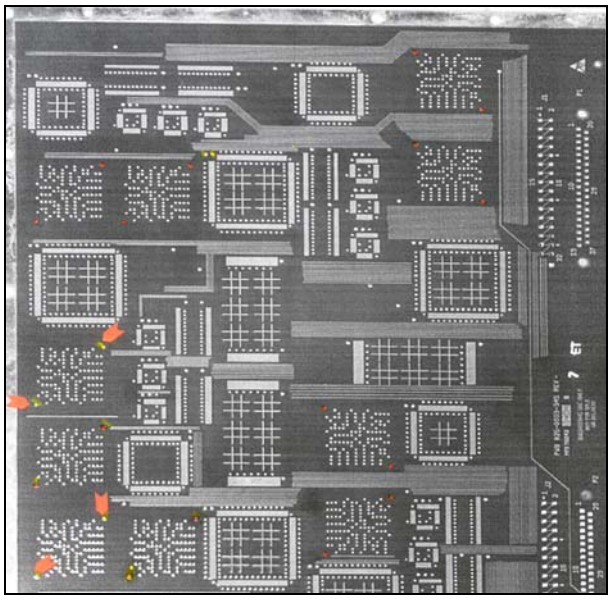

Figure 1. Test board with arrows for continuity check of CT-BGAs, bottom side.

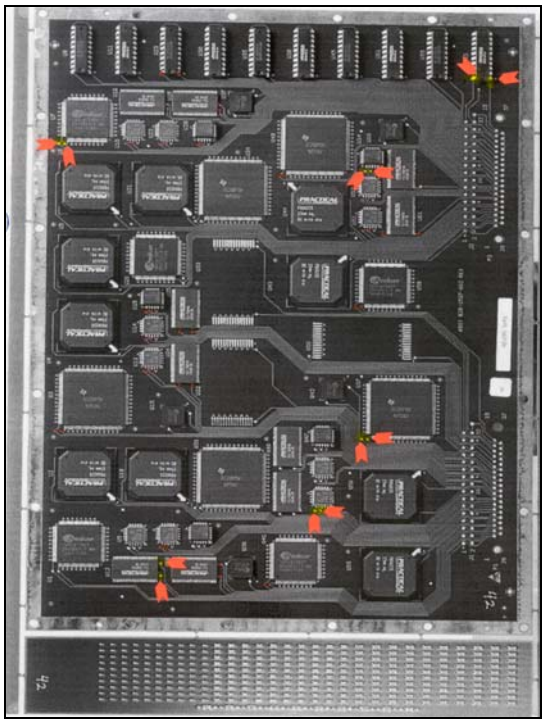

Figure 2. Test board continuity check, top side.
Points indicate where continuity tests were performed

Results:

Board #	Component Number	Exposure Testing
38	U49	Humidity Exposure
108	U44	Humidity Exposure
104	U35	Salt Atmosphere Exposure
104	U56	Salt Atmosphere Exposure
105	U3	Salt Atmosphere Exposure

Table 2. Components that failed continuity testing

Board 38: Component U49

- There was an open found between the ninth and tenth pins on the component. Those two pins were supposed to be shorted within the component.

- The open circuit was caused by a broken bond within the chip. This can be seen in the X-ray images (Figures 3 and 4).

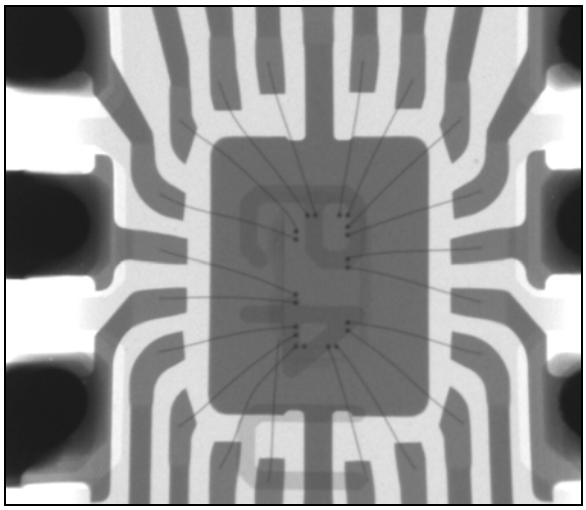

Figure 3.

