Reflow Techniques for Void Reduction

BTC Void Reduction For Yield and Performance Enhancement

Dave Heller
CEO, Heller Industries
September 29, 2016

Eliminate Voids
Improve Performance

- Improve heat dissipation of components or solder joint structures (i.e., current density increases with voiding)
- Improve long-term stability and reliability of solder joint against heat dissipation and vibration/shock
- May improve chip performance in high frequency applications

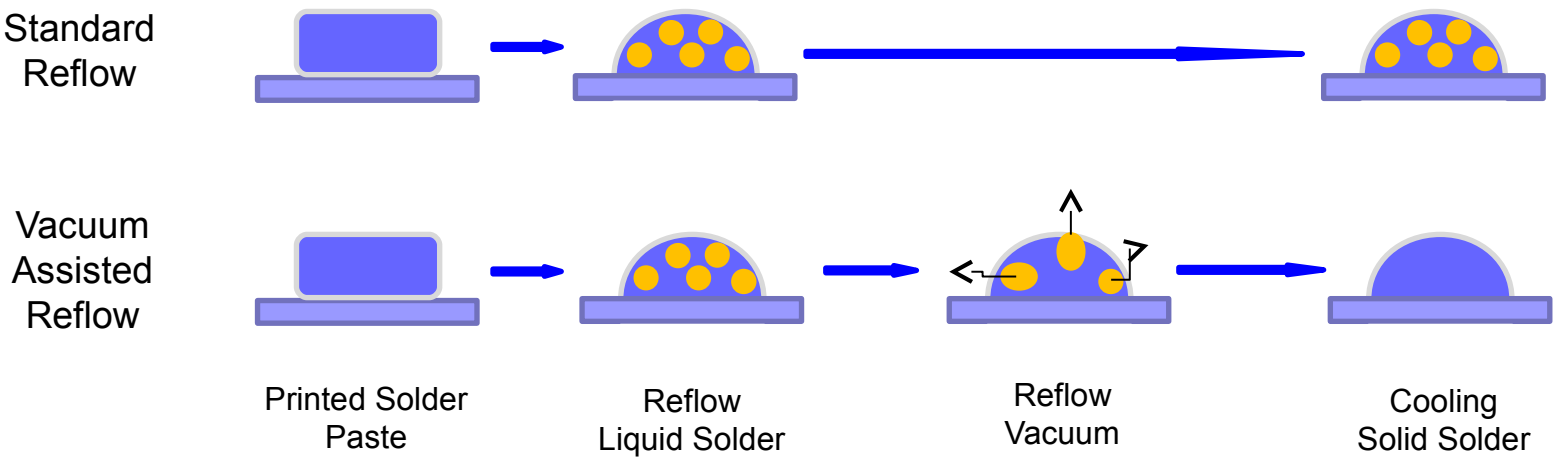
- *Void Reduction Reflow Technique 1*

Vacuum assisted reflow

Vacuum Assisted Reflow

- Vacuum-assisted reflow has been shown to reduce the voids in a solder joint by 99%
- Pressure is dropped to 5-20 Torr during liquidus of the soldering process
- Existing voids escape externally through the solder when vacuum is applied.
  - Trapped gas bubbles increase in size as pressure is reduced
  - Larger bubbles are more likely to collide with other bubbles and ultimately collide with the edge of liquid solder to escape
  - Larger bubbles are accelerated by stronger buoyancy forces making them more likely to escape

Vacuum Assisted Reflow



- Pressure inside trapped gas bubble changes according to Young-Laplace Equation

$$P_{bubble} = P_{ambient} + 2\gamma / r$$

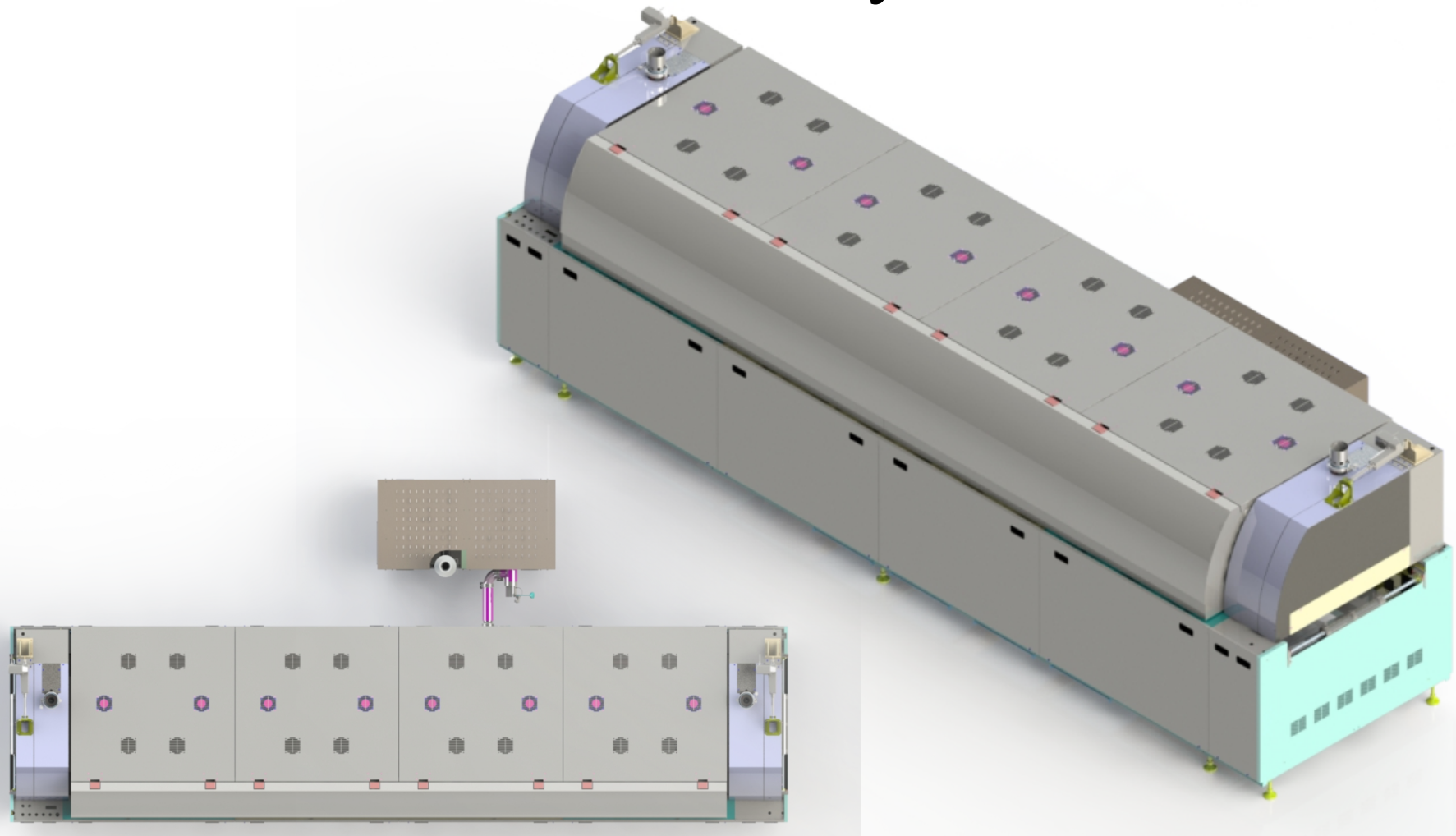
(where γ is surface tension and r is the radius of the bubble)

