SMT Dynamics

Successful Lead Free Implementation

K100 Solder Bar
2235 Liquid Flux
R520A SAC305 Solder Paste
K100 Solder Wire

Prepared by: Kester Market Development; Analytical Lab
Presented by: Peter Biocca and Tony Longo

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Overview:

SMT Dynamics in Anaheim, California is a contract assembler which has both leaded and lead-free processes in place at their facility. They have recently implemented a lead-free wave process and have been manufacturing lead-free SMT for some time now.
SMT Dynamics has the ability to build high reliability lead-free RoHS Compliant assemblies.

SMT Dynamics chose Kester as a technology partner to assist them in lead-free assembly. Recently a large build of high-end printer boards were assembled using **Kester's Lead-free Solutions** product line.

The Kester products used at SMT Dynamics for all lead-free builds are:

K100 Ultra-Pure Bar for wave assembly
2235 Water Washable Liquid Flux
R520A SAC305 Water Washable Solder Paste
K100, 331 Water Washable Flux Solder Wire

This document examines the lead-free processes used to successfully build 5000 high-end printer boards. It describes the process variables chosen to achieve high reliability builds but also offers details from the examination of these lead-free boards to the IPC-610D criteria.

This document was prepared with the permission from Carlos Rivas, Director of Operations at SMT Dynamics, Anaheim, California.

Further information on SMT Dynamics services and capabilities can be obtained on the web at www.smtdynamics.com. SMT Dynamics commonly produces Printed Circuit Board Assemblies using Flip Chip, Bare Die, BGA (Ball Grid Array), Micro BGAs, 0201 – 52 mm sq. components, and COB (Chip on Board) Assemblies.

Lead-free Process Summary:

Equipment: Wave Unit: Team Paragon Model WS-450PC- LF

New Lead-free Capable Wave Equipment used at SMT Dynamics

Features:

Spray Fluxer
5 sections of bottom-side convection heaters about 15 inches in width
Quartz heater, before wave solder, width about 6 inches
Chip wave, laminar wave
Titanuim solder pot and fingers

No top preheaters on this machine

2 cooler blowers after wave solder pot

6° inclination used at the conveyor, adjustable.

Cleaning Machine: Electrovert AquaStorm 200 with DI water only, no additives used.

Printer: DEK 265 Horizon, with laser cut stencils, 10% reduction for top-side assembly

Component Mounting: Siemens Siplace 80, S25HM and Siemens Siplace 80, F5HM

Reflow Oven: Vitronics-Soltec XPM820, air atmosphere used

Chemistries tested:

K100 Ultra-Pure Solder Bar
Kester 2235 Water Washable Liquid Flux
R520A SAC305 Solder Paste
K100 331, Solder Wire, 66 core (3% flux by weight), 0.031 inch diameter

Board Type: 0.062 inch thick ENIG, ground plane on connector J11

Board OEM: Printer board for FutureLogic Inc., a leading world wide manufacturer of thermal printers.

Board ID Number: 140-000-92-100 A revision

Components: Pure tin, matte tin, lead-free type SMD and Through-hole parts

Wave Solder Test Conditions:

Conveyor Speed: 61 centimeters per minute.

Solder temperature 265°C, only laminar wave used.

Preheater settings WS-450PC-LF: 135, 140, 150, 155, 160

Top-side preheat board: 129-131°C.

Contact solder width: 2 inches or 5.1 centimeters.

Contact Time: 5 seconds

Hand-soldering Process:

Soldering Station: EDSYN Solder Stations

Tip temperature: 750º F.

Tip type: Lead-free capable, various tip configurations to suit applications

Reflow Thermal Profile:

The thermal profile was measured using a Super M.O.L.E. Gold SPC Version 4.01 and the key points are summarized below for three thermo-couples.

Peak temperatures: 243.9, 245.0, 246.7 ºC, average is 254.2 ºC

Time above liquidus: 1:07, 1:09, 1:12 minute: seconds

Time to peak: 3:37, 3:31 minute: seconds

Time to Liquidus: 3:00, 2:56, 2:55 minutes: seconds

Slope to max: 3.82, 3.89, 3.54 minutes: seconds

Slope cooling: 2.99, 2.43, 2.57 minutes: seconds

Air atmosphere was used and the conveyor speed was set at 25 inches per minute.

Thermal reflow profile is attached.

SuperM.O.L.E.® Gold SPC V4.01 - SMSamp-L3.mpc
File Tag:SM_CNG_000680 Date: 05/09/06

M.O.L.E.® STATUS
Max Internal T: 36C
Battery: 4.922
Points: 426

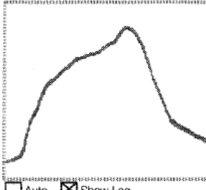
Active: 123X00
Interval: 00:00:01.0

Date: 05/09/06
Time: 17:17:06 V08.58

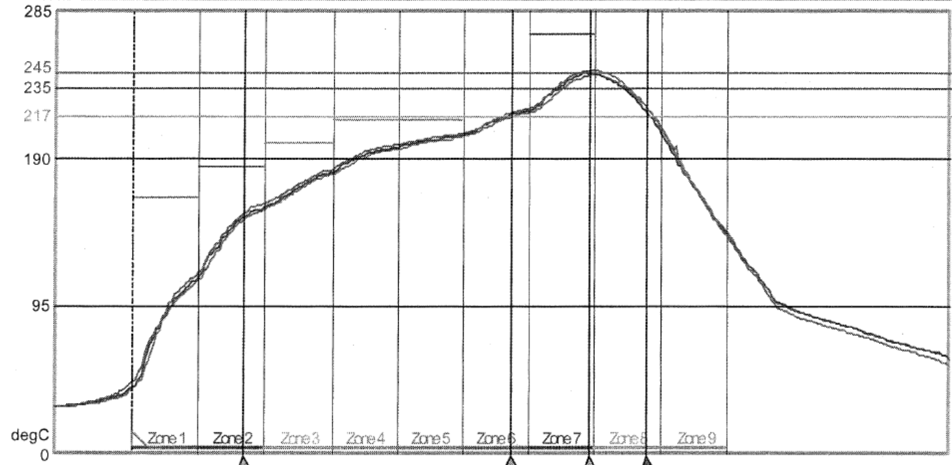
Tool status box

FUTURE LOGIC
140-00092-100 Rev A
FUT_LF01
BELT SPEED 25 in/min
VS-XPM820

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Length (IN)	13	13	13	13	13	13	13	13	13
Top (degC)	165	185	200	215	215	235	270	245	0
Bottom (degC)	165	185	200	215	215	235	270	245	0
Predict (degC)	165	185	200	215	215	235	270	245	0
Conveyor (In/Min)	25	Predict	25						



Auto ☒ Show Lag



	Value	C1 = 00:00:52r	C2 = 00:02:59r	C3 = 00:03:36r	C4 = 00:04:04r	Units
☒		151	217	243	221	degC
☒		153	218	244	218	degC
☒		154	219	246	221	degC
☐						