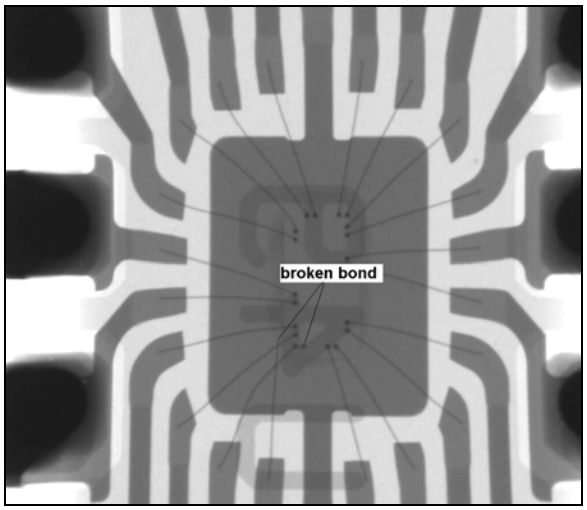

Figure 4.

ACI does not believe that this failure was caused by the humidity test. It is a packaging failure.

Board 108: Component U44

- Continuity testing showed that there is an open within the component after humidity testing. The location of the open circuit was identified but the root cause could not be determined. ACI does not believe that this failure was caused by the humidity test. It is a packaging failure.

Board 104: Component U35

- Component U35 showed open circuits where the component leads were supposed to be in series (daisy chained). X-ray analysis of this component revealed die with no internal wire bonds to the lead frame. Figure 5 is an X-ray image of the component showing no internal wire bonds. Figure 6 is the same component on board number 105 showing wire bonds properly attached to the die.

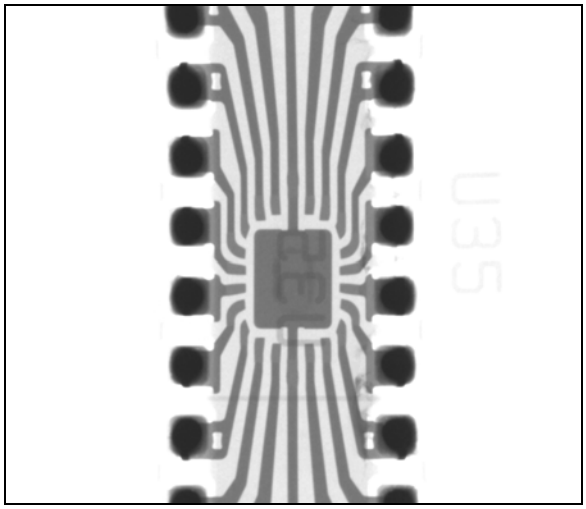

Figure 5.

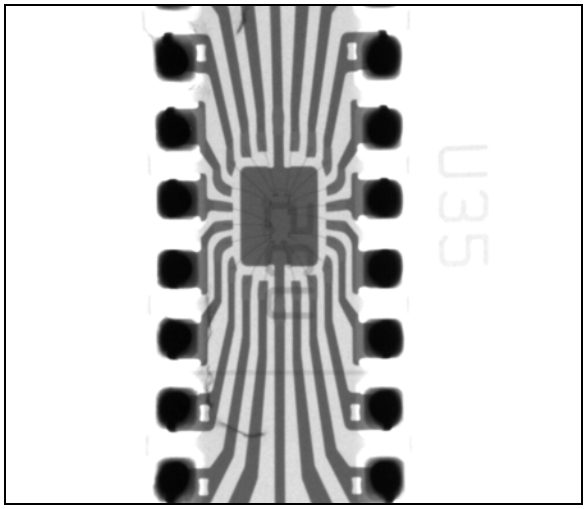

Figure 6.

The missing leads are attributed to a packaging failure.

Board 104: Component U56

- Continuity testing prior to and after the salt atmosphere exposure showed that there was an open circuit within the component (Figure 7). The location of the open circuit was identified between the two via locations marked with red arrows on Figure 8. The two should be electrically connected through the 3 BGA balls marked with blue arrows in Figure 8. Figure 9 is an image of the questionable area of component U56. ACI observed solder joint voiding, which may contribute to the open circuit. Figure 10 is an image of U55, a properly working component of the same model on the same board. Voiding was within specification, per IPC-A-610C, Section 12.2.12. There are significantly less voids in the solder in this component than on U56. Solder voids are a function of the reflow soldering manufacturing process and not a result from the salt atmosphere testing.