- Bubble size is then determined by ideal gas law using Pbubble

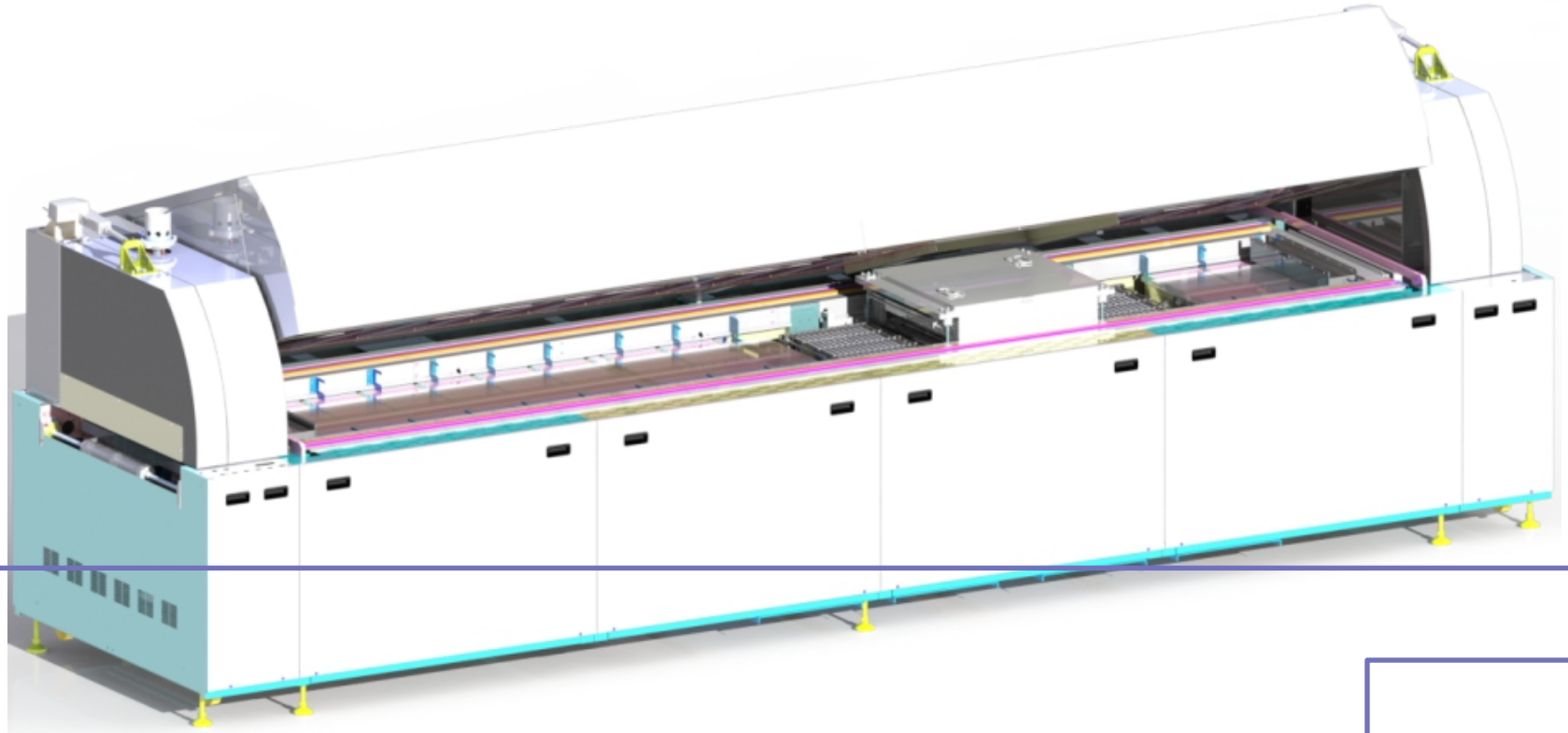
Convection Reflow with Vacuum Module

- Heller Industries has developed a vacuum module that inserts directly in its reflow oven line
- Vacuum module is inserted in zone directly after reflow peak (liquidus) has occurred
- Vacuum module incorporates IR heating to allow for liquidus after vacuum is achieved
- Convection reflow with vacuum module is continuous and allows thermal profiles to be directly ported from non-vacuum reflow applications
- Continuous operation facilitates low COO and high UPH

