EnviroMark™ 919G

No-Clean
Lead-Free
Solder Paste

Product Data Package

Developed by: Research & Development Group
Presented by: Market Development Engineering Group
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EnviroMark^{TM} 919G
No Clean Lead-Free Solder Paste
Data Package Contents

1. Lead Free in Electronics

USA

Lead is permitted in solder for electronics, however, American Industry was asked by the U.S. EPA to reduce the use of hazardous materials. Lead is on this list.
All conversions to lead-free processes are on a voluntary basis in North America, but many North American companies are recognizing that lead-free capabilities will be crucial for their European customers by June 2006
NEMI has selected Sn95.5Ag3.9Cu0.6 (SAC396) as the general-purpose alloy for lead-free soldering.
IPC's Solder Product Value Council (SPVC) has selected Sn96.5Ag3.0Cu0.5 (SAC305) as the general-purpose alloy for lead-free soldering.
Both alloys are available from Kester, however, Kester supports the IPC SPVC claim that SAC305 alloy is a better choice than the SAC396 for the following reasons:

- SAC305 is free from any patent restrictions.
- Less costly due to lower silver content
- Reduced tombstoning and component movement
- Less Ag_3Sn, reduction of crack initiation and brittle fracture

Kester has licensing agreements and pending patents on a variety of Lead-Free alloys and is capable of producing just about any lead-free solder alloy.

Kester supports the recommendation made by the IPC SPVC that the preferred lead-free alloy for SMT, wave soldering and hand soldering is Sn96.5Ag3.0Cu0.5.

Europe

- The European Union legislation called Waste form Electrical Equipment Directive (WEEE) calls for a ban on lead in all electronics by 7/1/2006.
- Printed Circuit Interconnection Federation (PCIF) and The International Tin Research Institute (ITRI) had conducted study for SnPb drop-in replacement and concluded that a workable alternative was the SnAgCu alloy family.
- Department of Trade and Industry (DTI) has concluded the SnAgCu alloys to be used for general purpose. DTI has also recognized that the SnAgBi alloys were very good with the strict elimination of any lead. They also elaborated that Zn alloys exhibit poor corrosion resistance and oxidation characteristics and there are no viable options for high Pb applications identified yet.

Asia Pacific

- Japanese Ministry of Industry and Trade Institute (MITI) has declared there will be a decrease of Pb used by Japanese manufacturers of 50% by 2000 with a further decrease of 66% by 2005
- Japan Electronic Industry Development Association (JEIDA) has published a Technology Roadmap in 2000 for the commercialization of lead free solder, which is listed below.

First adoption of lead free solders in mass produced good	1999
Adoption of lead free components	2000
Adoption of lead free solder in wave soldering	2000
Expansion of use of lead free solders in new products	2001
Expansion of use of lead free solders in new products	2001
General use of lead free solders in new products	2002
Full use of lead free solders in all new products	2003
Lead containing solders used only exceptionally	2005

Industry Links

IPC Pb-Free Forum	www.leadfree.org
PCIF	www.pcif.org.uk
NEMI	www.nemi.org
ICER	www.icer.org.uk
ITRI-UK	www.lead-free.org
SMART Group	www.smtuk.demon.co.uk
EIA	www.eia.org
EPA	www.epa.gov
ERI	www.nrc-recycle.org
NCMS	www.ncms.org
MITI	www.miti.go.jp

Additional Information

Additional information can be obtained from Kester's Web Site at http://www.kester.com/leadfree/leadfree update.htm or by e-mailing Literature@kester.com for Kester's recent Lead Free Information Packet.

2. Product Summary

As the emergence of lead free assembling quickly proliferates globally, EnviroMark™ 919G No Clean Lead Free Solder Paste is meant to provide the latest product development enhancements to maintain high yield manufacturing.

Kester EM919G is a lead-free, halide-free, air and nitrogen reflowable no-clean solder paste specifically designed for the thermal requirements of lead free alloys, including the Sn95.8Ag3.5Cu0.7 and Sn96.5Ag3.0Cu0.5 alloys. EM919G exhibits continual printability for the fine pitch (0.4mm/16 mils) and is able to print at high speeds up to 6"/s (150mm/s). EM919G offers excellent cosmetic appearance in the reflowed solder joints with smooth solder and light colored residues, closely resembling tin-lead joints. In addition, EM919G produces test probe friendly residues after soldering operations have been completed. EM919G is classified as Type ROL0 flux under IPC ANSI/J-STD-004A Joint Industry Standard.

Features of Kester's EM919G No-Clean Lead Free Paste:

- Lead free and no clean
- Halogen free and halide free chemistry
- Capable of print speeds up to 150 mm/sec (6 in/sec)
- Extended Stencil Life (process dependent)
- Excellent release from stencil
- Excellent printing characteristics on 0.4mm (16 mil) pitch
- Capable of 60 minutes break time in printing
- Low voiding characteristic
- Probe friendly residues
- Clean cosmetic aesthetics after reflow
- Resistant to slump
- Stable tack life
- Reflowable in air or nitrogen
- Classified as ROL0 per J-STD-004A
- Compliant to Bellcore GR-78-CORE

3 Industry Classification

3.1 Flux Composition

The flux medium EM919G is a rosin based No Clean flux. The non-volatile portion of the material is classified as rosin type (symbol RO) per IPC J-STD-004A. A rosin flux is defined in paragraph 3.2.5 of J-STD-004A as "Primarily composed of natural resin extracted from the oleoresin of pine trees and refined."

Results: Type RO

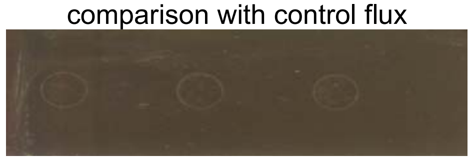
3.2 Copper Mirror

This test is designed to help define the level of activity of the flux and determine the corrosive properties of the material per IPC-TM-650, Test Method 2.3.32.

Test Method:

Non-activated rosin flux used as the control, polished glass slide with a 50nm layer of copper that was vacuum deposited, and the solder paste sample are the major materials needed for this test. The test begins by preparing and cleaning the copper mirror. The copper mirror is placed on a flat surface with the copper foil side up. Apply solder paste directly to the mirror without scratching the copper surface. Use a volume approximating 0.5mm thickness and 8.0mm diameter. One drop of the control flux is immediately placed adjacent to the solder paste deposit. The test states that the flux droplets are not allowed to touch. Then the slide is placed in an environmental chamber (23°C ± 2°C and 50 ± 5% RH) for 24 hours. The slide is then removed and cleaned. The copper mirror is then evaluated.

If there is no removal or breakthrough of the copper foil, the flux is classified as "L".
If there is less than 50% breakthrough or complete removal of the copper along the perimeter of the drop then the flux is defined as "M".
If there is greater than 50% breakthrough or complete removal of the copper than the flux is placed in the "H" category.

Paste	Results
EnviroMark™ 919G	No evidence of copper film being etched through in comparison with control flux  Kester EM919G passes L Category

3.3 Corrosion Test

The corrosion test is conducted per J-STD-004A specifications, IPC-TM-650 method 2.6.15. This test is designed to determine the corrosive properties of the flux residues under extreme environmental conditions. The test conditions used are 40^{o}C and 93 ± 2% RH for 240 hours. Any initial colour change that may develop when the test panel is heated during soldering is disregarded, but subsequent development of green-blue discolouration is regarded as corrosion.

Test Method:

The test panels used are copper coupons, each of size 51 mm x 51 mm x 0.50 mm. A circular depression of about 3.2mm deep is formed in the center of each test panel. One corner of each test panel is bent to facilitate subsequent handling with tongs.

Before performing the test, the test panels are first pre-treated. The panels are degreased with a suitable neutral organic solvent and then immersed in 5% sulfuric acid (by volume) at 65 ± 5^{o}C for 1 minute to remove the tarnish film. Then they are immersed in a solution of 25% m/v ammonium persulphate (0.5% v/v sulfuric acid) at 23 ± 2^{o}C for 1 minute to etch the surface uniformly. The panels are washed in running tap water for a maximum of 5 seconds followed by immersion in 5% sulfuric acid (by volume) at 23 ± 2^{o}C for 1 minute. They are then washed for 5 seconds in running tap water and rinsed thoroughly in deionized water. Finally they are rinsed with acetone and allowed to dry in clean air. The pre-treated test panels must be used as soon as possible or stored up to 1 hour in a closed container.

About 0.3 gram of solderpaste is weighed and placed in the center of depression of each test panel. The test panel is then lowered onto the surface of molten solder heated at about the temperature (T+50) ± 5^{o}C whereby T denotes the liquidous temperature of the lead-free alloy. The temperature is maintained for about 5 ± 1 seconds. The test specimens are then examined carefully at 20x magnification for subsequent comparison after humidity comparison. One set of specimens is placed in a clean dust-free dessicator which is conditioned at 23 ± 2^{o}C and 50 ± 5% RH for 240 hours. Another set of test specimens is suspended vertically in a humidity chamber controlled at 40 ± 1^{o}C and 93 ± 2%RH for 240 hours (10 days).