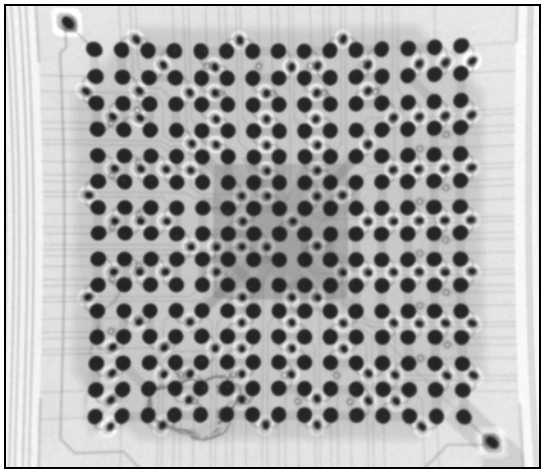

Figure 7.

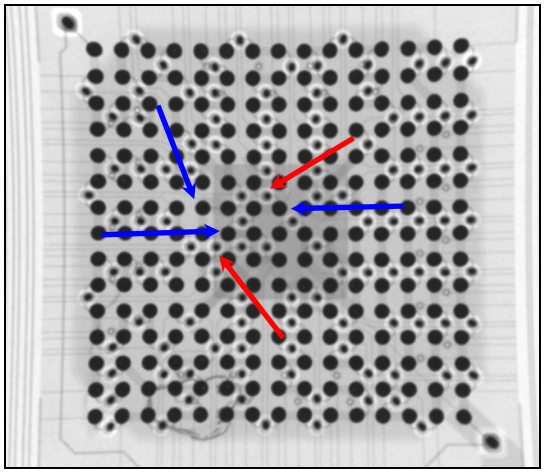

Figure 8.

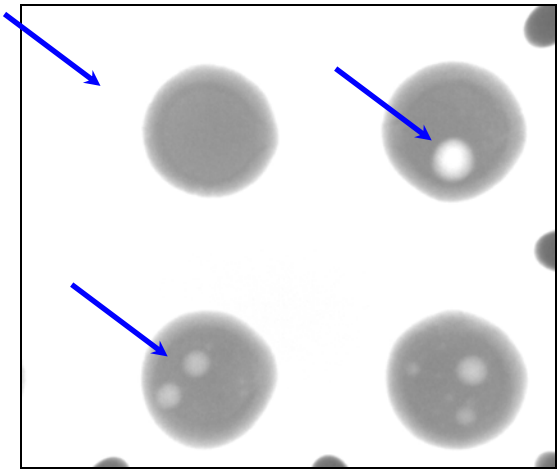

Figure 9.

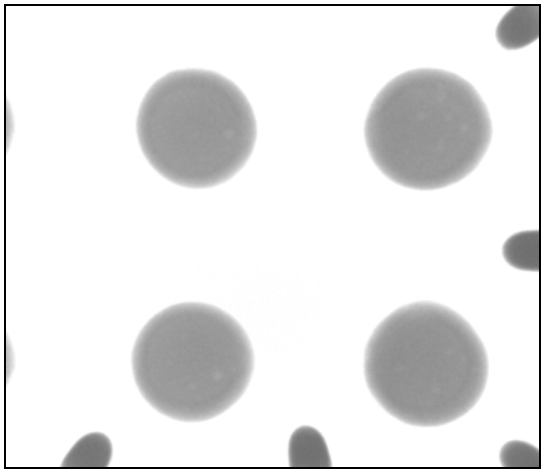

Figure 10.

Board 105: Component U3

- There was a resistance reading of 70.6 Ohms across the terminals of the component indicating an improperly wired component.
- The X-ray images show what could be solder thickness issues of the legs on the board as they seem to change throughout the whole part.
  - Figure 11: (60kV 50µA) Board 105 debris U3 bottom left corner top down
  - Figure 12: (60kV 50µA) Board 105 debris U3 bottom right corner top down
  - Figure 13: (60kV 50µA 45^{o} + rotation 55^{o} Oblique) Board 105 debris U3 pin 1
  - Figure 14: (60kV 50µA) Board 105 debris U3 pin 1
  - Figure 15: (60kV 50µA) Board 105 debris U3 upper right corner top down
  - Figure 16: (60kV 50µA 45^{o} + rotation 55^{o} Oblique) Board 105 debris U3 upper right corner
  - Figure 17: (60kV 50µA 45^{o} + rotation 55^{o} Oblique) Board 105 debris U3