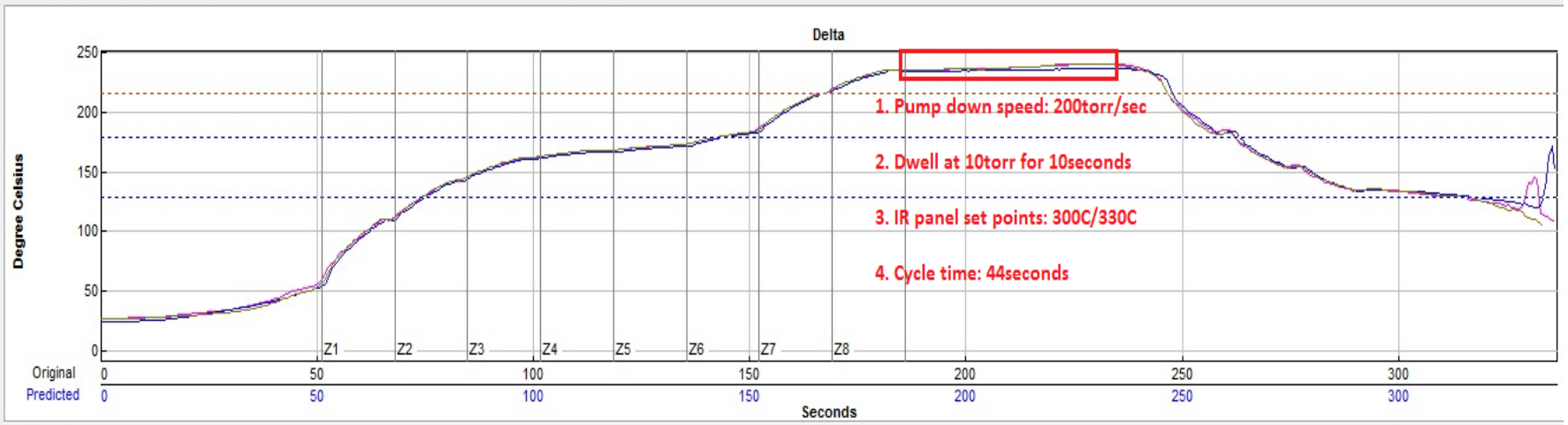
Inline Vacuum Reflow System



Inline Vacuum Reflow System - Layout



Reflow Profile with Vacuum



Profile | Cooling Slope

TCs	Soak Time 130-180°C		Peak Temp		Tot Time /217°C	
<TC2>	68.11	-68%	241.90	-24%	79.20	228%
<TC3>	69.69	-61%	238.28	-169%	80.45	236%
<TC4>	67.81	-69%	241.45	-42%	79.64	231%
Delta	1.88		3.62		1.25	
P.<TC2>	68.11	-68%	241.90	-24%	79.20	228%
P.<TC3>	69.69	-61%	238.28	-169%	80.45	236%
P.<TC4>	67.81	-69%	241.45	-42%	79.64	231%

	P.W.I.	cm/min	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Original Top	236%	120.0	200	190	190	180	180	200	275	275
Original Bottom			200	190	190	180	180	200	275	275
Predicted Top	236%	120.0	200	190	190	180	180	200	275	275
Predicted Bottom			200	190	190	180	180	200	275	275

Top and Bottom are the same

Vacuum Assisted Reflow Customer Test

March 10, 2013

Test Conditions

Sample #	Vacuum Level [torr]	Dwell Time [sec]	Oxygen [PPM]	Remark
1	5	30	400	
2	5	120	400	**
3	10	30	400	
4	10	60	400	
5	20	30	400	
6	20	60	400	
7	Atmospheric	-	400	
8	5	15	400	

*** Should be 60 seconds but mistakenly set to 120seconds*.

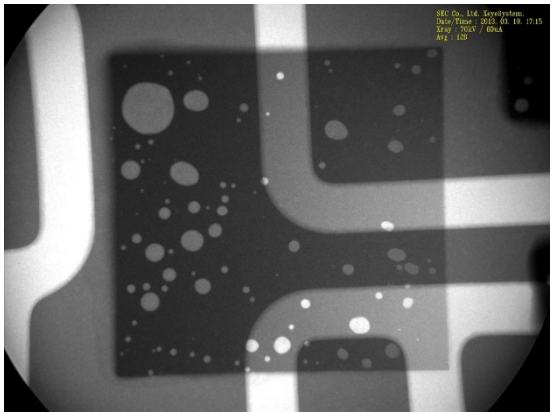
- Die size = 7, 10mm square
- Liquidus peak = 250oC
- Alloy type SAC 305 (217oC Melt Point)

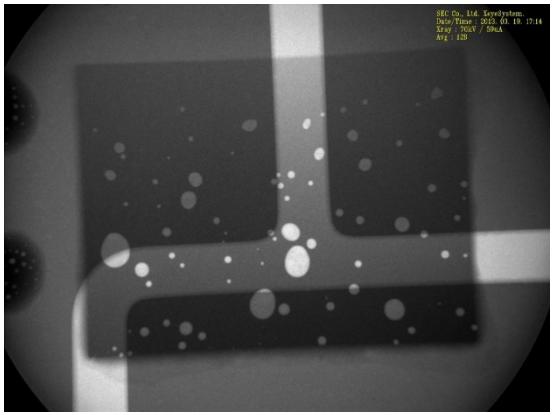
Test Results

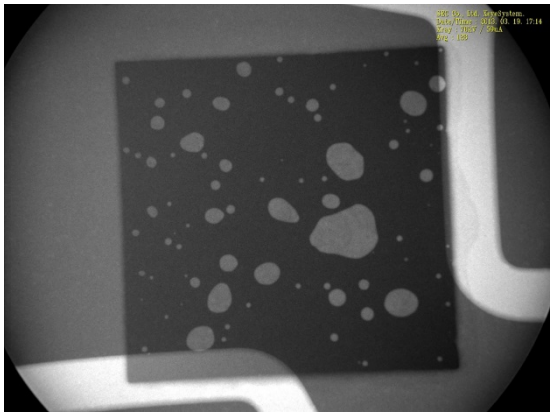
Void Ratio(Worst Case), [%]

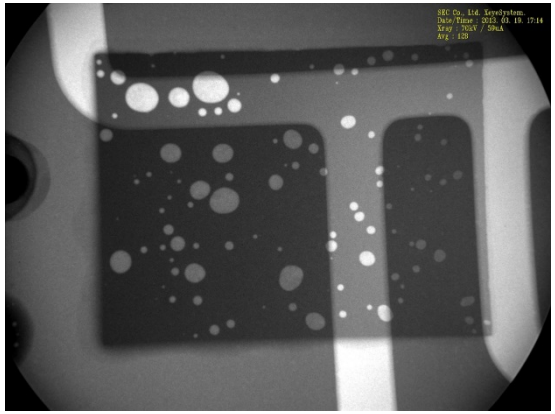
Sample	Vacuum Level [torr]	Dwell Time [sec]	Worst Case [%]
1	5	30	**0.21**
2	5	120	**0.39**
3	10	30	**0.36**
4	10	60	**0.26**
5	20	30	**0.20**
6	20	60	**0.47**
7	Atmospheric	-	**7.64**
8	5	15	**0.48**

Test #7 Details-No Vacuum



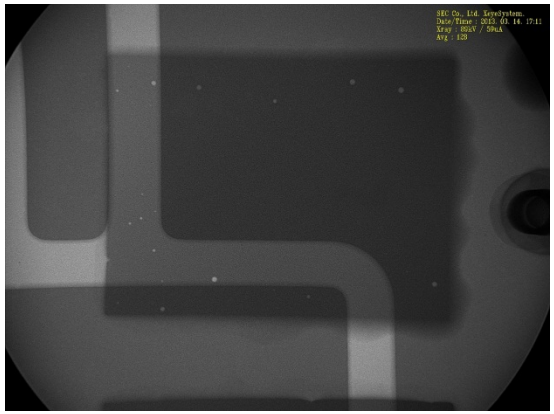
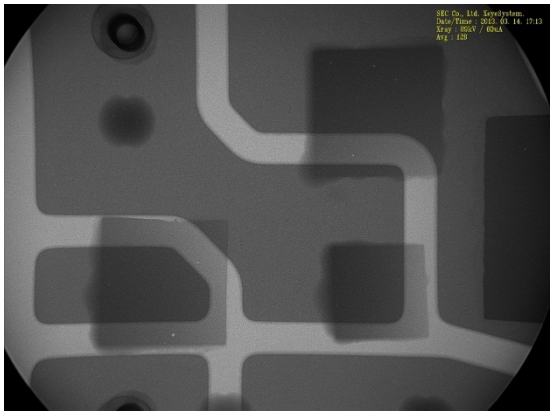
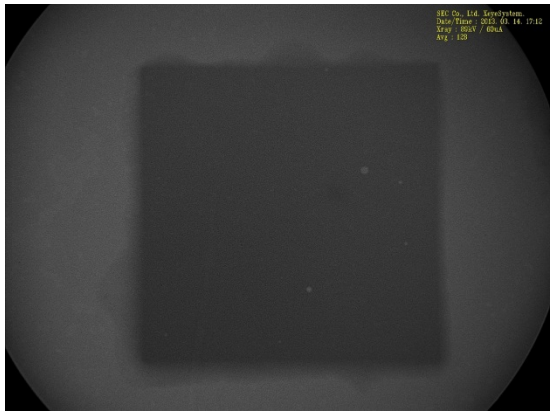
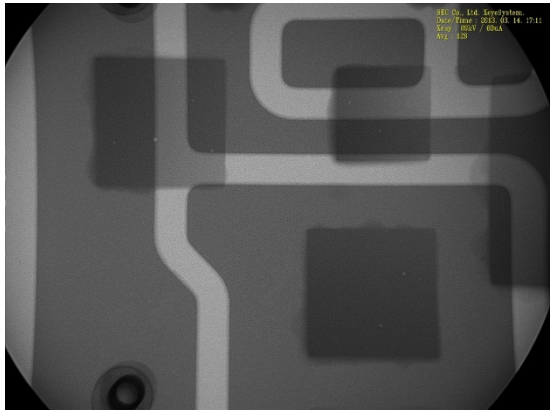
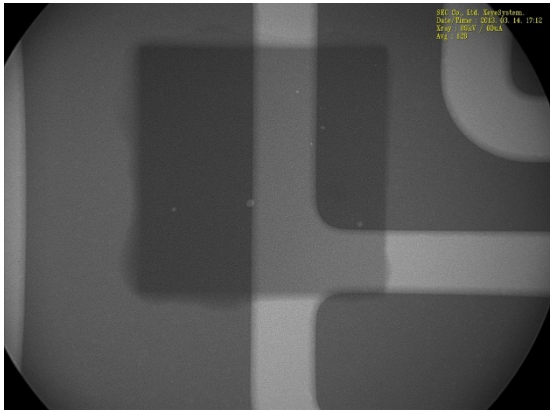
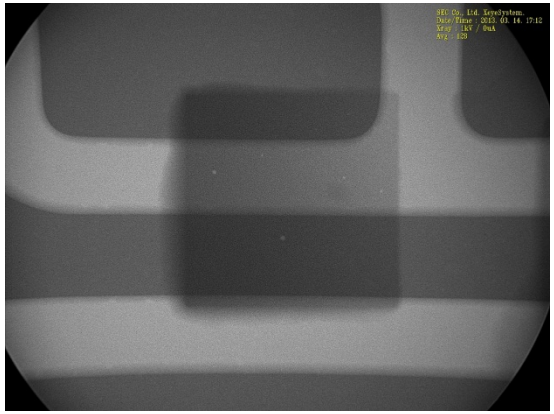