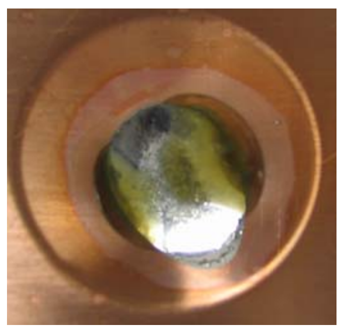
After the 240 hours period, the test specimens are removed from the chamber and examined at 20x magnification. They are compared with the reference test specimen for any evidence of copper corrosion.

Any initial change of colour that may develop when the test panel is heated during soldering can be disregarded. But subsequent development of green discolouration with observation of pitting of the copper panel is regarded as copper corrosion.

The evaluation standard is as follows:

Category	Condition
L	No evidence of copper corrosion
M	Minor corrosion observed
H	Major corrosion observed

Results:

Paste	Results
EM919G	No evidence of green corrosion  Kester EM919G passes L Category

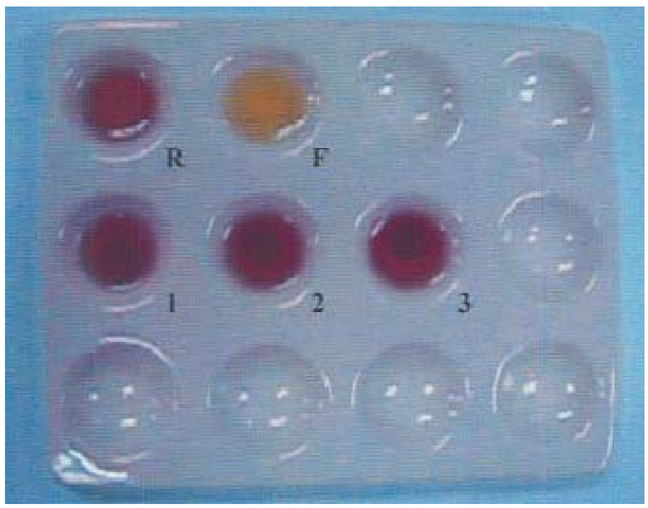
3.4 Spot Test

Spot Test is used to determine any fluorides that are not detectable in the Silver Chromate Test per IPC-TM-650, Test Method 2.3.35.1.

Conditions: A solution of zirconium nitrate and sodium alizarin sulfate is made. One drop of each solution is placed on a white spot plate to form three purple lakes of solution. One drop of the test flux is then placed into each purple spot. A clean glass rod is used to combine the test flux and the solutions.

The test is positive for fluorides if there is a change in color from purple to yellow.

Results: Pass (no fluorides detected)



The five different position of a ceramic plate marked R, F, 1, 2 and 3 correspond to the following:
R – Reference spot, containing the Zirconium-Alizarin purple lake only.
F – Fluoride spot, containing Zirconium-Alizarin purple lake and fluoride spike.
1, 2 and 3 – Three Zirconium-Alizarin purple lakes with one drop of solder paste each.

3.5 Halide Test

The halide content of EM919G solderpaste is determined by ion chromatography per IPC-TM-650 method 2.3.28.1.

Results: No chloride and bromide is detected.

3.6 Reliability

3.6.1 Surface Insulation Resistance per IPC

This test is to determine the degradation of electrical insulation resistance of printed circuit boards after exposure to the test flux. SIR testing is performed at an elevated temperature and humidity (85°C ± 2°C and 85% ± 2% RH for 168 hours) per IPC J-STD-004A.

Test Method:

IPC-B-24 test patterns (refer to Figure 1) are unpreserved bare copper comb patterns on bare FR-4 laminate with 0.4 mm lines and 0.5mm spacing. A standing bias potential of –50 volts DC is required as well as a meter capable of recording high resistance (10^{12} ohms) and a test voltage of 100 volts. The test coupons used are prepared with a 75% 2-propanol, 25% deionized water solution to remove all ionic contaminants. Then the boards are dried in an oven for a minimum of 3 hours at 60 °C. The test matrix performed on the paste is found in Table 1.

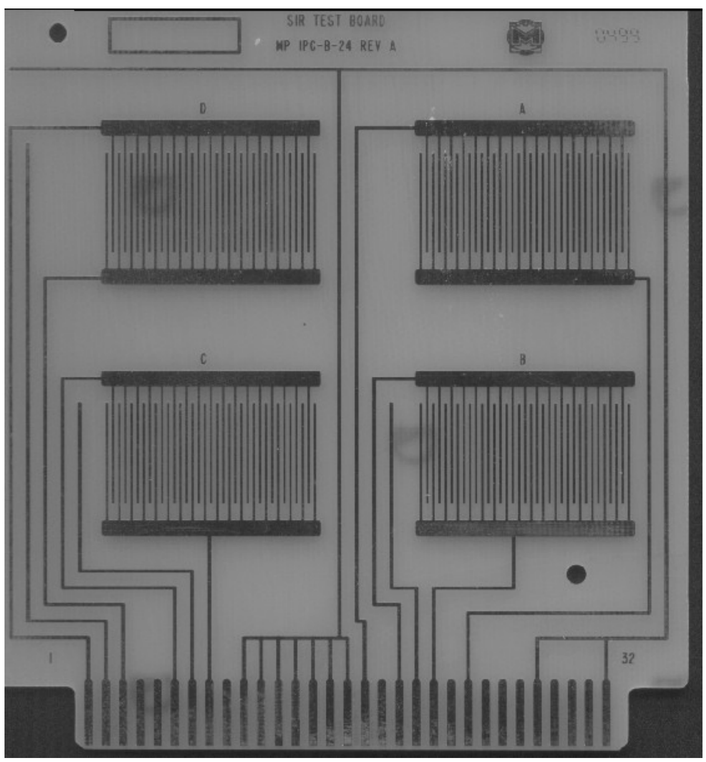


Figure 1: IPC-B-24 board

Table 1: IPC Surface Insulation Resistance Testing Matrix

Sample Set	Processed	Coupon Preparation	Post Cleaning	Number of Coupons
Sample	Yes	Precleaned	No	3
Control	No	Precleaned	N/A	3

The test coupons are examined under a 10x to 30x microscope within 24 hours of test completion. If dendrites are present and spans more than 25% of the original spacing then this constitutes a failure. The average SIR result is computed as the logarithmic average of all the test points. The average resistance values at 168 hours must also be at least 1 x 10^8 ohms. The test data results for this flux are found below in Table 2.

Results: Pass

Table 2: IPC Surface Insulation Resistance Results

Identity	Surface Insulation Resistance (ohms)			Disposition
	24 hrs	96 hrs	168 hrs	
Control	8.4 E+10	7.6 E+10	5.8 E+10	Pass
EM919G	1.3 E+10	1.4 E+10	1.2 E+10	

EM919G passes SIR per J-STD-004A with minimum SIR values of 1x10^8 ohms. Please refer to the raw data on the next page.

Table 3 : IPC Surface Insulation Resistance Results (Raw Data) :

Time	Identity	A	B	C	D
Day 1 (24hrs)	Blank control	8.01E+10	1.00E+12	1.39E+12	8.38E+10
		7.02E+10	4.14E+11	7.36E+10	7.17E+10
		6.37E+09	9.10E+09	3.00E+11	5.24E+09
	EM919G	1.56E+10	1.58E+10	1.90E+10	1.68E+10
		1.31E+10	1.22E+10	8.77E+09	8.93E+09
		1.70E+10	1.32E+10	1.07E+10	1.29E+10
Day 4 (96hrs)	Blank control	6.07E+10	6.49E+11	8.67E+11	6.34E+10
		5.07E+10	2.86E+11	5.27E+10	5.25E+10
		9.41E+09	1.17E+10	4.70E+11	8.53E+09
	EM919G	1.39E+10	1.64E+10	2.01E+10	1.56E+10
		1.41E+10	1.29E+10	1.16E+10	1.30E+10
		1.84E+10	1.33E+10	1.06E+10	1.58E+10
Day 7 (168hrs)	Blank control	3.37E+10	1.83E+11	6.37E+11	5.3E+10
		4.55E+10	2.16E+11	4.43E+10	4.39E+10
		9.09E+09	1.18E+10	3.68E+11	8.54E+09
	EM919G	1.17E+10	1.32E+10	1.62E+10	1.25E+10
		1.25E+10	1.17E+10	1.03E+10	1.19E+10
		1.50E+10	1.21E+10	9.53E+09	1.29E+10

3.6.2 Surface Insulation Resistance per Bellcore GR-78-CORE

This test is to determine the degradation of electrical insulation resistance of printed circuit boards after exposure to the test flux. SIR testing is performed at elevated an elevated temperature and humidity (35°C ± 2°C and 85% ± 2% RH).

Conditions: This test patterns used unpreserved bare copper comb pattern, IPC-B-25, on bare FR-4 laminate with 0.0125 inch spacing. Standing bias potential of –50 volts DC, a meter capable of recording high resistance (10^{13} ohms) as well as a test voltage of 100 volts is required. The test matrix for SIR testing for this flux is summarized in Table 4.

Table 4: Bellcore Surface Insulation Resistance Testing Matrix

Sample Set	Processed	Coupon Preparation	Post Cleaning	Number of Coupons
Sample	Yes	Precleaned	No	3
Control	No	Precleaned	N/A	3

Resistance measurements of the test specimens shall be taken at 24 hours and at 4 days. The resistance values must also be greater than 1 x 10^8 ohms for IPC-B -25 coupons and/or filament growth greater than 20% of the spacing is considered a failure. The test data results for this flux are found below Table 5.