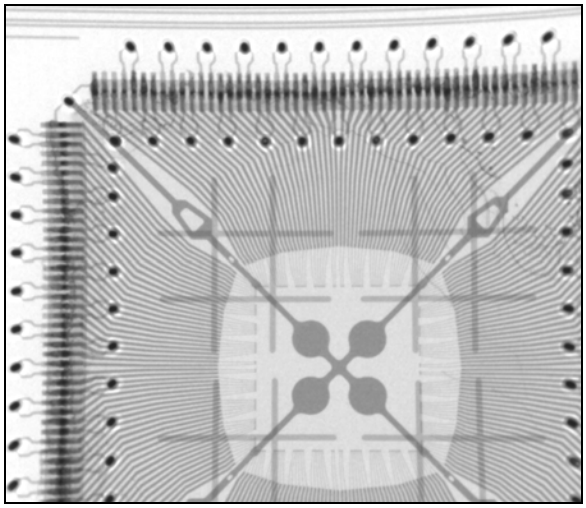

Figure 11. Board 105 debris U3 bottom left corner top down

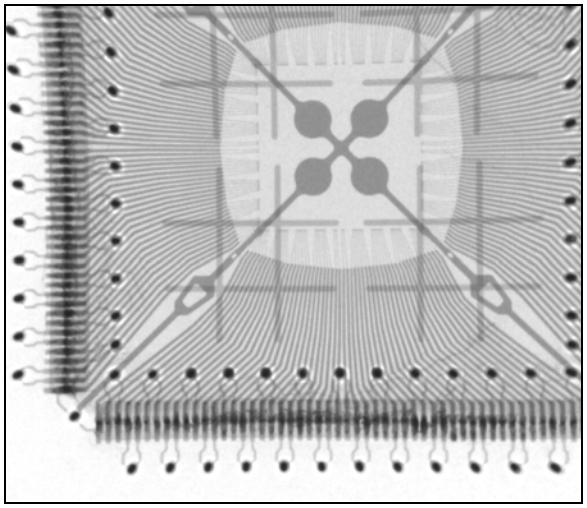

Figure 12. Board 105 debris U3 bottom right corner top down

NOTE: All images were taken with a Phoenix X-Ray PCB Analyzer 160 unit.

