

# RoHS Compliant - CTS ClearONE Terminator Reliability Test Data

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**RoHS Compliant BGA Resistor Array Design Validation Test Plan**

Table 1 below lists the tests performed as part of the Design Validation Test Plan.

Table 1 – DV Plan				
Test Name	Max Resistance Change	Standard Method	Test Condition	Test Description
Thermal Cycling (Joint Integrity)	N/A	JESD22-A104-B	J, Soak Mode 2	>33% part failure rate # cycles, 0°C to +100°C, 5 Minute Dwell, continuous data collection to 100% failure point
Thermal Cycling (Resistors)	0.50%	MIL-STD-202G, Method 107G	B	5 cycles, -65°C to +125°C
Short Time Overload	0.50%	MIL-PRF-83401 Para 4.8.10	-	2 ½ x rated voltage, 5 sec, (50V Max.) 1.5 watt max. per package, 0.06watt/resistor
Moisture Resistance	0.50%	MIL-STD-202G, Method 106G	-	240 hours, 0.1 rated load, -10°C to 65°C, 90% RH 1 watt max. package, 0.04watt @70C
Load Humidity	1.00%	MIL-STD-202G, Method 103B	-	1,000 hours, 0.1 rated load, 70 °C, 85-92% RH
High Temp Exposure	1.00%	MIL-PRF-83401 Para 4.8.19	-	240 hours, no load @ 125 °C
Load Life	1.00%	MIL-STD-202G, Method 108A	F	2,000 hours @ 70°C, rated load with forced air circulation.
Resistance to Solder Heat	0.25%	IPC/JEDEC J-STD-020A	I	Convection Reflow: 260°C Peak 20-40 seconds above 255°C 60-150 seconds above 217°C
Mechanical Shock	0.25%	MIL-STD-202G, Method 213D	I	100g, 1 msec., 3 shocks each plane
Low Temp Storage	0.25%	MIL-PRF-83401 Para 4.8.20	-	24 hours @ -65°C, no load
Low Temperature Operation	0.25%	MIL-PRF-83401 Para 4.8.9	-	24 hours @ -65°C, full load
TCR	200 ppm/°C	MIL-STD-202G, Method 304	-	-55°C to +125°C
Flammability		UL 94	-	UL 94V-0
Resistance to Solvents		MIL-STD-202G, Method 215K	-	

**Table 2 – DESIGN VERIFICATION PLAN & REPORT**

SYSTEM:	ASSEMBLY	PROGRAM: ClearONE RoHS		DESIGN ENG.:	S. Hreha			
BGA	TEST REPORT NO.	BL#22422 & #22423						
	RESISTANCE	25 Ohm – 475 Ohm						
# OF RESISTORS/PART	18-27	DATE OPEN: 12/02/05						
TEST NAME/SOURCE	ACCEPT. CRITERIA	TEST RESULTS	SAMPLE SIZE REQ'D	PART ID NO.	START DATE	COMP. DATE	PASS/ FAIL	REMARKS
Thermal Shock/ Thermal Cycle (Resistors)	Max. Delta R = 0.5%	Min. -0.009% Avg. 0.004% Max. 0.014%	10 parts with 18-27 resistors per part	N1- N10	12/08/05	12/08/05	PASS	
Short Time Overload	Max. Delta R = 0.5%	Min. -0.043% Avg. -0.014% Max. 0.006%	10 parts with 18-27 resistors per part	N1- N10	2/8/06	2/8/06	PASS	
Moisture Resistance	Max Delta R =0.5%	Min. -0.035% Avg. -0.009% Max. 0.029%	10 parts with 18-27 resistors per part	N41 to N50	12/16/05	12/26/05	PASS	
Load Humidity	(0.9V per Resistor)							
250 hr	Max Delta R =1.0%	Min. -0.017% Avg. -0.008% Max. 0.082%	10 parts with 18-27 resistors per part	N51 to N60	12/26/05	1/06/06	PASS	
500 hr	Max Delta R =1.0%	Min. -0.007% Avg. -0.019% Max. 0.082%	10 parts with 18-27 resistors per part	N51 to N60	12/26/05	1/16/06	PASS	
1000 hr	Max Delta R =1.0%	Min. 0.008% Avg. 0.038% Max. 0.104%	10 parts with 18-27 resistors per part	N51 to N60	12/9/05	12/19/05	PASS	
Load Humidity	BL21731 (0.9V per Resistor)							
250 hr	Max Delta R =1.0%	Min. -0.015% Avg. 0.002% Max. 0.023%	10 parts with 18-27 resistors per part	N1 to N10	12/26/05	1/06/05	PASS	
500 hr	Max Delta R =1.0%	Min. 0.002% Avg. 0.024% Max. 0.058%	10 parts with 18-27 resistors per part	N1 to N10	12/26/05	1/16/06	PASS	
1000 hr	Max Delta R =1.0%	Min. -0.007% Avg. 0.027% Max. 0.086%	10 parts with 18-27 resistors per part	N1 to N10	12/26/05	2/6/06	PASS	
High Temp Exposure	Max Delta R =1.0%	Min. -0.030% Avg. -0.007% Max. 0.018%	10 parts with 18-27 resistors per part	N11- N20	12/9/05	12/19/05	PASS	
Load Life								
250 hr	Max Delta R =1.0%	Min. -0.049% Avg. -0.029% Max. 0.005%	10 parts with 18-27 resistors per part	N61- N70	12/15/05	12/26/05	PASS	
500 hr	Max Delta R =1.0%	Min. -0.044% Avg. -0.024% Max. 0.014%	10 parts with 18-27 resistors per part	N61- N70	12/15/05	1/05/06	PASS	
1000 hr	Max Delta R =1.0%	Min. -0.041% Avg. -0.014% Max. 0.025%	10 parts with 18-27 resistors per part	N61- N70	12/15/05	1/26/06	PASS	
2000 hr	Max Delta R =1.0%	Min. -0.043% Avg. -0.018% Max. 0.030%	10 parts with 18-27 resistors per part	N61- N70	12/15/05	3/08/06	PASS	
Resistance to Solder Process	Max Delta R =0.25%	Min. 0.000% Avg. 0.037%	10 parts with 18-27 resistors	N11- N20	2/3/06	2/6/06	PASS	

**Table 2 – DESIGN VERIFICATION PLAN & REPORT**

SYSTEM:	ASSEMBLY	PROGRAM: ClearONE RoHS		DESIGN ENG.:	S. Hreha			
BGA	TEST REPORT NO.	BL#22422 & #22423						
	RESISTANCE	25 Ohm – 475 Ohm						
# OF RESISTORS/PART	18-27	DATE OPEN: 12/02/05						
TEST NAME/SOURCE	ACCEPT. CRITERIA	TEST RESULTS	SAMPLE SIZE REQ'D	PART ID NO.	START DATE	COMP. DATE	PASS/ FAIL	REMARKS
Heat		Max. 0.210%	per part					
Mechanical Shock	Max Delta R =0.25%	Min. -0.038% Avg. -0.014% Max. 0.005%	10 parts with 18-27 resistors per part	N21-N30	1/17/06	1/17/06	PASS	
Low Temp Storage	Max Delta R =0.25%	Min. -0.014% Avg. 0.000% Max. 0.020%	10 parts with 18-27 resistors per part	N11-N20	1/16/06	1/17/06	PASS	
Low Temp Operation	Max Delta R =0.25%	Min. -0.018% Avg. -0.004% Max. 0.012%	10 parts with 18-27 resistors per part	N1-N10	2/07/06	2/07/06	PASS	
TCR Cold	Max Delta R =200 PPM	Min. 48 PPM/C Avg. 65 PPM/C Max. 85 PPM/C	10 parts with 18-27 resistors per part	N1-N10	12/15/05	12/20/05	PASS	
TCR HOT	Max Delta R =200 PPM	Min. 95 PPM/C Avg. 109 PPM/C Max. 132 PPM/C	10 parts with 18-27 resistors per part	N1-N10	12/15/05	12/20/05	PASS	
Flammability	V0	NR	10 parts with 18-27 resistors per part	N31-N40	2/08/06	2/08/06	PASS	
Solvent Resistance	No physical damage	NR	10 parts with 18-27 resistors per part	N31-N40	1/16/06	1/16/06	PASS	

### Assembly Process Component Classification

- These components have been evaluated per IPC/JEDEC J-STD-020C

Moisture Sensitivity, LEVEL 1 unlimited at 30°C/90% RH  
 Soldering Process, LEVEL 1:IR/Convection Reflow 255-260°C, 20-40 seconds.  
 Chemical Compatibility, LEVEL 1.

**Thermal Cycle Testing**

**Device Details**

- The device is a Ceramic BGA package.
- Solder ball is copper with a Sn/Ni plating; the ball diameter is .030” for the 1.27mm pitch packages and 0.025” diameter for the 1.0mm pitch packages.
- The package substrate is 96% alumina solid ceramic with filled vias.
- Package properties:  
CTE of package is  $5.9 \times 10^{-6}$  in/in/°C in the X direction  
CTE of package is  $5.6 \times 10^{-6}$  in/in/°C in the Y direction  
Young’s Modulus is 330 GPa

**Test Board Details**

- Material is FR4 board with 3/8-ounce copper. Thickness is 0.062 inch. Number of layers is one. Size is 1 inch by 2 ¾ inch.
- Solder pad designed size, **1.00mm:** 0.020 inch diameter (actual 0.18 inch diameter)  
**1.27mm:** 0.020 inch diameter (actual 0.18 inch diameter)
- Pad type for all groups is non-solder mask defined style (NSMD).
- Designed solder mask clearance is 0.001 inch. Measured clearance is –0.001 to 0.002 inch. PCB supplier applied a solder mask over the exposed trace.
- Trace designed width is 0.010 inch and space is 0.029 inch. Measured width and space is 0.010 inch width and 0.028 inch spaces.
- Measured T<sub>g</sub> and CTE (above and below T<sub>g</sub>)

<b>Table 3 – Test Board Measured T<sub>g</sub> and CTE</b>			
Sample Orientation	CTE below T <sub>g</sub> (mm/mm °C)	CTE above T <sub>g</sub> (mm/mm °C)	T <sub>g</sub> (°C)
X	$8.3 \times 10^{-6}$	$7.5 \times 10^{-6}$	135.7
Y	$14.1 \times 10^{-6}$	$12.0 \times 10^{-6}$	135.2
Z	$5.0 \times 10^{-6}$	$25.0 \times 10^{-6}$	135.2

A thermo-mechanical analyzer (TMA) was used to perform the analysis.

### Solder Paste Type

- Water-Soluble paste, mildly activated. Indium WMA-SMQ 65
- The paste is an 90% solids version using -325 to +500 mesh size spherical powder of 63/37 Sn/Pb alloy. Type 3.
- Eutectic solder was selected for device attach so that the Baseline and Lead-Free Test groups would each see the same attach processes and temperatures. This allows for comparison of the device failure modes.

### Stencil Thickness and Aperture Opening (Desired Properties)

Table 4 – Stencil Thickness and Aperture Opening		
Pitch	Stencil Thickness	Aperture Opening
1.27mm	.006"	1:1 with land pad (.025")
1.00mm	.006"	1:1 with land pad (.020")

Note: Stencil aperture is dependent on solids loading, printing conditions including squeegee type, and squeegee speed.

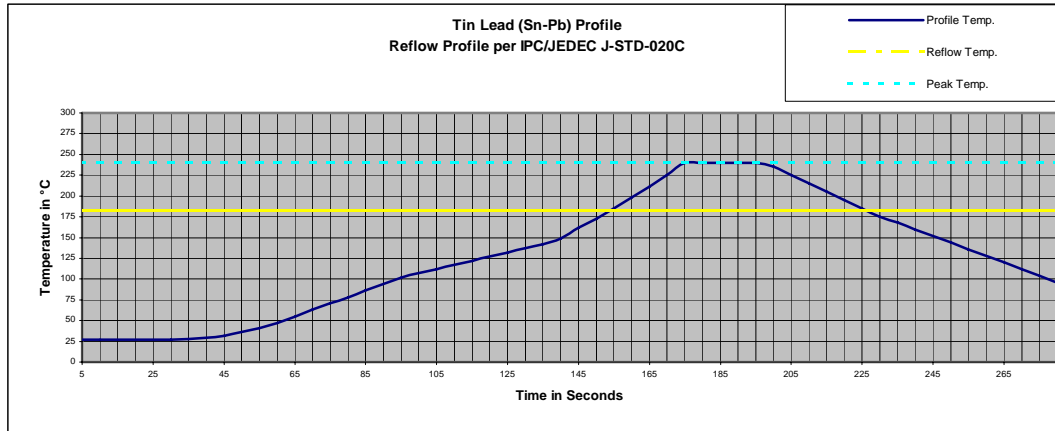
### Measured paste dimensions

Table 5 – 1.0mm Measured Paste Test Results			
Measured Paste Dimensions	Thickness (mils)	Volume (mils <sup>3</sup> )	Area (mils <sup>2</sup> )
Theoretical	6	1,884	314
Ave.	3.87	1089	280
Min.	3.45	869	233
Max.	4.44	1381	311
Range	.99	512	78
Std. Dev.	.29	148	17

Table 6 – 1.27mm Measured Paste Test Results			
Measured Paste Dimensions	Thickness (mils)	Volume (mils <sup>3</sup> )	Area (mils <sup>2</sup> )
Theoretical	6	2,946	491
Ave.	3.88	1395	359
Min.	3.25	1112	332
Max.	4.21	1572	400
Range	.96	638	68
Std. Dev.	0.24	150	17

### Test Board Assembly Steps

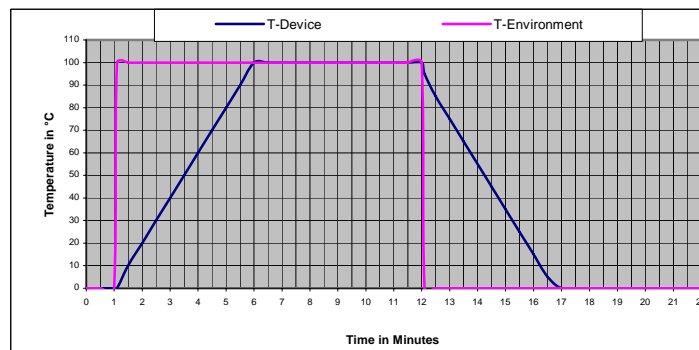
1. Stencil solder paste
2. Place parts in placement machine
3. Load parts into nozzle
4. Place on PCB
5. Reflow per IPC/JEDEC J-STD-020C, Level 1 profile.
6. Batch clean in DI H<sub>2</sub>O (resistivity requirement: 2-8 M ohm)  
Air dry.



**Note:** This profile was used for test board processing with eutectic solder. Assembly with lead-free solders will require a different profile. Each assembly site must establish a profile that works best in their unique application.

### Test Details

- Sample size: 32-piece minimum per group (1mm & 1.27mm) tested.
- Temperature cycle condition and temperature profile plot measured at board surface
- Extended thermal cycle test conditions:
  - Low temperature: 0 -0/-5°C
  - High temperature: 100 -0/-5°C
  - Dwell time at High temperature: 5 minutes
  - Environmental transition time = 10-15 seconds, UUT transition time = 4-6 minutes.
  - Dwell time at Low temperature: 5 minutes.



- Threshold resistance was nominal plus 10%. The resistance readings were monitored with a Cable Scan Series 90. Each part was monitored every 1 minute and 58 seconds.
- The testing was done in a double zone chamber.

### Failure criteria

- Open circuit (i.e. any resistance reading >100 Ohms)
- Any instance of measured resistance value exceeding the threshold resistance value ( $R > 100$  Ohms) shall be considered as OPEN. An OPEN followed by 10 additional OPENS within 10% of the time of the 1<sup>st</sup> OPEN shall be considered as a FAILURE and the TIME TO FAILURE shall be the time at which the 1<sup>st</sup> OPEN occurred. This is to avoid any measurement anomaly or noise. In case of multiple resistors per device, the 1<sup>st</sup> failure of any resistor within the device shall be considered as the device failure.

### Test Results

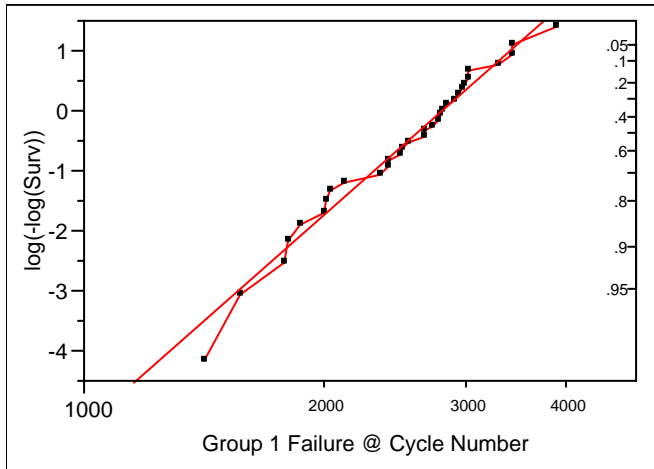
#### 1.00mm Pitch Groups

Table 7 – Shape and Characteristic Life of 1mm pitch groups				
Group Part Number	3x9 Baseline Lead	3x9 Lead-Free	4x9 Baseline Lead	4x9 Lead-Free
1	2037	6224	2019	5156
2	2852	6405	2841	Note 1
3	2781	Note 1	2972	5685
4	2544	Note 1	2670	Note 1
5	2738	Note 1	2195	Note 1
6	3036	Note 1	2504	6099
7	3299	Note 1	3410	6815
8	1786	Note 1	2361	Note 1
9	2788	Note 1	2813	Note 1
10	2813	Note 1	2406	6325
11	2000	Note 1	1933	5110
12	2903	4237	2840	5307
13	2669	7065	3086	3667
14	2988	5424	2751	4524
15	2499	Note 1	2544	5493
16	2497	4956	1498	5068
17	3026	Note 1	5797	Note 1
18	3441	6778	4008	4883
19	3434	Note 1	3311	6096
20	1412	Note 1	3395	Note 1
21	2984	Note 1	4150	Note 1
22	3899	6407	2639	6135
23	2670	Note 1	6185	Note 1
24	2406	Note 1	2632	Note 1
25	2356	Note 1	2949	6135
26	2121	7133	2115	3430
27	1805	4394	1645	6475
28	2411	Note 1	2019	6028
29	1871	Note 1	3470	6930
30	2943	Note 1	1511	3065
31	2015	Note 1	1638	Note 1
32	1568	Note 1	1988	4739

Notes:  
 1. These units were still functioning when the testing stopped after 7249 cycles.

### Characteristic Life for 1.00mm Pitch Groups

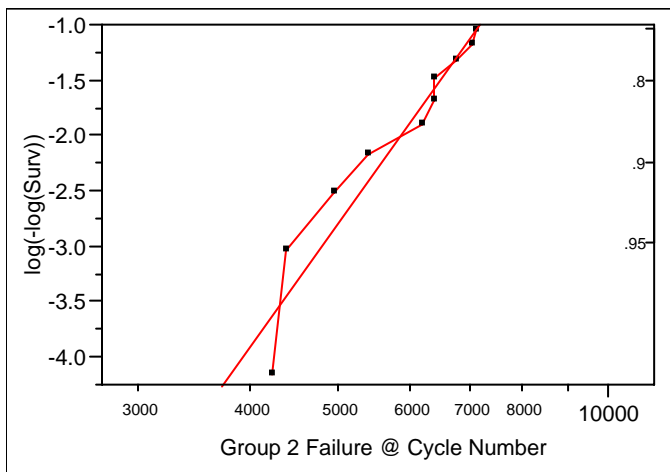
#### Baseline "Lead" - Weibull Plot of Product-Limit Survival Fit for 3x9



#### Weibull Parameter Estimates

Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	2807.188	2601.4683	3018.6	32
Beta	5.0715871	3.8121746	6.4944274	32

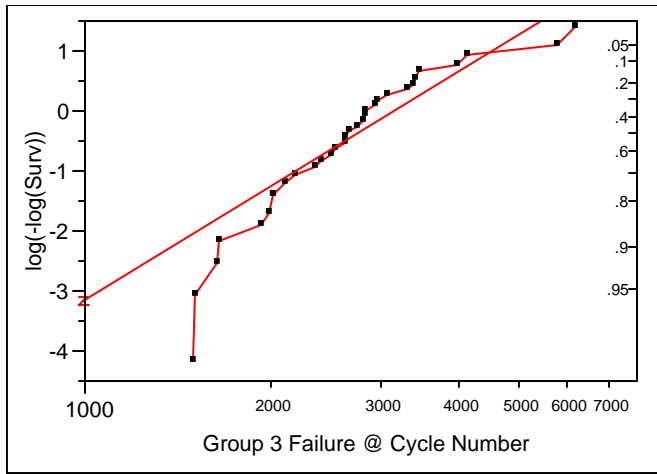
#### Lead-Free - Weibull Plot of Product-Limit Survival Fit for 3x9



#### Weibull Parameter Estimates

Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	8842.5059	7779.0253	11768.793	10
Beta	4.9291743	2.546213	8.4381017	10

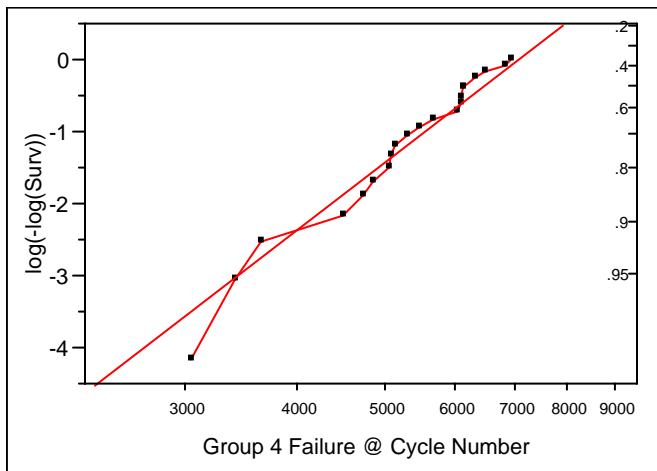
### Baseline "Lead" - Weibull Plot of Product-Limit Survival Fit for 4x9



#### Weibull Parameter Estimates

Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	3167.3575	2750.8119	3626.7316	32
Beta	2.7304739	2.1036932	3.4119288	32

### Lead-Free - Weibull Plot of Product-Limit Survival Fit for 4x9



#### Weibull Parameter Estimates

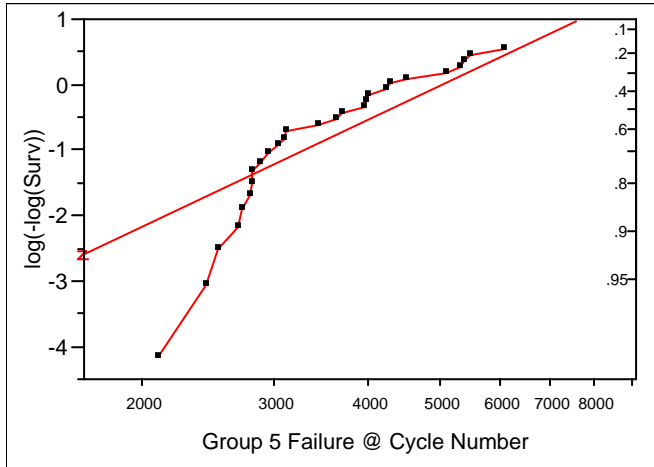
Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	7031.6114	6381.0915	7982.593	21
Beta	4.1823158	2.7784814	5.9437929	21

### 1.27mm Pitch Groups

<b>Table 8 – Shape and Characteristic Life of 1.27mm pitch groups</b>		
Group Part Number	4x9 Baseline Lead	4x9 Lead-Free
1	5414	2172
2	4502	1934
3	5107	2012
4	3998	3593
5	3975	5989
6	4031	3516
7	3101	Note 1
8	2535	2445
9	6103	1886
10	3126	4508
11	2702	1935
12	2734	4837
13	5330	5258
14	3645	6774
15	2955	5290
16	3059	2628
17	3457	3561
18	2887	2276
19	Note 1	2000
20	2824	4320
21	Note 1	3142
22	2817	1982
23	Note 1	6835
24	Note 1	6113
25	5509	1869
26	Note 1	3740
27	4290	2076
28	4248	3717
29	3723	6611
30	2451	3295
31	2799	3191
32	2111	3531
<b>Notes:</b> 1. These units were still functioning when the testing stopped after 7249 cycles.		

### Characteristic Life for 1.27mm Pitch Group 1.27mm Pitch Groups

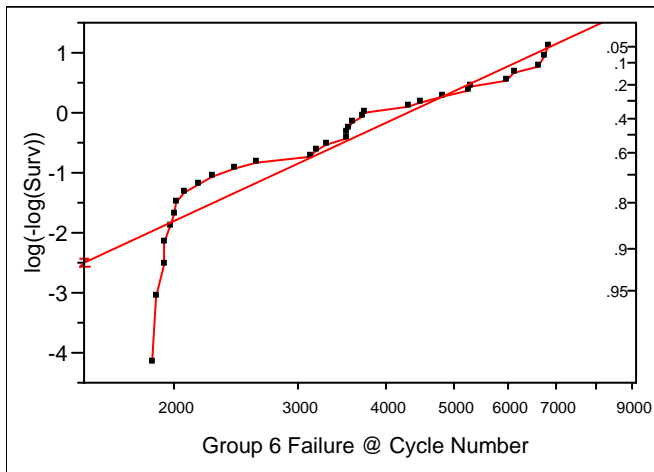
#### Baseline "Lead" - Weibull Plot of Product-Limit Survival Fit for 4x9



#### Weibull Parameter Estimates

Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	4994.0044	4236.785	5934.1143	27
Beta	2.3657455	1.7153472	3.11969	27

#### Lead-Free - Weibull Plot of Product-Limit Survival Fit for 4x9



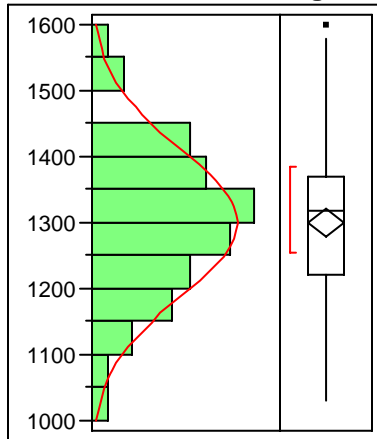
#### Weibull Parameter Estimates

Parameter	Estimate	Lower 95%	Upper 95%	N Failed
Alpha	4291.7803	3634.506	5037.6627	31
Beta	2.3341892	1.7437945	3.0154001	31

### Ball Shear Testing

- Ball-shear Testing per JEDEC JESD22-B117
- Shear (ram) speed = 100µm/second.
- Shear height = ¼ of the ball diameter.

**1.00mm 757 Series Un-aged**



Normal(1299.84,112.371)

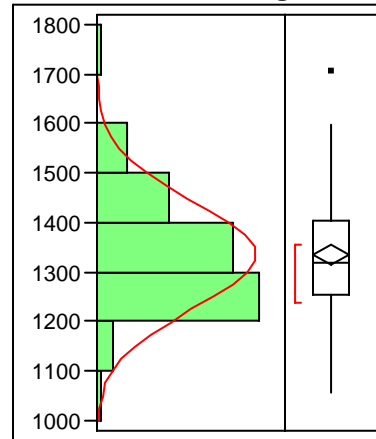
**Quantiles**

100.0%	maximum	1597.4
99.5%		1597.4
97.5%		1551.0
90.0%		1435.0
75.0%	quartile	1369.3
50.0%	median	1317.0
25.0%	quartile	1222.1
10.0%		1156.7
2.5%		1066.2
0.5%		1029.2
0.0%	minimum	1029.2

**Moments**

Mean	1299.841
Std Dev	112.37091
Std Err Mean	11.237091
upper 95% Mean	1322.1378
lower 95% Mean	1277.5442
N	100

**1.00mm 757 Series Aged**



Normal(1334.71,108.321)

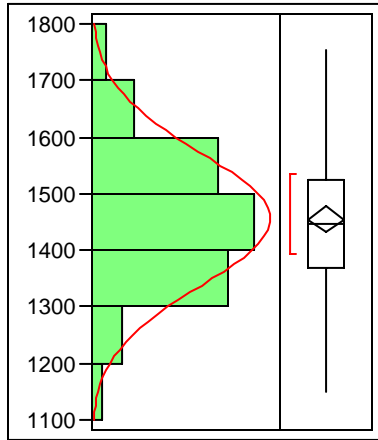
**Quantiles**

100.0%	maximum	1702.5
99.5%		1702.5
97.5%		1589.8
90.0%		1482.6
75.0%	quartile	1403.3
50.0%	median	1319.6
25.0%	quartile	1254.0
10.0%		1211.4
2.5%		1149.5
0.5%		1057.2
0.0%	minimum	1057.2

**Moments**

Mean	1334.707
Std Dev	108.32124
Std Err Mean	10.832124
upper 95% Mean	1356.2003
lower 95% Mean	1313.2137
N	100

### 1.27mm 756 Series Un-aged



Normal(1454.66,118.366)

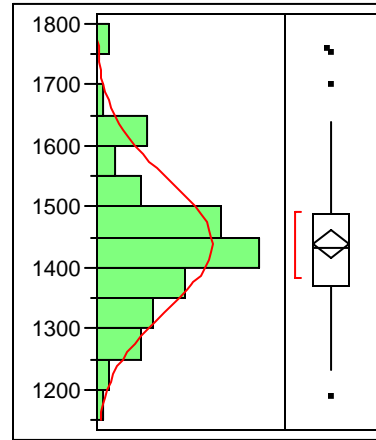
#### Quantiles

100.0%	maximum	1754.9
99.5%		1754.9
97.5%		1733.1
90.0%		1626.3
75.0%	quartile	1525.1
50.0%	median	1445.9
25.0%	quartile	1369.8
10.0%		1307.9
2.5%		1217.1
0.5%		1151.1
0.0%	minimum	1151.1

#### Moments

Mean	1454.659
Std Dev	118.366
Std Err Mean	11.8366
upper 95% Mean	1478.1454
lower 95% Mean	1431.1726
N	100

### 1.27mm 756 Series Aged



Normal(1439.07,108.898)

#### Quantiles

100.0%	maximum	1756.2
99.5%		1756.2
97.5%		1723.5
90.0%		1603.1
75.0%	quartile	1488.1
50.0%	median	1431.4
25.0%	quartile	1369.1
10.0%		1296.0
2.5%		1235.5
0.5%		1186.6
0.0%	minimum	1186.6

#### Moments

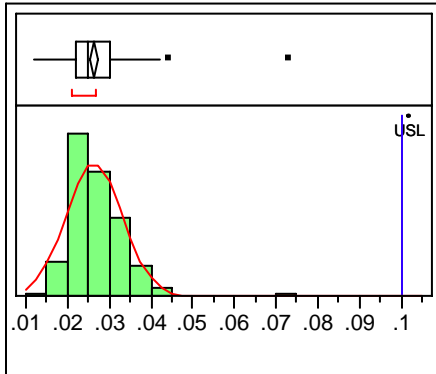
Mean	1439.073
Std Dev	108.89755
Std Err Mean	10.889755
upper 95% Mean	1460.6806
lower 95% Mean	1417.4654
N	100

### Ball Co-Planarity

- Ball Co-Planarity per JEDEC Standards: 0.10mm (0.004 inches)
- Instrument: Aetrium Test System
- Note: Limits are one-sided, therefore CpK = CpU = 2.589 (1.27mm) and 3.643 (1.00mm)

### Vanguard Co-planarity Data Co-planarity Distributions for 756 Series and 757 Series

RT2300B6 co-planarity (mm) - 1.27mm pitch



**Quantiles:**

100.0%	maximum	0.07200
99.5%		0.07196
97.5%		0.05300
90.0%		0.04400
75.0%	quartile	0.03900
50.0%	median	0.03300
25.0%	quartile	0.02800
10.0%		0.02300
2.5%		0.01705
0.5%		0.01501
0.0%	minimum	0.01500

**Moments:**

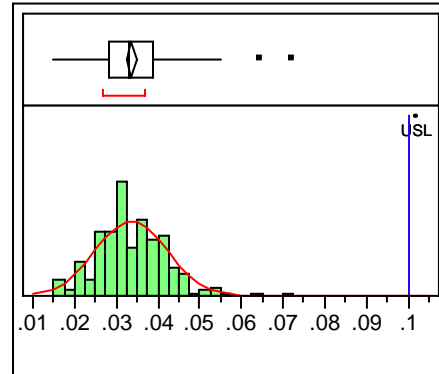
Mean	0.033615
Std Dev	0.008547
Std Err Mean	0.0006044
upper 95% Mean	0.0348068
lower 95% Mean	0.0324232
N	200

**Capability Analysis:**

Specification	Value	Portion	% Actual
Lower Spec Limit	.	Below LSL	.
Upper Spec Limit	0.1	Above USL	0.0000
Spec Target	.	Total Outside	0.0000

Capability	Index	Lower CI	Upper CI
CP	.	.	.
CPK	2.589	2.330	2.847
CPM	.	.	.
CPL	.	.	.
CPU	2.589	2.330	2.847

RT2402B7 co-planarity (mm) - 1.00mm pitch



**Quantiles:**

100.0%	maximum	0.07300
99.5%		0.07286
97.5%		0.03997
90.0%		0.03400
75.0%	quartile	0.03000
50.0%	median	0.02500
25.0%	quartile	0.02200
10.0%		0.02000
2.5%		0.01600
0.5%		0.01202
0.0%	minimum	0.01200

**Moments:**

Mean	0.026365
Std Dev	0.0067371
Std Err Mean	0.0004764
upper 95% Mean	0.0273044
lower 95% Mean	0.0254256
N	200

**Capability Analysis:**

Specification	Value	Portion	% Actual
Lower Spec Limit	.	Below LSL	.
Upper Spec Limit	0.1	Above USL	0.0000
Spec Target	.	Total Outside	0.0000

Capability	Index	Lower CI	Upper CI
CP	.	.	.
CPK	3.643	3.282	4.004
CPM	.	.	.
CPL	.	.	.
CPU	3.643	3.282	4.004