	Time To Ref	Low = 217	Med = 235	Hi = 245		Units
☒		00:03:00	00:03:23			degC
☒		00:02:56	00:03:21	00:03:37		degC
☒		00:02:55	00:03:20	00:03:31		degC
☐						

	T Above Ref	Low = 217	Med = 235	Hi = 245	Cure Factor	Units
☒		00:01:07	00:00:30	00:00:00	0%	degC
☒		00:01:09	00:00:31	00:00:01	1%	degC
☒		00:01:12	00:00:35	00:00:13	1%	degC
☐						

A	Zone Slopes	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
☒		**2.2**	1.5	0.7	0.5	0.3	0.5	0.8	-1.1	-2.1
☒		**2.3**	1.4	0.7	0.5	0.3	0.5	0.8	-1.2	-2.1
☒		**2.2**	1.4	0.7	0.5	0.2	0.5	0.8	-1.2	-2.2
☐										

	Summary Stats	Peak	Minimum	Max (+)Slope	Max (-)Slope
☒		243.9	30.6	3.82	-2.99
☒		245.0	30.6	3.89	-2.43
☒		246.7	31.1	3.54	-2.57
☐					
	RANGE	1106.1	1319.4	3.89	2.99

Observations:

About 24 assemblies were initially run and sent to FutureLogic. FutureLogic contracted CE Analytics for the IPC-610D evaluation. The report indicated excellent bonding with uniform intermetallic during cross-sectional analysis. The solder joints were void-free and no defects were observed.

Cross-sections done on copper leads also exhibited outstanding intermetallic formation. Cross-sectional testing revealed excellent bonding to the nickel base metal. The boards assembled were lead-free compatible with an ENIG finish. This was also observed on all SMD and through-hole devices.

The contact angles on SMD parts were exceptional and less than 90 degrees and free of defects.

A top-side fillet was obtained using K100 in the wave operation, including excellent flow around the annular rings. No solder defects were noticed.

Overall the validation was first rate, with the exception of connector J11. This connector was determined to be RoHS compliant from a material composition perspective. There were very minor cracks observed in the solder fillet on the wave side of the board. It was suspected that this was caused by shrinkage rates on the plastic pin connector used by this connector. This was confirmed by FutureLogic.

Subsequent connectors were hand soldered by hand using K100 cored wire with 331 core flux. The joints exhibited very good soldering with reduced cracking issues.

All joints were examined using a microscope at 10X. They were found to be bright and free of surface shrinkage effects. Hole-fill was adequate per J-STD-610D. Good wetting of the solder was noticed on boards sent to Kester for further analysis.

Drossing in the wave pot was very low and acceptable. The dam back plate could have been elevated slightly to avoid excessive back-spill, which was present. No discoloration of the dross was observed.

Flux was applied uniformly across the board. The air knife was set at 10° from the perpendicular to blow off the excess flux. Due to a higher preheat setting of 230 ^{o}C, a small amount of smoking was noticeable at the wave.

Hand-soldered joints also looked superb with smooth, shiny surfaces and low contact angles. These joints looked very similar to leaded joints normally done with Sn63Pb37.

Although the top-side preheat temperature was 230 ^{o}C, which is a little high for an alcohol flux, the wetting was excellent. This may be due to the higher activity of the Kester 2235 wave soldering flux. A lower preheat temperature is normally recommended.

Details extracted from the **Lead-free Validation Report** follow in the next pages.

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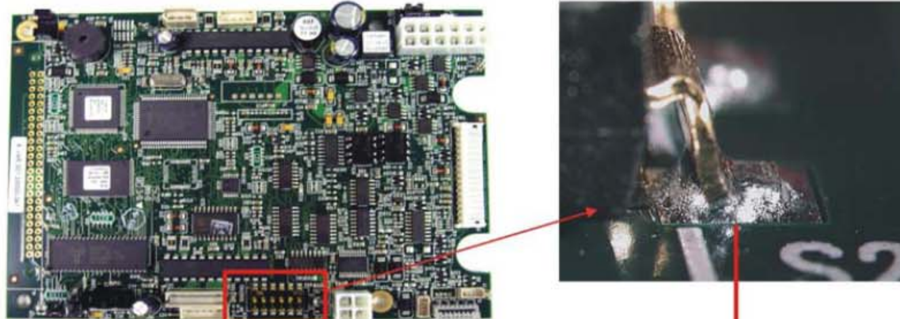
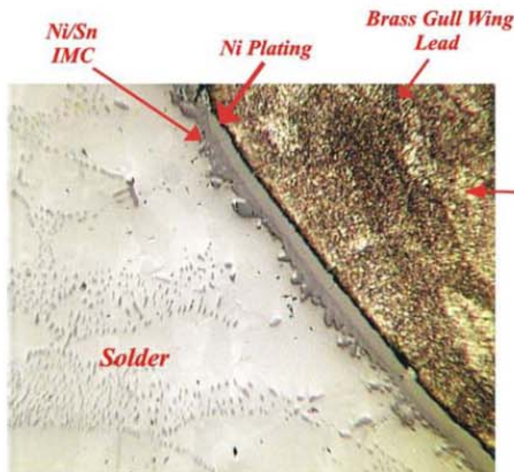
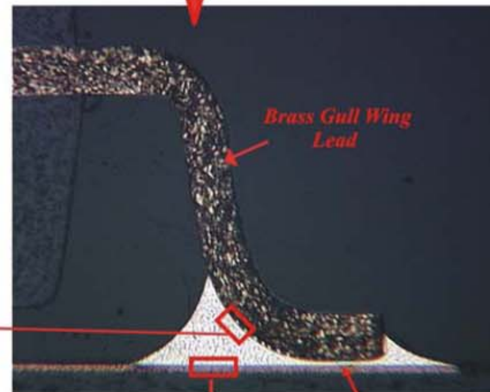
Typical Wetting Observed on Assembled Board on SMD Parts with R520A

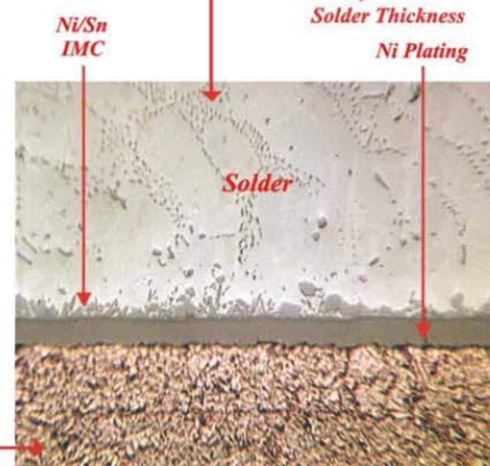
S-2 Switch component (Gull Wing lead)



The photomicrograph (below) reveals a good Ni/Sn intermetallic compound (IMC) reaction layer between the solder and the Ni barrier plating on the brass Gull Wing lead.







The photomicrograph (right) reveals a good Ni-Sn intermetallic compound (IMC) reaction layer between the solder and the Ni plating on the board.