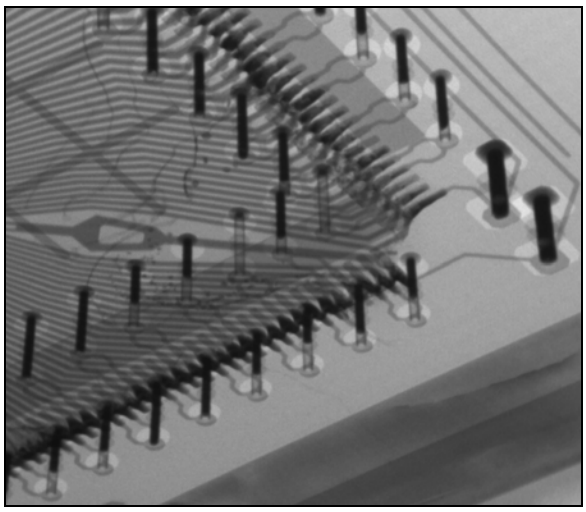

Figure 13. Board 105 debris U3 pin 1

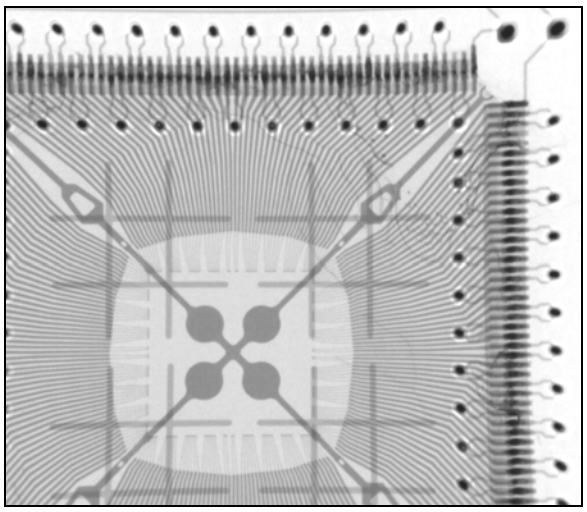

Figure 14. Board 105 debris U3 pin 1

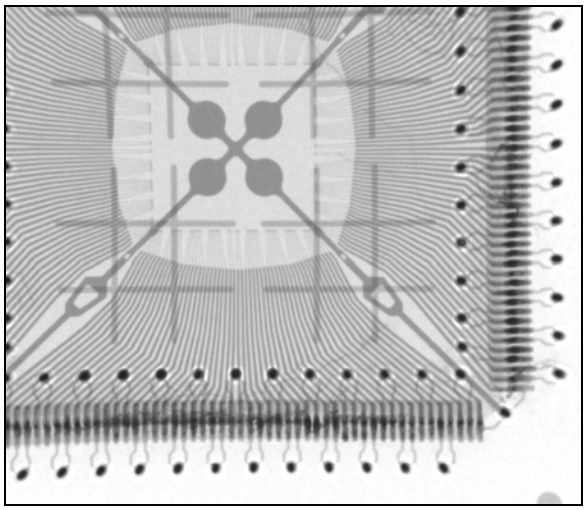

Figure 15. Board 105 debris U3 upper right corner top down

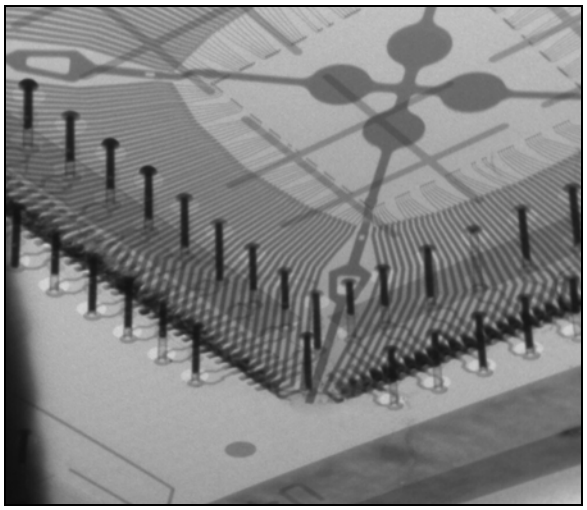

Figure 16. Board 105 debris U3 upper right corner

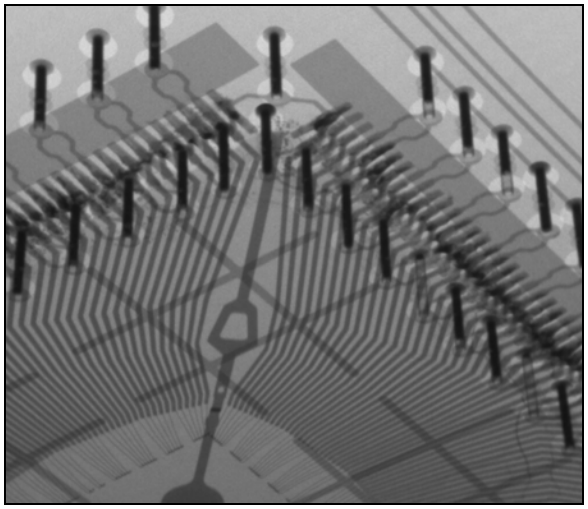

Figure 17. Board 105 debris U3

Optical images of the failed components after salt atmosphere exposure

NOTE: Only the salt fog exposed assemblies are displayed as the thermally stressed units (hardware which went through Temperature Humidity testing) did not indicate any visual evidence of damage. There was no visual damage observed on the hardware which went through Temperature Humidity testing.

