

CTS ClearONE Terminator Reliability Test Data

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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	>66% part failure rate # cycles, 0°C to +100°C, 5 Minute Dwell
Thermal Cycling (Resistors)	0.50%	MIL-STD-202F, Method 107G	B	5 cycles, -65°C to +125°C
Short Time Overload	0.50%	CTS	-	2 1/2 x rated voltage, 5 sec,(50V Max.) 1.5 watt max. per package, 0.06watt/resistor
Moisture Resistance	0.50%	MIL-STD-202F, Method 106F	-	240 hours, 0.1 rated load, -10°C to 65°C, 90% RH 1 watt max. package, 0.04watt @70C
Load Humidity	1.00%	CTS 1862	-	1,000 hours, 0.1 rated load, 70 °C, 85-92% RH
High Temp Exposure	1.00%	CTS	-	240 hours, no load @ 125 °C
Load Life	1.00%	MIL-STD-202F, Method 108A	F	2,000 hours @ 70°C, rated load with forced air circulation.
Resistance to Solder Heat	0.25%	MIL-STD-202, Method 210D	I	30 seconds dwell @ 218°C
Mechanical Shock	0.25%	MIL-STD-202F, Method 213B	I	100g, 1 msec., 3 shocks each plane
Low Temp Storage	0.25%	CTS	-	24 hours @ -65°C, no load
Low Temperature Operation	0.25%	CTS	-	24 hours @ -65°C, full load
TCR	200 ppm/°C	MIL-STD-202F, Method 304	-	-55°C to +125°C
Flammability		UL 94	-	UL 94V-0
Resistance to Solvents		MIL-STD-202F, Method 215J	-	

Design Verification Plan & Report

Table 2 – DESIGN VERIFICATION PLAN & REPORT - ENGINEERING EVALUATIONS								
SYSTEM:	ASSEMBLY		PROGRAM:			DESIGN ENG.:		R. Cooper
BGA	TEST REPORT NO.		BL21705					
	RESISTANCE		22 Ohm ± 5%					
	WORK SHEET NO.		4M-757-4090E-11D					
# OF RESISTORS/PART	32		DATE OPEN: 9/6/00					
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 32 resistors per part	N1-N10	8/23/00	8/24/00	Pass	
Short Time Overload	Max. Delta R = 0.5%	Min. -0.043% Avg. -0.014% Max. 0.006%	10 parts with 32 resistors per part	N1-N10	8/24/00	9/8/00	Pass	
Moisture Resistance	Max Delta R =0.5%	Min. -0.035% Avg. -0.009% Max. 0.029%	10 parts with 32 resistors per part	N41 to N50	8/23/00	9/5/00	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 32 resistors per part	N51 to N60	8/23/00	9/5/00	Pass	
500 hr	Max Delta R =1.0%	Min. -0.007% Avg. -0.019% Max. 0.082%	10 parts with 32 resistors per part	N51 to N60	8/23/00	9/15/00	Pass	
1000 hr	Max Delta R =1.0%	Min. 0.008% Avg. 0.038% Max. 0.104%	10 parts with 32 resistors per part	N51 to N60	8/23/00	10/6/00	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 32 resistors per part	N1 to N10	8/23/00	9/5/00	Pass	
500 hr	Max Delta R =1.0%	Min. 0.002% Avg. 0.024% Max. 0.058%	10 parts with 32 resistors per part	N1 to N10	8/23/00	10/11/00	Pass	
1000 hr	Max Delta R =1.0%	Min. -0.007% Avg. 0.027% Max. 0.086%	10 parts with 32 resistors per part	N1 to N10	8/23/00	11/1/00	Pass	
High Temp Exposure	Max Delta R =1.0%	Min. -0.030% Avg. -0.007% Max. 0.018%	10 parts with 32 resistors per part	N11- N20	8/23/00	9/26/00	Pass	
Load Life								
250 hr	Max Delta R =1.0%	Min. -0.049% Avg. -0.029% Max. 0.005%	10 parts with 32 resistors per part	N61- N70	8/23/00	9/18/00	Pass	
500 hr	Max Delta R =1.0%	Min. -0.044% Avg. -0.024% Max. 0.014%	10 parts with 32 resistors per part	N61- N70	8/23/00	9/29/00	Pass	
1000 hr	Max Delta R =1.0%	Min. -0.041% Avg. -0.014% Max. 0.025%	10 parts with 32 resistors per part	N61- N70	8/23/00	10/20/00	Pass	
2000 hr	Max Delta R =1.0%	Min. -0.043% Avg. -0.018% Max. 0.030%	10 parts with 32 resistors per part	N61- N70	8/23/00	12/1/00	Pass	
Resistance to Solder Process	Max Delta R =0.25%	Min. -0.039% Avg. -0.024%	10 parts with 32 resistors	N11- N20	9/28/00	10/2/00	Pass	

Table 2 – DESIGN VERIFICATION PLAN & REPORT - ENGINEERING EVALUATIONS

SYSTEM:	ASSEMBY	PROGRAM:	DESIGN ENG.:	R. Cooper				
BGA	TEST REPORT NO.	BL21705						
	RESISTANCE	22 Ohm ± 5%						
	WORK SHEET NO.	4M-757-4090E-11D						
# OF RESISTORS/PART	32	DATE OPEN: 9/6/00						
TEST NAME/SOURCE	ACCEPT. CRITERIA	TEST RESULTS	SAMPLE SIZE REQ'D	PART ID NO.	START DATE	COMP. DATE	PASS/ FAIL	REMARKS
Heat		Max. -0.110%	per part					
Mechanical Shock	Max Delta R =0.25%	Min. -0.038% Avg. -0.014% Max. 0.005%	10 parts with 32 resistors per part	N21- N30	8/23/00	9/11/00	Pass	
Low Temp Storage	Max Delta R =0.25%	Min. -0.014% Avg. 0.000% Max. 0.020%	10 parts with 32 resistors per part	N11- N20	9/26/00	9/28/00	Pass	
Low Temp Operation	Max Delta R =0.25%	Min. -0.018% Avg. -0.004% Max. 0.012%	10 parts with 32 resistors per part	N1-N10	9/11/00	9/14/00	Pass	
TCR Cold	Max Delta R =200 PPM	Min. 48 PPM/C Avg. 65 PPM/C Max. 85 PPM/C	10 parts with 32 resistors per part	N1-N10	9/11/00	9/11/00	Pass	
TCR HOT	Max Delta R =200 PPM	Min. 95 PPM/C Avg. 109 PPM/C Max. 132 PPM/C	10 parts with 32 resistors per part	N1-N10	9/11/00	9/11/00	Pass	
Flammability	V0	NR	10 parts with 32 resistors per part	N31- N40	9/27/00	9/27/00	Pass	
Solvent Resistance	No physical damage	NR	10 parts with 32 resistors per part	N31- N40	9/22/00	9/22/00	Pass	

Assembly Process Component Classification:

- These components have been evaluated per IPC-9504 (June 1998) to component classification 111.
 - ✓ Moisture Sensitivity, LEVEL 1 unlimited at 30 °C / 90% RH.
 - ✓ Soldering Process, LEVEL1 : IR/Convection Reflow 235 – 240 °C, 10-40 seconds.
 - ✓ Chemical Compatibility, LEVEL1.

Thermal Cycle Testing

Device Details

- The device is a Ceramic BGA package.
- Solder ball alloy is 10/90 Sn/Pb; the ball diameter is 0.030” for the 1.27 mm pitch packages and 0.025” diameter for the 1.0 mm pitch packages.
- The package substrate is 96% alumina solid ceramic with filled vias.
- Package properties:
 - CTE of package is 5.9×10^{-6} in/in/°C in the X direction
 - CTE of package is 5.6×10^{-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 0.018 inch diameter)
1.27mm : 0.025 inch diameter (actual 0.022 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.
- Surface finish is Hot Air Solder Level (HASL) to 1-ounce copper.
- Measured Tg and CTE (above and below Tg)

Table 3 – Test Board Measured Tg and CTE			
Sample Orientation	CTE below T _g (mm/mm °C)	CTE above T _g (mm/mm °C)	T _g (°C)
X	8.3×10^{-6}	7.5×10^{-6}	135.7
Y	14.1×10^{-6}	12.0×10^{-6}	135.2
Z	5.0×10^{-5}	25.0×10^{-5}	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 a 90% solids version using -325 to +500 mesh size spherical powder of 63/37 Sn/Pb alloy. Type 3.

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 and printing conditions including squeegee type and squeegee speed.

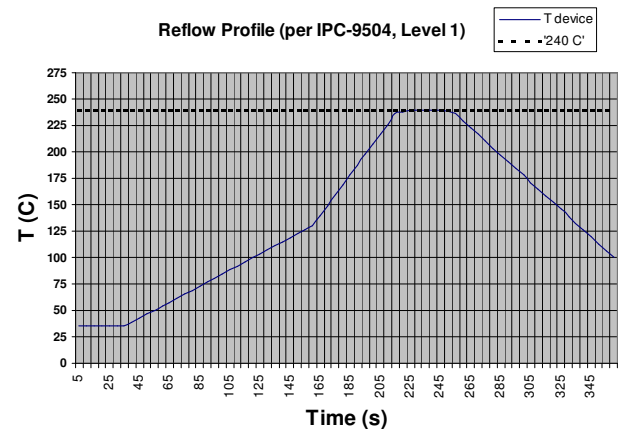
Measured paste dimensions

Table 5 – 1.0mm Measured Paste Test Results			
Measured Paste Dimensions	Thickness (mils)	Volume (mils ³)	Area (mils ²)
Theoretical	6	1,884	314
Avg.	4.08	1,141	280
Min	3.28	929	243
Max	4.57	1,347	341
Range	1.29	418	99
Std Dev	0.27	87	19

Table 6 – 1.27mm Measured Paste Test Results			
Measured Paste Dimensions	Thickness (mils)	Volume (mils ³)	Area (mils ²)
Theoretical	6	2,944	491
Avg.	3.83	1,380	360
Min	3.33	1,062	310
Max	4.28	1,695	427
Range	0.95	633	117
Std Dev	0.20	120	25

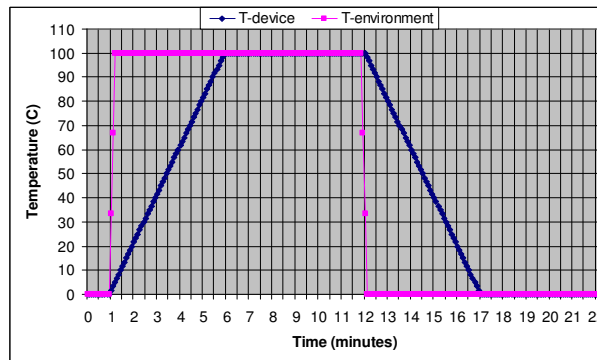
Board assembly steps

1. Stencil solder paste
2. Place parts in placement machine
3. Load part into nozzle
4. Place on PCB
5. Reflow per IPC-9504, Level I profile.
6. Batch clean in DI H₂O (resistivity requirement: 2 - 8 Mohm) air dry



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

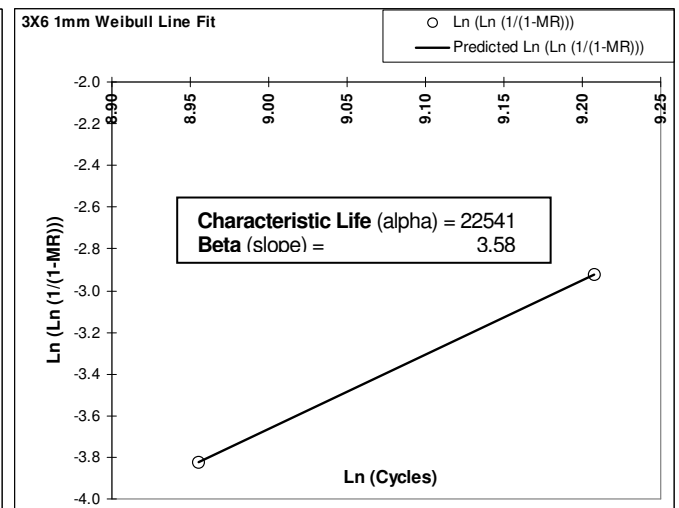
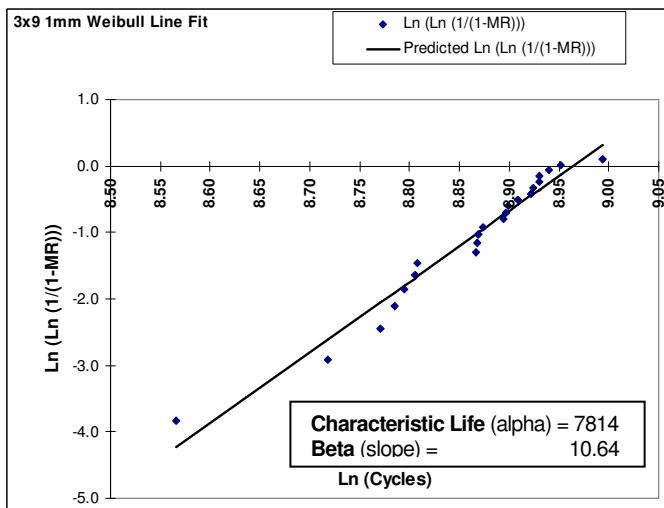
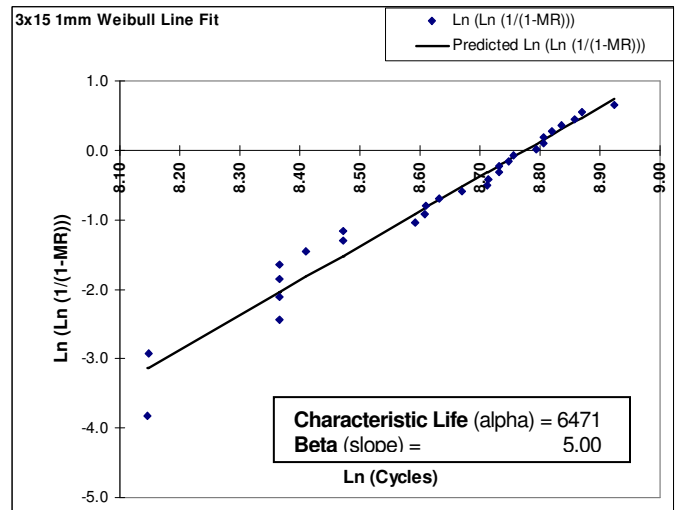
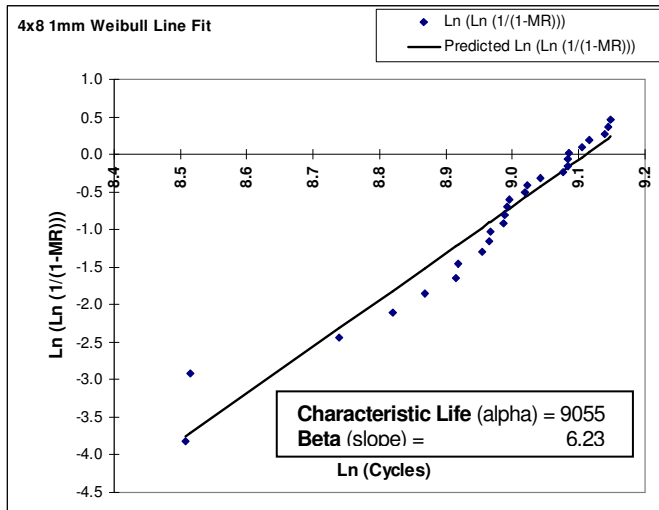
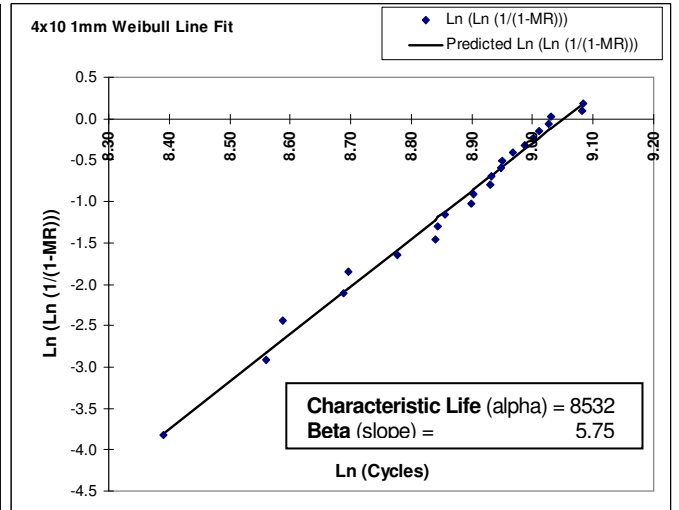
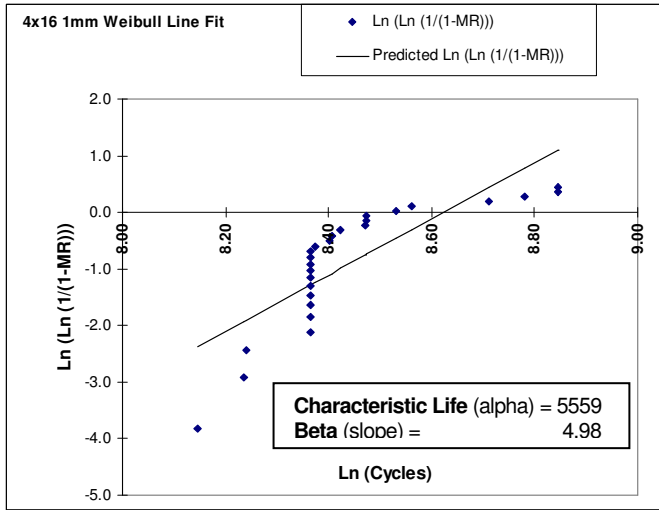
Test Results

1.00 mm pitch Groups

Table 7 – Shape and Characteristic Life of all 1 mm pitch groups							
Array/ Rank	3x6	3x9	3x12	3x15	4x8	4x10	4x16
1	7,747	5,251	3,466	3,453	4,952	4,403	3,449
2	9,970	6,110	4,776	3,457	4,991	5,216	3,772
3	+10K	6,447	5,091	4,296	6,241	5,366	3,792
4	+10K	6,534	5,234	4,297	6,764	5,930	4,296
5	+10K	6,598	5,815	4,297	7,096	5,979	4,296
6	+10K	6,669	5,928	4,300	7,438	6,477	4,296
7	+10K	6,686	6,280	4,495	7,462	6,899	4,296
8	+10K	7,089	6,609	4,775	7,735	6,935	4,296
9	+10K	7,099	6,784	4,776	7,825	7,016	4,296
10	+10K	7,112	6,817	5,386	7,835	7,327	4,297
11	+10K	7,146	6,895	5,479	7,988	7,357	4,297
12	+10K	7,294	7,203	5,491	8,008	7,554	4,297
13	+10K	7,304	7,383	5,611	8,044	7,567	4,297
14	+10K	7,322	7,864	5,820	8,063	7,690	4,337
15	+10K	7,393	7,961	6,078	8,263	7,706	4,452
16	+10K	7,496	8,209	6,086	8,287	7,849	4,474
17	+10K	7,508	8,423	6,192	8,454	8,008	4,553
18	+10K	7,553	8,575	6,200	8,738	8,115	4,776
19	+10K	7,554	9,111	6,296	8,804	8,200	4,783
20	+10K	7,625	9,225	6,347	8,807	8,330	4,789
21	+10K	7,722	9,352	6,588	8,822	8,363	5,073
22	+10K	8,051	9,522	6,668	8,997	8,787	5,225
23	+10K	+10K	9,761	6,678	9,092	8,808	6,070
24	+10K	+10K	9,914	6,774	9,307	+10K	6,506
25	+10K	+10K	9,937	6,875	9,354	+10K	6,934
26	+10K	+10K	10,069	7,037	9,400	+10K	6,934
27	+10K	+10K	10,070	7,109	+10K	+10K	+10K
28	+10K	+10K	+10K	7,513	+10K	+10K	+10K
29	+10K	+10K	+10K	+10K	+10K	+10K	+10K
30	+10K	+10K	+10K	+10K	+10K	+10K	+10K
31	+10K	+10K	+10K	+10K	+10K	+10K	+10K
32	+10K	+10K	+10K	+10K	+10K	+10K	+10K

Notes:

1. "+10K" = units which passed 10,000 cycles and were taken off test.
2. This data contains premature failures caused by improper assembly construction process for attaching BGA part to the PCB. As a result, the data indicates a worse result than can be attributed to the CTS BGA construction. Some failure analysis has been performed on these parts but it has not been completed.

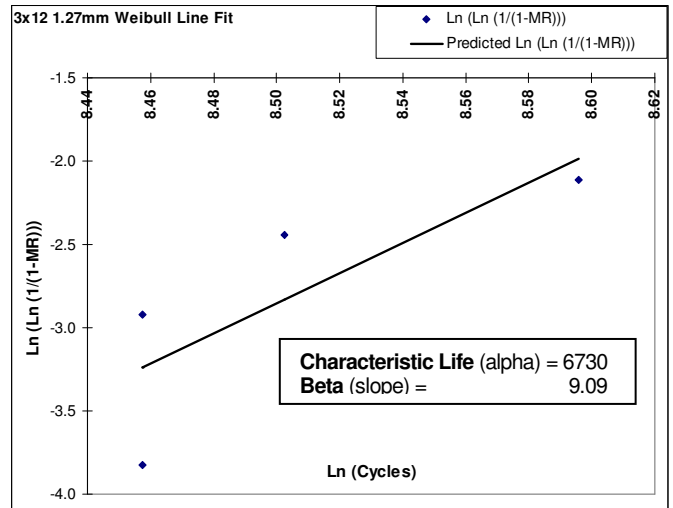
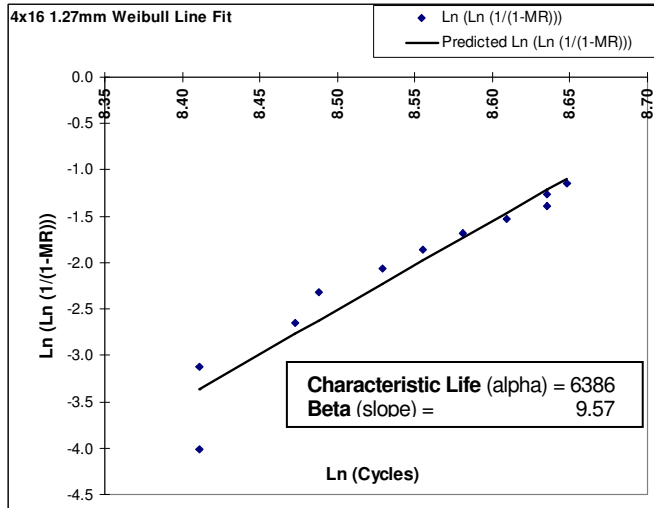


1.27 mm pitch Groups

Table 8 – Shape and Characteristic Life of all 1.27 mm pitch groups				
Array	3x6	3x12	4x9	4x16
1	+6K	4,711	+6K	4,495
2	+6K	4,711	+6K	4,495
3	+6K	4,927	+6K	4,783
4	+6K	5,410	+6K	4,855
5	+6K	+6K	+6K	5,059
6	+6K	+6K	+6K	5,194
7	+6K	+6K	+6K	5,330
8	+6K	+6K	+6K	5,482
9	+6K	+6K	+6K	5,626
10	+6K	+6K	+6K	5,626
11	+6K	+6K	+6K	5,698
12	+6K	+6K	+6K	+6K
13	+6K	+6K	+6K	+6K
14	+6K	+6K	+6K	+6K
15	+6K	+6K	+6K	+6K
16	+6K	+6K	+6K	+6K
17	+6K	+6K	+6K	+6K
18	+6K	+6K	+6K	+6K
19	+6K	+6K	+6K	+6K
20	+6K	+6K	+6K	+6K
21	+6K	+6K	+6K	+6K
22	+6K	+6K	+6K	+6K
23	+6K	+6K	+6K	+6K
24	+6K	+6K	+6K	+6K
25	+6K	+6K	+6K	+6K
26	+6K	+6K	+6K	+6K
27	+6K	+6K	+6K	+6K
28	+6K	+6K	+6K	+6K
29	+6K	+6K	+6K	+6K
30	+6K	+6K	+6K	+6K
31	+6K	+6K	+6K	+6K
32	+6K	+6K	+6K	+6K
33				+6K
34				+6K
35				+6K
36				+6K
37				+6K
38				+6K
39				+6K

Notes:

1. "+6K" = units which passed 6,000 cycles and were taken off test
2. Same as 1.0mm Pitch Note 2



Board Flex Testing

- Board Flex Testing per JISC 5202-1990
- Failures occurred as the unit was deflected to a point where an audible snap was heard.
- Visual examination confirmed ceramic failure.

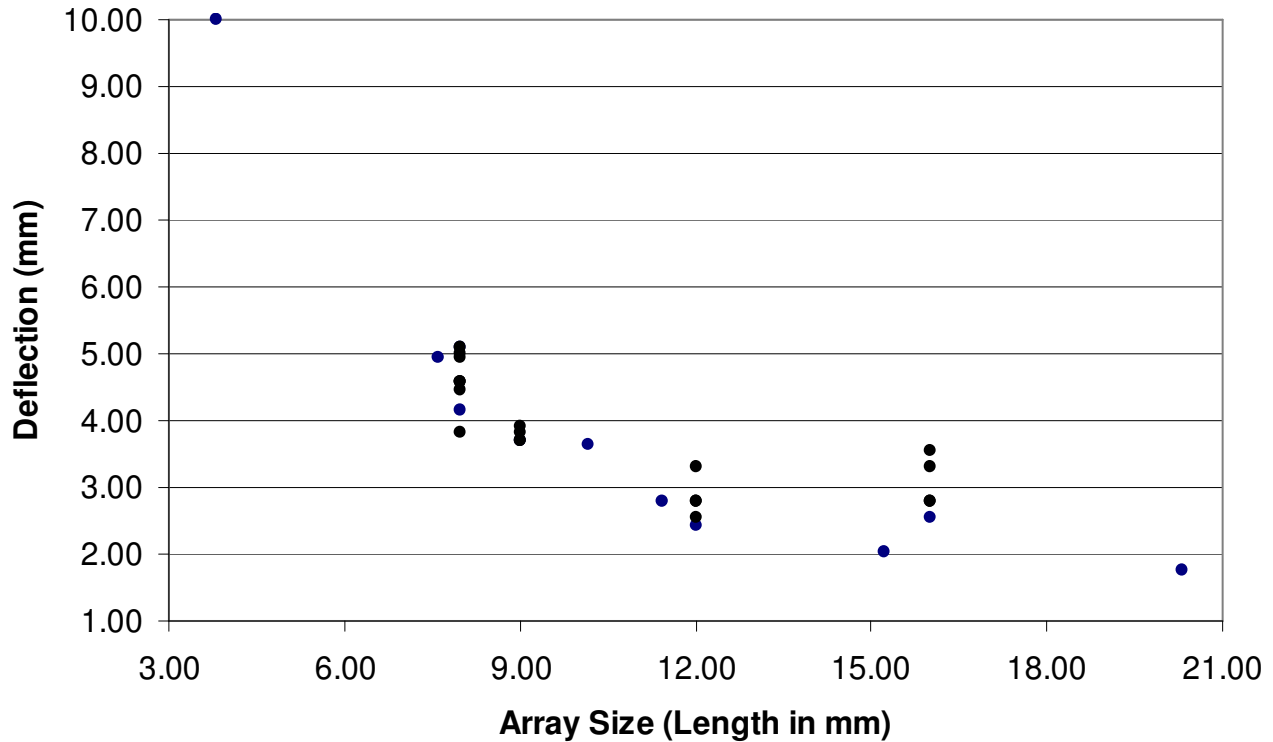
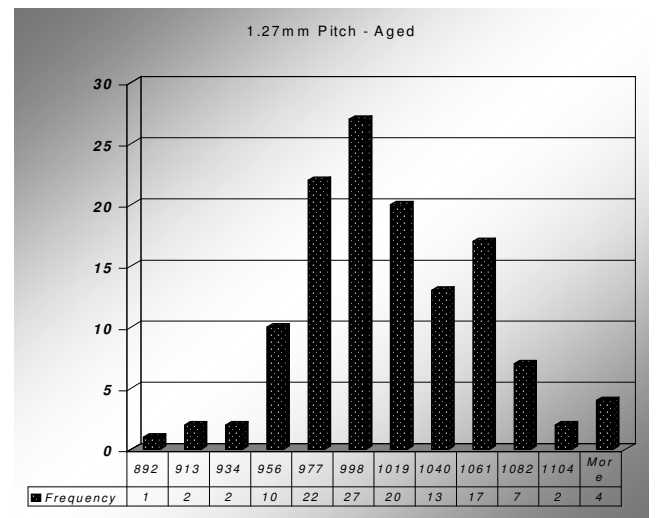
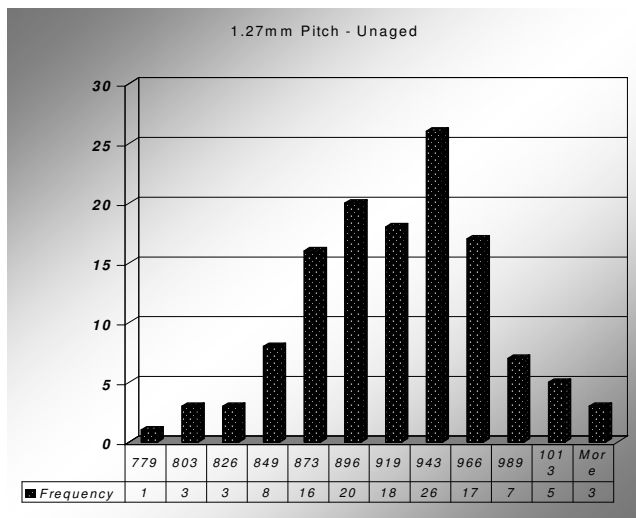
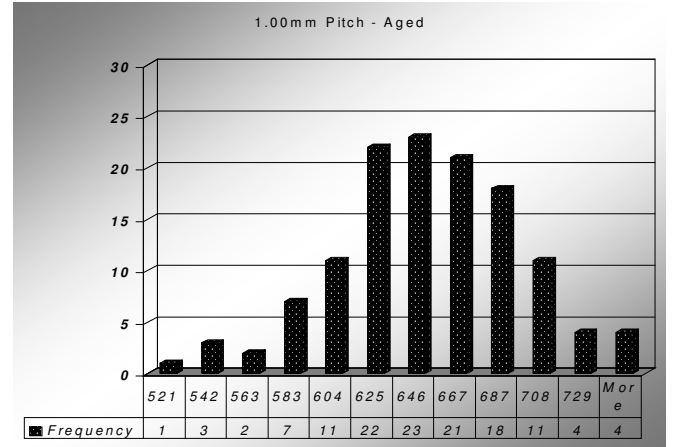
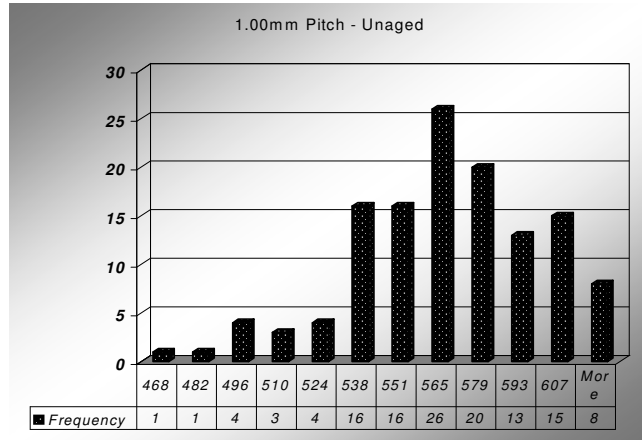


Table 9 – Board Flex Test Data							
Ceramic Length	Pitch	Array Size	Deflection at point of audible snap				
			UUT 1	UUT 2	UUT 3	UUT 4	UUT 5
3.81	1.27	3x3	10.00				
7.62	1.27	3x6	4.93				
8.00	1	4x8	5.08	5.08	4.45	5.00	4.57
8.00	1	3x8	4.17	4.95	4.57	4.57	3.81
9.00	1	4x9	3.68	3.68	3.91	3.81	3.68
10.16	1.27	3x8	3.63				
11.42	1.27	4x9	2.79				
12.00	1	3x12	2.41	2.79	2.79	2.54	3.30
15.24	1.27	3x12	2.03				
16.00	1	4x16	2.54	3.56	3.30	2.79	2.79
20.32	1.27	4x16	1.75				

Note: Data Sorted by Ceramic Length (all dimensions in mm)

Ball-Shear Testing

- Ball-Shear Testing per JEDEC JESD22-B117
- Shear (ram) speed = 100um/second.
- Shear height = 1/4 of ball diameter.



Ball Co-Planarity

- Ball Co-Planarity per JEDEC Standards : 0.10mm (0.004 inches)
- Instrument : Nikon
- Note : Limits are one-sided, therefore CpK = CpU = 2.062

Vanguard Coplanarity Data