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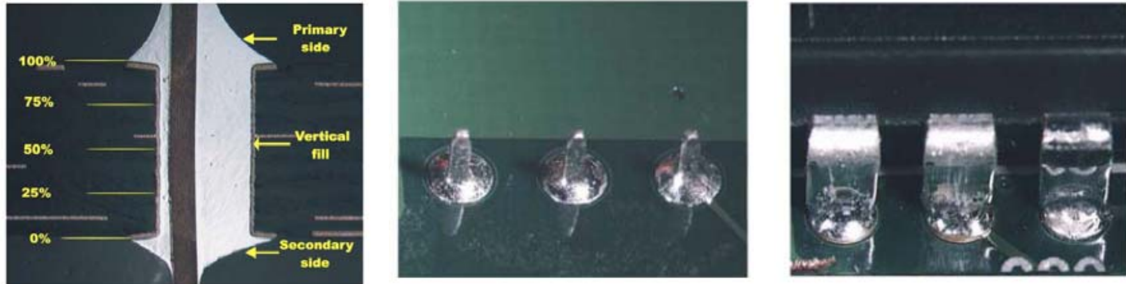
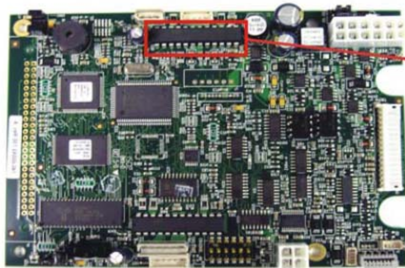
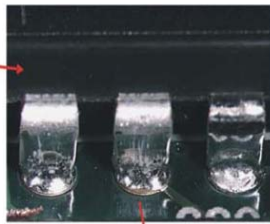
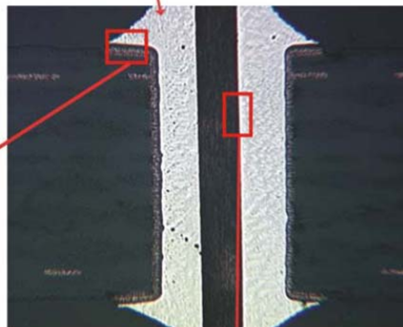
Excellent Hole-fill observed in Wave Soldered joints using K100.



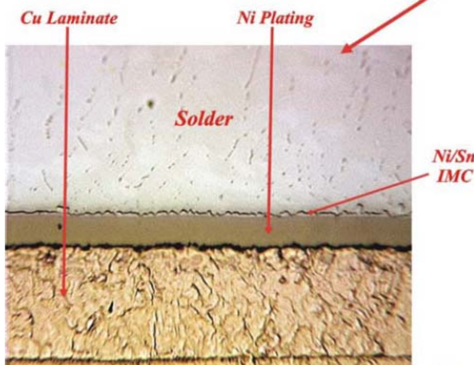
Wave Joints completely free of voids and excellent bonding observed.

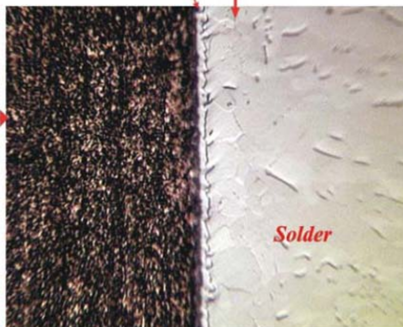






The photomicrograph (below) reveals an adequate Ni/Sn intermetallic compound (IMC) reaction layer between the solder and the Ni barrier plating on the Through-hole walls.





The photomicrograph (right) reveals a good Cu/Sn intermetallic compound (IMC) reaction layer between the solder and the Cu connector.

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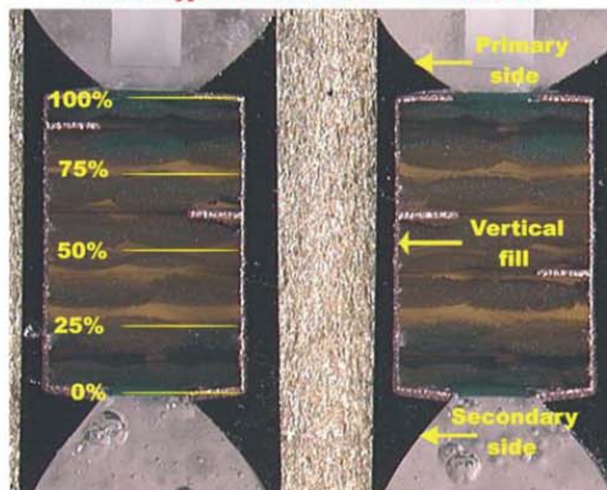
Excellent hole-fill with K100 Observed at Connector

Plated -Through Hole with Component lead - Minimum Acceptable Solder Conditions

Specification	Criteria	Class 1	Class 2	Class 3	Classification
7.5.5.1	Vertical fill of solder, Note 2,3	Not Specified	75%	75%	*Pass*
7.5.5.2	Wetting on primary side (solder destination side) of lead and barrel	Not Specified	180 Degrees	270 Degrees	*Pass*
7.5.5.3	Percentage of land area covered with solder on primary side (solder destination side)	0	0	0	*Pass*
7.5.5.4	Fillet and wetting on secondary side (solder source side) of lead and barrel	270 Degrees	270 Degrees	330 Degrees	*Pass*
7.5.5.5	Percentage of land area covered with solder on secondary side (solder source side)	75%	75%	75%	*Pass*

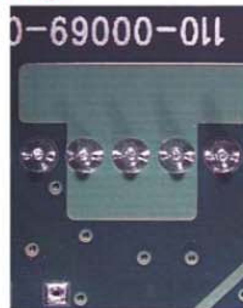
Note 1 Wetted solder refers to solder applied by the solder process.
Note 2 The 25% unfilled height includes both source and destination side depressions.
Note 3 Class 2 may have less than 75% vertical hole fill as noted in 7.5.5.1.

7.5.5.1 Supported Holes - Solder - Vertical Fill



7.5.5.2 Supported Holes - Solder - Primary Side - Lead to Barrel
7.5.5.3 Supported Holes - Solder - Primary Side - Land Area Coverage

7.5.5.4 Supported Holes - Solder - Secondary Side - Lead to Barrel
7.5.5.5 Supported Holes - Solder - Secondary Side - Land Area Coverage



Kester Laboratory Analysis of SMT Dynamics Assemblies

SMT Dynamics in Anaheim, CA requested an optical analysis of assemblies processed with the following materials:

- Kester R520A (SAC305, 89.5%, Type 3) lead free water-soluble paste.
- Kester 2235 lead free water-soluble liquid flux
- Kester K100 lead free bar solder
- Kester K100 Solder Wire with 331 core flux

Kester's Analytical Lab provided technical data with results presented for the following tests.:

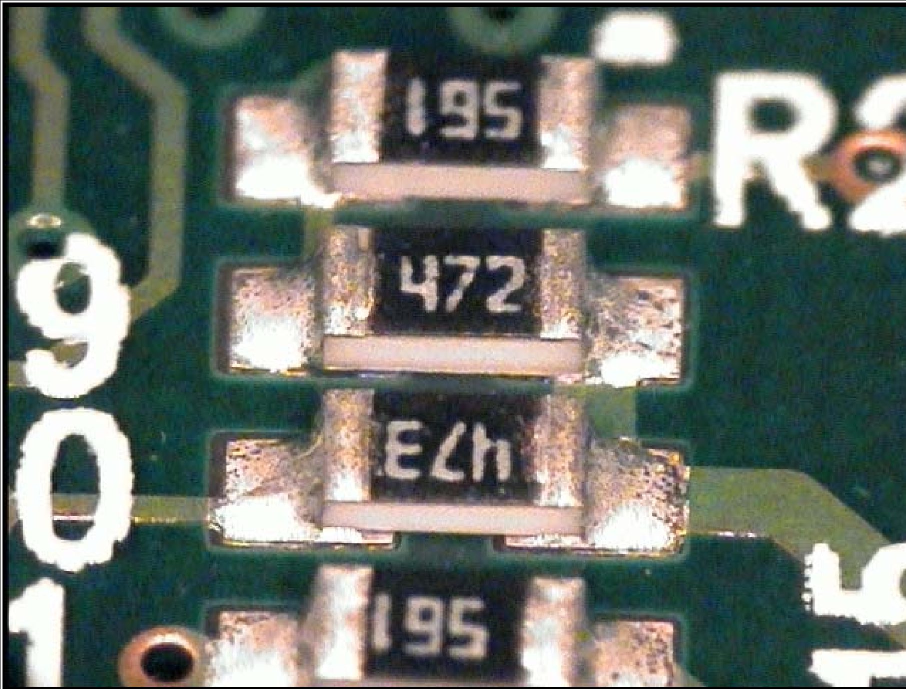
  - Visual analysis

SMT Dynamics supplied six PCB assemblies which were evaluated in this report.

Kester Equipment Set

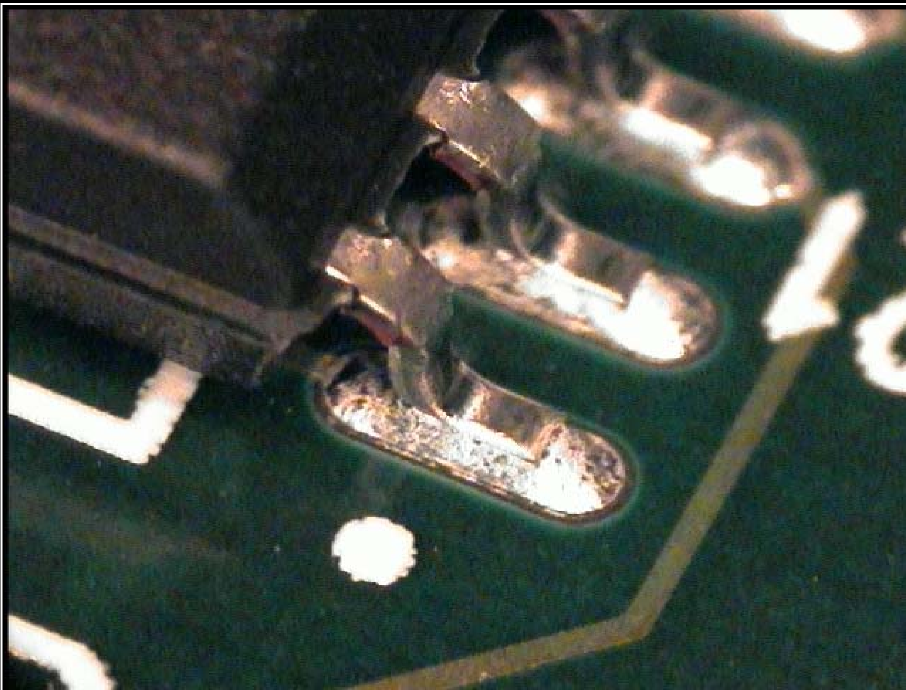
- The following was the equipment set that was used to conduct testing:
  - Hirox Hi-Scope KH-2200 MD3

Photo 1: Various SMT Resistors



- Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

Photo 2: SMT SOIC IC21



- Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

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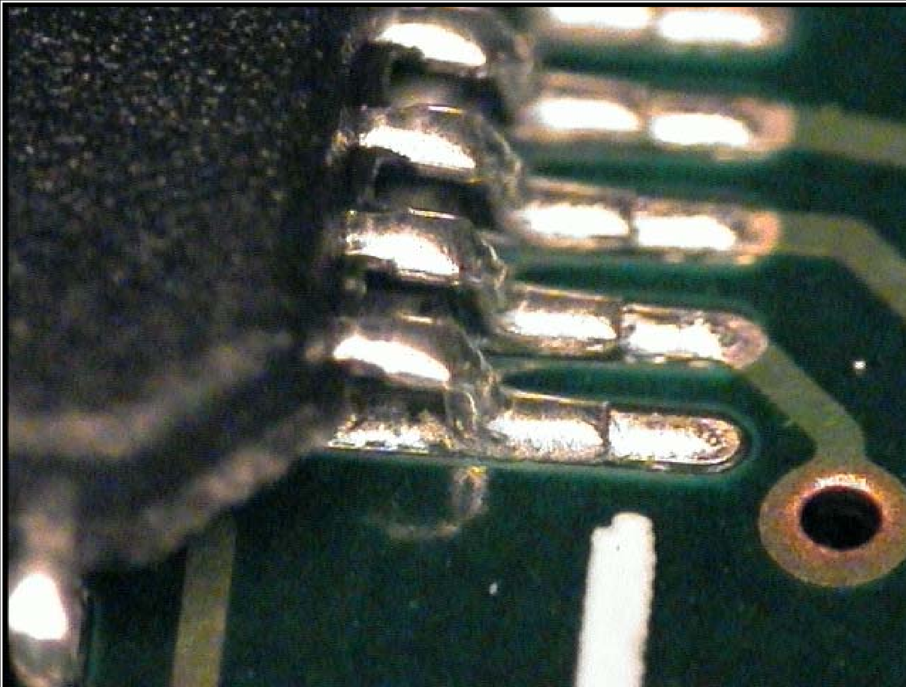
Photo 3: SMT QFP IC14	
	o Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1 o Exposed basis metal common with lead free alloys and is acceptable per IPC-A-610 revision D paragraph 5.2.1.

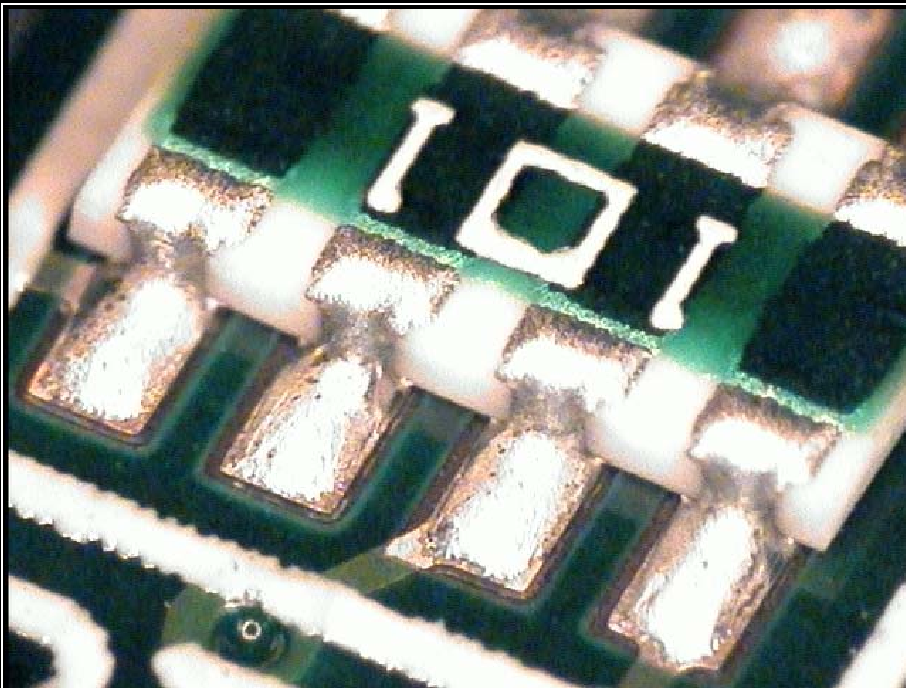
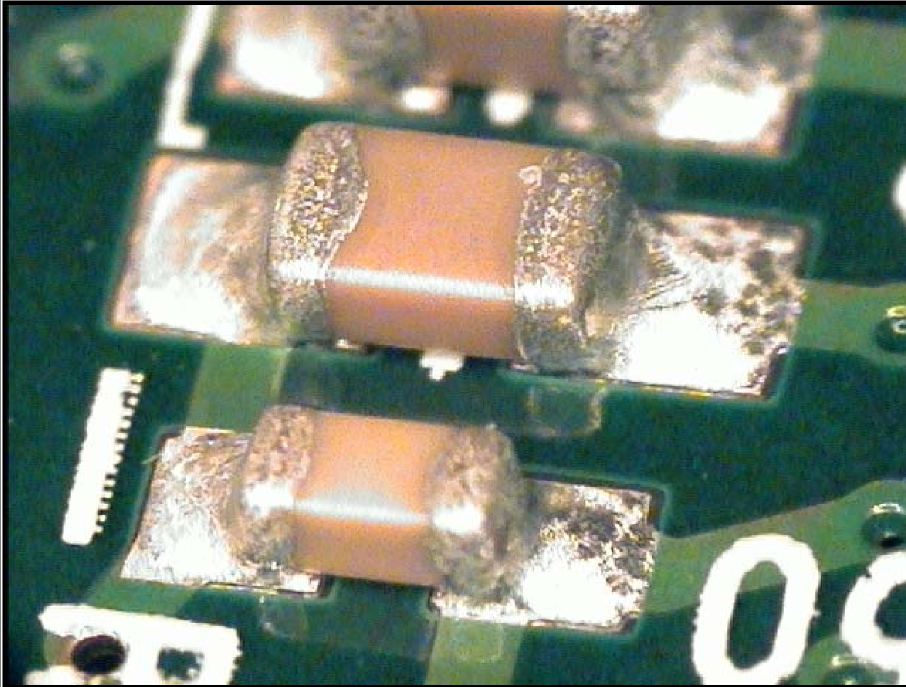
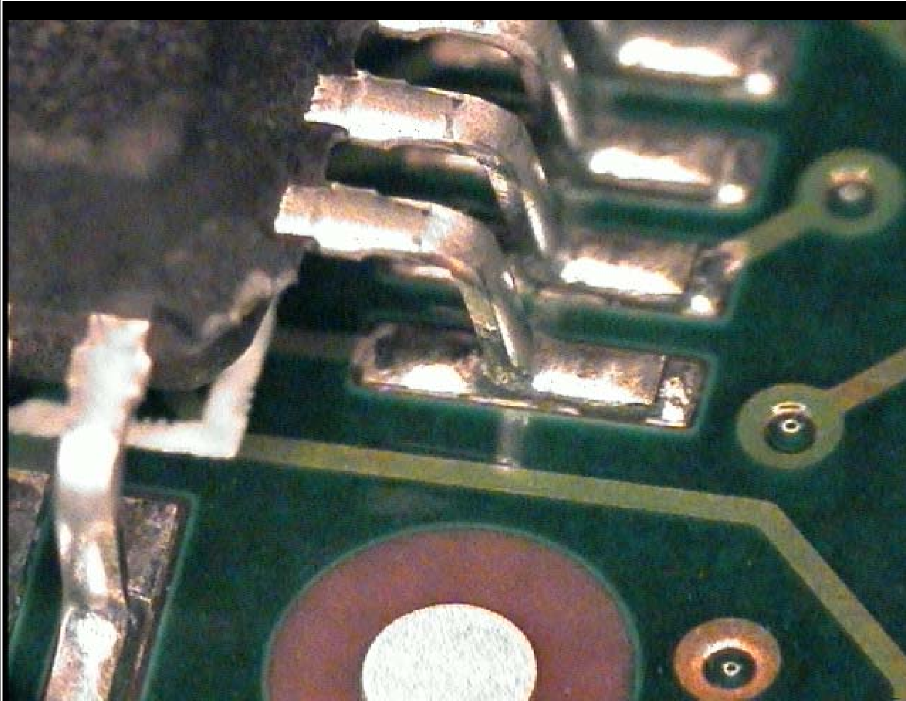
Photo 4: SMT Resistor Network R70	
	o Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

Photo 5: Various SMT Capacitors



- Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

Photo 6: SMT QFP IC23



- Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

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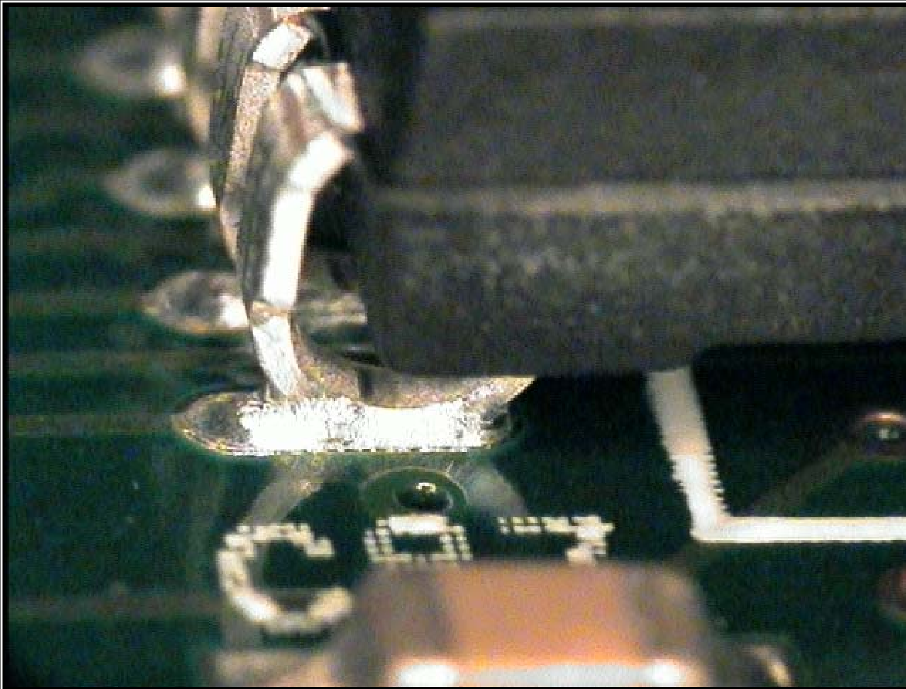
Photo 7: SMT DIP J-Lead IC1



- Leads meet Class 1,2,3 Acceptable levels per IPC-A-610 revision D paragraph 5.1

Photo 8: Through Hole DIP IC19

- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

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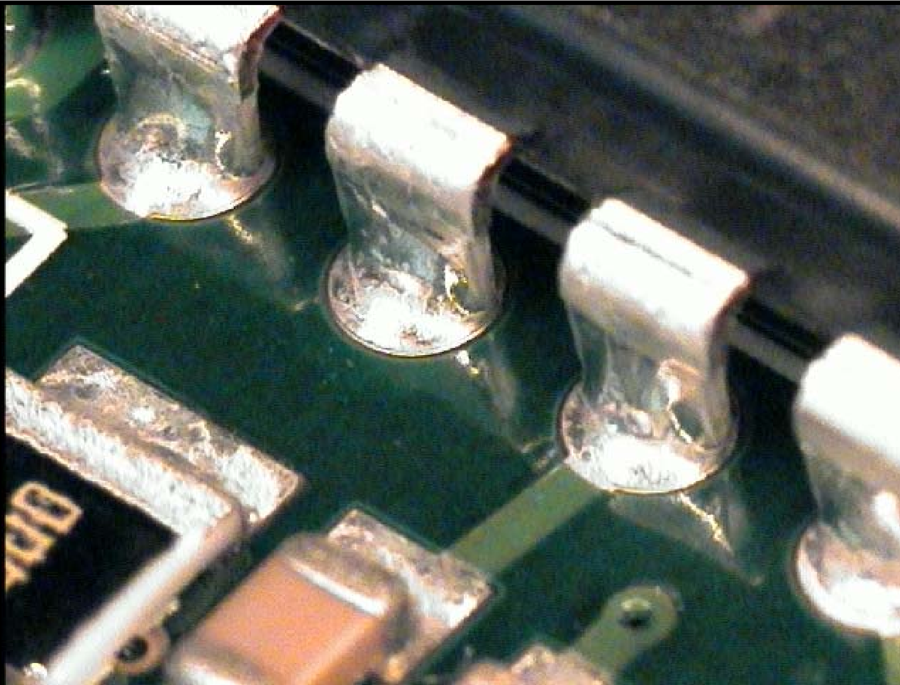
Photo 9: Through Hole DIP IC12 Top Side



- There is 100% vertical hole fill.
- Vertical hole fill meets class 3 requirements per IPC-A-610 revision D paragraph 7.5.5 Table 7-6.

Photo 10: Through Hole DIP IC12 Bottom Side

- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

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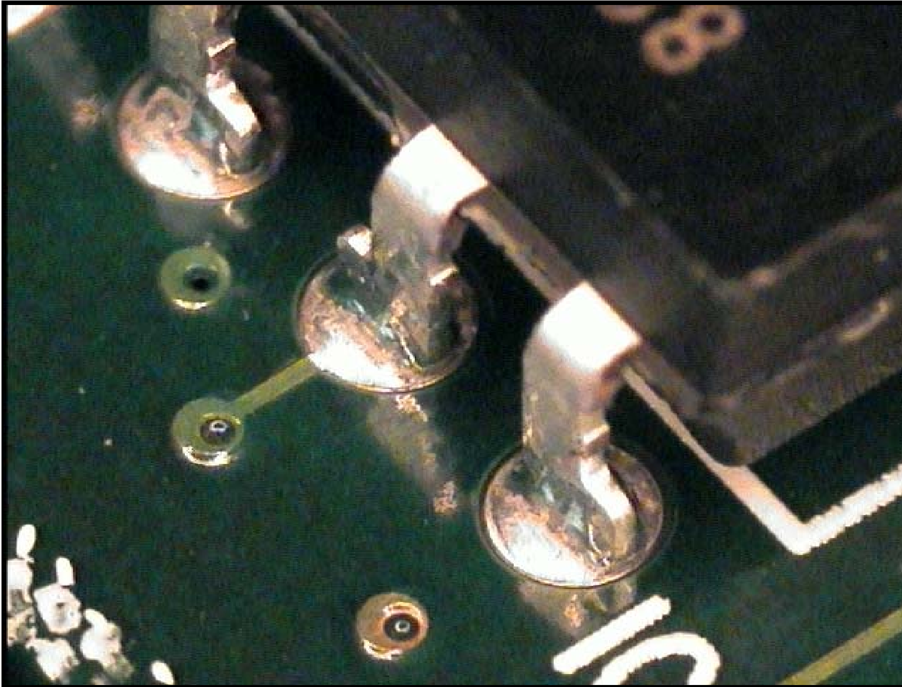
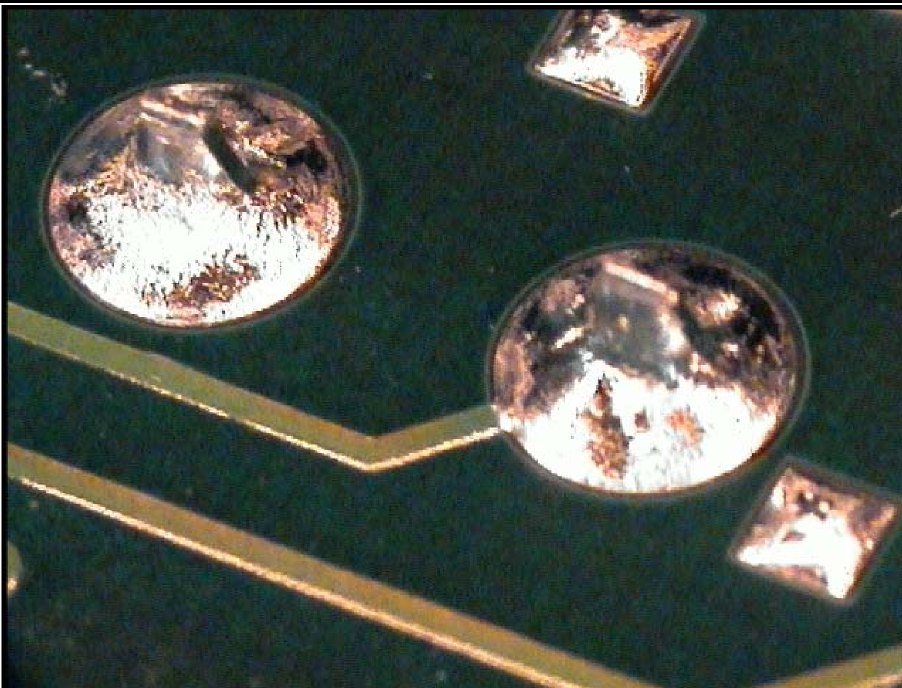
Photo 11: Through Hole DIP IC17 Top Side



- There is 100% vertical hole fill.
- Vertical hole fill meets class 3 requirements per IPC-A-610 revision D paragraph 7.5.5 Table 7-6.

Photo 12: Through Hole DIP IC17 Bottom Side



- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

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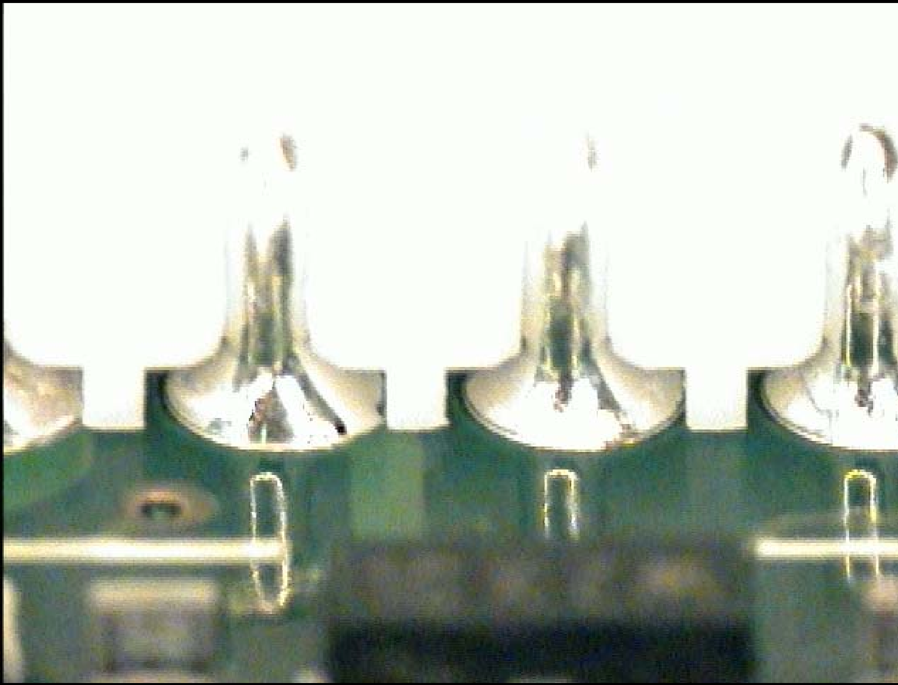
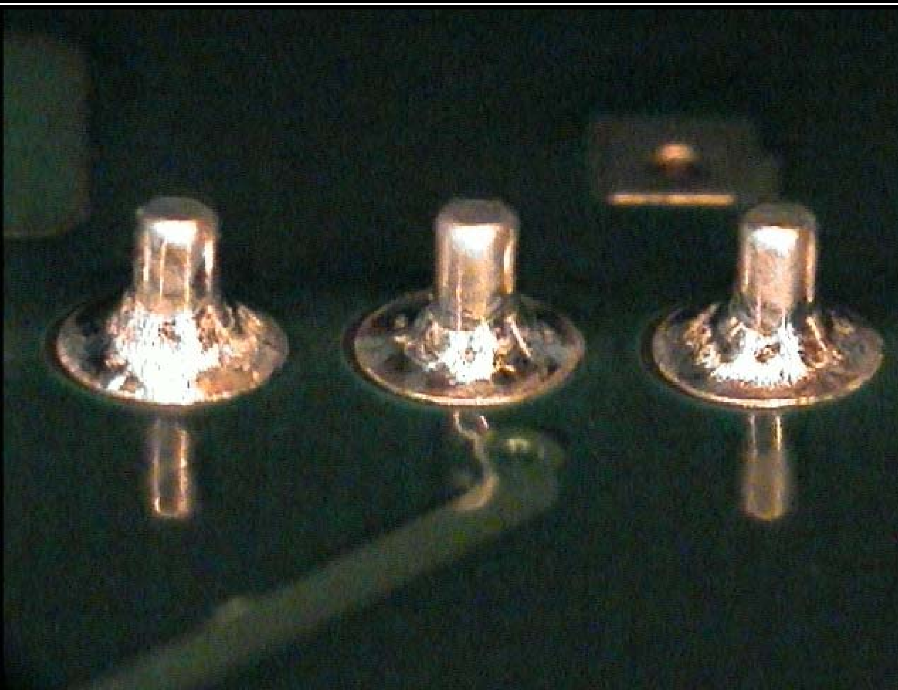
Photo 13: Through Hole SIP Connector U11 Top Side



- There is 100% vertical hole fill.
- Vertical hole fill meets class 3 requirements per IPC-A-610 revision D paragraph 7.5.5 Table 7-6.

Photo 14: Through Hole SIP Connector U11 Bottom Side



- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

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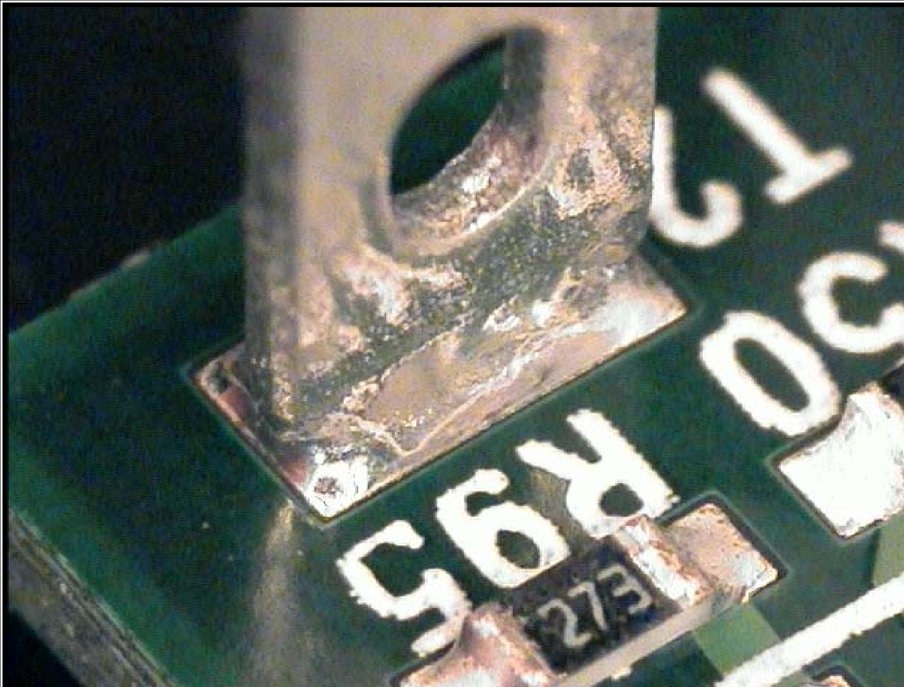
Photo 15: Through Hole Terminal T2 Top Side

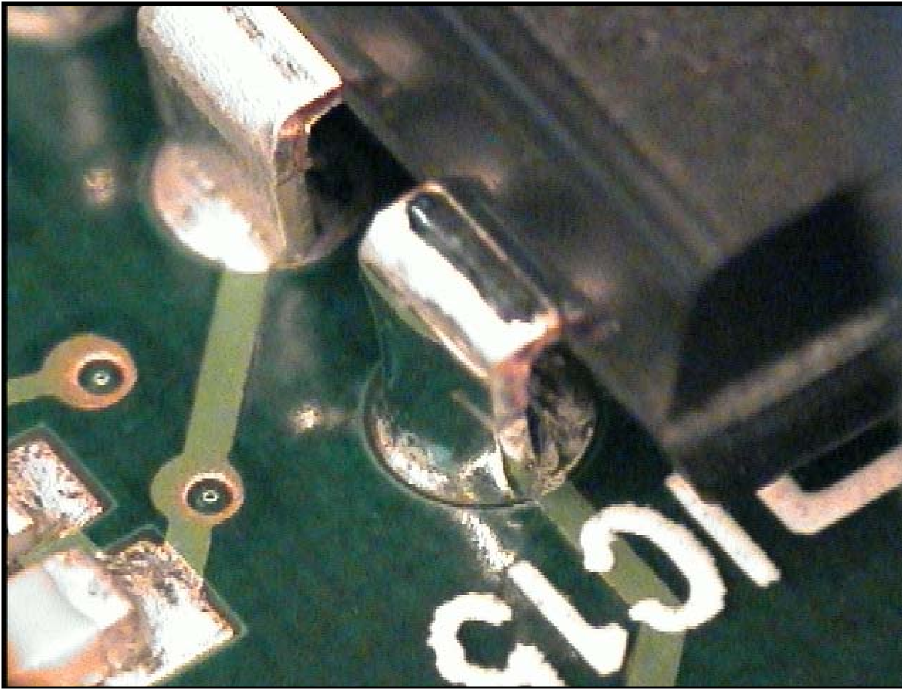


- There is 100% vertical hole fill.
- Vertical hole fill meets class 3 requirements per IPC-A-610 revision D paragraph 7.5.5 Table 7-6.

Photo 16: Through Hole Terminal T2 Bottom Side

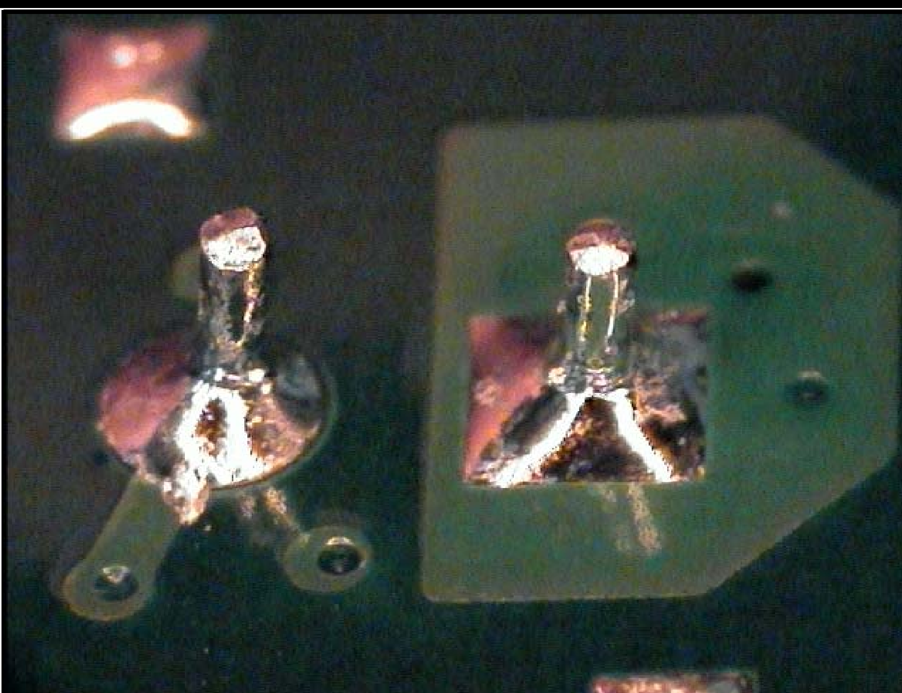
- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

Photo 17: Through Hole DIP IC15 Top Side



- There is 100% vertical hole fill.
- Vertical hole fill meets class 3 requirements per IPC-A-610 revision D paragraph 7.5.5 Table 7-6.

Photo 18: Through Hole DIP IC15 Bottom Side



- Leads meet Class 1,2,3 targets per IPC-A-610 revision D paragraph 7.5.5
- No void areas or surface imperfections.
- Leads and lands are well wetted.
- Leads are discernible.
- 100% fillet around leads.
- Solder covers lead and feathers out to a thin edge on land.
- No evidence of fillet lifting.

Lead-free Validation Conclusions:

- The lead-free assembly met customer expectations with the use of K100 alloy, R520A solder paste, 2235 liquid flux and K100 wire with 331 core flux.
- Both SMD and Through-hole parts exhibited exceptional wetting characteristics and excellent intermetallic formation.
- Low voiding was observed in all types of lead-free joints.
- Low contact angles were observed on SMD joints.
- 100% vertical hole-fill was observed with all through-hole joints.
- Wave soldering process optimization with the K100 Ultra-Pure solder was no different than traditional leaded systems.
- Kester 2235 liquid flux offered excellent activity on all components.
- K100 solder wire with 331 core flux provided good wetting of soldered components with no icicling or cold solder joints detected. No additional liquid flux was required for hand soldering. Joints assembled with K100 wire solder were smooth and bright.
- K100 wave soldered joints were as bright as Sn63Pb37 joints.
- Cosmetics for R520A SAC305 solder paste were excellent, but less shiny than the wave soldered joints.
- The solder connections met or exceeded Class 1,2,3 per IPC-A-610 revision D Paragraph 5.1.
- No discoloration of components or boards was noticed at the optimized temperatures used in all lead-free operations.

A final word from SMT Dynamics, Anaheim, California.

"As a contract manufacturer of high reliability products, we used K100 in our lead-free wave process and found excellent hole-fill, bright joints, free of defects. In the hand-soldering operation we used K100 solder wire, this gave us the same great results and the R520A solder paste gave us a problem free SMT process. We maintain the same quality and yields in our lead-free processes as our leaded process."

Carlos Rivas, Director of Operations, SMT Dynamics, Anaheim, CA.