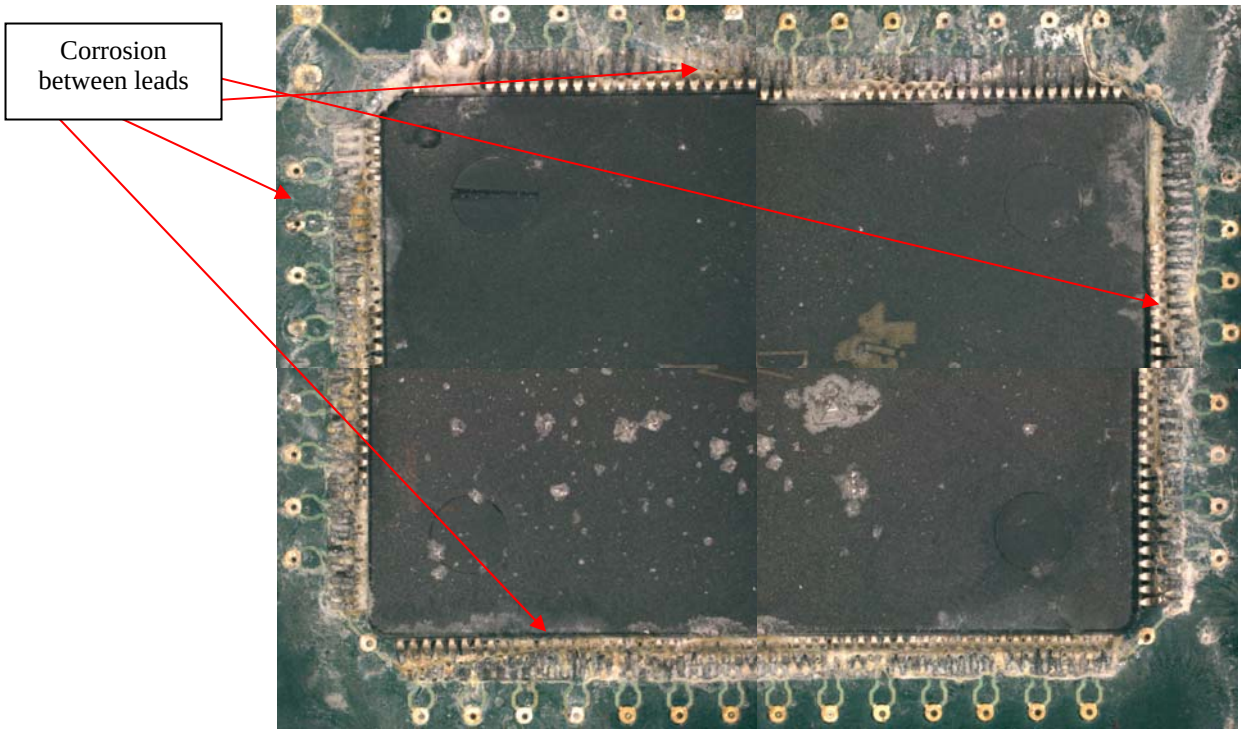

Figure 18. Optical image of QFP U3 from board 105 at 7X.

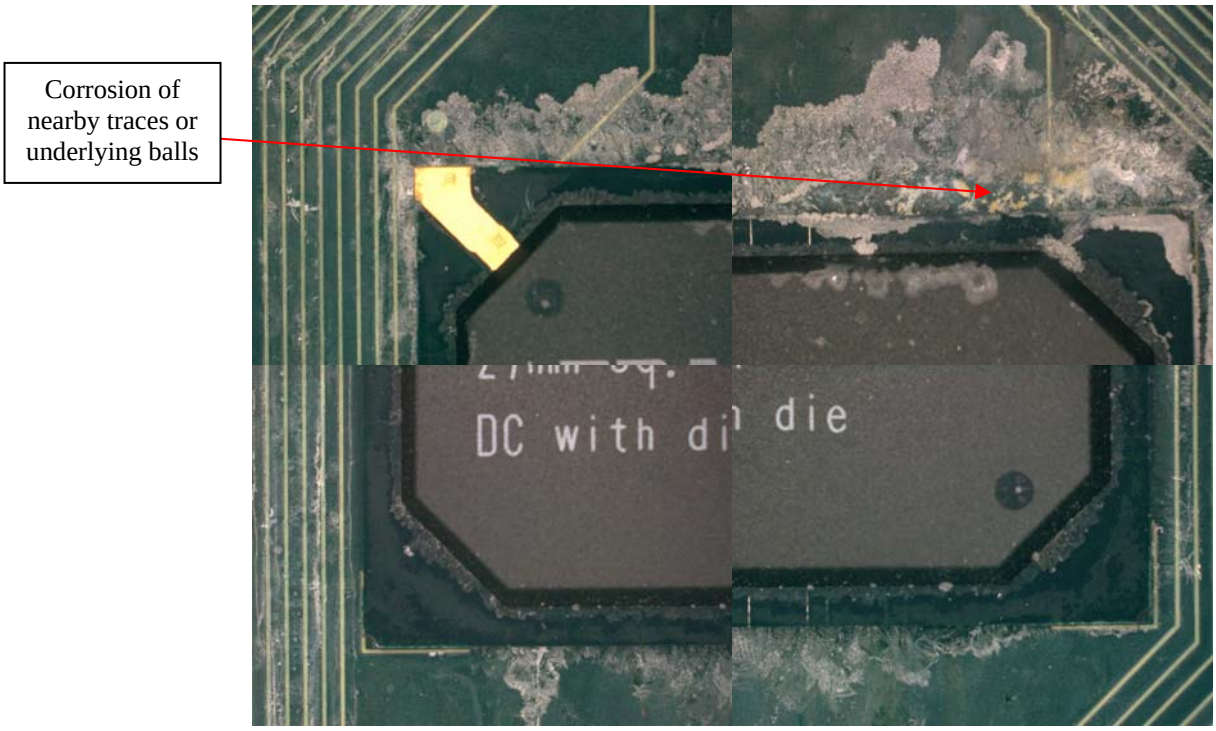

Figure 19 Optical image of BGA U56 from board 104 at 7X.