Results: Pass

Table 5: Bellcore Surface Insulation Resistance Results

	Blank	EM919G	Disposition
24 hours	1.8 E+12	8.4 E+11	Pass
96 hours	9.7 E+12	7.9 E+11	

Table 6 : Bellcore Surface Insulation Resistance Results (Raw Data) :

Time	Board #	A	B	C	D
Day 1 (24hr)	Blank Control	6.24E+12	4.75E+12	5.12E+11	1.44E+11
		5.25E+12	5.87E+12	1.24E+13	4.99E+12
		--	2.12E+11	--	4.45E+11
	EM919G	3.61E+11	3.43E+11	8.39E+11	2.69E+12
		2.17E+12	2.21E+12	2.26E+12	2.03E+12
		1.01E+11	7.56E+11	4.53E+11	5.73E+11
Day 4 (96hr)	Control	7.68E+12	9.98E+12	7.68E+12	3.99E+12
		1.10E+13	1.66E+13	1.99E+13	1.66E+13
		--	5.54E+12	--	9.07E+12
	EM919G (Air reflow)	7.18E+11	6.24E+11	9.98E+11	2.62E+12
		1.40E+12	1.34E+12	1.42E+12	1.29E+12
		1.84E+11	5.51E+11	3.96E+11	3.54E+11

3.6.3 Electromigration per Bellcore GR-78-CORE

This is a laboratory test used to characterize the chemical reactions of flux residues with an applied bias in an elevated temperature and humidity chamber. This test is used as a reliability predictor of flux residues.

Conditions: IPC-B-25 test coupons are prepared and the test flux is applied to the coupons. The IPC-B-25 boards are then processed in a reflow oven at the recommended profile. The environmental chamber is maintained at 65 ± 2°C and a minimum of 85% RH. A bias voltage of 10 volts and a test voltage of 100 volts are required. The sample set of boards is summarized below in Table 7.

Table 7: Bellcore Electromigration Test Matrix

Sample Set	Processed	Coupon Preparation	Post Cleaning	Number of Coupons
Sample	Yes	Precleaned	No	3
Control	No	Precleaned	N/A	3

The average insulation resistance value $S.I.R._{final}$ shall not degrade by more than a decade as a result of the applied bias:

$$S.I.R._{final} >= 1/10\ [S.I.R._{initial}]$$

A material passes this test when the resistance data does not degrade by more than a decade and there is no evidence of electromigration (filament growth) that reduces the conductor spacing by more than 20%. This visual examination is performed with backlighting at 10x magnification. The test data results for this flux are found below in Table 8.

Results: Pass

Table 8: Bellcore Electromigration Results

	Blank	EM919G	Degradation	Disposition
96 hours	6.4E+10 Ω	1.8E+09 Ω	None	Pass
500 hours	1.3E+11 Ω	6.7E+09 Ω	None	

Table 9: Bellcore Electromigration Results (Raw Data) :

Time	Identity	A	B	C	D
Day 4 (96 hrs)	Blank Control	1.34E+11	9.40E+10	6.51E+10	9.29E+10
		6.73E+10	1.09E+11	8.28E+10	6.00E+10
		7.83E+10	2.79E+10	4.07E+10	1.98E+10
	EM919G	1.73E+09	1.53E+09	2.39E+09	2.67E+09
		1.92E+09	1.92E+09	1.98E+09	2.78E+09
		1.26E+09	1.42E+09	1.20E+09	1.48E+09
Day 21 (500 hrs)	Blank Control	1.68E+11	1.88E+11	1.71E+11	1.45E+11
		1.11E+11	1.58E+11	1.51E+11	1.24E+11
		1.00E+11	8.80E+10	1.29E+11	1.10E+11
	EM919G	7.54E+08	6.12E+09	9.81E+09	1.09E+10
		8.24E+09	1.00E+10	1.02E+10	1.19E+10
		5.72E+09	6.65E+09	6.18E+09	7.60E+09

4. Printing

4.1 Fluidity Characteristics

The viscosity measurement is conducted as per J-STD-005 specifications using Malcom PCU-203 viscometer. Solderpaste is allowed to thaw to room temperature and then mixed to an even consistency. The jar of solderpaste is then conditioned in a controlled water bath of 25 ± 0.5°C for an hour. The instrument sensor is immersed into the paste and the paste is allowed to shear at 10 rpm until it begins to extrude from the outlet while maintaining the paste at 25 ± 0.5°C. It is being stabilized for 3 min before the viscosity is recorded.

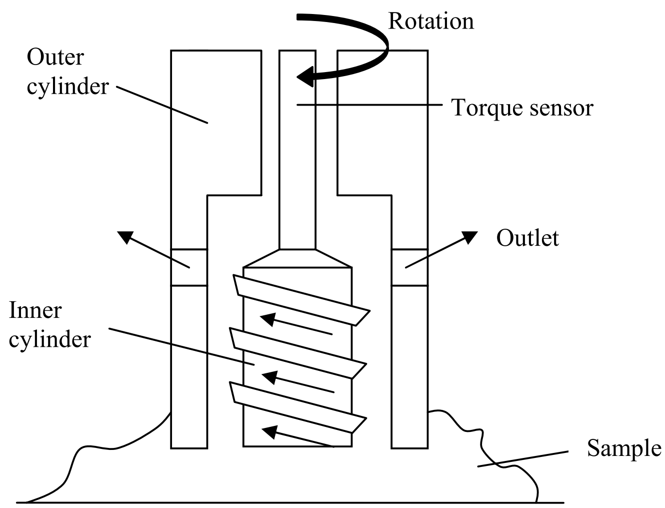


Figure 2: Schematic diagram of spiral pump measuring head

Typical viscosity is 1550 poise (88% metal, SnAg3.0Cu0.5 alloy, -325+500 mesh, 12% flux content)

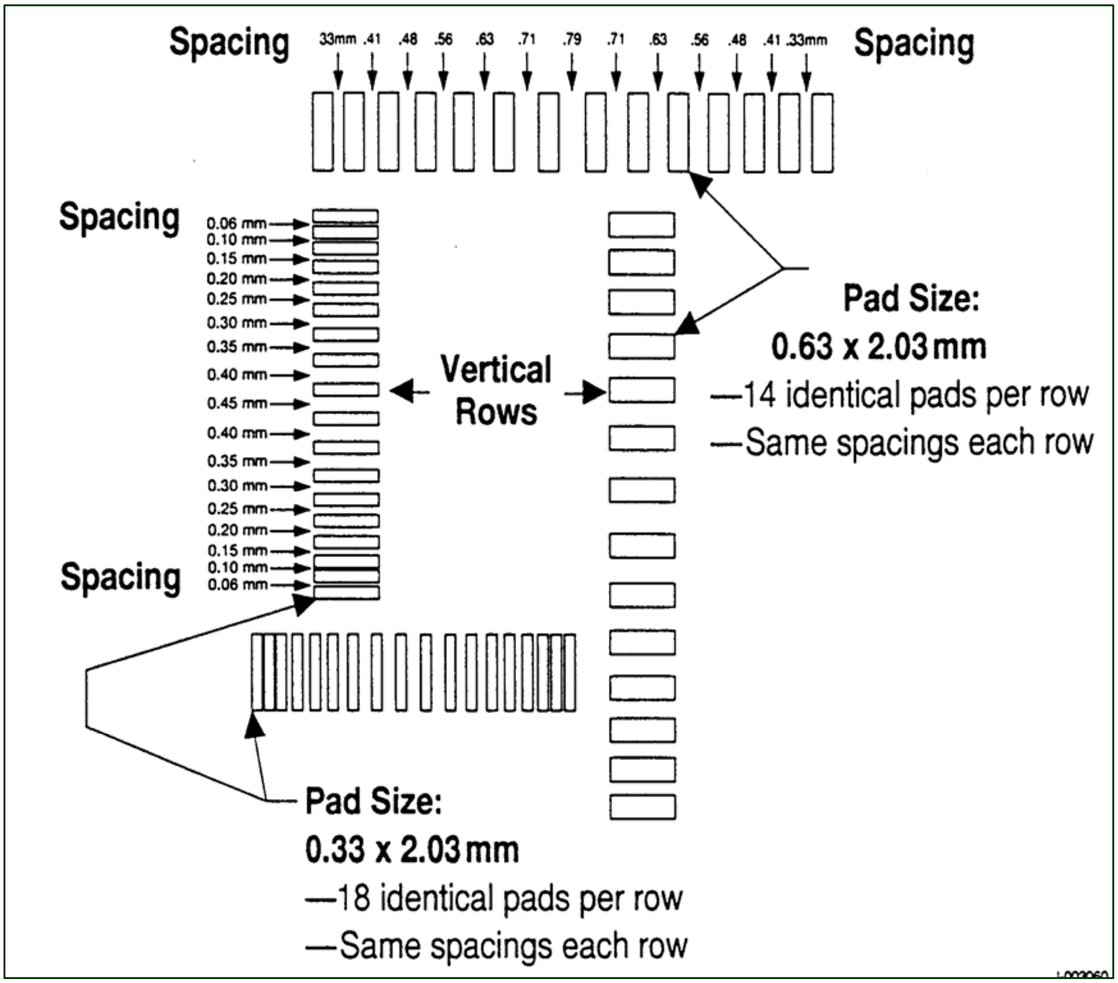
Typical viscosity is 1850 poise (88% metal, SnAg3.0Cu0.5 alloy, -400+500 mesh, 12% flux content)

The viscosity is measured using a Malcom PCU-203 viscometer at 10 rpm, 25°C and measurement taken after 9 min.

4.2 Slump

Under the slump test method per J-STD-005 specifications, Method 2.4.35, two sets of test specimens are prepared. A stainless steel stencil, IPC-A-21 of 8 mils (0.2 mm) thick is used as shown below. The spacing between the apertures varies from 0.06 mm to 0.45 mm with varying increments. The solderpaste is manually printed on a ceramic plate using this stencil.

Fig 3: IPC-A-21 Stencil



Two test specimens are prepared. One set of test specimen shall be marked as #1 and the other specimen as #2 to test for cold and hot slump respectively.

For cold slump test, specimen #1 is placed for 50 to 70 minutes at 25 ± 5°C and 50 ± 10%RH. The slump behavior is examined by observing the minimum spacing across which the paste has not merged.

For hot slump test, specimen #2 is heated in a air-circulating convection oven at about 180 °C for 1 minute after printing and cooled to ambient temperature and examined for slump. The minimum spacing across which the paste has not merged after the hot slump test is observed.

Results:

Table 10 : Slump Results

EnviroMark™ 919G (1 hr @ 25°C ± 5°C and 50% ± 5%RH)					
Stencil IPC-A-21 (0.2mm/~8mil Thick)					
Pad Size 0.63 x 2.03 mm			**Pad Size 0.33 x 2.03 mm**		
0.33mm or greater			**0.10mm or greater**		
Spacing Mm	**Hor.**	**Vert.**	**Spacing mm**	**Hor.**	**Vert.**
0.79	Pass	Pass	0.45	Pass	Pass
0.71	Pass	Pass	0.40	Pass	Pass
0.63	Pass	Pass	0.35	Pass	Pass
0.56	Pass	Pass	0.30	Pass	Pass
0.48	Pass	Pass	0.25	Pass	Pass
0.41	Pass	Pass	0.20	Pass	Pass
0.33	Pass	Pass	0.15	Pass	Pass
-	-	-	0.10	Pass	Pass
-	-	-	0.08	Pass	Pass
Result : Pass at room temp (no bridging at 0.33mm or greater)			Result : Pass at room temp (no bridging at 0.08mm or greater)		

Note: b = bridged

EnviroMark™ 919G (1 min @ 180°C ± 5°C and 35% ± 10%RH)					
Stencil IPC-A-21 (0.2mm/~8mil Thick)					
Pad Size 0.63 x 2.03 mm			Pad Size 0.33 x 2.03 mm		
0.33mm or greater			0.20mm or greater		
Spacing Mm	**Hor.**	**Vert.**	**Spacing mm**	**Hor.**	**Vert.**
0.79	Pass	Pass	0.45	Pass	Pass
0.71	Pass	Pass	0.40	Pass	Pass
0.63	Pass	Pass	0.35	Pass	Pass
0.56	Pass	Pass	0.30	Pass	Pass
0.48	Pass	Pass	0.25	Pass	Pass
0.41	Pass	Pass	0.20	Pass	Pass
0.33	Pass	Pass	0.15	Pass	Pass
-	-	-	0.10	b	b
Result : Pass at 180 °C (no bridging at 0.33mm or greater)			Result : Pass at 180 °C (no bridging at 0.10mm or greater)		

Note: b = bridged

EnviroMark™ 919G has good slump resistance per J-STD-005.

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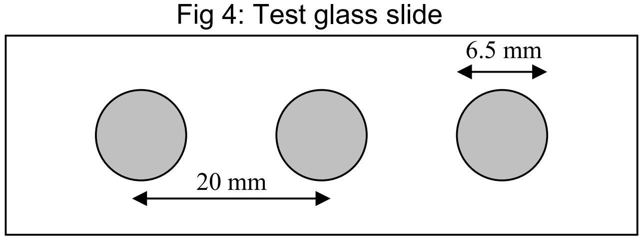
4.3 Static Tack Test

Kester EM919G is tested to IPC-TM-650, Method 2.4.44, which is the industry's standard tack test. The testing was conducted over a 24-hour period to verify the consistency of tack over time.

The tackiness test is conducted by using the Chatillon Tackiness Tester. Solderpaste deposits of 0.65 cm in diameter and 0.25 mm thick are printed onto a glass slide. The test probe is brought into contact with the printed paste specimens at a rate of 2.5 ± 0.5 mm/min and a force of 300 ± 30 grams. Within 5 seconds following the application of this force, the probe is withdrawn from the specimens at a rate of 2.5 ± 0.5 mm/min and the peak force required to break the contact is recorded. This force is known as the tackiness of the paste. The tack force is measured at different time intervals after the solderpaste specimens are left at room temperature.

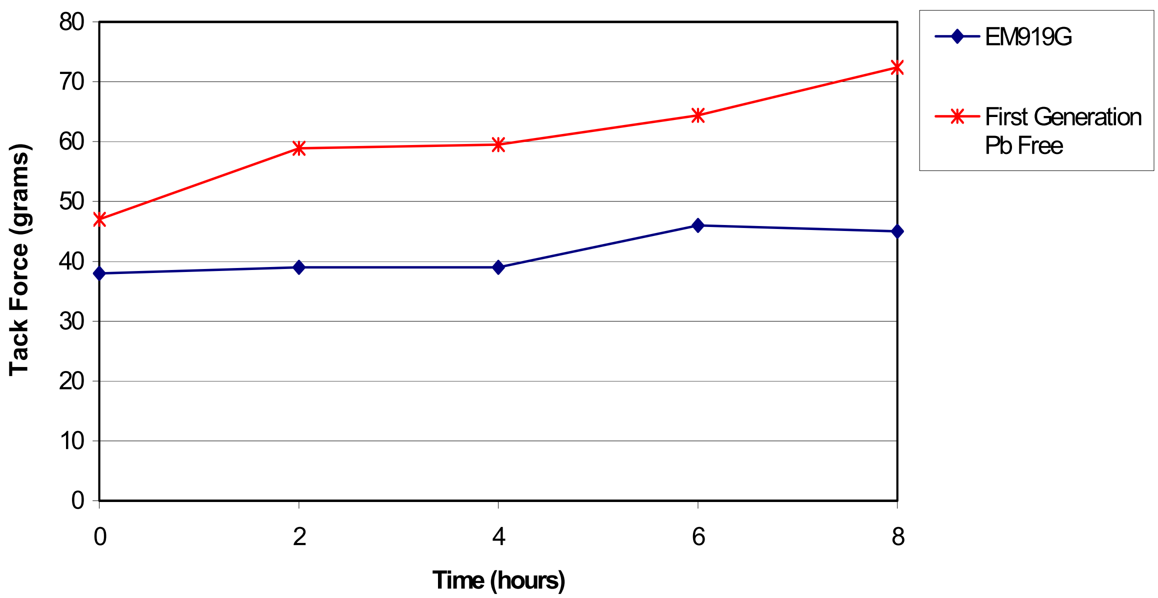
Fig 4: Test glass slide



Results:

EM919G remained very stable over the course of the test. This data indicates a stable tack value after boards are printed. This data is particularly applicable to production environments where printed boards are left waiting for components. A stable tack value indicates that EM919G will not present problems with a loss of tack if printed paste is left in the open environment. This data may vary depending on paste thickness, volume, component placement pressure and process conditions.

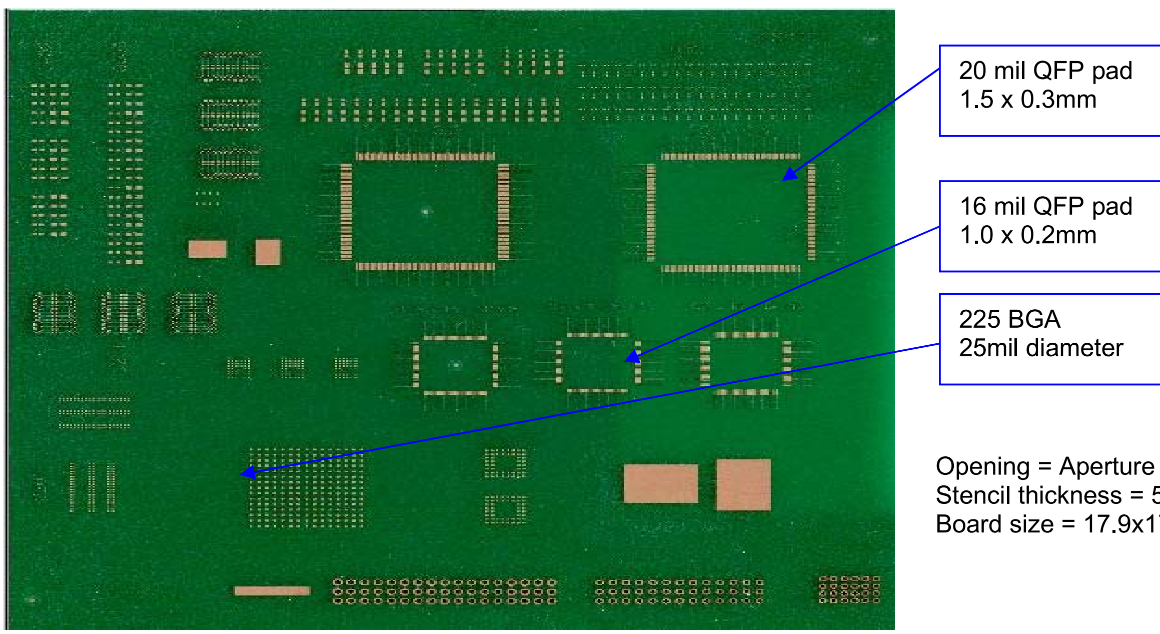
Figure 5: StaticTack



4.4 Printing Flexibility

Kester EM919G (SAC, Type 3 powder, 12% flux) was tested utilizing a MPM UP1500 fully automated stencil printer. Testing was conducted under typical production temperature and humidity conditions (23°C/73.4°F / 55%RH). EM919G was printed at 20mm/sec and 150mm/sec continuously for about 1 hour. The paste was observed at each print speed for rolling behavior, squeegee sticking and print definition.

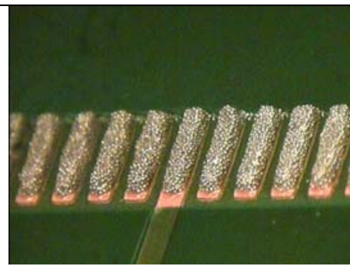
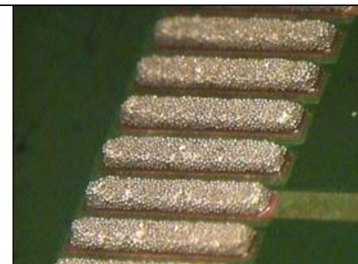
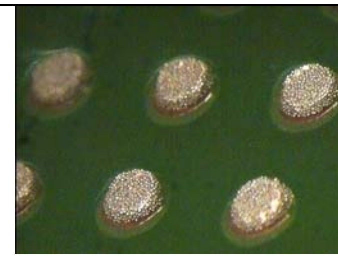
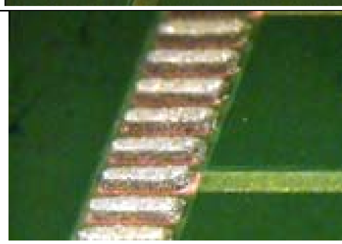
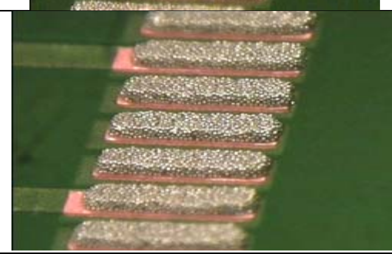
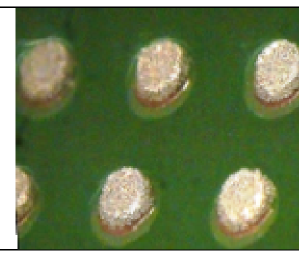
Test Condition Notes:
Test Vehicle Identifier: KS0003 Test Board (see Figure 6)
Stencil Type: Laser Cut / Electro-Polished
Stencil Thickness: 5 mil
Printer Type: MPM Ultraprint UP1500
Squeegee Material: Stainless Steel
Squeegee Length: 12”
Squeegee Angle: 45°
Temperature and Humidity of the Test Environment: 23°C/ 73.4°F / 55%RH

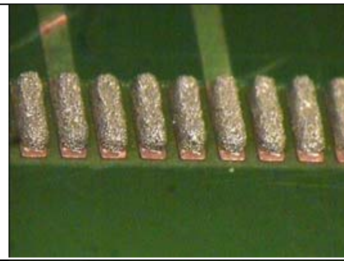
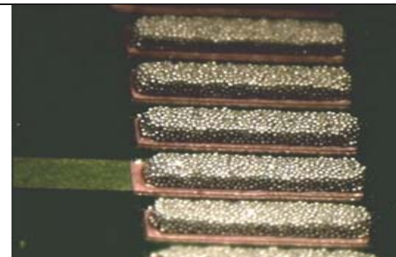
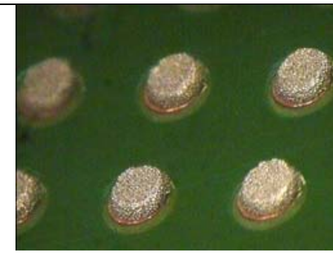
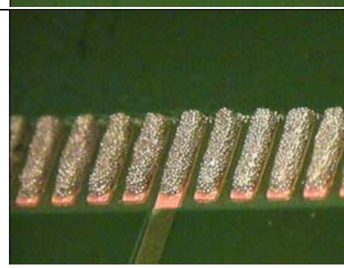
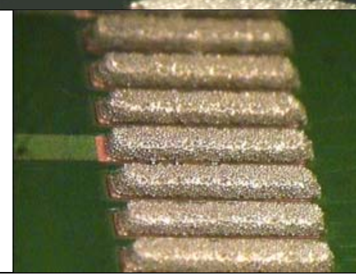
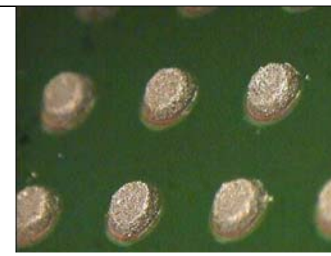


Opening = Aperture : pad (1:1)
Stencil thickness = 5mils
Board size = 17.9x17.5cm

Figure 6 : KS0003 Board1

Results:

Printer Used: MPM UP1500 KS0003 Board Print Speed: 20mm/sec, Print pressure: 4kg, Snap off Speed: 1mm/sec Test Environment: 23°C/ 73.4°F / 55%RH			
	16 mil QFP Pad 1.0 x 0.2 mm	20 mil QFP Pad 1.5 x 0.3 mm	BGA pad Dia = 25 mil
Initial			
After shear			

Printer Used: MPM UP1500 KS0003 Board Print Speed: 150mm/sec, Print pressure: 9kg, Snap off Speed: 1mm/sec Test Environment: 23°C/ 73.4°F / 55%RH			
	16 mil QFP Pad 1.0 x 0.2 mm	20 mil QFP Pad 1.5 x 0.3 mm	BGA pad Dia = 25 mil
Initial			
After shear			

EM919G was evaluated at different print speeds without demonstrating any degradation in printing performance at the various component locations after shearing.

4.5 Shear Sensitivity (Thixotropic Index and Non-Recovery Rate of Viscosity)

Kester EM919G (SAC, Type 3 powder, 12% flux) was tested on a Malcolm viscometer. The procedure is intended to determine the loss in viscosity over time under high amounts of shear. Readings are taken from the viscometer in the following order: 10 rpm, 3 rpm, 4 rpm, 5 rpm, 10 rpm, 20 rpm, 30 rpm and 10 rpm. The second and third readings at 10 rpm are compared for the purpose of this test. The first 10-rpm reading is considered a baseline "warm-up" viscosity. The subsequent 10-rpm readings are compared to each other to verify a stable viscosity after a high amount of shear. The second value is typically very near the initial value because very little shearing has occurred. (Having a high degree of consistency between the first and second 10-rpm readings is expected for most solder pastes.) The percent change between the second and third 10-rpm readings is recorded as the "Percent non-recovery of viscosity". The optimal percent non-recovery is 0%, or complete recovery of viscosity characteristics. Good paste formulations tend to be <5% in this test. Percent non-recovery over 5% indicates that the paste tends to shear thin substantially with a continuous applied stress.

Results: 3.51% non-recovery rate of viscosity. Detailed data is presented in Table 10 and 11.

Data Explanation:

The percent non-recovery of viscosity value is the amount of viscosity lost between the second and third viscosity readings at 10 RPM. It should be emphasized that this loss in viscosity represents the decrease in viscosity during a 6-minute period of consistent shear.

A solder paste with <5% loss of viscosity is considered excellent. This paste would continue to remain very stable on the stencil during a consistent, high-volume printing operation.

A solder paste with between 5 and 10% loss of viscosity should be considered marginal in terms of stencil stability. This paste may result in increased slumping and bridging as the stencil life is extended to more than 4 hours.

A solder paste that loses >10% of its viscosity during the test should be expected to shear thin excessively. Such a paste would become very "thin" on the stencil. This will ultimately result in severe slumping and a massive increase in bridging defects. This paste may work well in short production runs (or evaluations), but will fall apart under consistent printing applications.

Table 10: EM919G Thixotropic Index and Non-Recovery Rate of Viscosity

	V_{10A}	V_3	V_4	V_5	V_{10B}	V_{20}	V_{30}	V_{10C}
SPINDLE SPEED (rpm)	10	3	4	5	10	20	30	10
TIME TO MEASURE (min)	3	6	3	3	3	1	1	1
EM919G Viscosity (Poise)	1840	3551	3024	2700	1882	1420	1225	1816

TI (THIXOTROPY INDEX) = log (V_3) - log (V_{30})

R (NON-RECOVERY RATE OF VISCOSITY) = (V_{10B}-V_{10C}) / V_{10B} X 100

	TI/SSF	R
EM919G	0.46	3.51 %

Table 11: First Generation No Clean Lead Free Thixotropic Index and Non-Recovery Rate of Viscosity

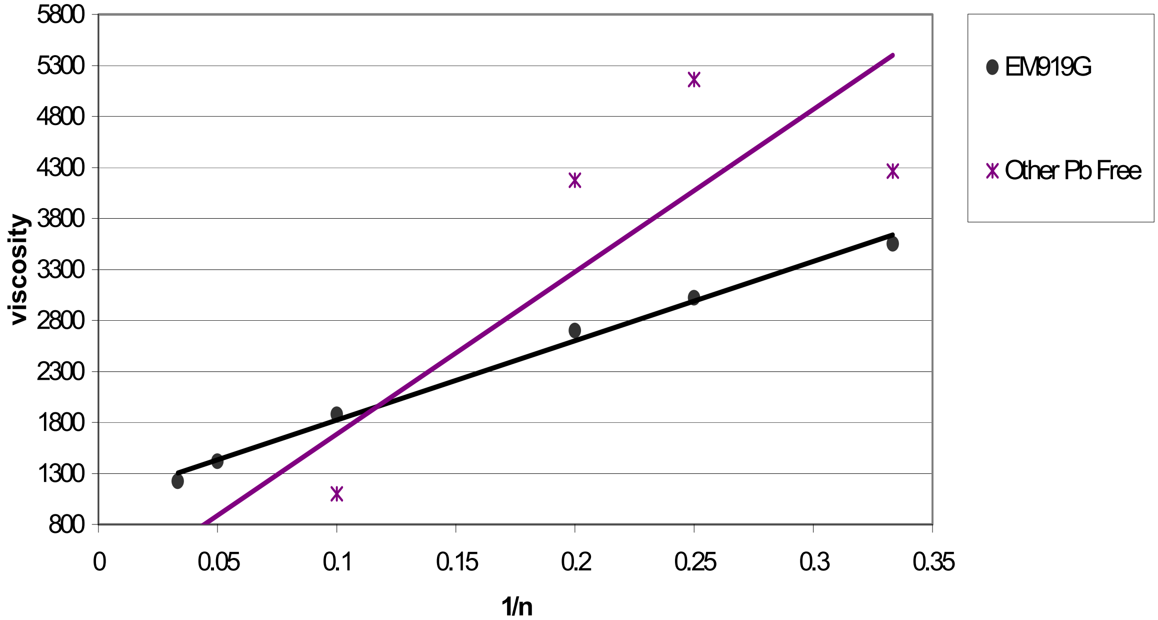
	V_{10A}	V_3	V_4	V_5	V_{10B}	V_{20}	V_{30}	V_{10C}
SPINDLE SPEED (rpm)	10	3	4	5	10	20	30	10
TIME TO MEASURE (min)	3	6	3	3	3	1	1	1
First Generation No Clean Pb-Free Solder Paste Viscosity	1840	3920	3380	2910	1890	1100	840	1640

TI (THIXOTROPY INDEX) = log (V_3) - log (V_{30})

R (NON-RECOVERY RATE OF VISCOSITY) = (V_{10B}-V_{10C}) / V_{10B} X 100

	TI/SSF	R
First Generation No Clean Pb-Free Solder Paste	0.67	13.2 %

Figure 7 : Shear Sensitivity of EM919G and a First Generation commercially available No Clean Lead Free Solder Paste



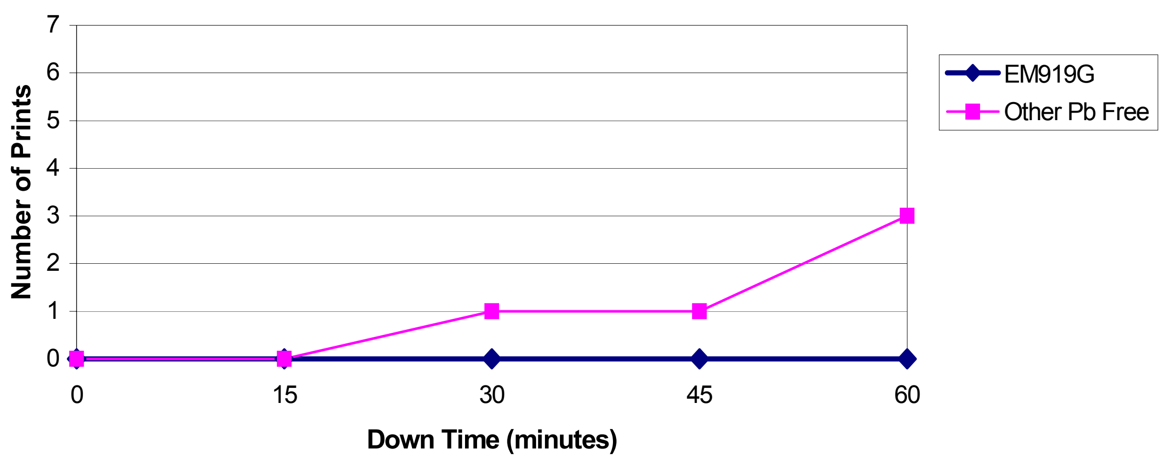
4.6 Relax/Recovery (Dwell Time)

Kester EM919G solderpaste was tested utilizing an MPM fully automated stencil printer. Testing was conducted under typical production temperature and humidity conditions (23^{o}C / 73.4^{o}F and 50% RH). EM919G was subjected to print breaks ("relaxations") of varying lengths to see how the product would respond to printer downtime. Solder paste deposits were examined visually after downtimes of 15 to 60 minutes. For the purpose of this test, a "pass" is considered a solder paste deposition of at least 95% on a 20-mil QFP pad area.

Results:

Kester EM919G solderpaste was capable of a 60 minute "relaxation" without causing any print related problems. This indicates that the stencil printer can be left idle for at least 60 minutes without requiring any kneading before printing the first board. The chart on the following page compares the relax & recovery characteristics of EM919G to previous generation No-Clean Pb-free paste. EM919G clearly opens the process window in the area of printer downtimes.

Figure 8 : Relax/Recovery Data for EM919G



4.7 Flux Percent Recommendation

The recommended flux percentage for stencil/screen printing applications is as follows :
12.0% flux by weight (88.0% metals by weight) for SnAgCu alloys of mesh –325+500.
12.0% flux by weight (88.0% metals by weight) for SnAgCu alloys of mesh –400+500.

Please contact your local Product/Technical Support Group for recommended flux percent.

4.8 Printing Parameters

a)	Squeegee Blade	:	80 to 90 durometers Rubber or Stainless Steel
b)	Squeegee Speed	:	Capable to a maximum speed of 150mm/sec
c)	Stencil Material	:	Brass, Stainless Steel, Nickel Plated, Molybdenum
d)	Snap off	:	0 ~ 0.5 mm (dependent upon board design and machine capability) Although on-contact (zero snap-off) is normally recommended for fine-pitch application, it is still advisable to provide proper snap-off distance so that the stencil or PCB can be separated from the substrate smoothly and gradually to ensure good solder deposits.
e)	Operating conditions	:	Optimal ranges are 21-25^{o}C (70-77^{o}F) and 35–65%RH

5 Reflow

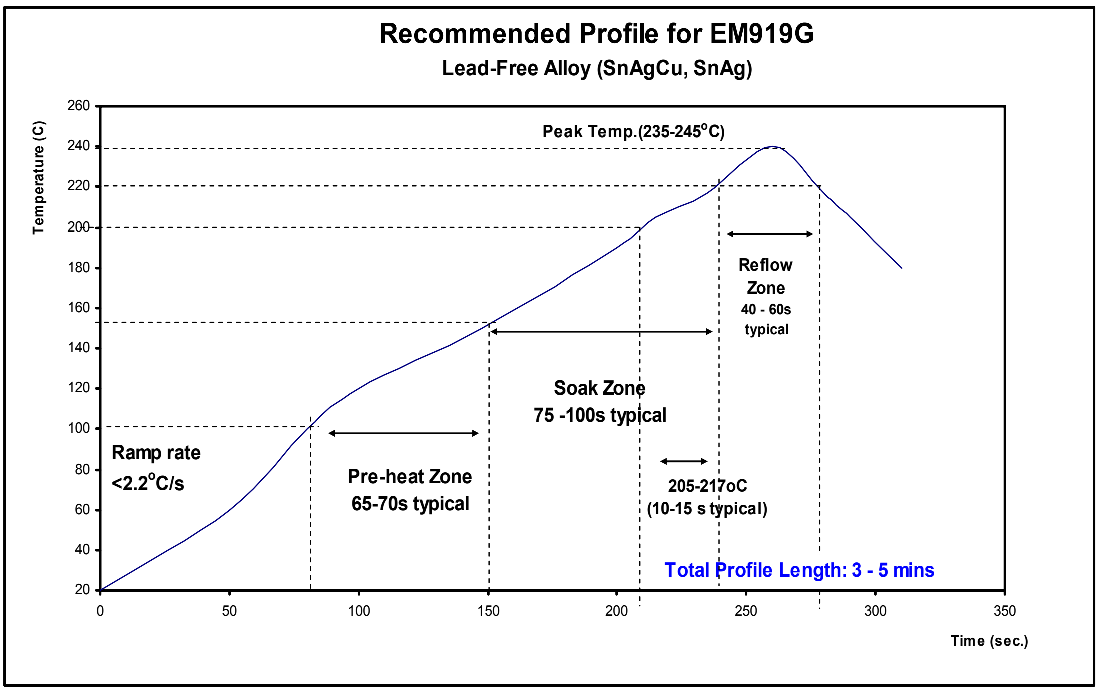
5.1 Reflow Environment

Kester EM919G was designed for excellent wetting and spreading performance in air reflow environments. When the reflow environment is inerted with nitrogen, wetting is enhanced.

5.2 Reflow Profile Recommendation

The recommended reflow profile is located in Figure 9.

Figure 9: Recommended Reflow Profile



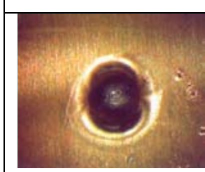
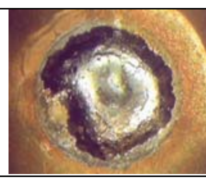
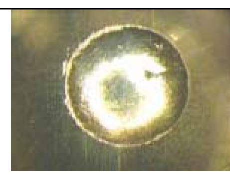
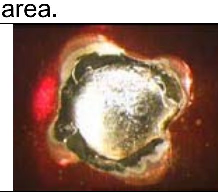
- A gentle linear ramp-up profile is preferred to reflow low to medium thermal mass assemblies.
- Lower peak temperatures may require longer dwell time for better joint cosmetics.
- Fast cooling is typically recommended as it encourages finer grain growth and hence better solder interconnect joints. This will depend on thermal shock and component sensitivity. Refer to component suppliers' guidelines and specifications.
- Above information is a guideline. Since EM919G is a highly active solderpaste, it can solder effectively over a wide range of profiles. It is possible that the optimal settings for a given assembly may vary from the above profiles based on your circuit board design, board thickness, components used, reflow oven equipment and mix of defects.

5.3 Solderability/Wetting

The solderability of Kester EnviroMark 919G was investigated and compared on various surface metallization when reflowed per the recommended reflow profile in air as illustrated in Section 5.2 and Figure 9.

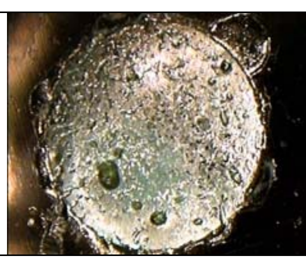
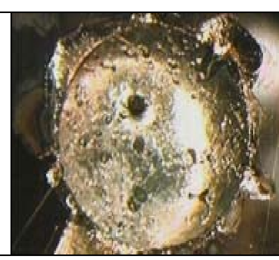
Procedure:
Samples were prepared by stencil printing solder paste deposits of 6.5mm in diameter and 6 mils thick onto the oxidized coupons. The coupons used are of brass and nickel substrates. The coupons were reflowed under air using a Heller convection oven. The reflowed coupons were visually inspected for wetting, spreading and coalescing of the solder and graded according to the figure below:

Grading for wetting:

Grading			
4	3	2	1
Condition where no solder seems wetted, and the molten solder becomes one or more solder balls (non-wetting)	Condition where almost all the solder paste-coated part is wetted by the solder (including the de-wetted)	Condition where all the solder paste-coated part is wetted by the solder.	Condition where the solder dissolved from the solder paste wets the test plate, and the wetted area becomes larger than the paste coated area.
			

Remarks: Grading of 1 gives the best wetting and grading of 4 with the worst wetting.

Results :

Paste	**Wetting Results**		
	Brass	**Nickel**	**Copper**
EM919G	2	2	2
			

The solderability of EM919G was investigated and compared on various surface metallization when reflowed in air environment. Kester EM919G has excellent wettability on brass, nickel and copper metallization in air reflow.

5.4 Solderball Test

The solder ball test is conducted per J-STD-005 Method 2.4.43. The aim of this test is to determine the reflow property of a solderpaste.

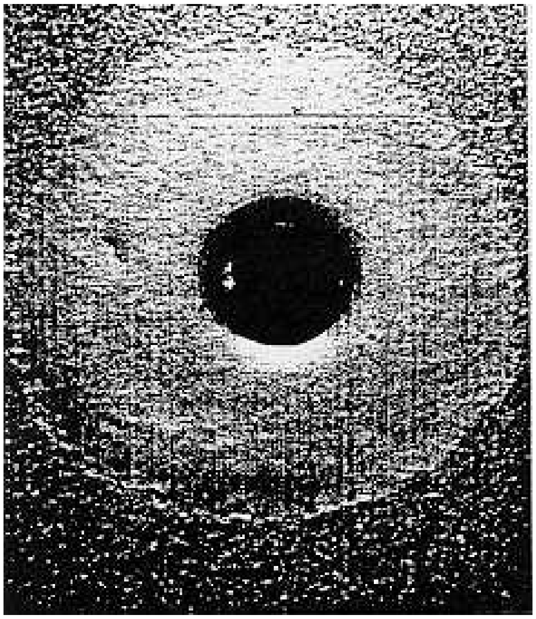
Two test specimens are prepared by printing three solderpaste deposits of 0.65 cm in diameter and 0.25 mm thick onto a glass slide using a stencil (same as Tackiness Test). The printed deposits should be uniform in thickness with no solder particles between them.

One set of test specimen is reflowed within 15 ± 5 minutes after printing. The other test specimen is stored at 25 ± 3^{o}C and 50 ± 10% RH for 4 hours ± 15 minutes after printing and then reflowed. Both specimens are reflowed on a hot plate that is heated at a temperature of 25 ± 3^{o}C above the liquidous temperature of the solder alloy. As soon as the solder has melted, the specimens are withdrawn from the hot plate. The reflow shall occur within 20 seconds after the specimen is placed in contact with the hot plate.

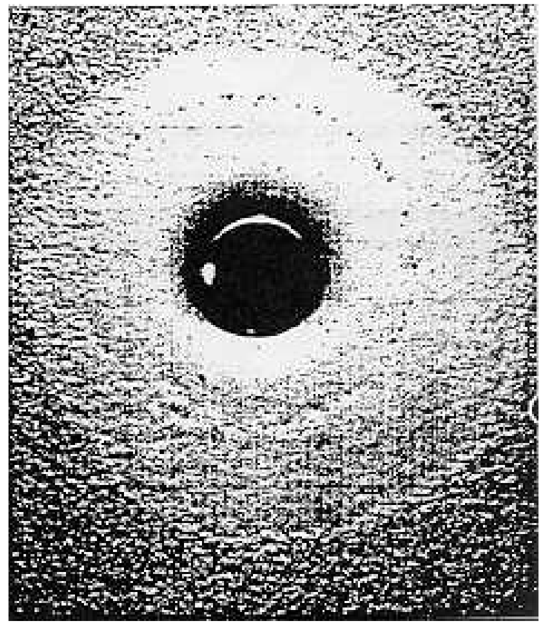
The reflowed specimens are inspected under 10x to 20x magnification. The solder ball size and number are compared with the solder ball test standards stated in J-STD-005 specifications, illustrated in the following page.

Paste	Result
EnviroMark 919G	Preferred

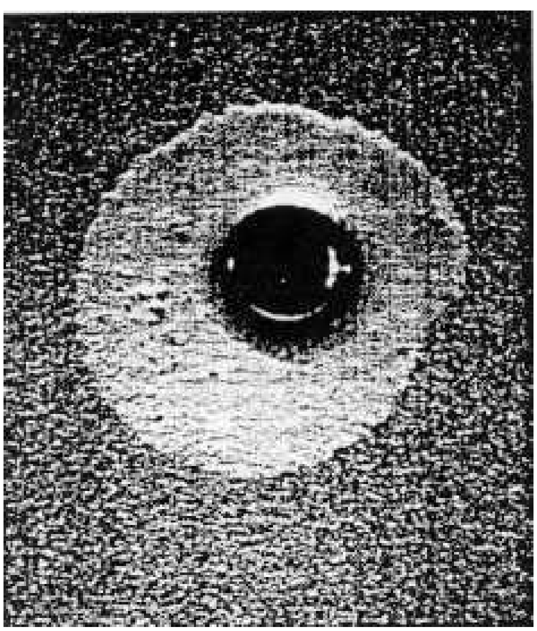
J-STD-005 Solder Ball Test Standards



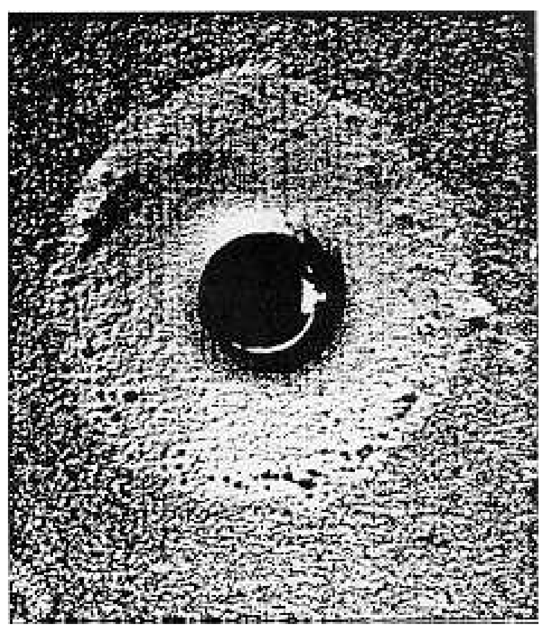
Preferred



Acceptable



Unacceptable: Clusters



Unacceptable

5.5 Voiding Characteristic

A voiding test was performed. Test board with BGA pads was printed with EM919G paste and then reflowed using the different profiles in air environment. The BGA pads were then observed for voiding using x-ray.

Profile	Ramp rate 50-100ºC (ºC/sec)	Preheat 100-150ºC (sec)	Soak 1 150-205ºC (sec)	Soak 2 205-217ºC (sec)	Dwell >217ºC (sec)	Peak Temp (ºC)	Results
Profile 1 (short)	2.20	69	68	10	42	238	Pass IPC Class III
Profile 2 (medium)	1.58	65	84	16	60	245	Pass IPC Class III
Profile 3 (long)	0.88	65	89	31	60	245	Pass IPC Class III

Comments:
Based on internal study, EM919G has superior voiding performance and conforms to the voiding requirements for Class III per IPC-7095 when reflowed under a wide range of profiles.

5.6 Residue Characteristic

The residue is categorized as light color. The majority of the residue flows away from the soldered interconnection.

Results:

Paste	In Air Reflow	In Nitrogen Reflow
EM919G		

5.7 Residue Probeability

Kester EM919G was tested for probeability using a Chatillon Digital Force Gauge. Probeability is the ease of penetration for numerous hits over time, without clogging the probe tip or preventing conductivity. EM919G residues were penetrated 100 times and the residue built up at probe tip was monitored through measurement of probe force and visual inspection. Testing was conducted under typical production temperature and humidity conditions(23^oC / 73^oF and 52% RH).

Results:

Response	Typical Pb Free No-Clean Solder Paste	EM919G
Residue on pin probe tip after 100 probe cycles	 Residue accumulated on pin probe tip	 Pin probe tip remained clean

Comments:
EM919G residue is soft and probeable.

6 Application Guidelines

6.1 Storage Recommendations

Storage in refrigeration is recommended as the optimum storage condition in order to maintain consistent viscosity, reflow characteristics and overall performance. Hence Kester EnviroMark™ 919G solderpaste should be stored at 0 – 10°C (32 - 50°F) refrigeration and the shelf life is 4 months (from the date of manufacturing).

6.2 Paste Preparation

The solderpaste is recommended to be thawed from refrigerated condition to the room temperature before opening the jar. The jar should not be opened when it is cold so as to prevent moisture condensation on the paste, which may disturb the performance of the paste.

The recommended thawing time is at least 3 hours when it is initially taken out from the refrigerator at 0 - 10°C. In cases of shift production, it is advisable for the shift operators to draw the solderpaste from the storage room for the next shift to ensure sufficient recondition time for the solderpaste before the next shift commences.

After thawing, the paste from the jar should be stirred lightly in circular movements of at least 15 turns to ensure that the paste is mixed homogeneously before printing. A stainless steel spatula can be used for stirring. The paste can also stirred using a solderpaste softener. For Malcom SPS-1 softener the recommended spin time with insert is about 4 minutes and without insert is about 1-3 minutes after the paste has been thawed for 3 hours at 25 °C.

The paste packed in cartridges should be thawed under similar conditions as the jar but dispensed from the cartridge to initiate shear.

6.3 Printing Tips

a) Place sufficient amount of solderpaste on the stencil. Add fresh paste to replenish the consumed amount. It is important to minimize the quantity of paste left on the stencil to ensure continuous printing.

b) After a certain period of continuous printing, it is important to thoroughly clean the bottom or both the top and bottom sides of the stencil to ensure smooth printing. Any smearing of paste on the bottom side of the stencil to the board can result in solderballs.

c) It is recommended to clean both the top and bottom side of the stencil before break.

d) Used paste on the stencil is not advisable to be scooped back into the original jar to prevent mixture and contamination of fresh paste. It should be placed in a separate empty jar for reuse if necessary.

e) In cases where only half of the solderpaste in the jar is used, the plastic insert should be returned until it comes into contact with the surface of the unused solderpaste, recap, retape and stored in a cool area when not in use, preferably into the refrigerator to minimize exposure of the solderpaste.

7. Shelf Life

The shelf life for EnviroMark™ 919G No Clean Solder Paste is 4 months (from DOM) when held under 0-10°C (32-50°F) refrigeration and unopened.

8. Health and Safety

Kester EnviroMark™ 919G solderpaste may be hazardous to health or the environment during handling and use. Please read the Material Safety Data Sheet and the warning label before using this product.

9. Product Summary

We hereby summarize the features of Kester EnviroMark™ 919G paste:

- Lead free and no clean
- Halogen free and halide free chemistry
- Capable of print speeds up to 150 mm/sec (6 in/sec)
- Extended Stencil Life (process dependent)
- Excellent release from stencil
- Excellent printing characteristics on 0.4mm (16 mil) pitch
- Capable of 60 minutes break time in printing
- Low voiding characteristic
- Probe friendly residues
- Clean cosmetic aesthetics after reflow
- Resistant to slump
- Stable tack life
- Reflowable in air or nitrogen
- Classified as ROL0 per J-STD-004A
- Compliant to Bellcore GR-78-CORE

10. Licensing Agreements

Kester is licensed to manufacture, use, and sell any solder product covered by U.S. Patent Number 5,527,628 that is assigned to ISURF.

Kester is also licensed to manufacture and sell solder compositions patented by Senju/Matsushita with Japanese Patent JP3027441.

KESTER VISION STATEMENT

Smart Products. Great Service. No Boundaries.

Kester will be the leading global supplier of high performance interconnecting materials and related services for the electronic assembly and component assembly markets.

To achieve this we will focus on customer-driven innovation and exceptional service worldwide.

KESTER IS A GLOBAL SUPPLIER OF ELECTRONIC ASSEMBLY AND COMPONENT ASSEMBLY MATERIALS AND SERVICES

Solderpaste	Soldering Fluxes & Chemicals
Bar Solder	Cored Wire Solder
Solid Wire Solder	Solder Preforms
Flux Pens™ Plating Anodes	SE-CURE™ Polymer Products
Temporary Solder Masks	Tip Thinner & Desoldering Braid
Wafer/substrate bumping solderpaste	Solder spheres for CSPs and
BGAs Solder Recycling Program *	Solder Reclaim Service *

Solder Analysis Program
Tacky Soldering Fluxes (TSF's) for FC, BGA and CSP packaging
Thermal interface materials (TIM) for heat transfer solutions

* :Available in DP only.

Kester Global Locations

GLOBAL
HEADQUARTERS

USA

515 East Touhy Ave.
Des Plaines, IL 60018-2675

Phone: (+1) 847-297-1600
Fax: (+1) 847-390-9338
Email:
customerservice@kester.com

Customer Service
Phone: 800-2-KESTER
Fax: (+1) 847-699-5548

ASIA-PACIFIC
HEADQUARTERS

Singapore

500 Chai Chee Lane
Singapore 4690224

Phone: (+65) 6 449-1133
Fax: (+65) 6 242-9036
Email:
customerservice@kester.com.sg

EUROPEAN
HEADQUARTERS

Germany

Ganghoferstrasse 45
D-82216 Gerlinden
Germany

Phone: (+49) 8142-4785-0
Fax: (+49) 8142-4785-62
Email:
customerservice@kester-eu.com

Mexico

Corretera International. Km 6.5
Esquina Boulevard del Castillo
Porque Industrial
Nogales, Son. 84000
Mexico

For customer service call the Global Headquarters facility

Japan

20-11 YokoKawa 2-Chome,
Sumida-ku
Tokyo 130, Japan

Tel: (+81) 3-3624-5351
Fax (+81) 3-3626-6253

Email: jpsales@kester.com.sg

Brantford, Canada

68 Prince Charles Road
Brantford, Ontario
Canada N3T 5N9

For customer service call the Global Headquarters facility

Penang, Malaysia

Hotel Equatorial Penang,
Unit 2
Lower Level 3, No. 1
Jalan Bukit Jambul 11900
Penang, Malaysia

Tel: (+60) 4-641-4633
Fax: (+60) 4-641-4634

Email:
mssales@kester.com.sg

Bromont, Canada

Technologie Estrie Inc.
30, boul. de l'Aéroport
Bromont (Québec)
Canada J2L 1S6

For customer service call the Global Headquarters facility

Taiwan

4th Floor, No. 128
Lane 235
Pao-Chiao Road
Hsien-Tien City
Taipei Hsien, Taiwan
Republic of China

Tel: (+886) 2-8912-1066
Fax: (+886) 2-8912-1072

Email: twsales@kester.com.sg

Brazil

Av. Tegula
888 B. Ponte Alta
Atibaia-SP Brazil
CEP-12952-820

Tel: (+55) 11-3472-1350
Fax (+55) 11-3472-1380

Email:
comercial@kester.com.br

China

Block B, #03-03/08
No. 5 Xing Han Street
Suzhou Industrial Park
Suzhou 2105021
China

For customer service call the Asia-Pacific Headquarters facility

Johor Bahru, Malaysia

PLO 113, Fasa 3
Kawasan Perindustria Senai
81400 Senai, Johor, Malaysia

Tel: (+60) 7-598-4113
Fax: (+60) 7-598-3103

Plauen-Neuensatz, Germany

Zum-Plom 5
DE-08541
Plauen-Neuensatz
Germany

For customer service call the European Headquarters facility