High Temperature Reliability of Components for Power Computing with SAC305 and Alternative High Reliability Solders with Isothermal Aging at 25ºC, 50ºC and 75ºC

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ABSTRACT

This experiment considers the reliability of a variety of different electronic components under isothermal aging and subsequent thermal cycling (TC) testing. The components are evaluated on 0.200" power computing printed circuit boards with OSP and a several different solder alloys. Single-sided assemblies were built separately for the Top-side and Bottom-side of the boards. This data is for boards on the FR4-06 substrate.

Isothermal storage at high temperature was used to accelerate the aging of the assemblies. Aging Temperatures were 25ºC, 50ºC, and 75ºC. Data from aging times of 0-Months (No Aging, baseline), 12-Months, and 24-Months will be presented.
Following isothermal aging, the assemblies were subjected to thermal cycles of -40°C to +125°C on a 120 minute thermal profile. The test was subject to JEDEC JESD22-A104-B standard high and low temperature test in a single-zone environmental chamber to assess the solder joint performance.

The principal test components are 5 mm, 6mm, 13mm, 15mm, 17mm, 31mm, 35mm and 45 mm ball grid array (BGA) packages with solder ball pitch varying from 0.4 mm to 1.27 mm. Most of the BGA packages are plastic over-molded, while the 31mm and 45mm packages are Super-BGAs (SBGAs). Several surface mount resistors (SMRs) are also considered in order to understand the effect of solder paste composition on paste-only packages.

The primary solder for package attachment in this experiment is standard SAC305, with SnPb eutectic comparison/baseline. Two alternative solders designed for high-temperature reliability are also considered.

KEY WORDS: BGA, PCB, Reliability, Solder, SAC 305, lead free, High Reliability Solder, HALT, JEDEC.

NOMENCLATURE

BGA	Ball Grid Array
EPA	Environmental Protection Agency
FC	Flip Chip
FR	Flame Retardant
HALT	Highly Accelerated Life Test
JEDEC	Joint Electron Device Engineering Council
OSP	Organic Solderability Preservative
PCB	Printed Circuit Board
RoHS	Restriction of Hazardous Substances
SEM	Scanning Electron Microscopy
SMR	Surface Mount Resistors
TC	Temperature Cycling
WEEE	Waste from Electrical and Electronic Equipment

Symbols

Ag	Silver
Bi	Bismuth
Cu	Copper
Ni	Nickel
Pb	Lead
Sb	Antimony
Sn	Tin

Greek Symbols

β	Slope
η	Characteristic Life
ρ	Probability plot

Subscripts

T_g	Glass Transition Temperature

INTRODUCTION

Thermally-induced stresses due to cyclic temperature variations from power cycling and other sources play a large role in determining the reliability of electronic packages. The reliability effects of thermo-mechanical cycling are particularly severe in products intended for use in harsh environments. Consequently, accelerated life testing that simulates these natural effects is vital in determining applicable product lifetimes.

The electronic packaging industry has been moving away from the use of Lead (Pb) due to the increasing awareness of the health and safety concerns surrounding its use. This has forced a move away from Eutectic Tin-Lead (63Sn-37Pb) solder, as well as other lead-bearing solders such as 60Sn-40Pb.

The use of Tin-Lead solders dates back at least to the Roman Empire. Following thousands of years of use in other applications, Sn-Pb solders were adopted as the predominant interconnect materials for the electronics packaging industry [1,2]. The advantageous material properties of Tin-Lead (SnPb) solder – such as a good melting temperature, excellent solderability, and suitability for both reflow and wave soldering processes – made it the solder solution from the inception of the modern industry.

However, the majority of electronic wastes (e- wastes) are not recycled and instead end up as land-fill. Recently, significant health problems relating to long-term exposure to lead even at low levels have raised concerns over the Lead in e-waste. In response to concerns over potential lead contamination from e-waste, new rules in Japan and regulations from the European Union (RoHS and WEEE) have forced the electronics packaging industry to phase out the use of Lead (Pb) in solders [3, 4, 5].

Current industry standards for ball grid array (BGA) and solder interconnect reliability testing rely mainly on pass/fail electrical continuity test criterion, with limited knowledge of factors contributing towards the failure. A variety of factors affect the reliability of the solder joints used in electronic assemblies. Chip dimension, differences in component structure, and BGA pad size are some of the factors to be considered, in addition to the primary consideration of the solder material properties.

Both the composition and microstructure of the solder joint will affect its bulk properties. These will determine the joint's ability to provide the necessary mechanical and electrical connection and therefore mediate the reliability of the joint. Although an initial microstructure will be present following assembly – which will involve one or more soldering steps –this structure will continue to evolve over the lifetime of the joint. Both inherent variability in the as-reflowed microstructure and subsequent evolution must be taken into consideration because of their strong influence on joint reliability.

During a Thermal Cycling (TC) test, solder materials are typically subjected to higher temperatures above half of their melting point (i.e. greater than 0.5 in terms of their homologous temperature), facilitating thermally driven evolution and failure mechanisms. The combination of unequal coefficients of thermal expansion (CTEs) and temperature changes can result excessive thermo-mechanical fatigue, leading to weakening of the solder joints and eventually to failure.

EXPERIMENTAL SETUP

Test Vehicle

The test vehicle (TC1-SRJ) has dimensions of 173 mm x 254 mm with a board thickness of 5 mm (200 mil). The tool-hole diameter is 3.8 mm diameter and the distance from edge of package to the center of the holes is 7mm. There are 6 Copper (Cu) layers with 14,607 pins, 3590 through-hole, and 11017 SMT per board. The board surface finish is organic solderability preservative (OSP).

Each board has land patterns available for the placement of 249 components, although SMR components are electrically daisy-chained together for readout through a single channel. The design pattern used for the top and bottom side of the board are different. In total, there are 19 channel readouts and one ground for the top-side, and an additional 39 channel readouts on the bottom-side (ground shared). The test vehicle design is shown in Figure 1.

Two different printed circuit board materials were tested: FR4-06 and a very low loss PPO blend. The FR4-06 board material used in this experiment was a high-temperature multifunctional glass-epoxy laminate with a glass-transition temperature (T_g) of 170°C, whereas the PPO blend resin board material used in this experiment was a high temperature Polyphenylene Ether blend with a glass-transition temperature (T_g) of 210°C.

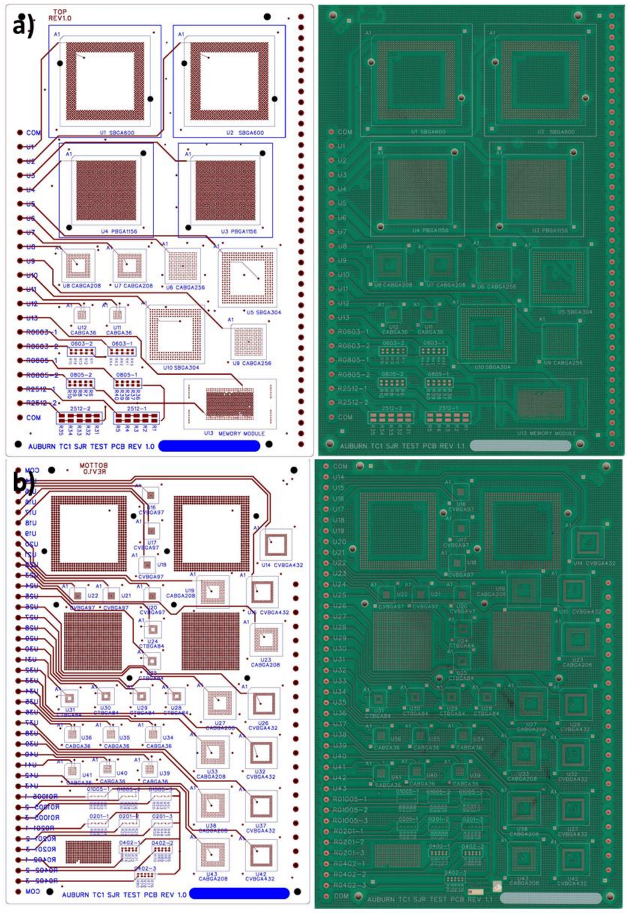

Figure 1. Test Vehicle Design: a) Top-Side and b) bottom-side of the TC1-SRJ test vehicle.

Surface Mount Assembly

Dummy-die components were used. Each component was daisy-chained (electrically) so that a failure at any interconnect in the package would show up during a resistance measurement.

A total of 880 test vehicles were built: 720 boards of FR4-06 substrate material, and 160 boards of PPO blend substrate material. An additional 30 FR4-06 boards were used for setup purposes during build/assembly. The test vehicles were built in two groups: 660 boards were assembled as 'Top-side' boards, with only the top-side components mounted, while 220 boards were assembled as 'Bottom-side' boards, with only the bottom-side components mounted.

This experiment is designed to evaluate the effect of long-term isothermal aging of several lead-free solder alloys, including SAC105 and SAC305. The test matrix with the board groupings is shown in Figure 2, below. There are four (4) aging times (0, 6, 12, and 24 months) and three different aging temperatures (25°C, 50°C, and 75°C).

		Top Side		Bottom Side		Total	Aging
FR 406	SAC	30 [30,0,0]	74 [74,0,0]	10 [10,0,0]	25 [25,0,0]	99[99,0,0]	No Aging
	SnPb	14 [14,0,0]		5 [5,0,0]			
	Alloy A	30 [30,0,0]		10 [10,0,0]			
PPO Blend	SAC	15 [15,0,0]	30 [30,0,0]	5 [5,0,0]	10 [10,0,0]	40 [40,0,0]	
	SnPb	15 [15,0,0]		5 [5,0,0]			
FR 406	SAC	90 [30,30,30]	162 [44,44,74]	30 [10,10,10]	55 [15,15,25]	217 [59,59,99]	6 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	30 [0,0,30]		10 [0,0,10]			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	9 [0,0,9]	39 [0,0,39]	
	SnPb	15 [0,0,15]		4 [0,0,4]			
FR 406	SAC	90 [30,30,30]	132 [44,44,44]	30 [10,10,10]	45 [15,15,15]	177 [59,59,59]	12 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	0		0			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	10 [0,0,10]	40 [0,0,40]	
	SnPb	15 [0,0,15]		5 [0,0,5]			
FR 406	SAC	90 [30,30,30]	162 [44,44,74]	30 [10,10,10]	55 [15,15,25]	217 [59,59,99]	24 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	30 [0,0,30]		10 [0,0,10]			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	10 [0,0,10]	40 [0,0,40]	
	SnPb	15 [0,0,15]		5 [0,0,5]			
		Total Top Side =	650 [236,132,282]	Total Bottom Side =	219 [80,45,94]	Total Boards = 869[316,177,376]	

Number of Total Board [# aged at 25C, # aged at 50C, # aged at 75C]

Figure 2. Test Matrix.

The principal test components are ball grid array (BGA) packages of 5 mm, 6mm, 13mm, 15mm, 17mm, 31mm, 35mm and 45 mm with solder ball pitch varying from 0.4 mm to 1.27 mm. Three different solder paste compositions were used, in combination with four different solder ball compositions. Several lead-less packages, including a variety of surface mount resistors (SMRs) and a land grid array (LGA) socket were also used. Figure 3 enumerates the components used with the TC1-SRJ test vehicle. The LGA socket was used to house the memory module, a pin grid array (PGA) that was attached by hand following assembly. Heat sinks for the 45mm and 35mm components were also added by hand following the standard assembly work.

The three solder pastes used in this test were SnPb (eutectic), SAC305 (Type 4), and Alloy A (Sn3.8Ag0.7Cu3Bi1.4Sb0.15Ni). Two different aperture stencils were used: one for the top-side and one for the bottom-side. The top-side stencil was 127 microns (5 mil) thick, while the bottom-side was 76 microns (3 mil) thick. Bottom-side boards were double-printed in order to get adequate solder volume on the fine-pitch components. During reflow soldering, two different reflow profiles were for each of the top/bottom side assemblies: one for SnPb and one for the Pb-free solders.

During and following assembly, a number of quality assurance steps were taken. Setup boards were used to check solder paste height and volume, and to verify solder wetting. Additionally, several components on one of the setup boards were sacrificed in a ‘pry test’ in order to assure the mechanical strength of the solder joints as reflowed. The resistance of each component was checked by hand following reflow (excluding the socketed components, which were hand-assembled into the LGA sockets later). Open channels were noted and eliminated from inclusion in further testing. Boards were also inspected visually and via (transmission) x-ray analysis to determine typical solder-joint quality following reflow. XRD voiding analysis and shear (“pry”) testing indicated excellent build quality, and yield was very high in electrical testing.

Component	Solder Ball Material	Pitch	Dimension
SBGA 600	SAC305	1.27mm	45mm
SBGA 600	SnPb	1.27mm	45mm
PBGA 1156	SAC 305	1.00mm	35mm
PBGA 1156	SAC 105	1.00mm	35mm
PBGA 1156	SnPb	1.00mm	35mm
SBGA 304	SAC 305	1.27mm	31mm
SBGA 304	SnPb	1.27mm	31mm
CABGA 256	SAC 305	1.0mm	17mm
CABGA 256	SAC 105	1.0mm	17mm
CABGA 256	SnPb	1.0mm	17mm
CABGA 208	SAC 305	0.8mm	15mm
CABGA 208	SAC 105	0.8mm	15mm
CABGA 208	SnPb	0.8mm	15mm
CABGA 208	Alloy A	0.8mm	15mm
CABGA 208	Alloy B	0.8mm	15mm
CVBGA 432	SAC 305	0.4mm	13mm
CVBGA 432	SAC 105	0.4mm	13mm
CVBGA 432	SnPb	0.4mm	13mm
CABGA 36	SAC 305	0.8mm	6mm
CABGA 36	SAC 105	0.8mm	6mm
CABGA 36	SnPb	0.8mm	6mm
CABGA 36	Alloy A	0.8mm	6mm
CABGA 36	Alloy B	0.8mm	6mm
CTBGA 84	SAC 305	0.5mm	6mm
CTBGA 84	SAC 105	0.5mm	6mm
CTBGA 84	SnPb	0.5mm	6mm
CVBGA 97	SAC 305	0.4mm	5mm
CVBGA 97	SAC 105	0.4mm	5mm
CVBGA 97	SnPb	0.4mm	5mm
Memory Module	(PGA+Socket)		
1210 SMR	100% Sn		3.2x2.6mm
1206 SMR	100% Sn		3.2x1.6mm
0805 SMR	100% Sn		2.0x1.2mm
0603 SMR	100% Sn		1.6X0.8mm
0402 SMR	100% Sn		1.0X0.5mm
0201 SMR	100% Sn		0.6x0.3mm
01005 SMR	100% Sn		0.4X0.2mm

Figure 3. Component Matrix

Test Setup

The electrical components for this experiment were daisy chained for electrical continuity testing and in situ monitoring throughout the thermal cycling (TC) test. The resistance for each component was independently monitored during the temperature cycle test, except for SMRs, which were chained in groups of 5. To assess the solder joint reliability, test vehicles were subjected to a thermal cycling (TC) test based on the JEDEC JESD22-A104-B standard high and low temperature test. The test was carried out in a single-zone environmental chamber, with peak temperature of -40°C and +125°C. Overall cycle time was 120 minutes, with 15 minute dwells and 45 minute ramps. Three chambers were used, one for the 0-Month ("No Aging") and 12-Month aging groups, a second chamber for the 6-Month aging group, and a third for the 24-Month aging group.

The boards were placed vertically in the chamber and the wiring passed through the independent access ports to a software-based monitoring system. The monitoring system consists of a switching system and digital multi-meter (DMM) in conjunction with custom interface boards. Monitoring was done by cyclically scanning the resistance on each channel in a basic 2-wire resistance test. Channels that exhibited five (5) consecutive threshold-exceeding events were recorded as a failure in the monitoring system.

Each aging group was subjected to 3000+ thermal cycles. Data is presented for 3000 TC for the 0-Month (No Aging) group, 3000 cycles for the 6-Month aging group, ~2400 cycles for the 12-Month aging group, and ~500 cycles for the 24-Month aging group. The failure data was analyzed and the reliability of the solder joints was determined in terms of the characteristic life (η) and slope (β) using standard two parameter Weibull analysis.

RESULTS AND DISCUSSIONS

Temperature Cycling Results

The temperature cycling test results below show some of the highlights from the reliability data from the 0-Month (No Aging) group, 12-Month aging group, and 24-Month aging groups. For analysis purposes, we have highlighted key points using data from 'representative' parts in cases when several components show similar overall behavior. Specifically, for the smaller plastic ball grid array packages (5mm – 17mm), the No Aging failure trends are similar, so we will begin by illustrating overall trends using data from the CABGA 208 component.

The CABGA 208 component is found on both the top and bottom side of the board and within all groups, allowing for multiple comparisons across various experimental parameters. Below are a few key points from the failure data of this component.

When examining the effect of various solder paste and sphere combinations, the Characteristic Life values show the following pattern for the No Aging Group, listed from best to worst:

(1) Matched Alloy A* (Alloy A spheres + paste),
(2) SAC305 spheres doped with Alloy A paste,
(3) Matched SAC305 (SAC305 spheres + paste), and
(4) Matched SnPb (SnPb spheres + paste).

*Note that Matched Alloy A data is available only for the CABGA 208 and CABGA 36 components.

Under our thermal cycling (TC) test, components balled with SAC305 spheres are more reliable than equivalent SAC105 balled components. This pattern holds for both SAC305 and Alloy A solder pastes. No difference is seen in the pattern of failures when comparing components found on the Top-Side of the board and the Bottom-Side of the board, with the exception of the Alloy B (Bi doped) spheres.

Figures 4-6 show Weibull plots for the CABGA 208 component for No Aging, 12-Month Aging, and 24-Month Aging. Note that every subgroup may not appear on each graph and color coding of groups varies. Data is from 75ºC aging unless otherwise marked.

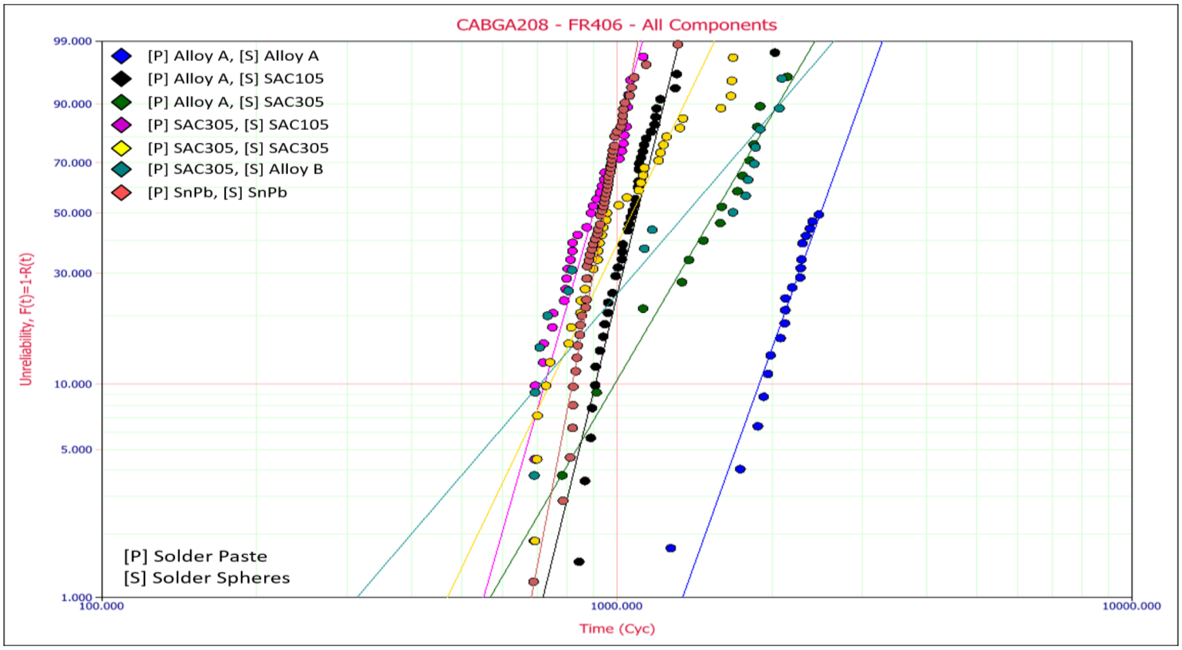

Figure 4. Weibull Plot: CABGA208 – FR4-06 – No Aging

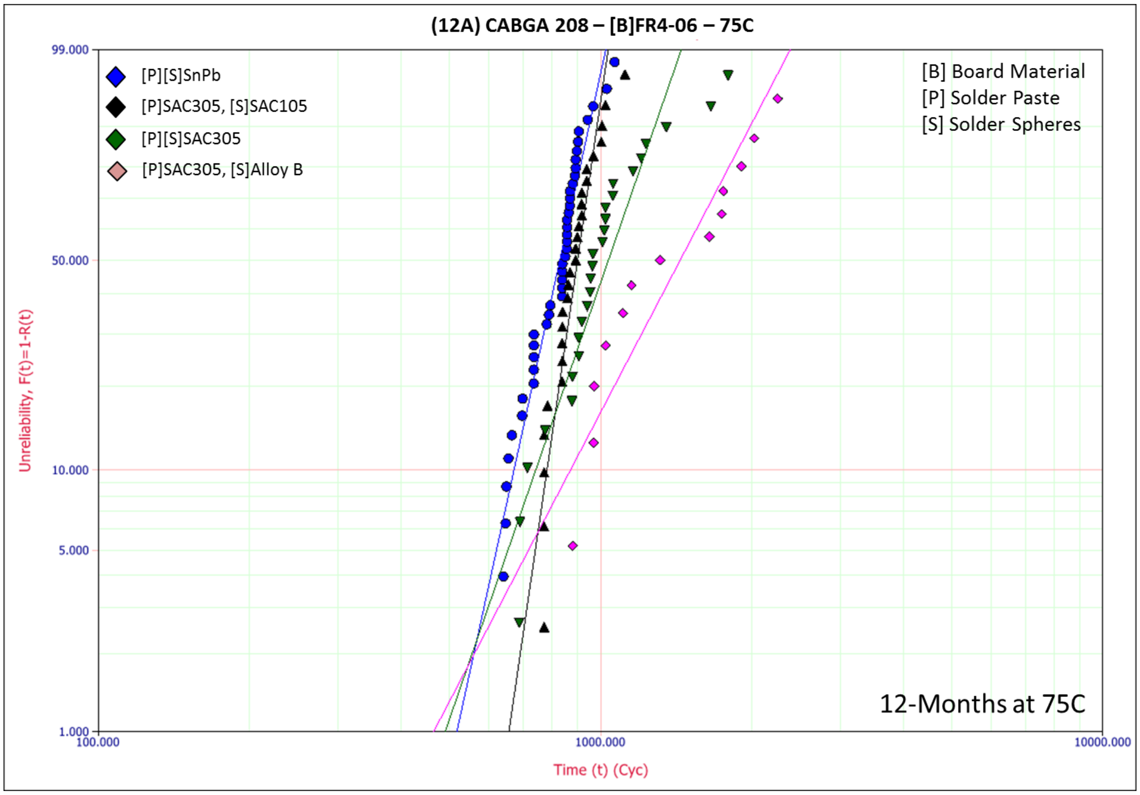

Figure 5. Weibull Plot: CABGA208 – FR4-06 – 12-Month

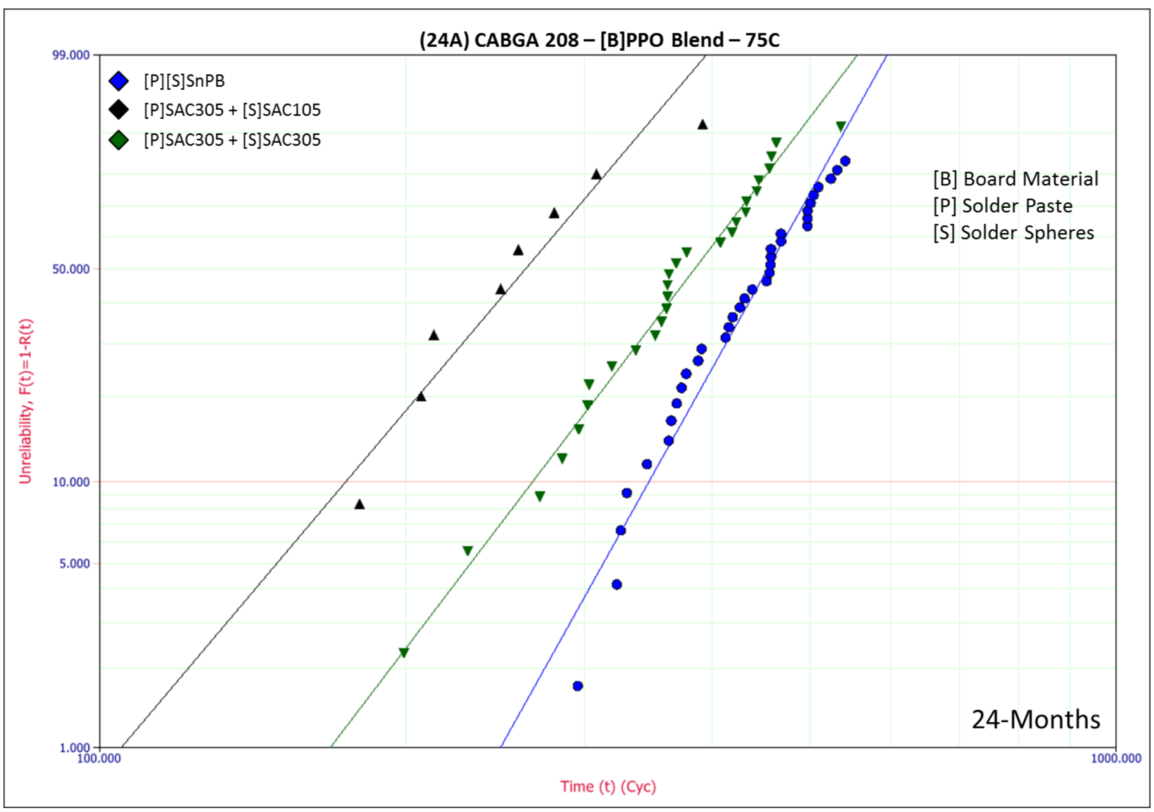

Figure 6. Weibull Plot: CABGA208 – PPO Blend – 24-Month

Figure 7 shows the trend in characteristic life based on the available solder material combinations for the CABGA 208 component on the FR406 substrate for the No Aging and 12-Month (75ºC) Aging groups. Figure 8 shows the data for SnPb on FR4-06 for the No Aging, 12-Month (75ºC) Aging, and 24-Month (75ºC) Aging groups.

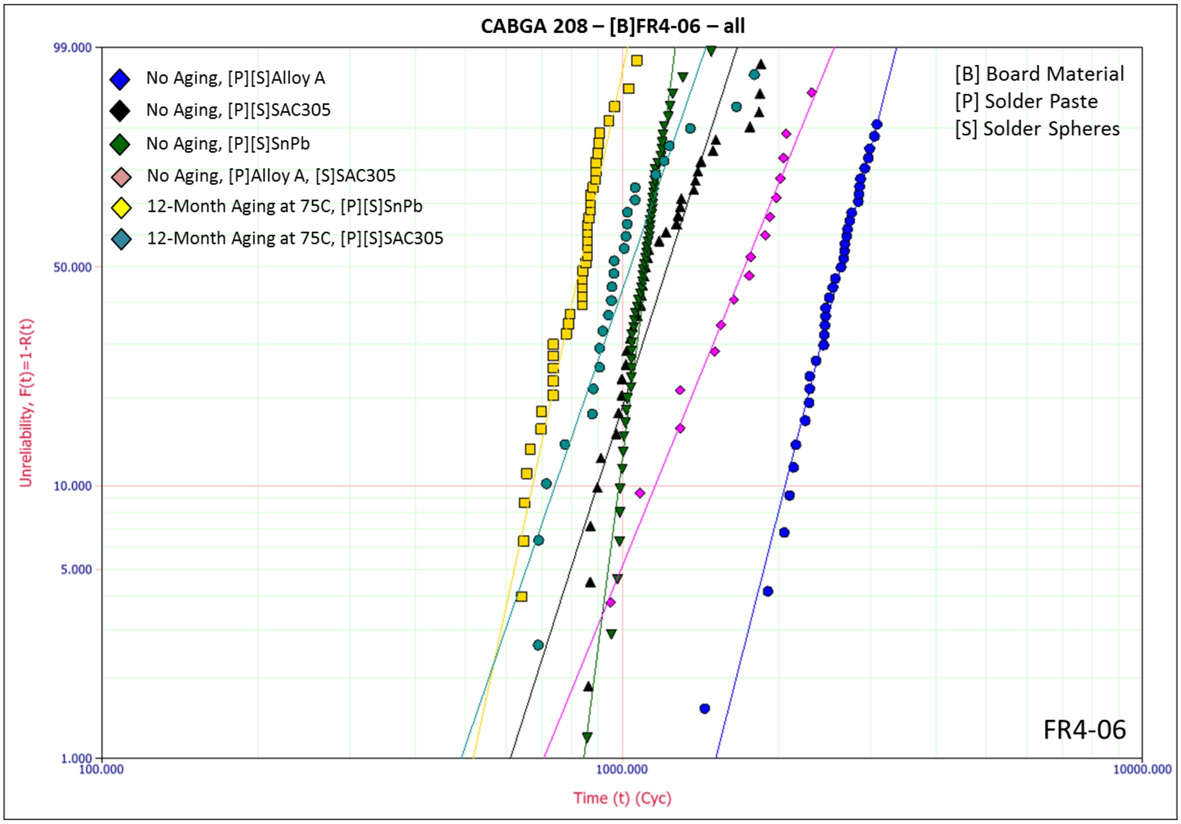

Figure 7. Weibull Plot: CABGA208 – FR4-06 – No Aging and 12-Month (75ºC)

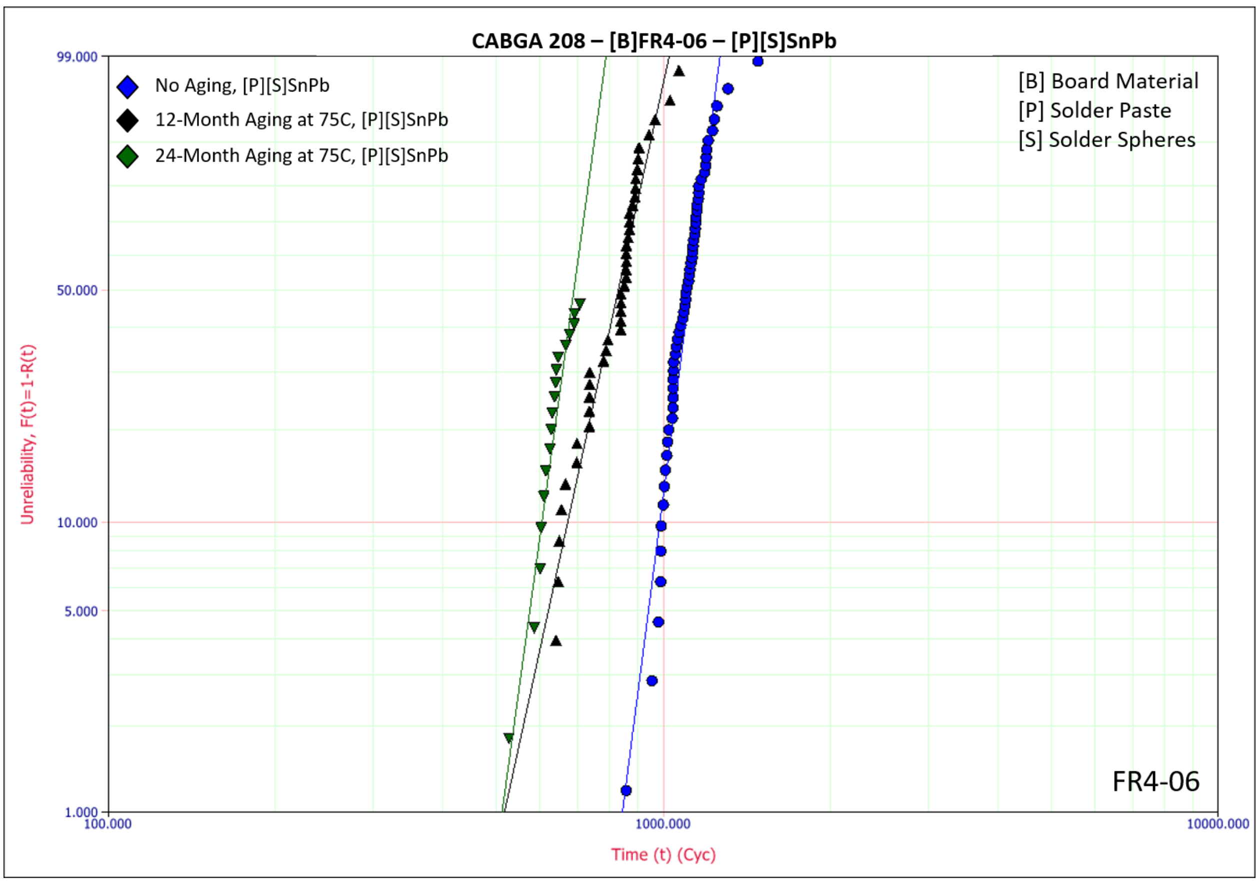

Figure 8. Weibull Plot: CABGA208 – FR4-06 – SnPb

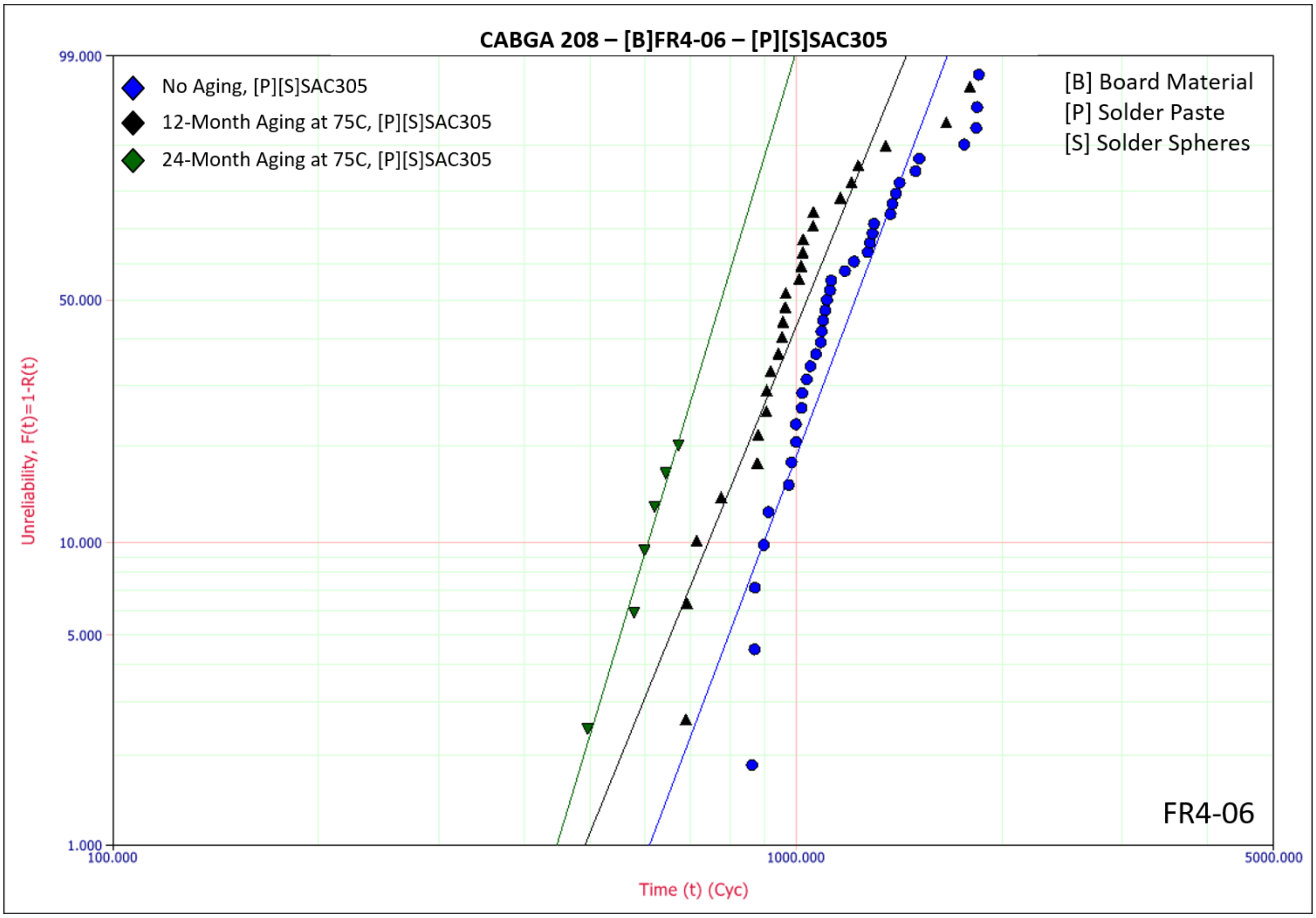

Figure 9. Weibull Plot: CABGA208 – FR4-06 – SAC305

Although the No Aging reliability data show similar trends for all of the smaller plastic packages (5mm-17mm), this does not appear to extend universally to aged data. In particular, the amount of degradation of the lead-free solders relative to tin-lead solder appears to be package-dependent. In contrast to the CABGA 208 package, where the SnPb solder is clearly superior in the 24-Month aging group (Figure 6), Figures 10 and 11 show somewhat different behavior. A cross-over between the SnPb and SAC305 (matched) solders is seen in Figure 10 for the CABGA 256 component, and Figure 11 shows SAC305 solder still superior to SnPb for the CVBGA 432 package. Note that Figures 6, 9, and 10 are all preliminary data from the 24-Month aging group, and are therefore on the PPO Blend substrate (failures occur earlier on the PPO Blend) and the possibility exists that this behavior will be different on FR4-06.

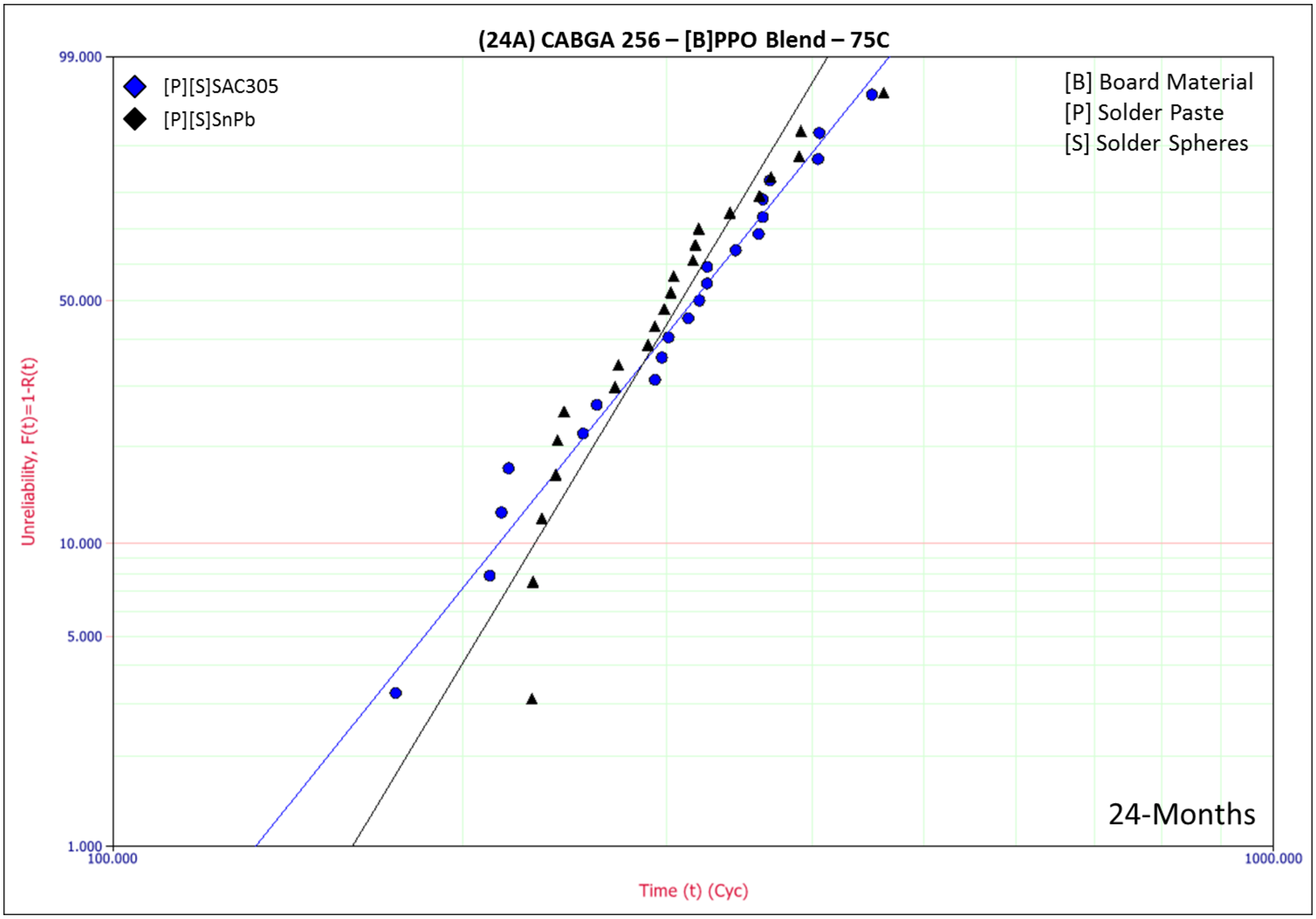

Figure 10. Weibull Plot: CABGA256 – PPO Blend – 24-Month

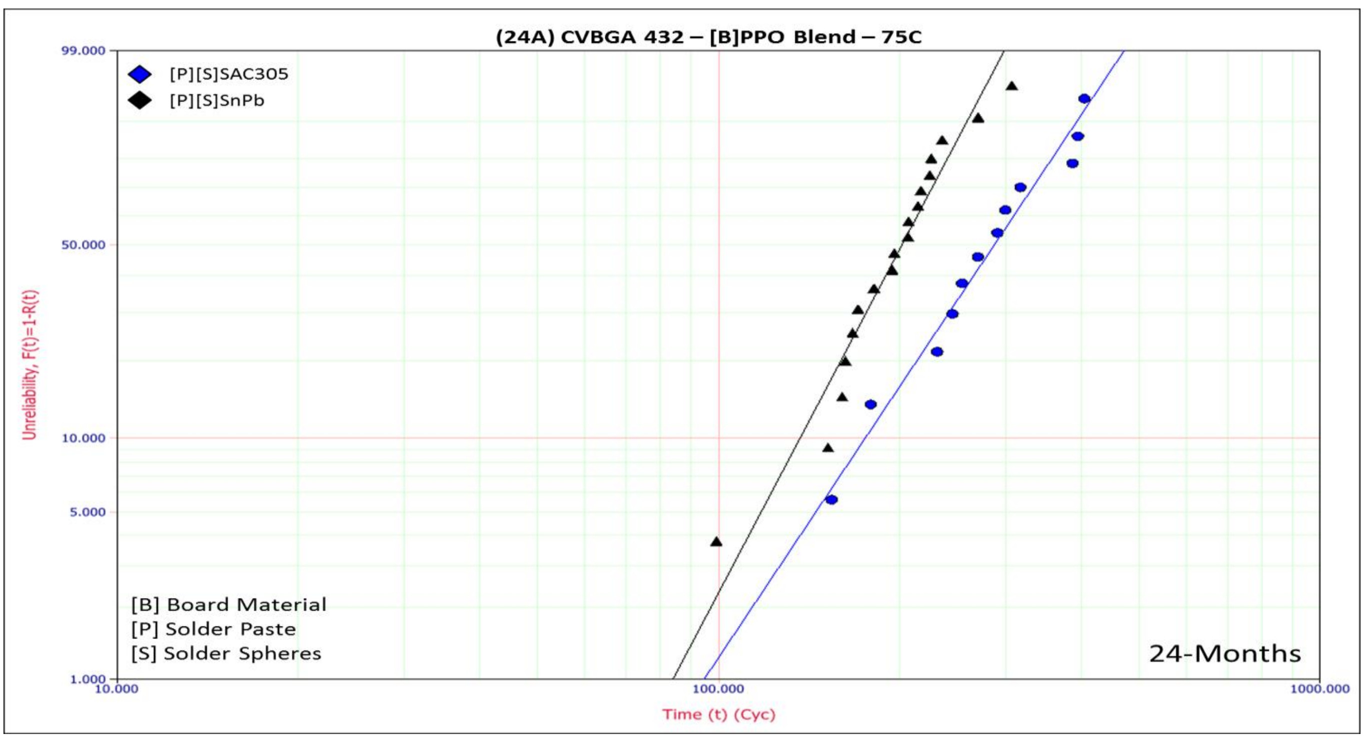

Figure 11. Weibull Plot: CVBGA432 – PPO Blend – 24-Month

Other components show somewhat different trends in their failure data even within the same aging group. The reliability trends for the PBGA 1156 package are slighly different than those of the smaller plastic BGAs. The PBGA 1156 is a 35mm component found only on the top-side of the board, with 1.0mm pitch. With a solid 34x34 I/O array, it has by far the largest I/O count in this experiment.

The key difference between the data from the PBGA 1156 and the other plastic packages is that there is not a significant improvement seen in the reliability of the solder joints when doping with Alloy A paste for the PBGA 1156. Characteristic life values are similar for SAC305 and Alloy A paste. Figure 12 shows the Weibull data for the PBGA 1156 package on the FR4-06 substrate (No Aging and 12-Month Aging).

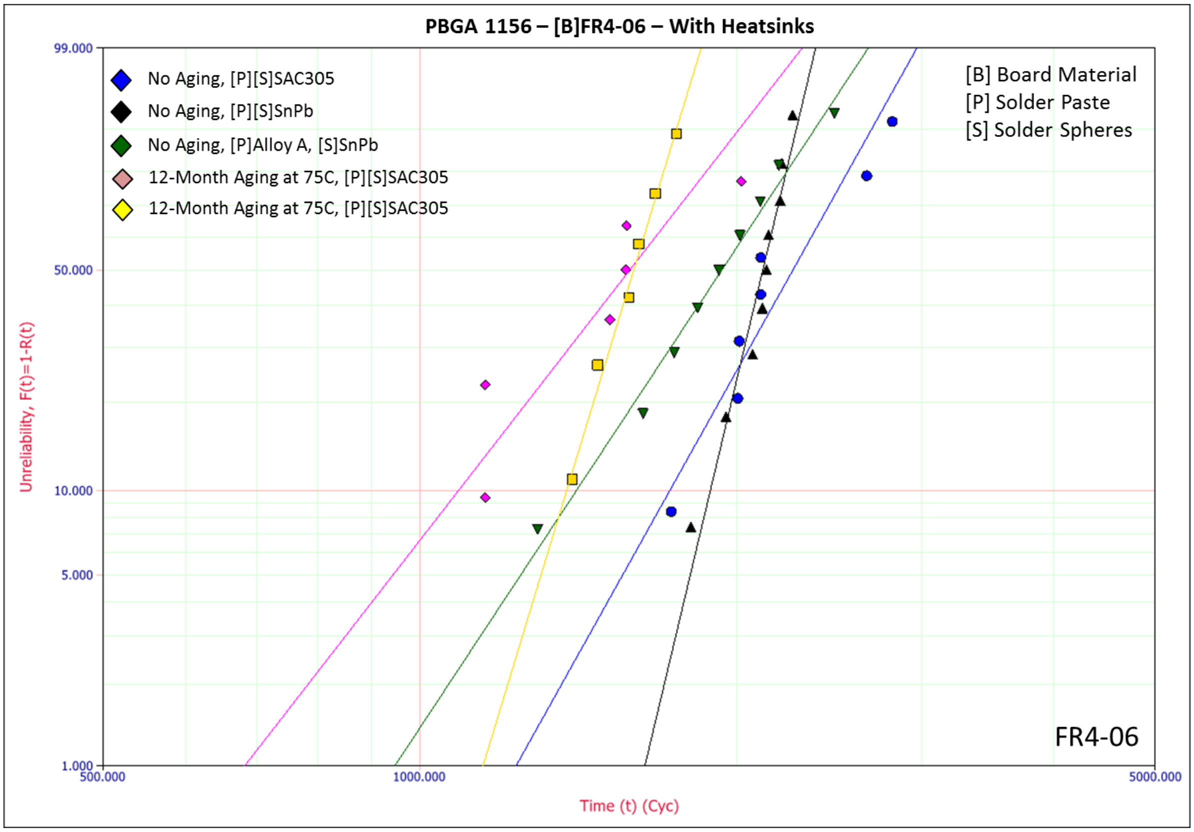

Figure 12. Weibull Plot: PBGA1156 – No Aging and 12-Month (75ºC)

Another interesting difference can be seen between the failure data of the plastic packages discussed so far and the two Super-BGA (SBGA) packages tested: the SBGA 304 and the SBGA 600. These are cavity-down, metal-capped components, and so are structurally quite different from the previously discussed packages. Both SBGAs are large-pitch (1.27mm) components and are found only on the top-side of the board. The SBGA 304 package has a footprint of 31mm x 31mm, while the SBGA 600 component has a footprint of 45mm x 45mm.

Similar to the PBGA 1156, there is not a reliability improvement seen with the use of Alloy A paste for these components. Additionally, the reliability of these two SBGA packages is higher on the PPO Blend substrate than on the FR4-06 substrate in this experiment, which reverses the trend from all of the plastic packages, including both the smaller packages and the larger PBGA 1156. Figure 13 shows the Weibull data for the CABGA 304 package on the FR4-06 substrate (No Aging and 12-Month Aging).

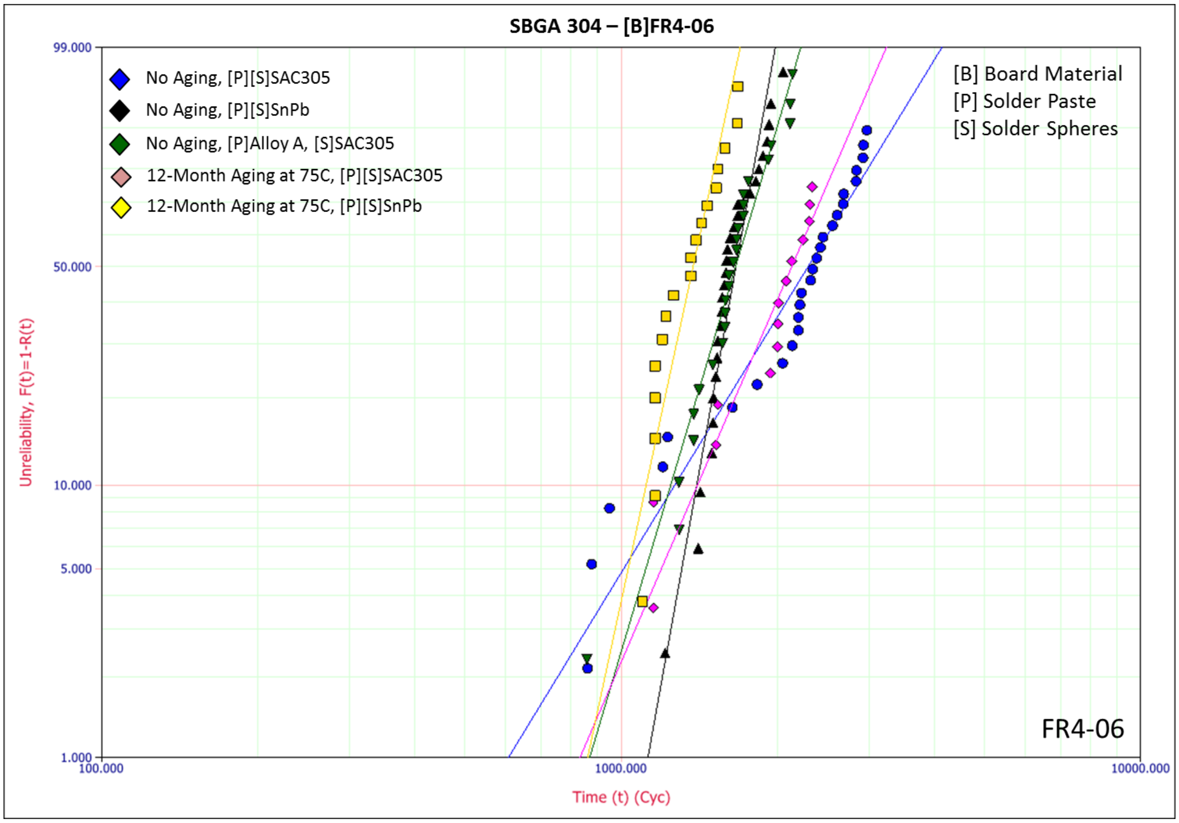

Figure 13. Weibull Plot: SBGA304 – No Aging and 12-Month (75ºC)

Summary and Conclusions

The failure data for the No Aging group was found to follow specific trends depending on the type and size of the component. The smaller plastic ball grid array (BGA) packages (5mm – 17mm) show the following pattern in Characteristic Life value, listed from best to worst:

(1) Matched Alloy A* (Alloy A spheres + paste),
(2) SAC305 spheres doped with Alloy A paste,
(3) Matched SAC305 (SAC305 spheres + paste), and
(4) Matched SnPb (SnPb spheres + paste).

*Note that Matched Alloy A data is available only for the CABGA 208 and CABGA 36 components.

However, aging data indicates that even components that show similar initial reliability trends may display differences after isothermal aging. Lead-free alloys appear to show faster deterioration with aging than eutectic SnPb solder when examining the changes from No Aging to 12-Months Aging, to 24-Months Aging. Nonetheless, even at 24-Months of aging, a cross-over in reliability may not be seen: some components show a cross-over in reliability but others do not.

A larger plastic BGA component, the PBGA 1156, shows similar failure trends in terms of most particulars. However, one key difference exists. The PBGA does not show a significant improvement in joint reliability during Alloy A paste doping.

Two SBGA components, the SBGA 304 and SBGA 600, also show differences in failure data trends to the smaller plastic ball grid arrays. Like the PBGA 1156, these packages do not show an improvement in reliability via Alloy A paste doping (in fact, reliability is lower in the doped case). Moreover, both of the SBGA components show a reversal of the substrate-effect seen in the plastic packages and display higher reliability on the PPO Blend substrate than on the FR4-06 substrate.

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High Temperature Reliability of Components for Power Computing with SAC305 and Alternative High Reliability Solders with Isothermal Aging at 25^{o}C, 50^{o}C and 75^{o}C

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Outline/Agenda

- Introduction
- Test Matrix
- Test Vehicle and Assembly
- Thermal Cycle and Measurements
- Results of Experiments
- Conclusions
- Q & A

Test Matrix

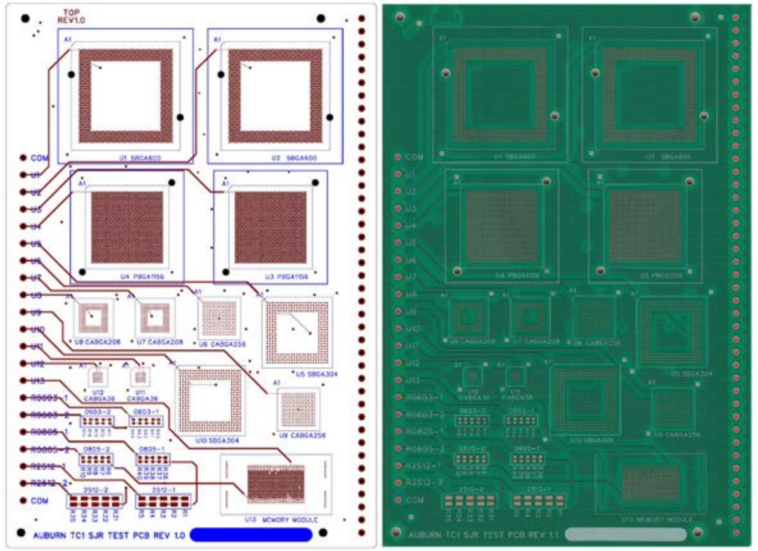
		Top Side		Bottom Side		Total	Aging
FR 406	SAC	30 [30,0,0]	74 [74,0,0]	10 [10,0,0]	25 [25,0,0]	99[99,0,0]	No Aging
	SnPb	14 [14,0,0]		5 [5,0,0]			
	Alloy A	30 [30,0,0]		10 [10,0,0]			
PPO Blend	SAC	15 [15,0,0]	30 [30,0,0]	5 [5,0,0]	10 [10,0,0]	40 [40,0,0]	
	SnPb	15 [15,0,0]		5 [5,0,0]			
FR 406	SAC	90 [30,30,30]	162 [44,44,74]	30 [10,10,10]	55 [15,15,25]	217 [59,59,99]	6 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	30 [0,0,30]		10 [0,0,10]			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	9 [0,0,9]	39 [0,0,39]	
	SnPb	15 [0,0,15]		4 [0,0,4]			
FR 406	SAC	90 [30,30,30]	132 [44,44,44]	30 [10,10,10]	45 [15,15,15]	177 [59,59,59]	12 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	0		0			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	10 [0,0,10]	40 [0,0,40]	
	SnPb	15 [0,0,15]		5 [0,0,5]			
FR 406	SAC	90 [30,30,30]	162 [44,44,74]	30 [10,10,10]	55 [15,15,25]	217 [59,59,99]	24 months
	SnPb	42 [14,14,14]		15 [5,5,5]			
	Alloy A	30 [0,0,30]		10 [0,0,10]			
PPO Blend	SAC	15 [0,0,15]	30 [0,0,30]	5 [0,0,5]	10 [0,0,10]	40 [0,0,40]	
	SnPb	15 [0,0,15]		5 [0,0,5]			
		Total Top Side =	650 [236,132,282]	Total Bottom Side =	219 [80,45,94]	Total Boards = 869[316,177,376]	

Number of Total Board [# aged at 25C, # aged at 50C, # aged at 75C]

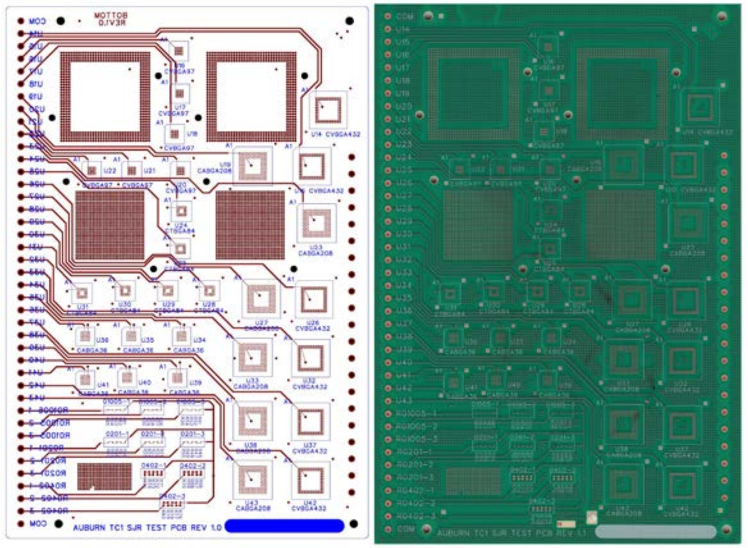
Test Board Designs

- Board Dimensions: 10” x 6.81” x 0.2”   with 6 Cu layers, 14,600+ pins, etc.
- A mixture of BGA, CSP package, PGA package, resistor packages, and connectors have been incorporated
- SAC105, SAC305, and Alloy A (Sn3.8Ag0.7Cu3Bi1.4Sb0.15Ni) lead-free solder balls, along with Bi doped lead free solder balls on select packages
- Boards are assembled with components on one side only (Top or Bottom)

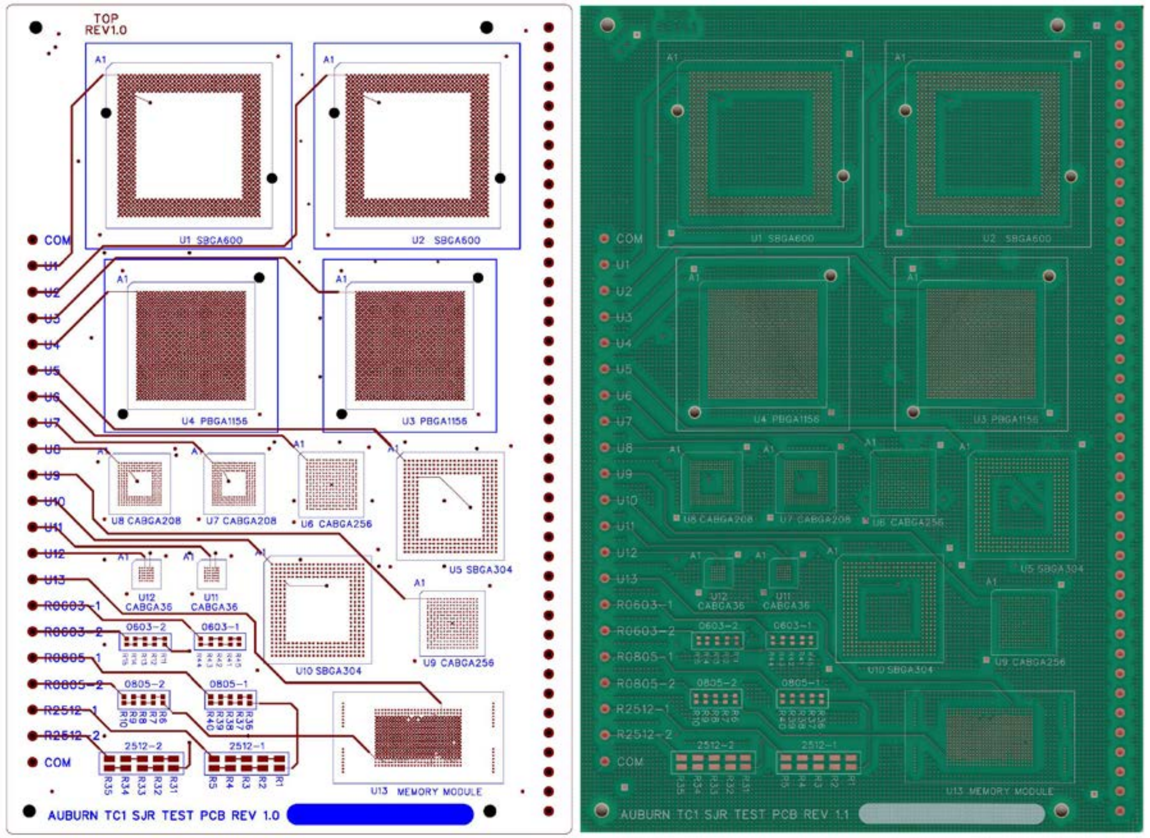
Top Side



Bottom Side



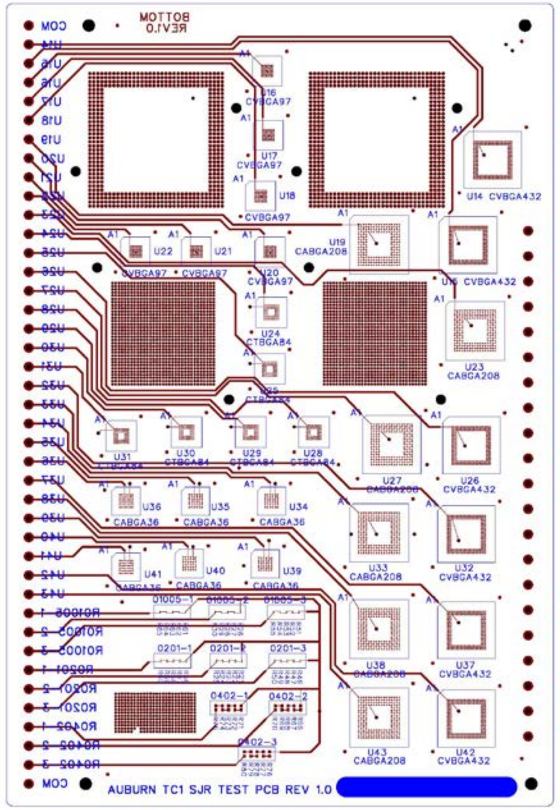
Top-Side Assembly View

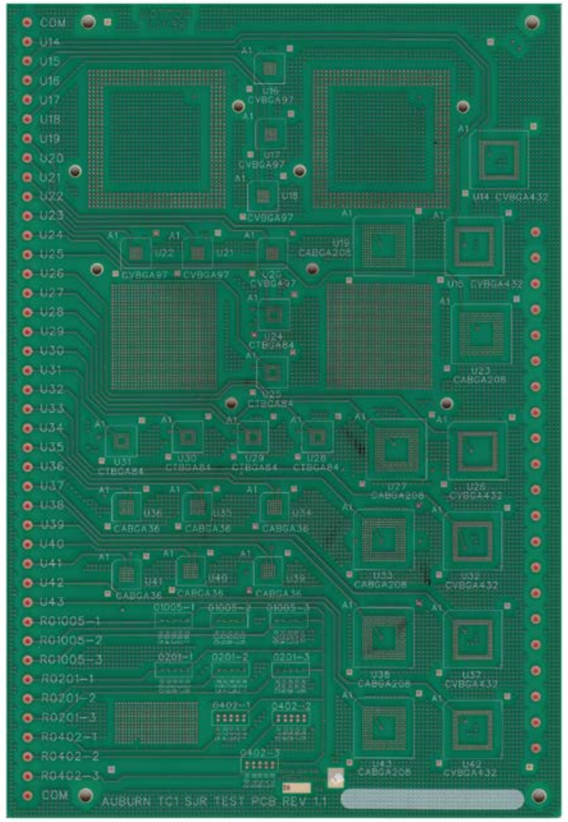


Top	FR4-06	PPO Blend
SAC305	300	60
SnPb	150	60
Alloy A	90	0

- Package sizes: 45mm, 35mm, 31mm, 17mm, 15mm, 6mm
- Pitches: 0.8mm, 1.0mm and 1.27 mm
- SMR 0603, 0805, 1206, and 1210
- 15-19 channel readouts (+GRD)

Bottom-Side Assembly View



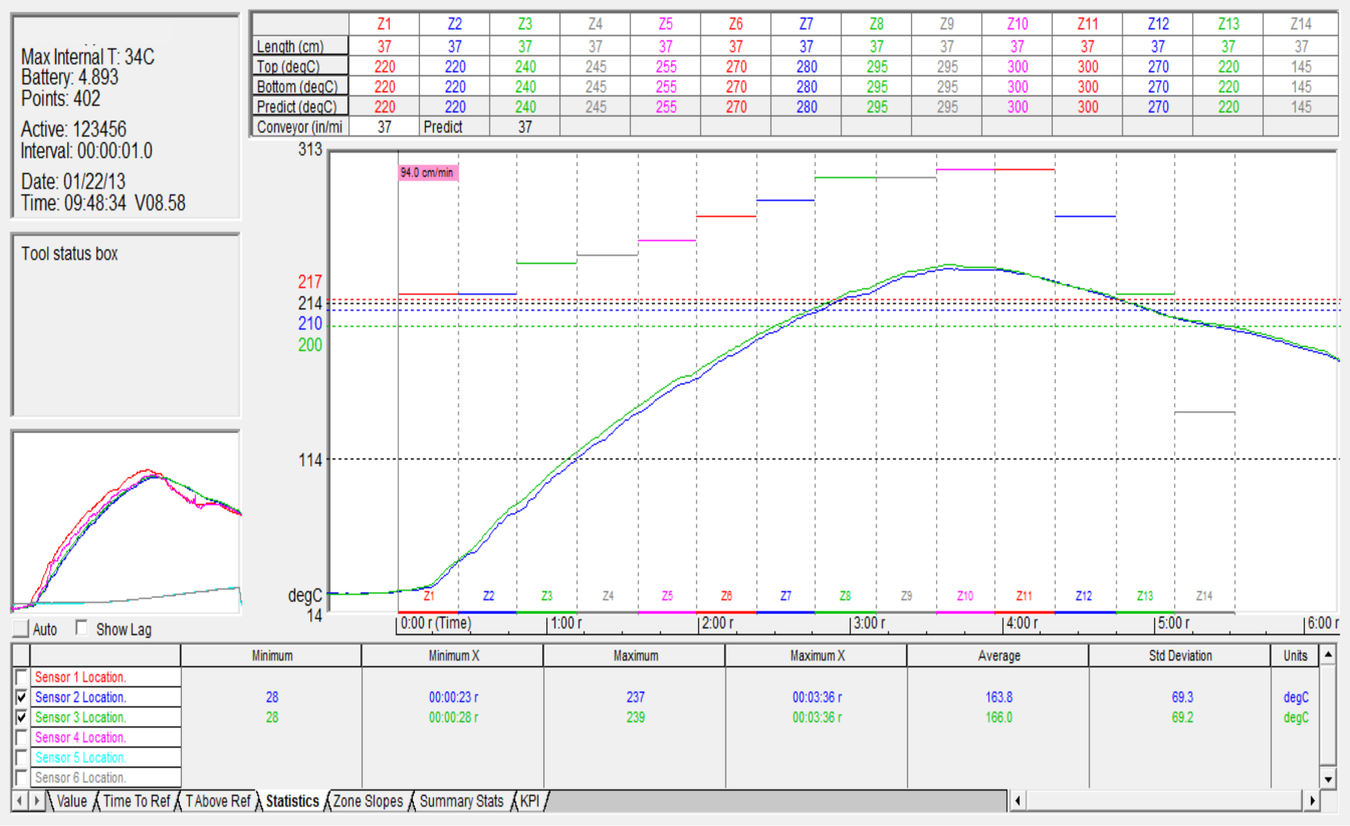


Bottom	FR4-06	PPO Blend
SAC305	100	20
SnPb	50	20
Alloy A	30	0

- Package sizes: 15mm, 13mm, 6mm, 5mm
- Pitches: 0.4mm, 0.5mm and 0.8mm
- SMR 01005, 0201, and 0402
- Up to 39 channel readouts (+GRD)

Top-Side Reflow Profile

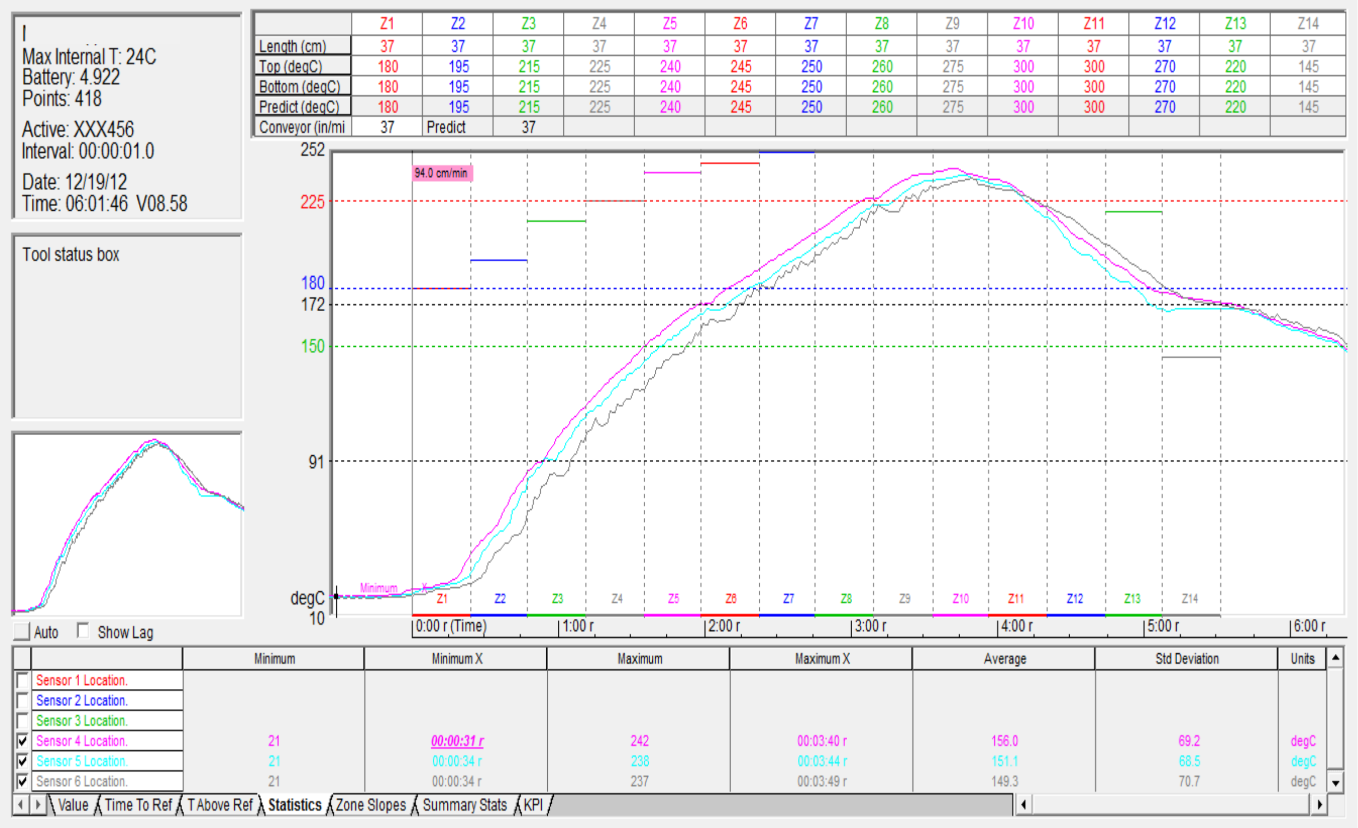
- 2 reflow profiles were used for the top-side:
  - 1 for SAC305 (“Type 4”) paste and Alloy A paste
  - 1 for SnPb (eutectic) paste



Top-side Lead-free Reflow Profile

Bottom-Side Reflow Profile

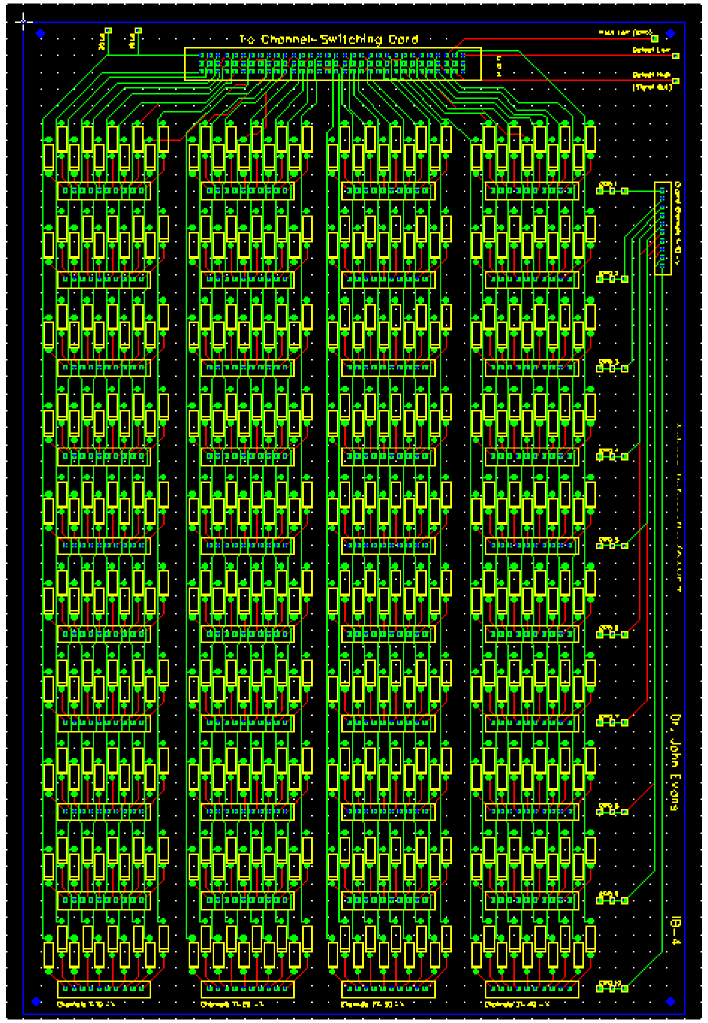
- 2 reflow profiles were used for the bottom-side:
  - 1 for SAC305 (“Type 4”) paste and Alloy A paste
  - 1 for SnPb (eutectic) paste



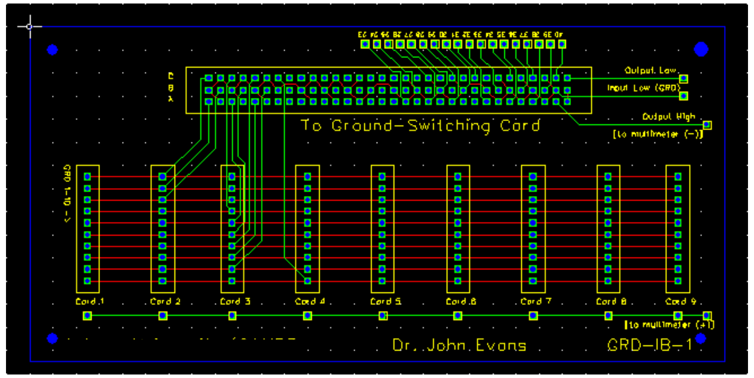
Bottom-side Lead-free Reflow Profile

New Testing Protocol Developed

Primary Interface Board Design



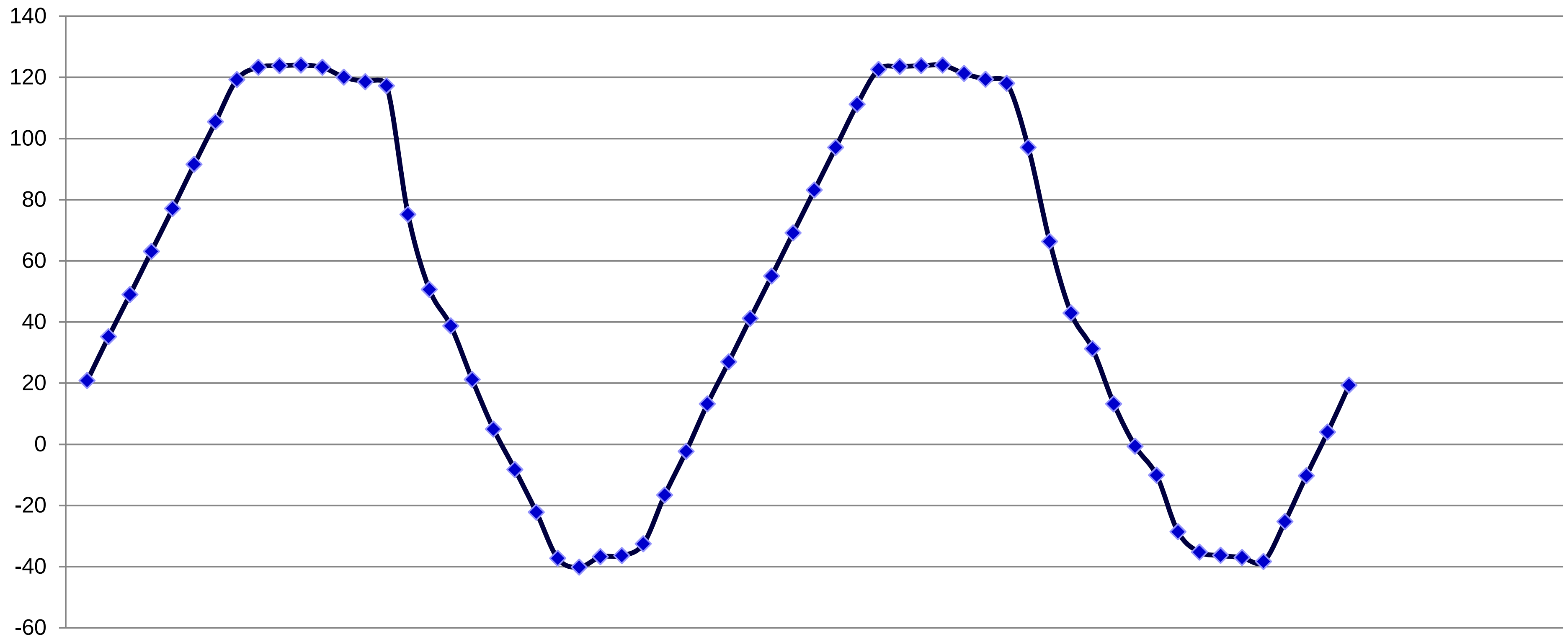
Supplementary Interface Board Design



- Updated Monitoring Setup
- Designed and Fabricated new interface boards for monitoring 3600 channels using one (1) Multiplexer, as opposed to the traditional 400 channel-setup previously employed.
- New Test Method approach tests each of the component once every 5 minutes.

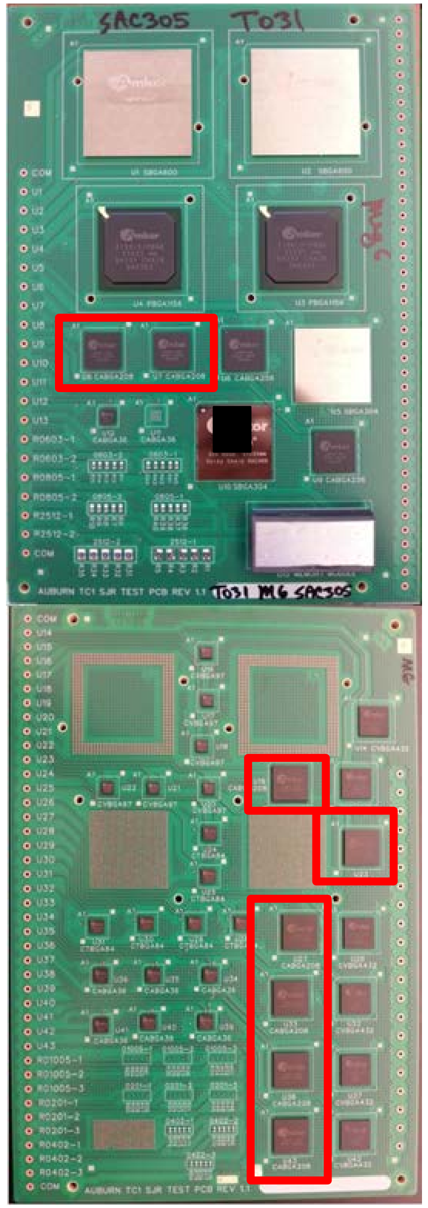
Temp. Profile for Thermal Chambers

- 45 min Ramps with 15 min dwells at +125 ° and -40 ° Celsius
- New Test method was developed, Measurement every 5 minutes
- Differs from Standard JEDEC-JESD22A104D Test Profile due to hardware limitations



CABGA 208

- **Note: The basic trends from the CABGA 208 hold true for all the available data from the small packages (5mm-17mm), so this data can be taken as a stand in for the small plastic BGA packages as a whole.**
- The CABGA 208 component is found on both the top and bottom side of the board and within all groups, allowing for multiple comparisons across various experimental parameters.
- No difference is seen in the pattern of failures when comparing components found on the Top-Side of the board and the Bottom-Side of the board, with the exception of the Alloy B (Bi doped) spheres.

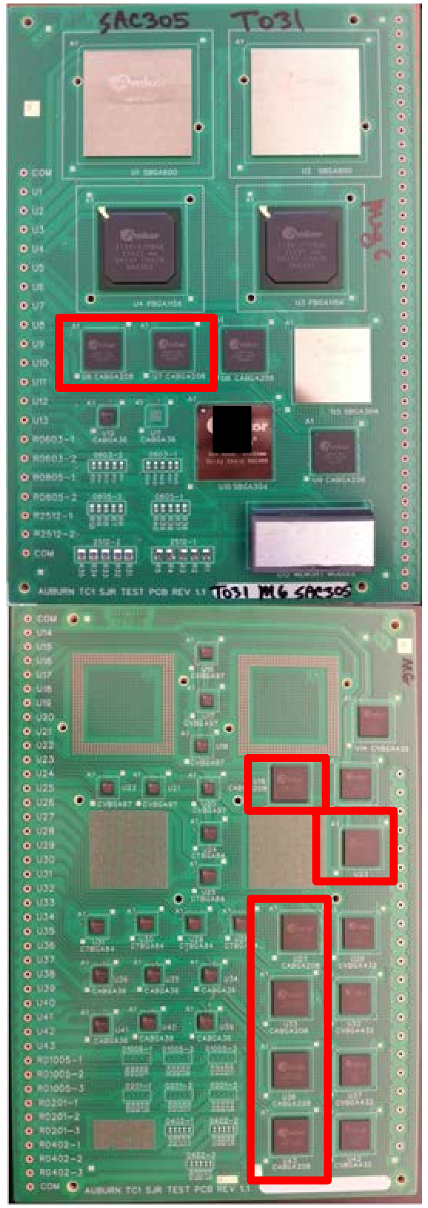


CABGA 208

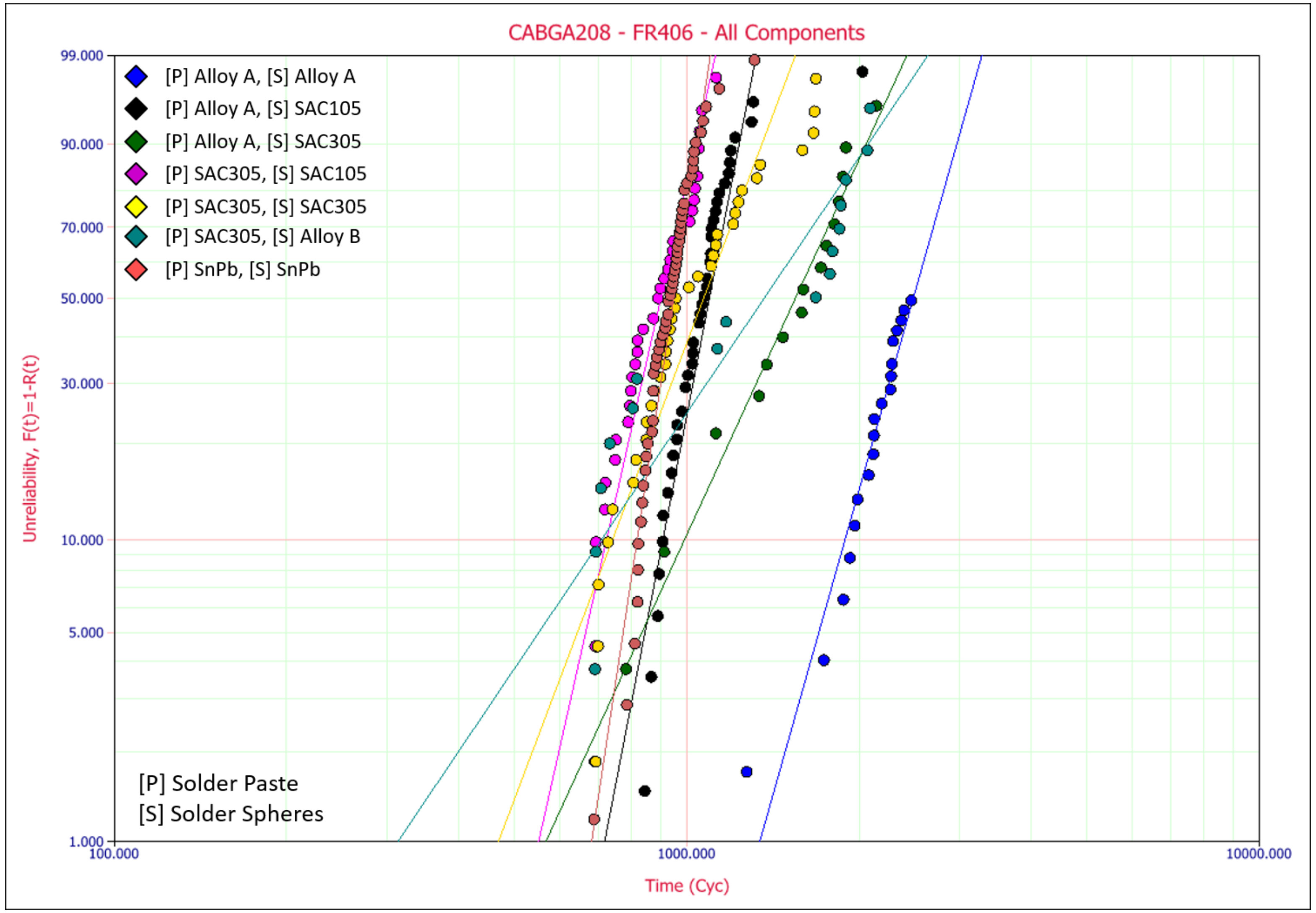
- The Characteristic Life values show the following pattern, listed from best to worst:
  1. Matched Alloy A*
  2. [S]SAC305 doped with [P] Alloy A
  3. Matched SAC305
  4. Matched SnPb

* Matched Alloy A data is available only for the CABGA 208 and CABGA 36 components

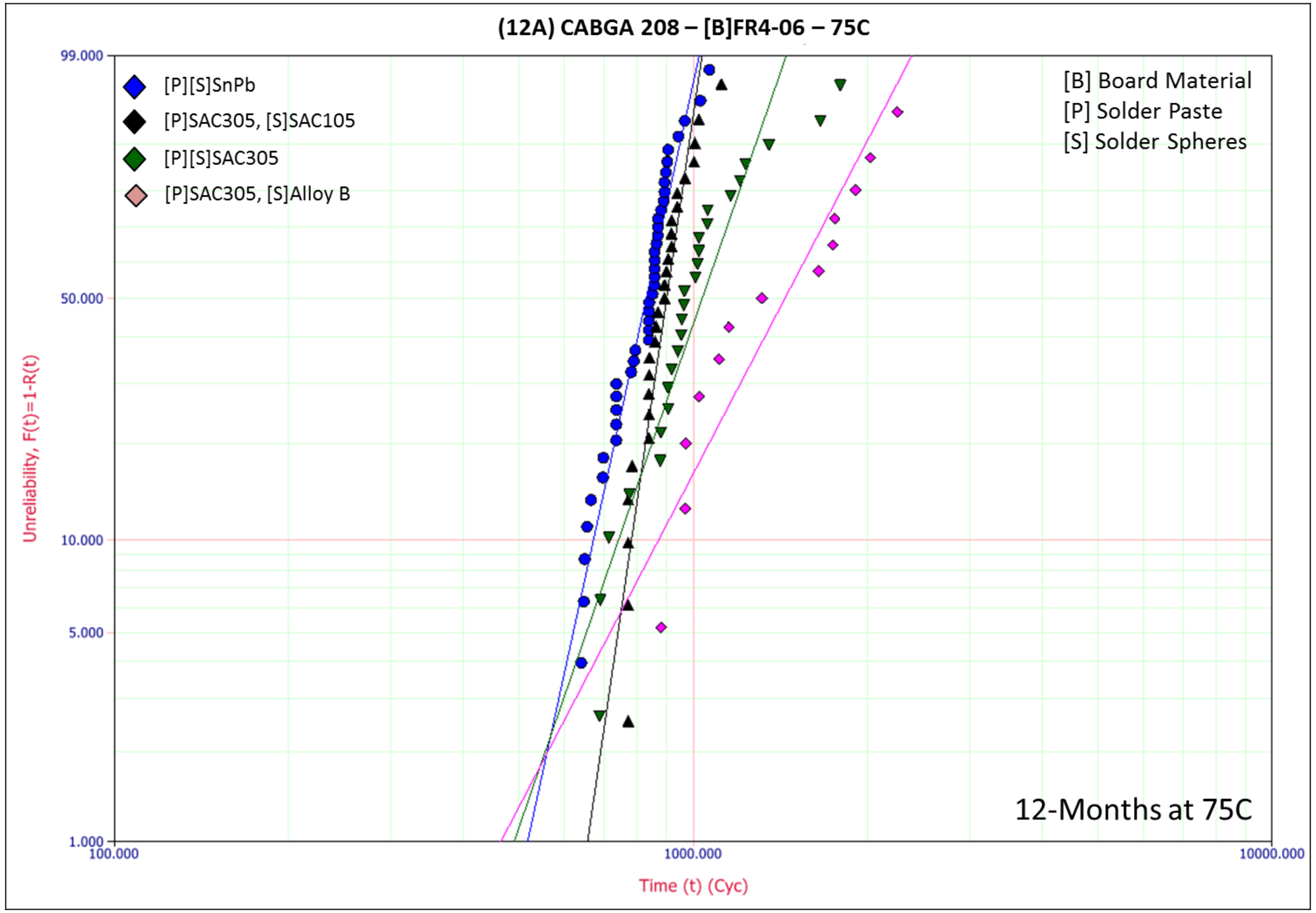
- Components balled with SAC305 spheres are more reliable than equivalent SAC105 balled components. This pattern holds for both SAC305 and Alloy A solder paste.
- Components assembled on FR4-06 substrates are more reliable than equivalent components assembled on PPO Blend substrates.



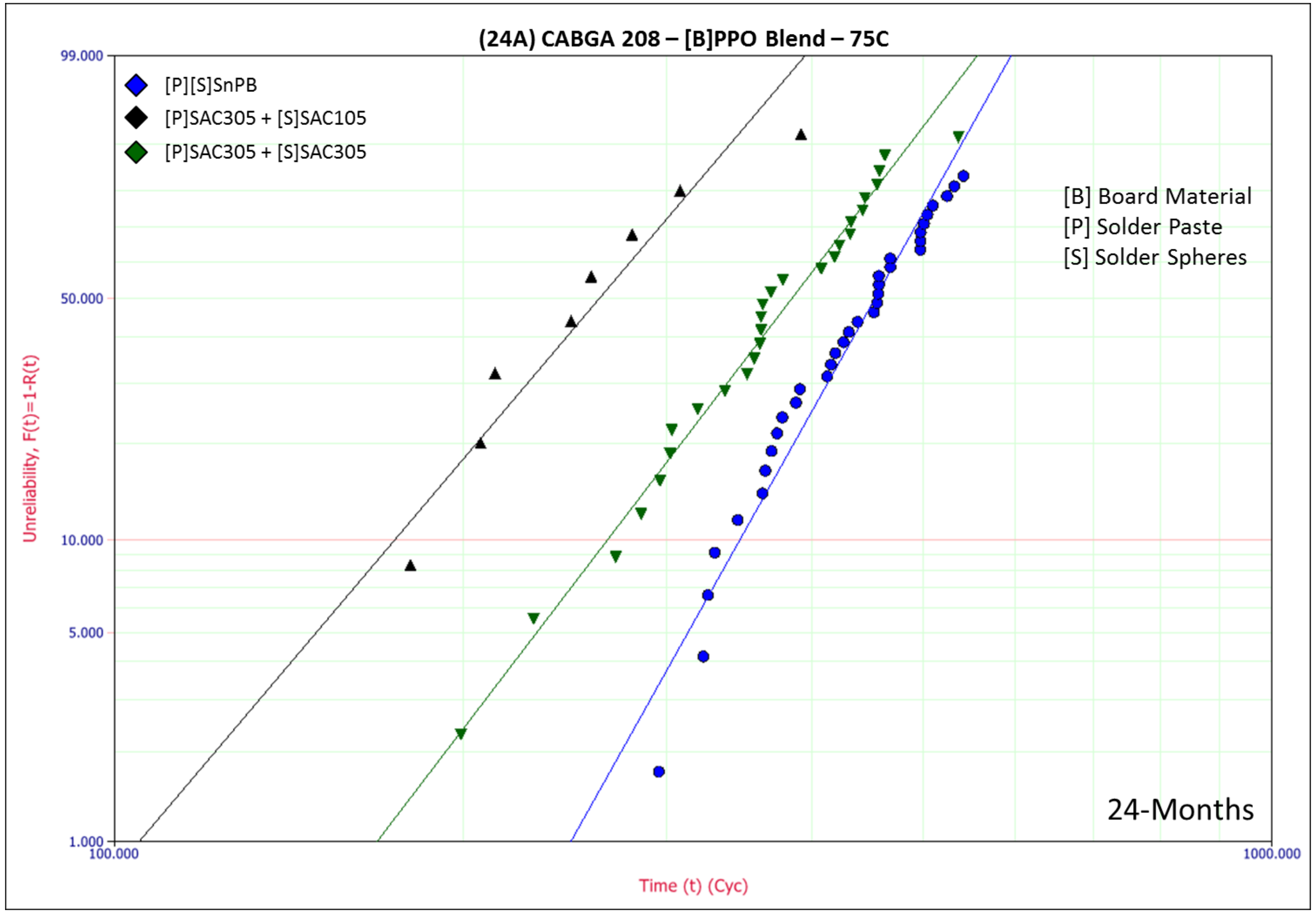
CABGA 208 – No Aging



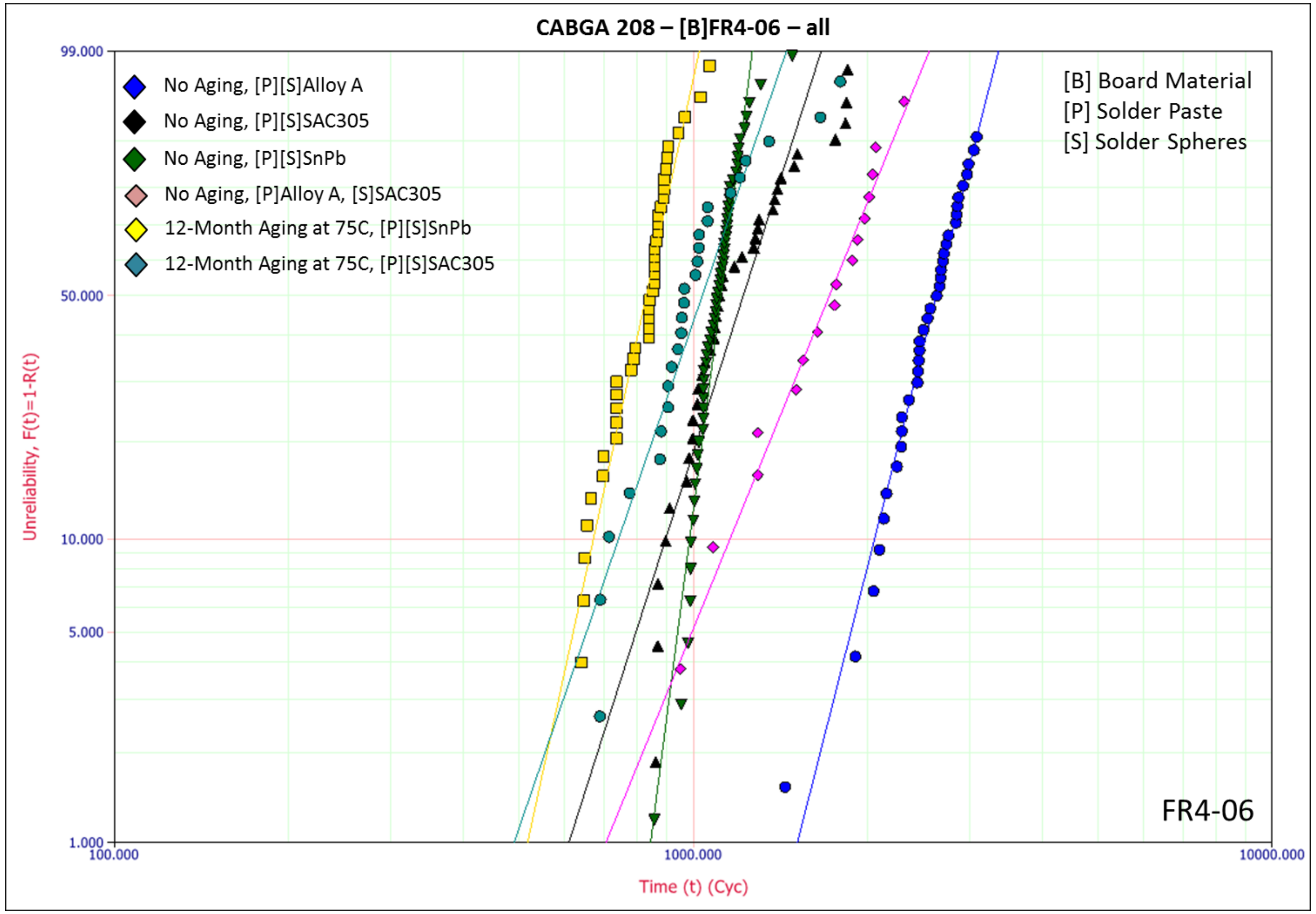
CABGA 208 – 12-Month Aging



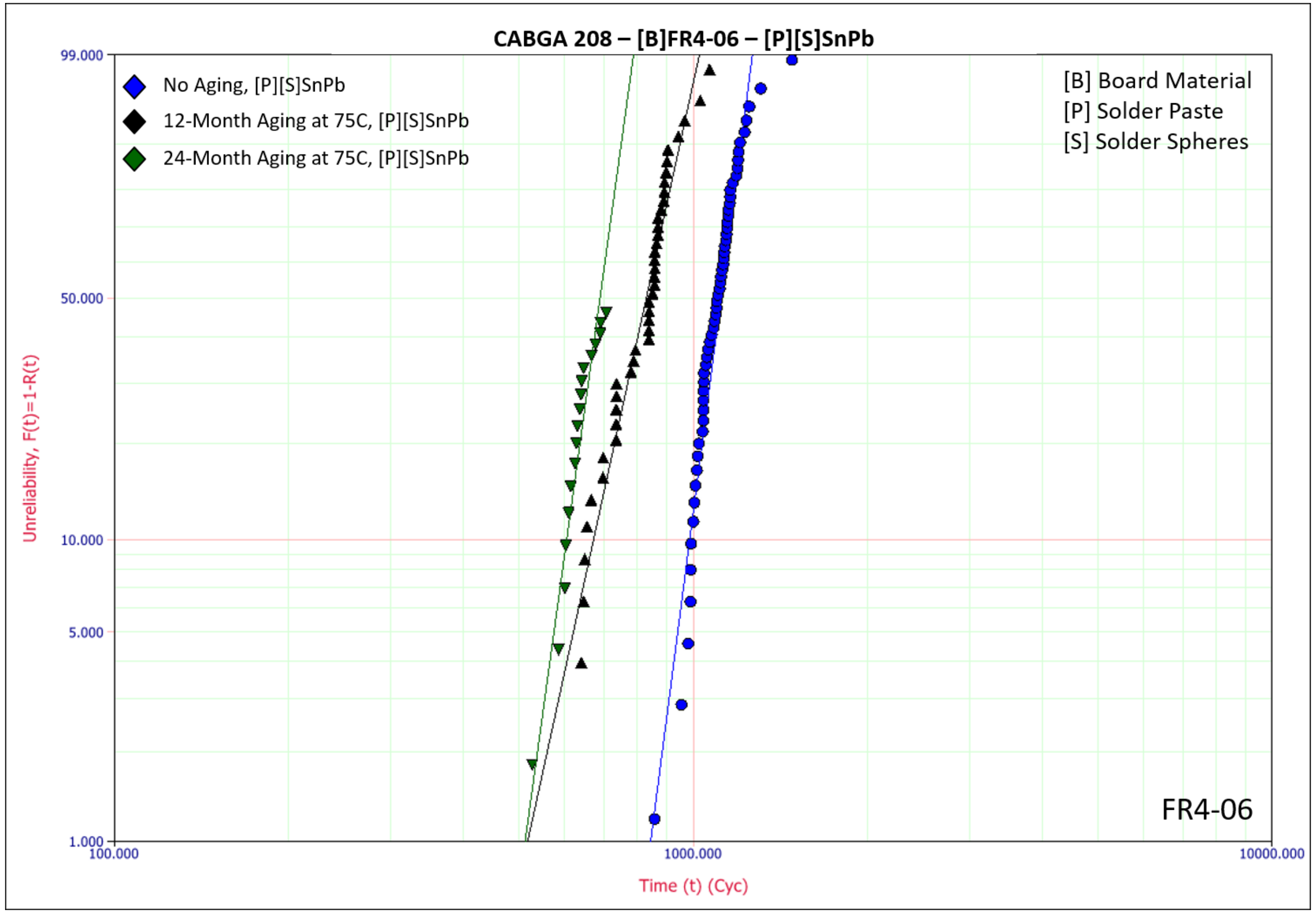
CABGA 208 – 24-Month Aging



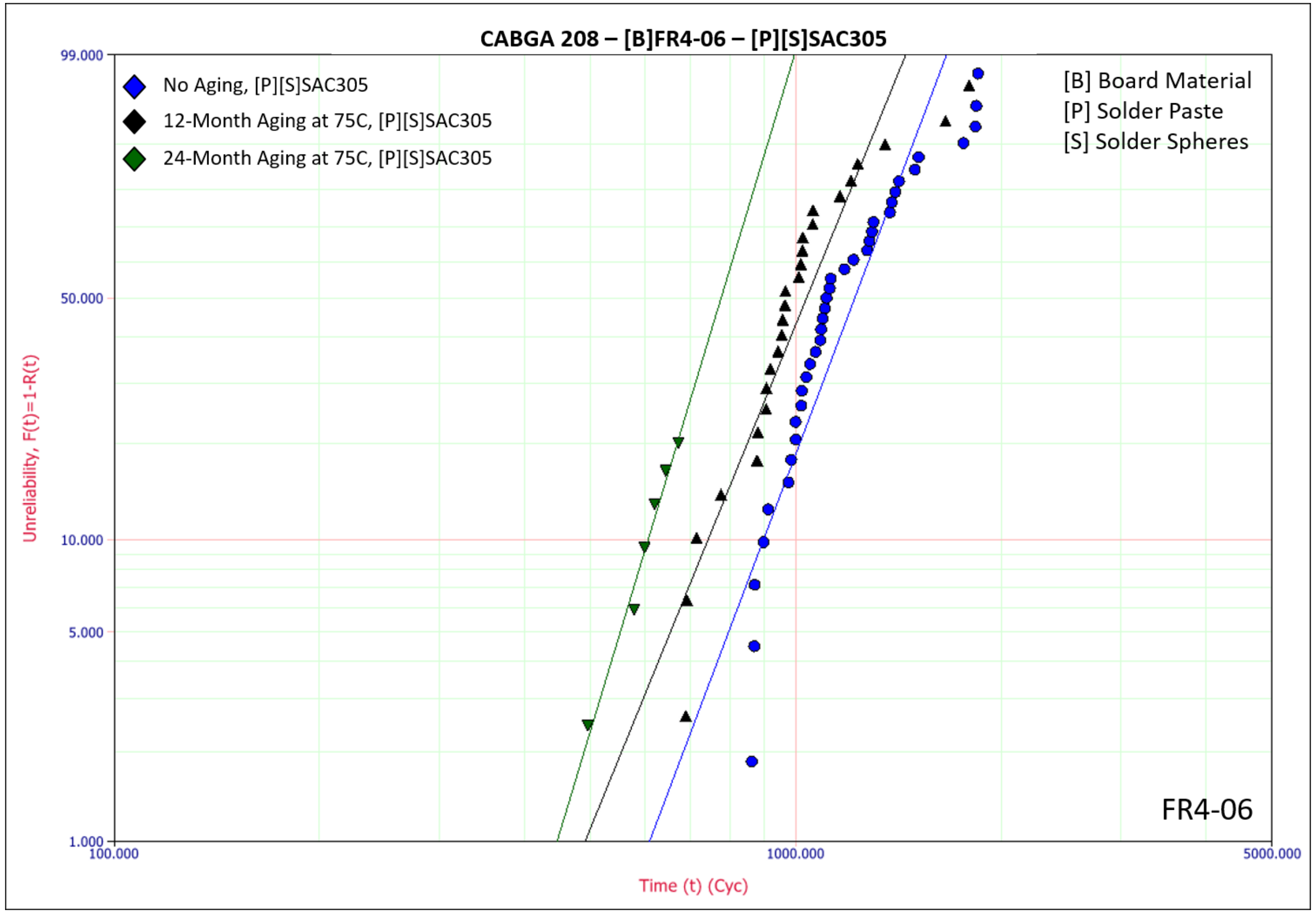
CABGA 208 – No Aging and 12-Month Aging



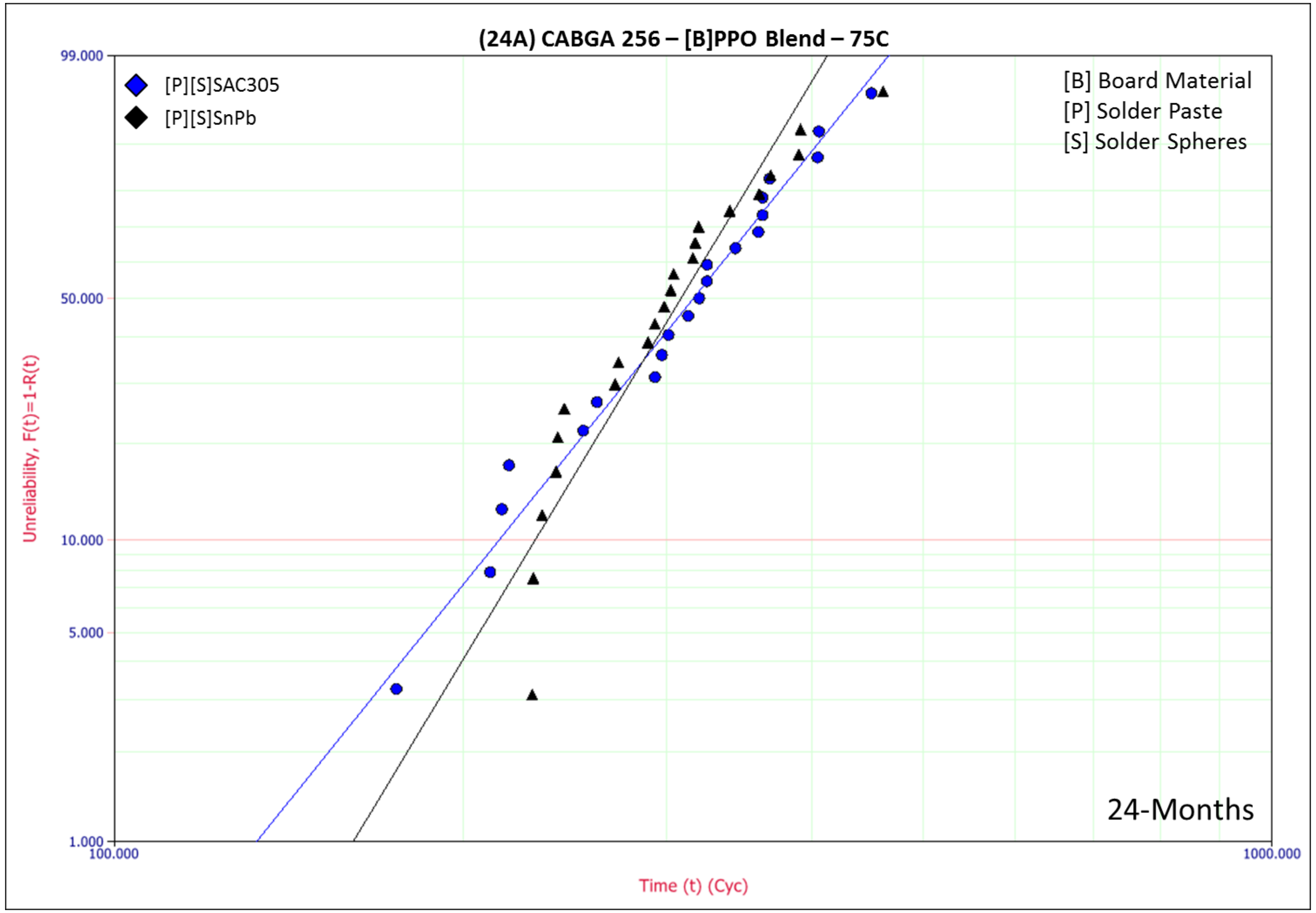
CABGA 208 – SnPb



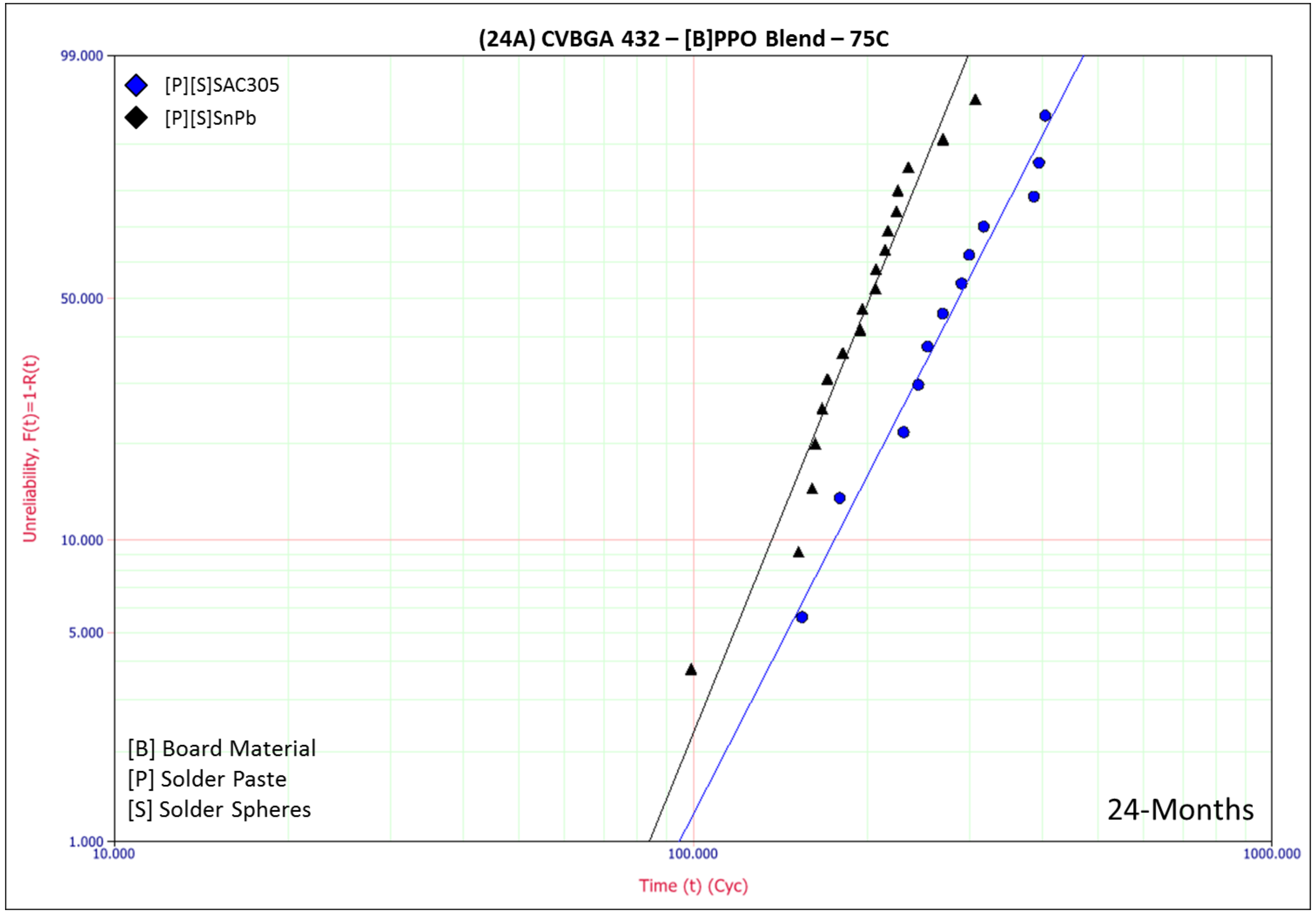
CABGA 208 – SAC305



CABGA 256 – 24-Month Aging

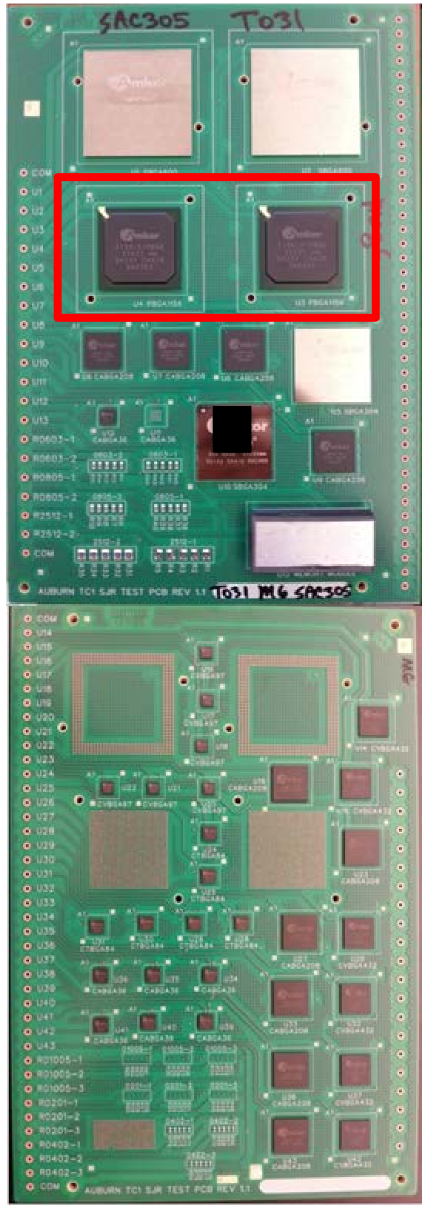


CVBGA 432 – 24-Month Aging



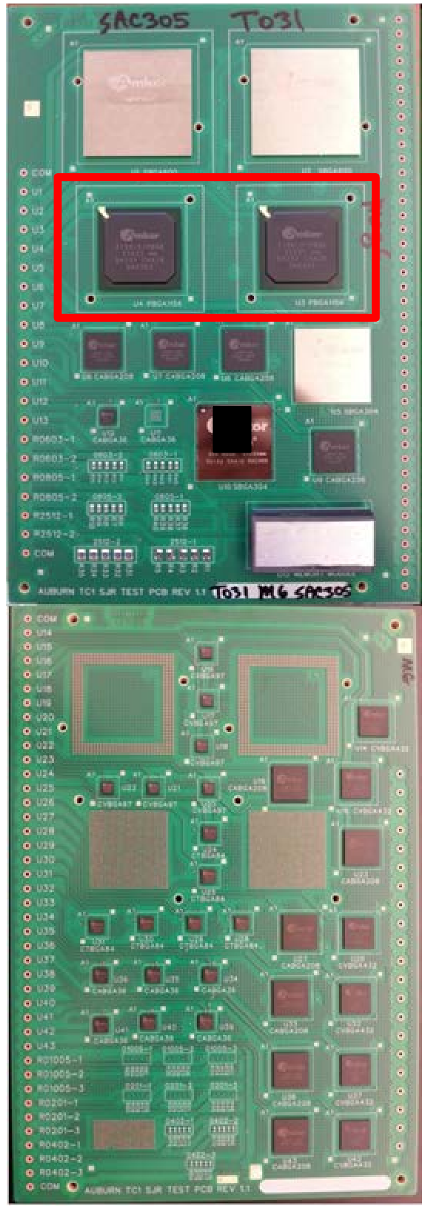
PBGA 1156

- The PBGA 1156 is a 35mm component found only on the top-side of the board, with 1.0mm pitch. With a solid 34x34 I/O array, it has by far the largest I/O count in this experiment.
- Many early failures are for packages with the heat-sinks attached, with failures occurring later for packages without heat-sinks.
- When looking at solder sphere composition, this component clearly exhibits the standard trend of SAC305 > SAC105 for thermal cycling reliability.

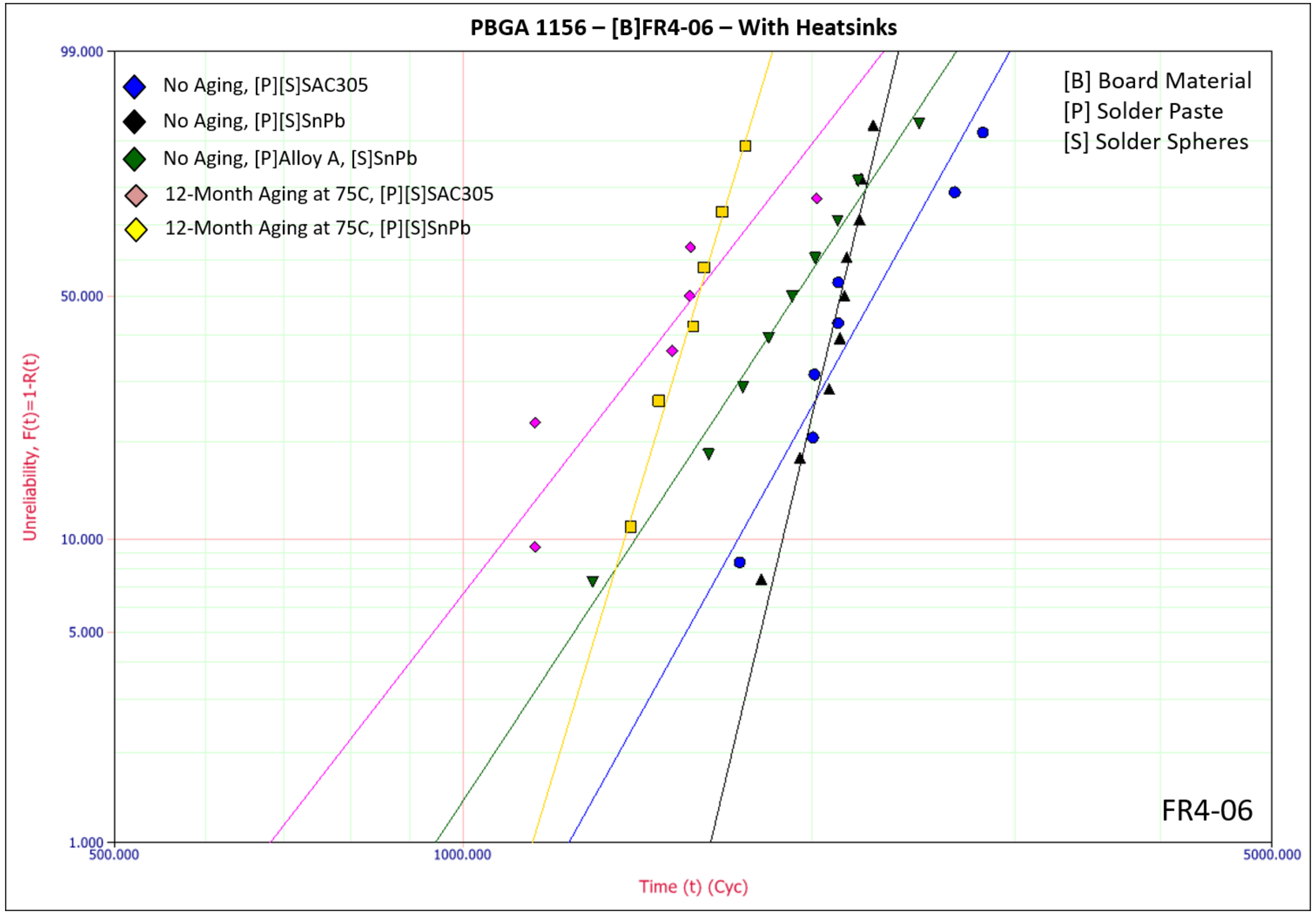


PBGA 1156

- However, in both the No Aging and 6-Month Aging data (i.e. all currently available data), this particular component does not appear to show an improvement with the use of Alloy A paste.
- The substrate effect remains the same as that observed for all plastic packages (for which comparison data is available), with the PPO Blend substrate performing worse than the FR4-06.

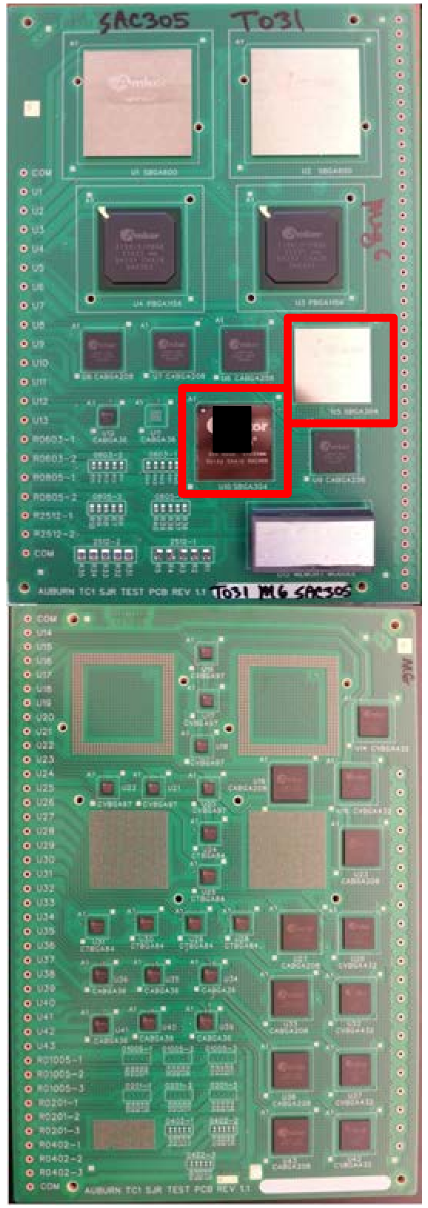


PBGA 1156 – No Aging and 12-Month Aging



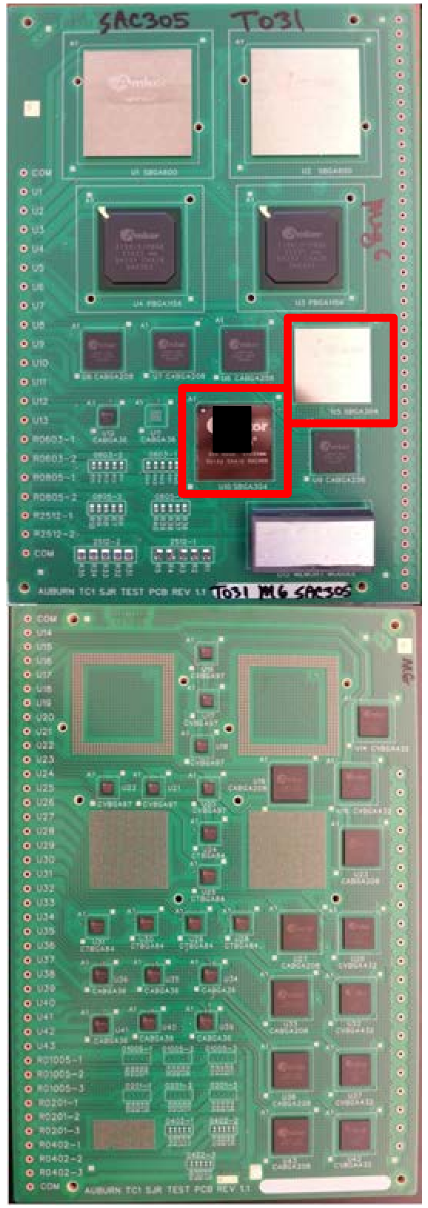
SBGA 304

- The SBGA 304 package is a large-pitch (1.27mm) component found only on the top-side of the board. This metal-capped package has a footprint of 31mm x 31mm.
- For this package, one interesting trend is particularly note-worthy: the reliability is higher on PPO Blend as compared with FR406. (Insufficient failure data is available to plot for PPO Blend substrates in No Aging Group.) This reverses the trend seen with the plastic packages (all of which have smaller pitch).

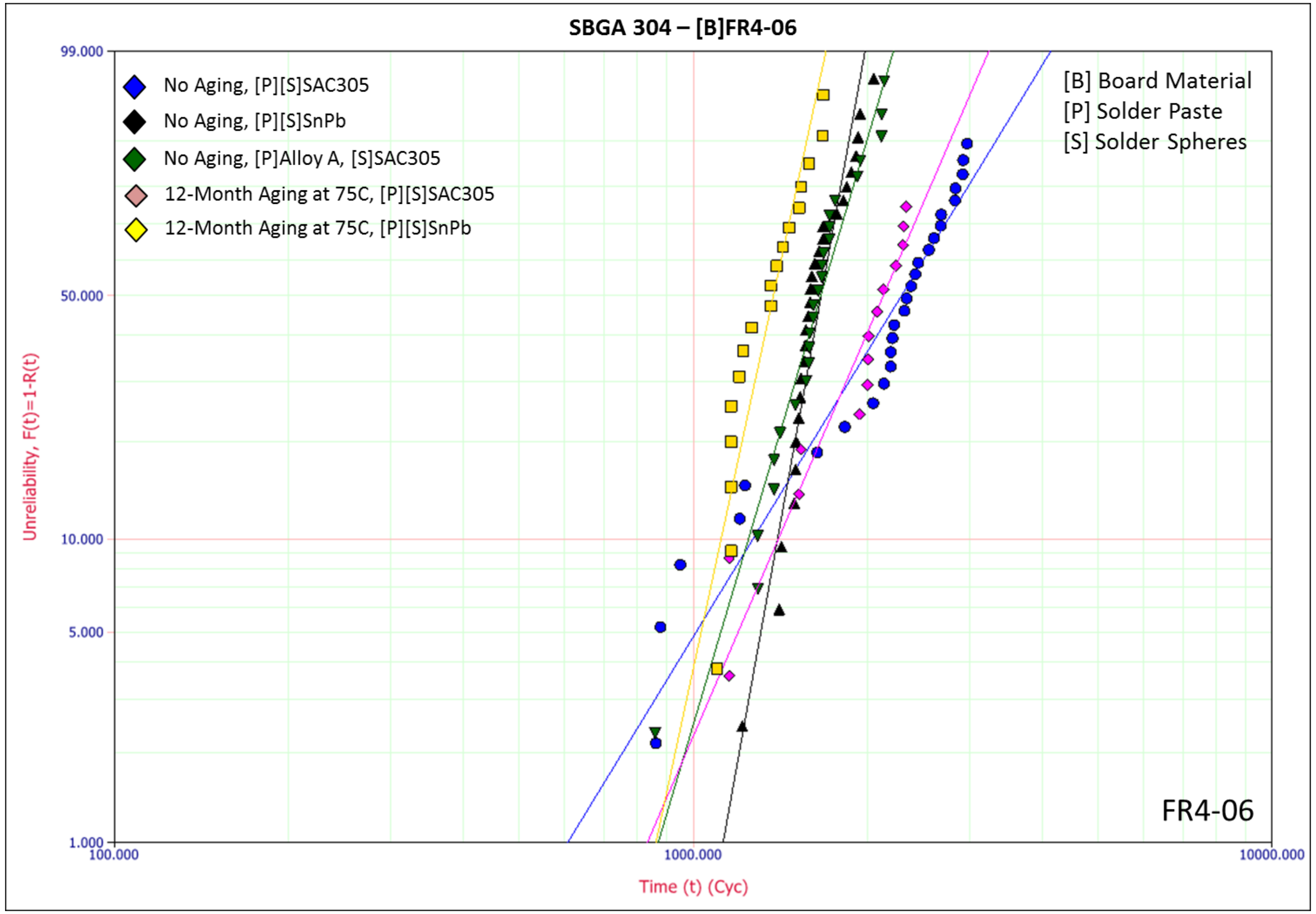


SBGA 304

- Additionally, Alloy A paste underperforms SAC305 paste with SAC305 packages, which contradicts the trend from the smaller packages.
- However, it should be noted that overall reliability of this package is higher in all cases than that of the smaller plastic BGAs, so overall system reliability should be judged on basis of improvements to the reliability of the smaller packages, which is observed with Alloy A Paste.



SBGA 304 – No Aging and 12-Month Aging



Conclusions

- For the small Plastic BGA packages, Characteristic Life values show the following pattern, listed from best to worst:
  1. Matched Alloy A*
  2. [S]SAC305 doped with [P] Alloy A
  3. Matched SAC305
  4. Matched SnPb

* Matched Alloy A data is available only for the CABGA 208 and CABGA 36 components

- Other packages do not show improved reliability with Alloy A paste.
- Components balled with SAC305 spheres are more reliable than equivalent SAC105 balled components.
- Components that show similar reliability trends with No Aging, may show differences in the relative degradation of SAC305 and SnPb during Isothermal Aging

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Thank You!

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Questions?