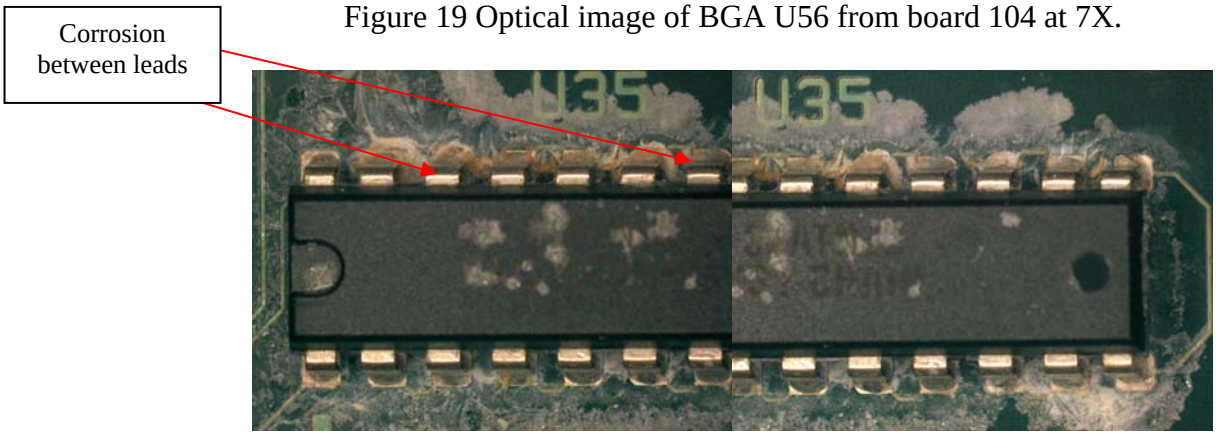

Figure 20 Optical image of SOIC U35 from board 104 at 7X**.**

Visual inspection of failed salt atmosphere components exhibited corrosion between the leads. This level of corrosion was consistent between all boards and components.

The goal of this test is to determine if hardware can survive in a corrosive salt atmosphere, simulating exposure effects from a seacoast environment. Corrosion will appear on all unprotected surfaces. As indicated, all salt atmosphere failures were attributed to electronic packaging failures or wiring defects. None were attributed to exposure to a corrosive environment.

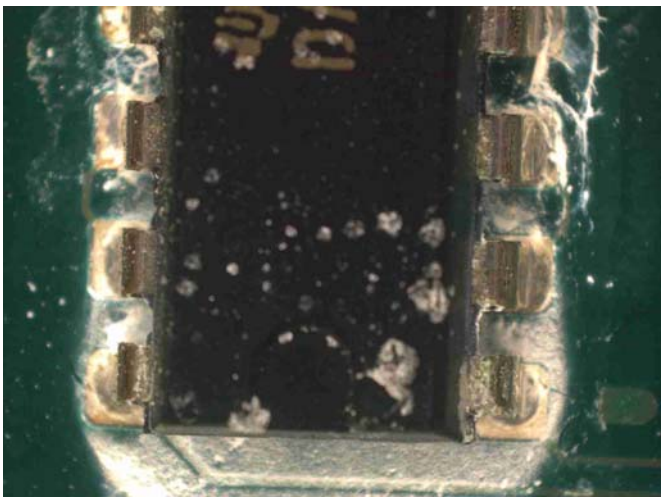

Figure 21. Example of SnCu(NI) Solder Joint.

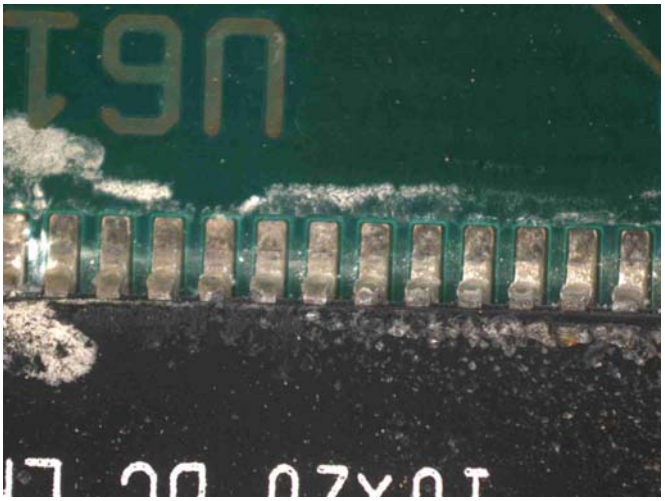

Figure 22. Example of SnAgCuBi Solder Joint

In performing a visual inspection, there was no difference between the Tin Lead (SnPb) solder joints and the Tin Silver Copper (SnAgCu), Tin Silver Copper Bismuth (SnAgCuBi), and the Tin Copper (SnCu) Lead Free solder joints. This corresponds to the continuity test results which indicated that all failures were attributed to electronic packaging failures and not the Salt Atmosphere tests.