Test #1 w/ 5 Torr for 30 seconds

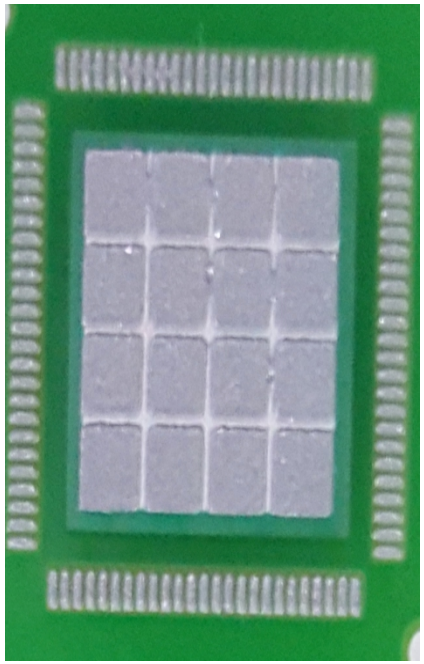
0.21% worst case voids

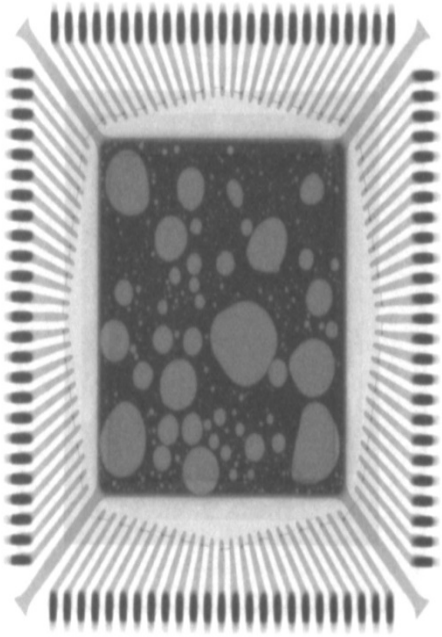
Results Stencil Design #2

1. QFN “MLF 100” of With Vacuum & Without Vacuum

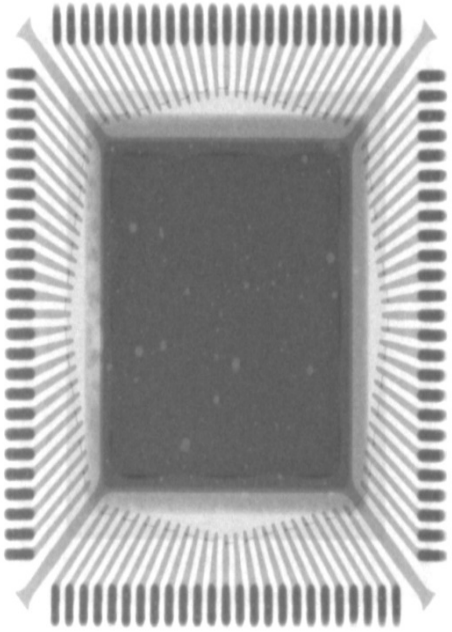
Type 2



without Vacuum

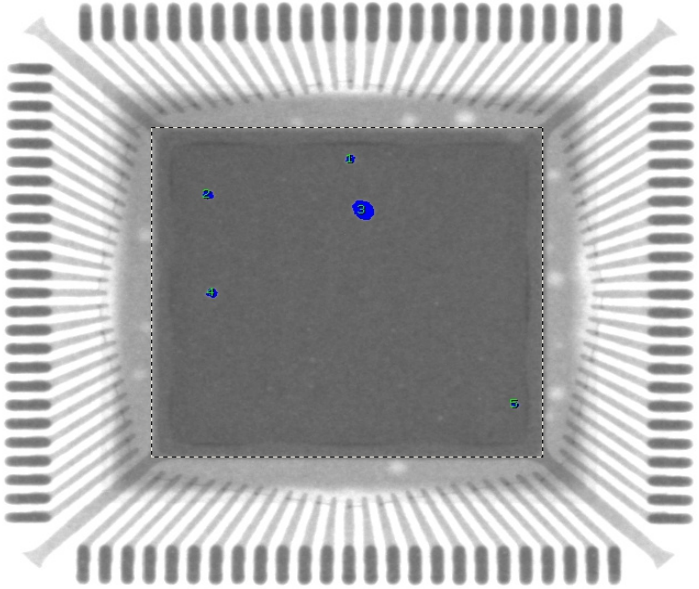


with Vacuum (5torr 60sec)



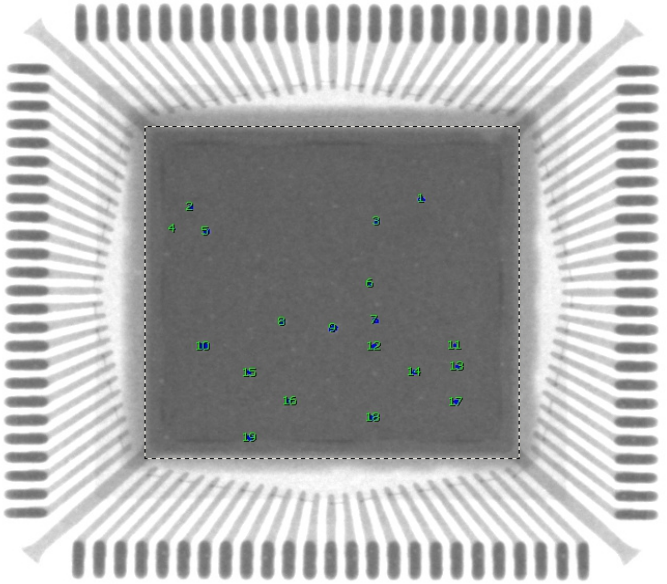
Results

ENIG (20torr / 30sec)



Object Count	5
Object Area	0.2059
Total Area	508.7804
Total Area Ratio	0.04%
AOI Area	48.7241
AOI Area Ratio	0.42%

ENIG (20torr / 60 sec)



Object Count	19
Object Area	0.176
Total Area	508.7804
Total Area Ratio	0.03%
AOI Area	50.6555
AOI Area Ratio	0.35%

Vacuum Reflow Devoiding Summary

- Heller Industries now offers vacuum-assisted reflow through the inclusion of a vacuum module in its reflow oven line
- Vacuum-assisted reflow with convection heating utilizes continuous operation thermal profiles for low COO and high UPH.
- Heller Industries utilizes advanced pumping package with high capacity for fast pump-down time.
- Recent customer demonstration showed 10X reduction in voids, meeting spec of <1% total void area
- Reflow time under vacuum of 15 seconds was able to achieve <1% total void area spec.
- All pressures tested < 20 Torr met <1% total void area spec

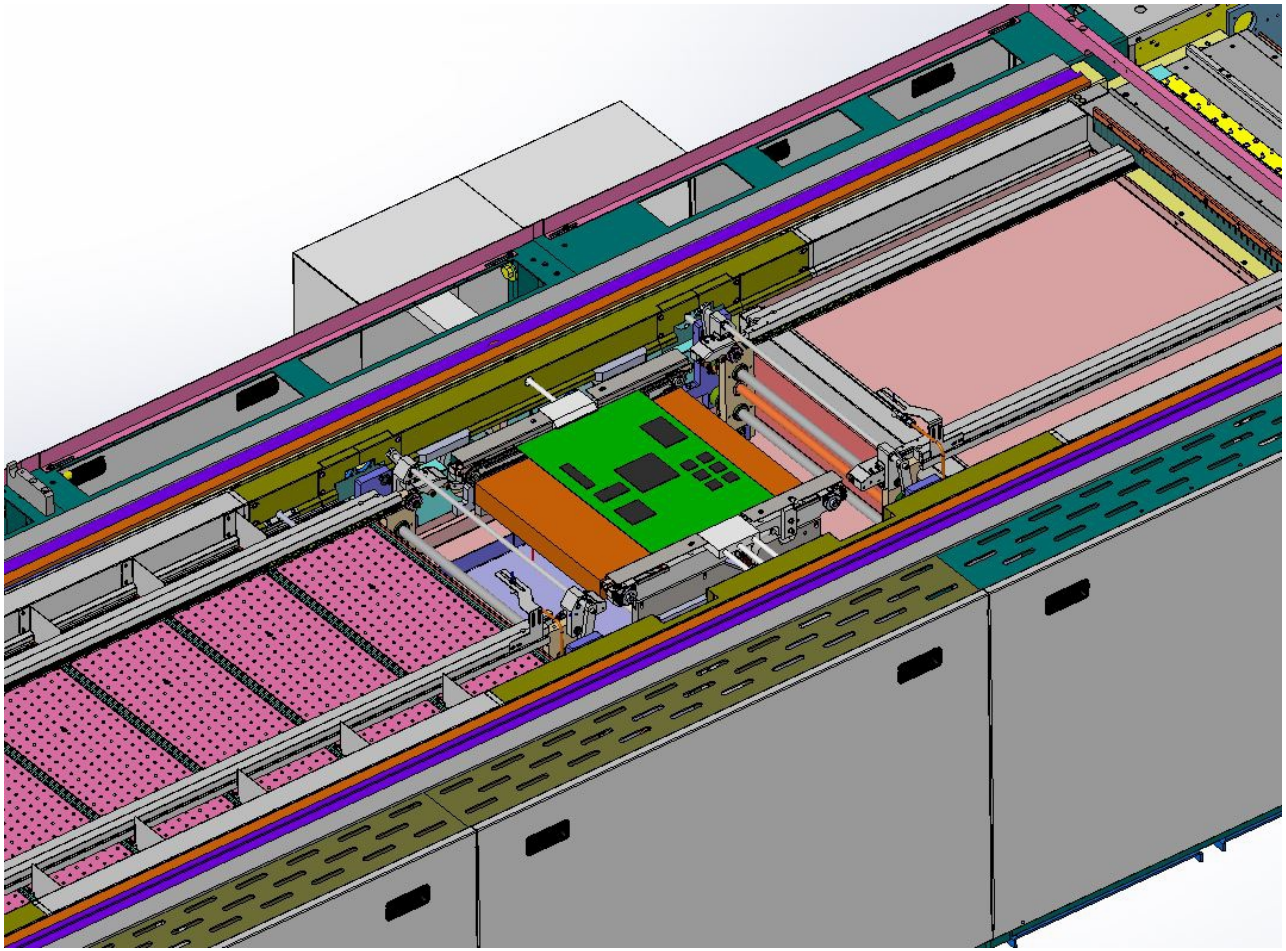
- *Void Reduction Reflow Technique 2*

Ultrasonics VOID reducing reflow

Overview

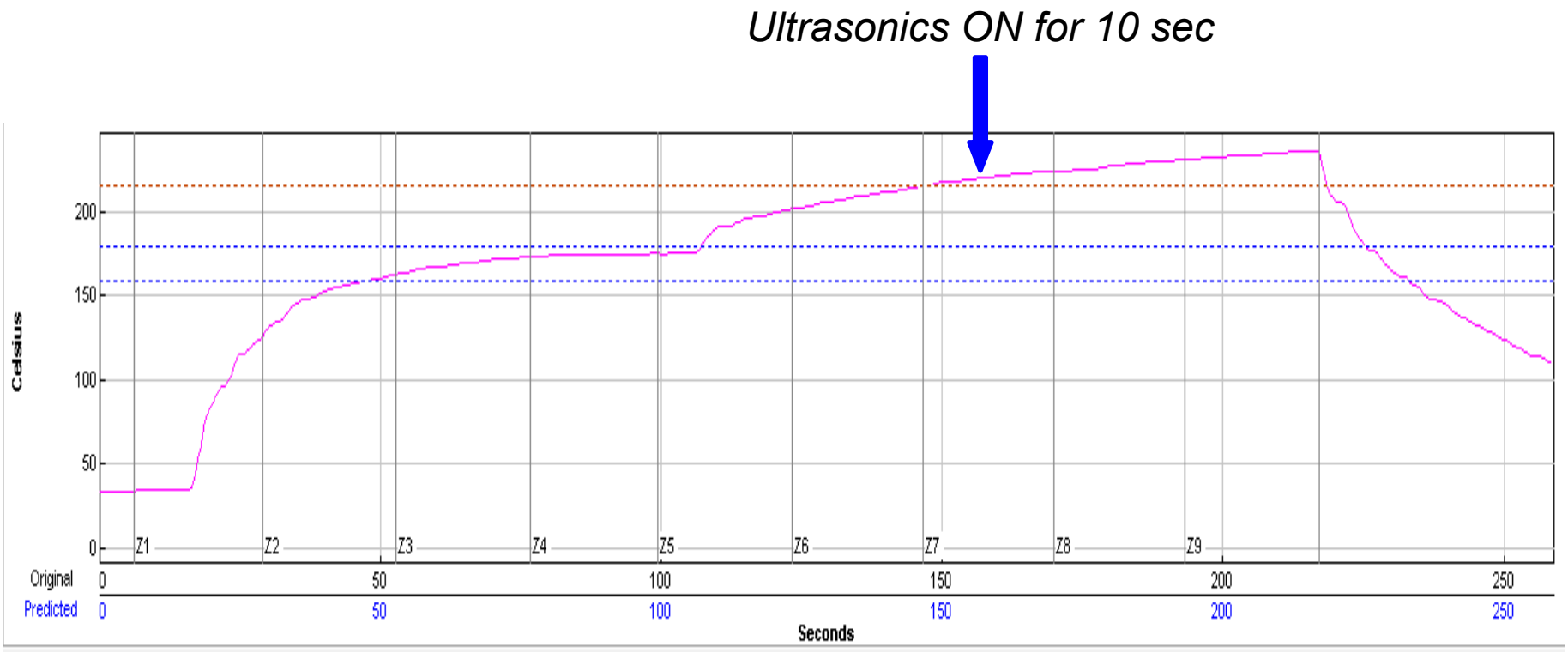
- Heller Industries is working on solder devoiding solution that utilizes ultrasonics application to printed circuit board during solder reflow
- Ultrasonics are applied when solder is in liquid state
- Cavitation (in theory) works to
  i. Stretch voids/bubbles so they combine with other voids and touch outer surface of solder to devoid
  ii. Shocks bubbles during compression so that bubbles break in to numerous very small bubbles
- Ultrasonics also creates movement and mixing of bubbles which enhances coalescence and subsequent elimination

Ultrasonics Station in Convection Oven



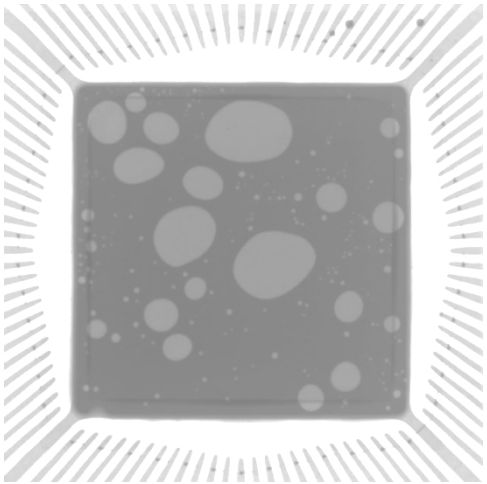
Ultrasonics Test Reflow Profile

Sample #	vibration duration (s)	Soak time (s) (160<T<180)	time above melting point (s) T>217 C	Maximum temperature (°c)	Total time (s)
4	10	60	70	238	200



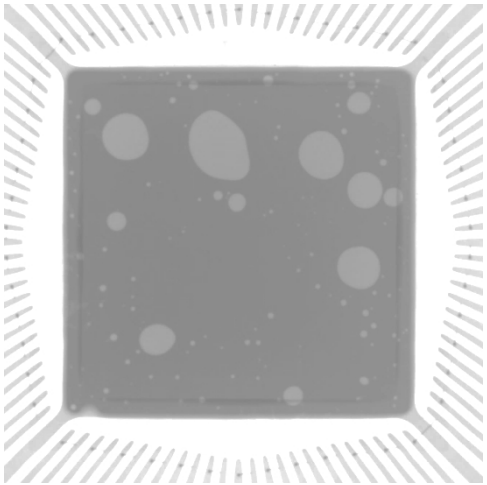
Void Results – No Ultrasonics

Sample #	vibration duration (s)	Soak time (s) (160<T<180)	time above melting point (s) T>217 C	Maximum temperature (°c)	Total time (s)
1	0	50	60	239	208



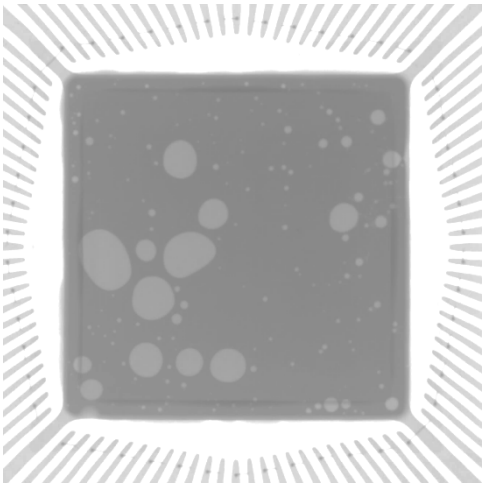
3

Total void% =25.18
Largest void% =4.14



2

Total void% =13.16
Largest void% =2.82

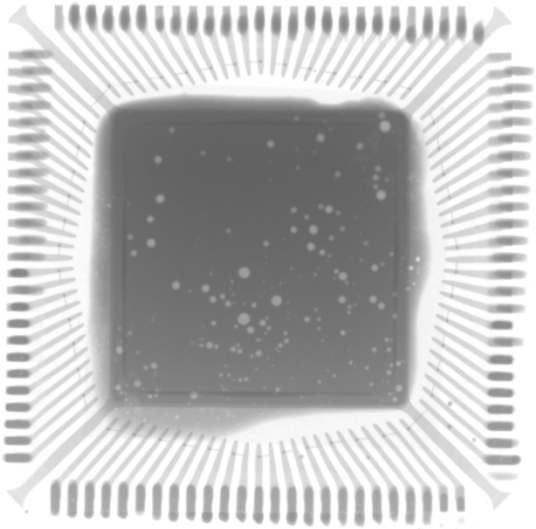


1

Total void% =14.03
Largest void% =2.08

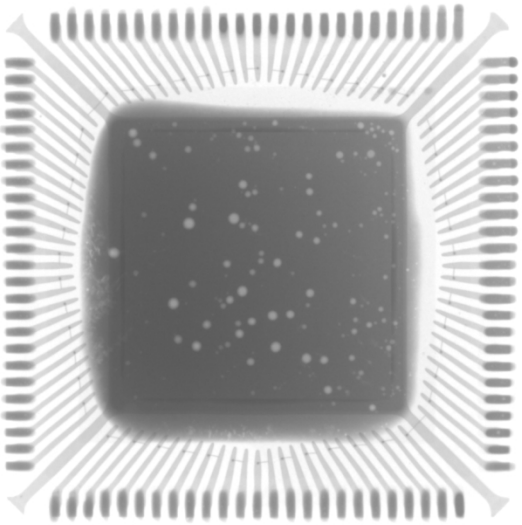
Void Results – Ultrasonics ON for 10

Sample #	vibration duration (s)	Soak time (s) (160<T<180)	time above melting point (s) T>217 C	Maximum temperature (°c)	Total time (s)
3	10	46	76	238	220



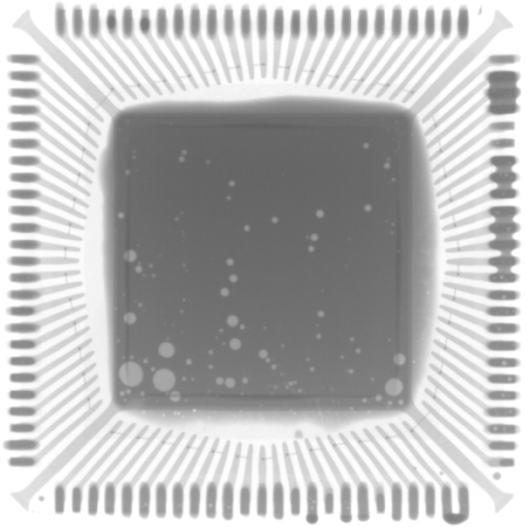
3

Total void% =4.26
Largest void% =0.15



2

Total void% =3.77
Largest void% =0.13



1

Total void% =4.53
Largest void% =0.58

Ultrasonics Devoiding Reflow Summary

- Ultrasonics applied to PCB's after solder liquidus has demonstrated significant reduction in voids – both size and total percent
- Ultrasonics are applied to PCB's at very low levels and for very short durations – i.e., 10 sec and microns of displacement.
- Heller Industries is currently engineering ultrasonics coupler stations into its convection reflow ovens to facilitate solder