Conclusions:

There were a total of five continuity failures from the group of points tested (Table 3). The following is a summary of the failure analysis performed:

Board 38: Component U49: The open circuit was caused by a broken bond within the chip.

Board 108: Component U44: Continuity testing showed that there is an open within the component after salt exposure.

Board 104: Component U35: Open circuits where the component leads were supposed to be in series (daisy chained).

Board 104: Component U56: Continuity testing showed that there was an open circuit within the component.

Board 105: Component U3: There was a resistance reading of 70.6 Ohms across the terminals of the component indicating an improperly wired component.

All other components passed Humidity Exposure and Salt Atmosphere testing.

Based on the components and boards tested, the Tin Lead (SnPb) solder joints and the Tin Silver Coppers (SnAgCu) solder joints were not the root cause of failure. It was determined that the failures were cause by packaging or wiring defects.

Based on the Salt Atmosphere and Humidity Exposure tests performed, Tin Silver Copper (SnAgCu), Tin Silver Copper Bismuth (SnAgCuBi), and the Tin Copper (SnCu) Lead Free solder joints reliability was equivalent to Tin Lead (SnPb) solder joints.

Board #	Solder Alloy	Component Number	Exposure Testing
38	SnPb	U49	Humidity Exposure
108	SnAgCu	U44	Humidity Exposure
104	SnAgCu	U35	Salt Atmosphere Exposure
104	SnAgCu	U56	Salt Atmosphere Exposure
105	SnAgCu	U3	Salt Atmosphere Exposure

Table 3. Components that failed continuity testing.

Customer Service Survey

As the National Electronics Manufacturing Center Of Excellence, we are constantly striving to better serve our customers. In order to meet this goal, we would value your input on our performance. At your convenience, please fill out the following survey questions and fax it back to (610) 362-1289. Thank You.

Customer Name _____ *Title* _____

Company Name _____ *Date* _____

Project/Service _____

☐ *Mfg.* ☐ *Failure Analysis* ☐ *Materials Qualification* ☐ *Other*_____

Please rate the following categories on a scale of 0 - 10 *Circle only one number per line:*

0 = Lowest Score *5 = Average Score* *10 = Highest Score*
0 = Strongly Disagree *5 = Neutral* *10 = Strongly Agree*

Job or service was completed to your satisfaction.	0	1	2	3	4	5	6	7	8	9	10
ACI met your needs and expectations.	0	1	2	3	4	5	6	7	8	9	10
Job or service was delivered on time.	0	1	2	3	4	5	6	7	8	9	10
Your materials were returned in proper condition.	0	1	2	3	4	5	6	7	8	9	10
I am confident in the results of the ACI service.	0	1	2	3	4	5	6	7	8	9	10
It was easy to order services from ACI.	0	1	2	3	4	5	6	7	8	9	10
The report was accurate and easy to understand.	0	1	2	3	4	5	6	7	8	9	10
ACI personnel kept me informed during the service.	0	1	2	3	4	5	6	7	8	9	10
I would recommend ACI to a colleague.	0	1	2	3	4	5	6	7	8	9	10
I would use ACI's services in the future.	0	1	2	3	4	5	6	7	8	9	10
ACI compares favorably to its competitors.	0	1	2	3	4	5	6	7	8	9	10

How did you first learn of ACI's services?

☐ *Internet* ☐ *Mail* ☐ *EMPFasis* ☐ *Colleague* ☐ *Other* _____

I annually specify or influence the purchase of equipment, materials, products and/or services that cost:

☐ *Over $1M* ☐ *$500K-$1M* ☐ *$100K-$500K* ☐ *$10K-$50K* ☐ *Under $10K*

What other services can ACI provide for you?

☐ *Training* ☐ *Lab Services* ☐ *Mfg. Services* ☐ *Engineering* ☐ *Other* _____

Recommendations / Comments: