Network Centric Systems
Raytheon Company
McKinney, TX 75071

EER-2009-34171-004 **December 22, 2009**
Engineering Evaluation Report

NASA/DOD LEAD-FREE ELECTRONICS PROJECT: COMBINED ENVIRONMENTS TEST

by
Cynthia Garcia

Jeff Bradford

Bill Russell

CONTRACT: C40C-DO17-03

Approved for public release; distribution is unlimited.

Acknowledgements

The authors thank Bill Beair, Bill Vuono and Gary Eiland with McKinney Circuit Card Assembly for providing the Anatech event detectors and Mark Taylor, Larry Taylor and Bob Sparks with the Raytheon Environmental Test Laboratory for executing the test.

Abstract

Combined environments testing was conducted for the NASA/DoD Lead-Free Electronics project. The purpose of the project was to validate and demonstrate lead-free solders as potential replacements for conventional tin-lead solders used on circuit card assemblies against the requirements of the aerospace and military electronics community.

The solder alloys tested include: Sn3.0Ag0.5Cu, Sn0.7Cu0.05Ni (≤0.01Ge) and Sn37Pb. These solder alloys were used to assemble various components on two different printed wiring board test vehicles: manufactured and rework. The test vehicles were subjected to a combined environments test consisting of thermal cycling from −55 to +125 degrees Celsius at a ramp rate of 20 degrees Celsius per minute, dwell at the temperature extremes for 15 minutes and pseudorandom vibration of 10 g_{rms}. After every 50 cycles, the vibration level was increased by 5 g_{rms} until a maximum of 55 g_{rms} was reached. The test vehicles were electrically monitored for 650 cycles using event detectors.

The solder joint failure data of a given component type, component finish and solder alloy were evaluated using 2-parameter Weibull analysis. The reliability of the lead-free solder alloys was compared to the baseline tin-lead (Sn37Pb) solder alloy.

Contents

Abstract i
List of Figures iv
List of Tables ix
Foreword 1
Summary 1
Introduction 3
Methods, Assumptions and Procedures 4
Solder Alloys 4
Tin-Silver-Copper (Sn3.0Ag0.5Cu) 4
Tin-Copper (Sn0.7Cu0.05Ni (≤0.01Ge)) 4
Tin-Lead (Sn37Pb) 4
Flux 4
Test Vehicle 5
Manufactured Test Vehicle 6
Rework Test Vehicles 15
Thermal Aging, 100°C for 24 hours 29
Assembly Irregularities 30
Test Plan 31
Electrical Continuity Test 31
Combined Environments Test 31
HALT Chamber 31
Test Profile 31
Test Execution 32
Results and Discussion 33
Pretest Inspection 33
Manufactured Test Vehicles Results and Discussion 34
BGA-225 Results and Discussion 37
CLCC-20 Results and Discussion 43
CSP-100 Results and Discussion 48
TQFP-144 Results and Discussion 54
TSOP-50 Results and Discussion 58
Electroless Nickel Immersion Gold (ENIG) Manufactured Test Vehicle Results and Discussion 63
Rework Test Vehicle Results and Discussion 68
BGA-225 Results and Discussion 70
CLCC-20 Results and Discussion 77
CSP-100 Results and Discussion 79

PDIP-20 Results and Discussion 82
TQFP-144 Results and Discussion 83
TSOP-50 Results and Discussion 86
Electroless Nickel Immersion Gold (ENIG) Rework Test Vehicle Results and Discussion 92
Statistical Analysis 102
Comparing Statistical Analysis with 2005 JCAA/JG-PP Study 106
Conclusions 107
Recommendations 108
References 109
Appendixes 111
Appendix A: Manufactured Assembly Raw Test Data 112
Appendix B: Rework Assembly Raw Test Data 128
Appendix C: Pretest Inspection Logs 140
Appendix D: Environmental Test Laboratory Logs 194
Appendix E: Post Test Inspection Logs 206
Appendix F: Vibration Profiles 238
List of Symbols, Abbreviations and Acronyms 258

List of Figures

Figure 1 Manufactured and Rework Test Vehicle without Break-Off Coupon 6
Figure 2 Example Reflow Oven Profile (SnPb) 8
Figure 3 Example Wave Solder Profile (SnPb) 9
Figure 4 Example Reflow Oven Profile - Lead-Free (SAC305) 11
Figure 5 Example Wave Solder Profile - Lead-Free (SN100C) 12
Figure 6 Example Reflow Oven Profile – Lead-Free (SN100C) 14
Figure 7 Example Wave Solder Profile – Lead -Free (SN100C) 15
Figure 8 Thermocouple Map, Bottom Side of the Test Vehicle** 17
Figure 9 Example Reflow Oven Profile - Lead-Free (SAC305) 20
Figure 10 Example Wave Solder Profile - Lead-Free (SN100C) 21
Figure 11 Rework Order = Batch A 23
Figure 12 Example Lead-Free Rework Profile for area array components, removal and replacement 24
Figure 13 Example Reflow Oven Profile – Lead-Free (SAC305), being used for SnPb Rework Assemblies 26
Figure 14 Example Wave Solder Profile – Lead-Free (SN100C), being used for SnPb Rework Assemblies 27
Figure 15 Rework Order = Batch B 28
Figure 16 Example SnPb Rework Profile for area array components, removal and replacement 29
Figure 17 Shows the location of the traces that are missing for the CSP component. 30
Figure 18 Missing trace of QFN-20, component U15 30

Figure 19 QualMark Model OVS-4 HALT/HASS Chamber 32
Figure 20 Initial Combined Environments Test Profile 32
Figure 21 Photograph of Test Vehicles in Test Chamber 33
Figure 22 Manufactured and Rework Test Chamber Set-up 33
Figure 23 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 37
Figure 24 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles 38
Figure 25 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Manufactured Test Vehicles 38
Figure 26 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 39
Figure 27 Weibull Plot of Tin-Lead BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles 40
Figure 28 Weibull Plot of Tin-Lead BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles less one outlier 40
Figure 29 Weibull Plot of Tin-Lead BGA-225 with Tin-Lead Solder Paste on Manufactured Test Vehicles 41
Figure 30 Weibull Plots of BGA-225 on Manufactured Test Vehicles 42
Figure 31 Effect of Tin-Lead Contamination on Tin-Copper Soldered BGA-225 on Manufactured Test Vehicles 42
Figure 32 Effect of Tin-Lead Contamination on Tin-Silver-Copper 305 Soldered BGA-225 on Manufactured Test Vehicles 43
Figure 33 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 44
Figure 34 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Copper Solder Paste on Manufactured Test Vehicles 45
Figure 35 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Manufactured Test Vehicles 45
Figure 36 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 46
Figure 37 Weibull Plot of Tin-Lead CLCC-20 with Tin-Copper Solder Paste on Manufactured Test Vehicles 46
Figure 38 Weibull Plot of Tin-Lead CLCC-20 with Tin-Lead Solder Paste on Manufactured Test Vehicles 47
Figure 39 Weibull Plots of CLCC-20 on Manufactured Test Vehicles 48
Figure 40 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Silver-Copper 305 49
Figure 41 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Copper Solder Paste on Manufactured Test Vehicles 49
Figure 42 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Manufactured Test Vehicles 50
Figure 43 Weibull Plot of Tin-Lead CSP-100 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 51
Figure 44 Weibull Plot of Tin-Lead CSP-100 with Tin-Copper Solder Paste on Manufactured Test Vehicles 51
Figure 45 Weibull Plot of Tin-Lead CSP-100 with Tin-Lead Solder Paste on Manufactured Test Vehicles 52
Figure 46 Weibull Plots of CSP-110 on Manufactured Test Vehicles 53

Figure 47 Weibull Plot of Tin PDIP-20 with Tin-Copper Solder on Manufactured Test Vehicles 54
Figure 48 Percentage of Manufactured PDIP Failures by Wave Solder 54
Figure 49 Weibull Plot of Matte Tin TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 55
Figure 50 Weibull Plot of Matte Tin TQFP-144 with Tin-Copper Solder Paste on Manufactured Test Vehicles 55
Figure 51 Weibull Plot of Matte Tin TQFP-144 with Tin-Lead Solder Paste on Manufactured Test Vehicles 56
Figure 52 Weibull Plot of Tin-Lead Dipped TQFP-144 with Tin-Copper Solder Paste on Manufactured Test Vehicles 57
Figure 53 Weibull Plots of Tin TQFP-144 on Manufactured Test Vehicles 58
Figure 54 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 59
Figure 55 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Copper Solder Paste on Manufactured Test Vehicles 59
Figure 56 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Lead Solder Paste on Manufactured Test Vehicles 60
Figure 57 Weibull Plot of Tin-Lead TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles 61
Figure 58 Weibull Plot of Tin-Lead TSOP-50 with Tin-Copper Solder Paste on Manufactured Test Vehicles 61
Figure 59 Weibull Plot of Tin-Lead TSOP-50 with Tin-Lead Solder Paste on Manufactured Test Vehicles 62
Figure 60 Weibull Plots of TSOP-50 on Manufactured Test Vehicles 63
Figure 61 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle 64
Figure 62 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste 64
Figure 63 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle 65
Figure 64 Comparison of ENIG and Immersion Silver Board Finish for Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper Solder Paste 66
Figure 65 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle 66
Figure 66 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste 67
Figure 67 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Flux Only on Rework Test Vehicles 71
Figure 68 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Flux Only on Rework Test Vehicles less outliers 72
Figure 69 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Batch A Rework Test Vehicles 72
Figure 70 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Batch A Rework Test Vehicles less outlier 73
Figure 71 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Rework Test Vehicles 74

Figure 72 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 74
Figure 73 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Batch B Rework Test Vehicles 75
Figure 74 Weibull Plot of Reworked Tin-Lead BGA-225 with Flux Only on Rework Test Vehicles 75
Figure 75 Weibull Plots of BGA-225 on Rework Test Vehicle 76
Figure 76 Weibull Plots of Reworked BGA-225 on Rework Test Vehicle 77
Figure 77 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Rework Test Vehicles 78
Figure 78 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 78
Figure 79 Weibull Plots of CLCC-20 on Rework Test Vehicles 79
Figure 80 Weibull Plot of Reworked Tin-Silver-Copper 105 CSP-100 with Flux Only on Rework Test Vehicles 80
Figure 81 Weibull Plot of Reworked Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Batch A Rework Test Vehicles 80
Figure 82 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 81
Figure 83 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Rework Test Vehicles 81
Figure 84 Weibull Plot of CSP-100 on Rework Test Vehicles 82
Figure 85 Weibull Plot of Reworked Tin PDIP-20 with Tin-Lead Solder on Rework Test Vehicles 83
Figure 86 Weibull Plot of Tin-Silver-Copper 305 TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 84
Figure 87 Weibull Plot of Tin-Silver-Copper 305 TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles less outliers 84
Figure 88 Weibull Plot of Tin-Lead Dipped TQFP-144 with Tin-Lead Solder Paste on Rework Test Vehicles 85
Figure 89 Weibull Plots of TQFP-144 on Rework Test Vehicles 85
Figure 90 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch A Rework Test Vehicles 86
Figure 91 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch A Rework Test Vehicles less outlier 87
Figure 92 Weibull Plot of Tin TSOP-50 with Tin-Lead Solder Paste on Rework Test Vehicles 87
Figure 93 Weibull Plot of Reworked Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Wire on Rework Test Vehicles 88
Figure 94 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 89
Figure 95 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Lead Solder Paste on Rework Test Vehicles 89
Figure 96 Weibull Plot of Tin-Lead TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles 90
Figure 97 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch B Rework Test Vehicles 90

Figure 98 Weibull Plot of Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles 91

Figure 99 Weibull Plots of TSOP-50 on Rework Test Vehicles 91

Figure 100 Weibull Plots of Reworked TSOP-50 on Rework Test Vehicles 92

Figure 101 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle 93

Figure 102 Comparison of ENIG and Immersion Silver Board Finish on Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Rework Test Vehicles 93

Figure 103 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle less outlier 94

Figure 104 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Rework Test Vehicles 95

Figure 105 Weibull Plot of Tin-Silver-Copper CLCC-20 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle 95

Figure 106 Comparison of ENIG and Immersion Silver Board Finish for Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Rework Test Vehicles 96

Figure 107 Weibull Plot of Tin-Lead Solder Dipped TQFP-144 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle 97

Figure 108 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead Solder Dipped TQFP-144 with Tin-Lead Solder Paste on Rework Test Vehicles 97

Figure 109 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Electroless Nickel Immersion Gold Rework Test Vehicle 98

Figure 110 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles 99

Figure 111 Weibull Plot of Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Electroless Nickel Immersion Gold Rework Test Vehicle 99

Figure 112 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles 100

Figure 113 Chart of Variance Component Analysis of All Data 102

Figure 114 Chart of Variance Component Analysis of Manufactured Data 103

Figure 115 Relative Reliability of Components for Tin-Lead Solder on Manufactured Test Vehicles less ENIG 104

Figure 116 Relative Reliability of Components for Tin-Silver-Copper 305 Solder on Manufactured Test Vehicles less ENIG 104

Figure 117 Relative Reliability of Components for Tin-Copper Solder on Manufactured Test Vehicles less ENIG 105

Figure 118 Interaction and 95-Percent Confidence Intervals for BGA-225 Components - All Data 105

Figure 119 Interaction and 95-Percent Confidence Intervals for Mfg BGA-225 Components excluding ENIG 106

Figure 120 Comparison Chart of Variance Components Analysis of both the 2005 JCAA/JG-PP Lead-Free Solder Project and the 2009 NASA-DoD Lead-Free Solder Electronics Project Manufactured Data 107

List of Tables

Table 1 Project Stakeholders 3
Table 2 Solder Alloys 4
Table 3 Solder Alloys and Associated Flux 5
Table 4 Component Finish Matrix – SnPb Manufactured Test Vehicles (Batch C) 6
Table 5 Component Finish Matrix – Lead-Free Manufactured Test Vehicles (Batch E) 9
Table 6 PDIP Component Finishes – Lead-Free Manufactured Test Vehicles (Batch E) 10
Table 7 Component Finish Matrix – Lead-Free Manufactured Test Vehicles (Batch G) 12
Table 8 PDIP Component Finishes – Lead-Free Manufactured Test Vehicles (Batch G) 13
Table 9 Component Finish Matrix – Lead-Free Rework Test Vehicles (Batch A) 18
Table 10 Component Finish Matrix – Lead-Free Rework (Batch A) 22
Table 11 Component Finish Matrix – SnPb Rework Test Vehicles (Batch B) 24
Table 12 Component Finish Matrix – SnPb Rework (Batch B) 27
Table 13 Number of Failed Components by Manufactured Test Vehicle 35
Table 14 Number of Failed Components by Board Finish, Component, Component Finish and Solder Alloy on Manufactured Test Vehicles 36
Table 15 Number of Failed Components by Solder Alloy on Manufactured Test Vehicles excluding ENIG 37
Table 16 Summary of Manufactured Test Vehicle Test Results 68
Table 17 Number of Failed Components by Rework Test Vehicle 69
Table 18 Number of Failed Components by Board Finish, Component, Component Finish, Solder Alloy, New Component Finish and Rework Solder on Rework Test Vehicles 70
Table 19 Summary of Rework Test Vehicle Test Results 101
Table 20 Variance Component Analysis of All Data 102
Table 21 Variance Component Analysis of Manufactured Data 103
Table 22 Comparison of Manufactured Test Vehicle Test Results to 2005 JCAA/JG-PP Lead-Free Solder Project Results 107
Table 23 Manufactured Assembly Raw Data 112
Table 24 Rework Assembly Raw Data 128

Foreword

Environmental regulatory actions and free market forces are threatening the use of tin-lead solders in defense electronics manufacturing. There's growing concern that the use of lead in aerospace and military electronics may be banned in the future. The pressure to reduce or remove lead from manufacturing is on the rise where environmentalists and regulators are focusing their attention on eliminating lead from all electronics. Though we operate with an exemption, aerospace and military electronics may be impacted by the consumer electronics manufacturer's move to lead-free products. This will make it difficult for aerospace and military programs to procure electronic components fabricated with tin-lead solder. While work has been done to determine lead-free solder reliability for commercial electronic products, there is little data published on the reliability of lead-free solders on high reliability, high performance military electronic products. In November 2006, the NASA-DoD Lead-Free Electronics Project was launched to build on the results from the 2005 JCAA/JG-PP Lead-Free Solder Project. The new project focused on the rework of tin-lead and lead-free solder alloys and included the mixing of tin-lead and lead-free solder alloys. The majority of testing mirrored the testing completed for the JCAA/JGPP Lead-Free Solder Project. The project was managed by Kurt Kessel from the NASA Technology Evaluation for Environmental Risk Mitigation (TEERM) Principle Center.

The combined environments test was one of several tests selected by the consortium to determine lead-free solder joint reliability under combined thermal cycle and vibration environmental exposures. The test was conducted from February 12, 2009 through June 14, 2009 using a QualMark Model OVS-4 HALT/HASS chamber located in the Raytheon Environmental Test Laboratory (ETL) in McKinney, Texas. The combined environments test was performed using a temperature range between -55 to 125 degrees Celsius with a 20 degree Celsius per minute temperature ramp. The dwell time at each temperature extreme was approximately fifteen minutes. A ten g_{rms} pseudorandom vibration was applied to the test vehicles during testing. After fifty cycles were completed the pseudorandom vibration was increased by five g_{rms} until the maximum level of 55 g_{rms} was reached or 50 – 63% of components had failed. ETL personnel can run 15 test vehicles in the chamber at a time. A total of 27 test vehicles were tested in two runs, where the first run had 15 and the second run had 12 test vehicles in the chamber.

The test vehicles were circuit card assemblies designed and fabricated per IPC-6012, Class 3 to evaluate solder joint reliability. The solder joints of each component were part of a continuous electrical pathway that was monitored during testing by an event detector. The test vehicles were assembled per IPC J-STD-001, Class 3 requirements by BAE Systems. Two variations of test vehicles were tested: manufactured and rework. The purpose of the manufactured test vehicle was to simulate the construction of current military circuit card assembly technology. The purpose of the rework test vehicles was to test different combinations of lead-free solder with tin-lead solder. The mixing of solders would help identify the best solder alloy combination for rework. The lead-free solder alloys tested were Sn3.0Ag0.5Cu, Sn0.7Cu0.05Ni (≤0.01Ge) and the baseline, eutectic Sn37Pb. Tin-silver-copper solder alloys are currently the leading choice of the electronics industry for lead-free solder. Tin-copper solder alloys are commonly used in wave solder applications in the consumer electronics industry. Board finish was also a factor in this testing. Most of the test vehicles were fabricated with an immersion silver finish, but two test vehicles had an electroless nickel/immersion gold (ENIG) board finish.

Summary

The manufactured and rework test vehicles were inspected per J-STD-001, Class 3 requirements. The inspector documented observations before and after combined environments testing. The manufactured and rework test vehicles were subjected to 650 cycles of thermal and vibration testing.

The failure data was analyzed by component type, component finish and solder alloy using 2-parameter Weibull analysis with ReliaSoft Weibull++7 software. Overall, the component type had the greatest effect on solder joint reliability performance. The plated-through-hole components proved to be more reliable than the surface mount technology components. The plated-through-holes (PTH), PDIP-20, TQFP-144 and QFN-20 components performed the best. The BGA-225 components performed the worst.

Solder alloy had a secondary effect on solder joint reliability. In general, tin-lead finished components soldered with tin-lead solder paste were the most reliable with the exception of some components with lead contamination in the solder joints. In general, tin-silver-copper soldered components were less reliable than the tin-lead solder controls. The lower reliability of the tin-silver-copper solder joints does not necessarily rule out the use of tin-silver copper solder alloy on military electronics based on these results. In several cases, tin-silver-copper solder performed statistically as good as or equal to the baseline, eutectic tin-lead solder.

Tin-lead contamination on BGA-225 components degrades early life performance of tin-copper solder paste, but it also degrades the early life performance of tin-silver-copper solder paste. The effect of tin-lead contamination on BGA-225 components soldered with tin-silver-copper solder paste was less than the effect of tin-lead contamination on tin-copper solder.

In general, when comparing the results within the batch of reworked test vehicles, the reworked components were found to be less reliable than components that did not get solder joint rework. The least reliable were reworked lead-free CSP-100 and reworked lead-free BGA-225 components, these did not survive beyond 200 cycles.

When comparing the performance of components soldered onto the two different test vehicle board finishes, immersion silver and electroless nickel immersion gold (ENIG); the immersion silver finish of the manufactured test vehicles had better reliability of solder joints than components soldered onto and ENIG surface finish.

Based on the results, lead content must be understood and controlled if the reliability of tin-silver-copper solder will be utilized on military electronics. Further investigation in terms of destructive physical analysis and microsection analysis are recommended for reworked components, especially, the lead-free solder reworked components on test vehicle serial numbers 180 and 181, due to the number of early life failures on each.

Since this test only evaluated solder joint reliability, additional tests must be done to validate assembly reliability with respect to the effect of higher reflow temperatures on printed circuit boards and functional integrated circuits. Additional testing on some functional military electronics is also recommended.

Introduction

Environmental concerns and increased regulations of lead usage in conventional tin-lead solder are threatening the aerospace and military electronics manufacturing industry. The regulations began by banning lead additives in gasoline and paint products. The pressure to reduce or remove lead from manufacturing is growing where environmentalists and regulators are focusing their attention on eliminating lead from electronics all together.

The European, Asian, United States environmental regulatory actions and free market forces threaten the use of tin-lead solders in defense electronics manufacturing. The European Union has adopted legislation governing the re-use and recycling of electronics waste, known as the Waste from Electrical and Electronic Equipment (WEEE) Directive. In addition, Europe has started implementing the Restriction of Hazardous Substances (RoHS) that bans the use of lead and other substances beginning 1 July 2006. Proactively, Japan is eliminating lead from consumer electronics with many major Japanese electronics companies announcing the move to lead-free electronics. The U.S. Environmental Protection Agency (EPA) has cited lead and lead compounds as one of the top seventeen chemicals imposing the greatest threat to human health. In implementing Executive Order 12856, the EPA has reduced the reporting threshold of lead and lead compounds to 100 pounds per year; therefore, increasing reporting by 13% at an estimated average report cost of $23,700 per using facility. This reporting requirement has imposed an estimated added administrative burden of $95 million to the electronics industry per year. Future U.S. regulatory action may ban all solders containing lead.

Although, currently exempt from the European legislation, there is a growing concern that legislation may ban the use of lead in aerospace and military electronics. Even with the exemption, aerospace and military electronics will be impacted by the consumer electronics manufacturer's move to lead-free products. As more commercial electronics manufactures move to lead-free technology, aerospace and military programs will find it difficult to procure electronic components fabricated with tin-lead solder. The commercial electronics sector is driving component and board suppliers to provide primarily lead-free surface finishes and alloys. Electronic component manufactures are switching to lead-free finishes. Lead-free components are finding their way into aerospace and military electronics under government acquisition reform initiatives. It is possible that parts with lead-containing finishes may become impossible to procure or the acquisition cost for military grade lead-containing components will become prohibitive. The price of tin-lead solder may rise or the supplies of tin-lead solder may diminish due to low market demand. The aerospace and military community may have little leverage once the lead-free movement gains momentum.

While work has been done to determine lead-free reliability for commercial, general and dedicated service electronic products, there has been little comprehensive data published on the reliability of lead-free solders on high reliability, high performance electronic products. A project was initiated by the Department of Defense (DoD) and a consortium was formed to evaluate lead-free solders and to determine whether they are suitable for use in high reliability electronics. The consortium consists of a partnership between the DoD, National Aeronautics and Space Administration (NASA), and several defense electronics contractors to conduct solder joint reliability testing of lead-free solder alloys.

In November 2006, the NASA-DoD Lead-Free Electronics Project was launched to build on the results from the 2005 JCAA/JG-PP Lead-Free Solder Project. The new project focused on the rework of tin-lead and lead-free solder alloys and included the mixing of tin-lead and lead-free solder alloys. The majority of testing mirrored the testing completed for the JCAA/JGPP Lead-Free Solder Project. The project was managed by Kurt Kessel from the NASA Technology Evaluation for Environmental Risk Mitigation (TEERM) Principle Center. The project stakeholders are listed in Table 1.

Table 1 Project Stakeholders

NASA	**Rockwell Collins**	**Celestica**
Defense Microelectronics Activity	**Boeing**	**Texas Instruments**
NAVSEA – Crane	**BAE Systems**	**Honeywell**
Air Force	**Lockheed Martin**	**Scorpio Solutions**
Raytheon	**Harris**	**Nihon Superior**
ITB, Inc.	**COM DEV**	**PWB Interconnect Solutions**

Methods, Assumptions and Procedures

Solder Alloys

The solder alloys in the test matrix are tabulated in Table 2 and discussed below.

Table 2 Solder Alloys

Solder Alloy	Nomenclature	Designation	Melting Temperature
Sn3.0Ag0.5Cu	Tin-Silver-Copper	SAC305	217 °C (422.6 °F)
Sn0.7Cu0.05Ni+Ge	Tin-Copper	SN100C	227 °C (440.6 °C)
Sn37Pb (baseline)	Tin-Lead	SnPb	183 °C (361 °F)

Tin-Silver-Copper (Sn3.0Ag0.5Cu)

Tin-silver-copper solder alloys are thought to be the leading choice of the commercial electronics industry for lead-free solder. The Sn3.0Ag0.5Cu is recommended by industry and research consortia as a prime candidate for replacing SnPb solder. Sn3.0Ag0.5Cu is commercially available and currently used in electronic applications. It has been determined that alloys with compositions within the range of Sn3.0-4.0Ag0.5-1.0Cu all have a liquidus temperature around 217 degrees Celsius and have similar microstructures and mechanical properties.

This alloy was chosen for reflow soldering because it has shown the most promise as a primary replacement for tin-lead solder. The consortia decided to include at least one “general purpose” alloy to be evaluated, and it was determined tin-silver-copper solder alloy would best serve this purpose. Conclusions drawn from literature suggest that this alloy has good mechanical properties and may be as reliable as tin-lead in some applications.

BAE Systems reviewed several SAC305 solder alloys for printing, reflow, and cleaning characteristics before choosing Kester EnviroMark™ 907.

Tin-Copper (Sn0.7Cu0.05Ni (≤0.01Ge))

This alloy is commercially available and the general industry trend has been to switch to the nickel stabilized tin-copper alloy over standard tin-copper due to its superior performance. In addition, this nickel-stabilized alloy does not require special solder pots and has not shown joint failures in specimens with more than four years of service. The cost of the bar solder form of this alloy is relatively low when compared to other lead-free solder alloys in bar form.

The superior performance of the tin-copper-nickel alloy has been confirmed by university research, which found that the nickel addition facilitates solidification of the alloy as a fine uniform eutectic structure. The nickel addition works by suppressing the growth of primary tin dendrites that are the cause of shrinkage defects in the unmodified alloy. This mode of solidification enhances the fluidity of the alloy close to the melting point, an important property needed in a solder to compare it with tin-lead solder at the same superheat. The tin-copper-nickel alloy is representative of a new class of modified tin-copper solders that are increasing in popularity as the limitations of tin-silver-copper alloys, in some applications, become apparent.

Nihon Superior SN100C will be used for this project.

Tin-Lead (Sn37Pb)

The alloy is the eutectic tin-lead used as the baseline solder alloy.

Flux

The flux systems used during soldering were "low residue" or no-clean fluxes. The group chose to clean the test vehicles after processing even though no-clean fluxes were used with some solders. Additionally, reflow was accomplished without inert nitrogen, which may have created a smaller soldering process window (a credit to the BAE Systems crew for creating a quality test vehicle under such tough processing conditions).

Table 3 Solder Alloys and Associated Flux

Solder Alloy	Flux		
	Reflow Soldering	Wave Soldering	Manual Soldering
SAC305	ROL1	N/A	R Heat Stabilized Resin ROL0 Tacky Flux
SN100C	ROL0	ORL0	R Heat Stabilized Resin ROL0 Tacky Flux
SnPb baseline	ROL0	Type ORM0	ORL0 ROL0 Tacky Flux

Table provided by BAE Systems Irving, Texas

N/A = Due to board numbers and components, the solder alloy was not used in the assembly processes
R = Rosin Base
ROL0 = Rosin, Low or no flux/flux residue activity, no halide present
ROL1 = Rosin, Low or no flux/flux residue activity, halide present
ORM0 = Organic, Moderate flux/flux residue activity, no halide present

Test Vehicle

The test vehicle was a circuit card assembly designed per IPC-SM-785 and IPC-9701 to evaluate solder joint reliability. The test vehicle printed wiring board was designed and fabricated per IPC-6012, Class 3 (Qualification and Performance Specification for Rigid Printed Boards). The board had six layers and an overall dimension of 14.5 X 9 X 0.09 inches thick. The board design included a break-off coupon containing the IST and copper dissolution test components. Break-off coupons were divided into two groups: those processed through reflow and wave solder processing (Batches A-rwk, C, E and G) and those removed prior to reflow and wave solder processing (Batch B-rwk). Additional capacitance measurements were taken by BAE Systems on break-off coupons that underwent lead-free reflow and wave solder processing. Coupons that underwent tin-lead reflow and wave solder processing were divided into three separate pieces for testing at Rockwell Collins. Coupons not submitted through reflow or wave solder processing went to PWB Interconnect Solutions for Interconnect Stress Test (IST) testing.

For the purposes of CET, the break-off coupon was removed; therefore, the dimensions of the boards were 12.75 X 9 inches. There were two variations of the test vehicle; manufactured and rework. The details of each variation are provided below. A sample of a manufactured and rework test vehicle is shown in Figure 1.

The team evaluated board finishes for use with the tin-lead and lead-free solders. The finishes included: immersion silver, organic solderability preservative (OSP), and immersion tin and electroless nickel/immersion gold (ENIG). Each surface finish has its advantages and limitations. For example, ENIG is susceptible to "black pad", a persistent BGA assembly problem, and can cause premature failure of solder joints. Immersion tin and OSP lose solderability after several exposures to reflow conditions and OSP exhibits poor wetting with some solders.

Project stakeholders and participants selected MacDermids Sterling immersion silver surface finish for the majority of the test vehicles. Immersion silver has the best balance of desirable properties: good wetting by solders, good solder joint reliability, good long-term solderability upon storage, and retention of solderability after multiple reflow cycles. In addition, several major electronic manufacturing companies are currently using immersion silver in production.

A limited number of test vehicles were assembled using an electroless nickel/immersion gold (ENIG) surface finish (Uyemura Kat 450 ENIG). The project stakeholders determined ENIG would be a good secondary surface finish; it has good planarity and solderability and can withstand multiple reflows. In addition, ENIG performs well when considering substrate shelf-life, corrosion resistance, assembly process window, thermal resistance over repeated temperature excursions, and good reworkability.

The test vehicle printed circuit board was designed with daisy-chained pads that complemented the daisy chain in the components. Therefore, the solder joints on each component had a continuous electrical pathway monitored by an event detector during testing. Each component had its own distinct pathway (channel). Failure of one solder joint on a component during testing breaks the continuous electrical pathway and is recorded as an event.

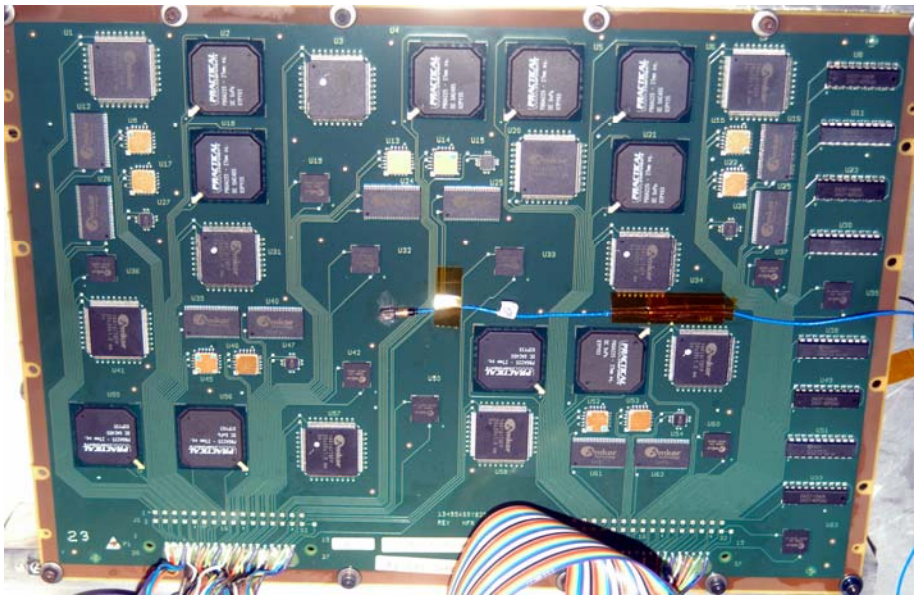


Figure 1 Manufactured and Rework Test Vehicle without Break-Off Coupon

Manufactured Test Vehicle

SnPb Manufactured (Batch C)

Printed Wiring Boards

- 12.75"X 9"X 0.09" (without break-off coupon)
- 6 layers of 0.5 ounce copper
- FR4 per IPC-4101/26 with a minimum Tg of 170°C
- Immersion Ag surface finish
- Serial Numbers received: 20, 21, 22, 23, and 24

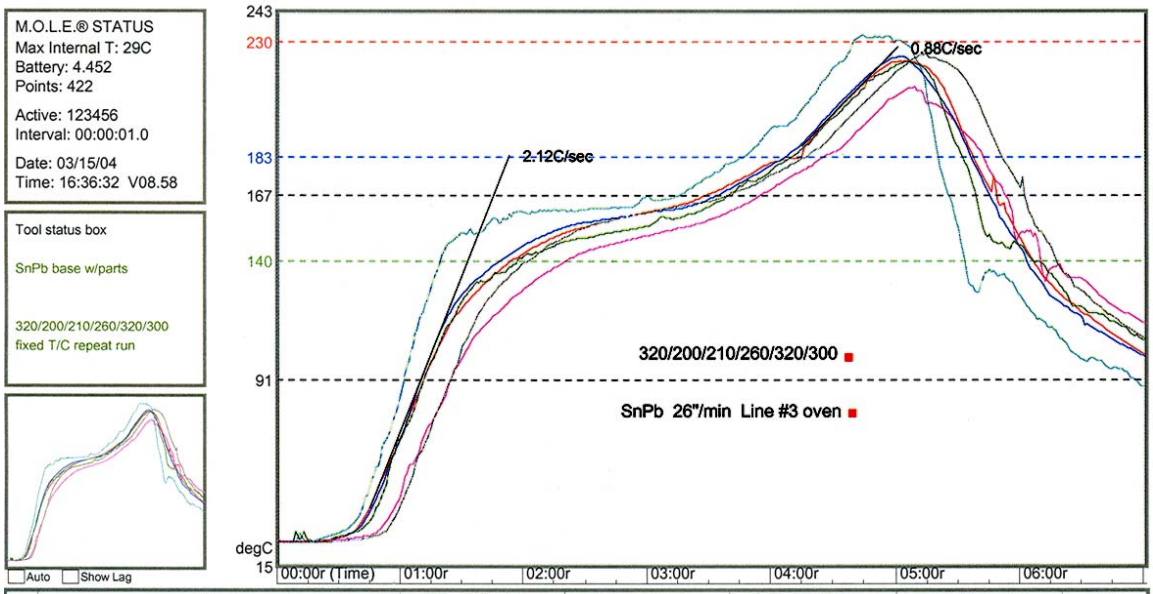
Table 4 Component Finish Matrix – SnPb Manufactured Test Vehicles (Batch C)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18	BGA-225	SAC405	SnPb	
U43	BGA-225	SAC405	SnPb	
U04	BGA-225	SAC405	SnPb	
U06	BGA-225	SAC405	SnPb	
U55	BGA-225	SAC405	SnPb	
U02	BGA-225	SnPb	SnPb	
U05	BGA-225	SnPb	SnPb	
U21	BGA-225	SnPb	SnPb	
U44	BGA-225	SnPb	SnPb	
U56	BGA-225	SnPb	SnPb	
U09	CLCC-20	SAC305	SnPb	
U13	CLCC-20	SAC305	SnPb	
U22	CLCC-20	SAC305	SnPb	
U46	CLCC-20	SAC305	SnPb	
U53	CLCC-20	SAC305	SnPb	
U10	CLCC-20	SnPb	SnPb	
U14	CLCC-20	SnPb	SnPb	
U17	CLCC-20	SnPb	SnPb	
U45	CLCC-20	SnPb	SnPb	
U52	CLCC-20	SnPb	SnPb	
U32	CSP-100	SAC105	SnPb	
U33	CSP-100	SAC105	SnPb	
U35	CSP-100	SAC105	SnPb	
U50	CSP-100	SAC105	SnPb	
U63	CSP-100	SAC105	SnPb	
U19	CSP-100	SnPb	SnPb	
U36	CSP-100	SnPb	SnPb	

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U37	CSP-100	SnPb	SnPb	
U42	CSP-100	SnPb	SnPb	
U60	CSP-100	SnPb	SnPb	
U08	PDIP-20	NiPdAu		SnPb
U23	PDIP-20	NiPdAu		SnPb
U49	PDIP-20	NiPdAu		SnPb
U59	PDIP-20	NiPdAu		SnPb
U11	PDIP-20	Sn		SnPb
U30	PDIP-20	Sn		SnPb
U38	PDIP-20	Sn		SnPb
U51	PDIP-20	Sn		SnPb
U15	QFN	Matte Sn	SnPb	
U27	QFN	Matte Sn	SnPb	
U28	QFN	Matte Sn	SnPb	
U47	QFN	Matte Sn	SnPb	
U54	QFN	Matte Sn	SnPb	
U01	TQFP-144	Matte Sn	SnPb	
U07	TQFP-144	Matte Sn	SnPb	
U20	TQFP-144	Matte Sn	SnPb	
U41	TQFP-144	Matte Sn	SnPb	
U58	TQFP-144	Matte Sn	SnPb	
U03	TQFP-144	SnPb Dip	SnPb	
U31	TQFP-144	SnPb Dip	SnPb	
U34	TQFP-144	SnPb Dip	SnPb	
U48	TQFP-144	SnPb Dip	SnPb	
U57	TQFP-144	SnPb Dip	SnPb	
U12	TSOP-50	SnBi	SnPb	
U25	TSOP-50	SnBi	SnPb	
U29	TSOP-50	SnBi	SnPb	
U39	TSOP-50	SnBi	SnPb	
U61	TSOP-50	SnBi	SnPb	
U16	TSOP-50	SnPb	SnPb	
U24	TSOP-50	SnPb	SnPb	
U26	TSOP-50	SnPb	SnPb	
U40	TSOP-50	SnPb	SnPb	
U62	TSOP-50	SnPb	SnPb	

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SnPb
    - Preheat = ~ 120 seconds @140-183°C
    - Solder joint peak temperature = 225°C
    - Time above reflow = 60-90 sec
    - Ramp Rate = 2-3 °C/sec
- Wave Soldering
- Location – BAE Systems Irving, Texas
- Wave Profile = SnPb
    - Solder Pot Temperature = 250°C
    - Preheat Board T = 101°C
    - Peak Temperature = 144°C
    - Speed: 110 cm/min



Value	C1 = 00:01:24r	C2 = 00:02:48r	C3 = 00:04:12r	C4 = 00:05:36r	Units
t/c11 embedded U2 bga	114	158	182	185	degC
t/c7 embedded U42 csp	119	158	186	183	degC
t/c3 topside laminate U44 bga	114	153	184	174	degC
t/c8 embedded U44 bga	91	148	176	190	degC
t/c5 topside laminate U42 csp	148	162	198	130	degC
t/c9 embedded U37 csp	91	158	181	211	degC

T Above Ref	Low = 140	Med = 183	Hi = 230	Cure Factor	Units
t/c11 embedded U2 bga	00:04:14	00:01:24	00:00:00	0%	degC
t/c7 embedded U42 csp	00:04:16	00:01:30	00:00:00	0%	degC
t/c3 topside laminate U44 bga	00:04:12	00:01:23	00:00:00	0%	degC
t/c8 embedded U44 bga	00:03:50	00:01:18	00:00:00	0%	degC
t/c5 topside laminate U42 csp	00:04:14	00:01:34	00:00:23	0%	degC
t/c9 embedded U37 csp	00:04:16	00:01:35	00:00:00	0%	degC

Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
t/c11 embedded U2 bga	25	00:00:00r	222	00:05:02r	140.7	55.4	degC
t/c7 embedded U42 csp	25	00:00:04r	224	00:05:01r	140.6	55.3	degC
t/c3 topside laminate U44 bga	26	00:00:00r	222	00:05:04r	138.4	54.0	degC
t/c8 embedded U44 bga	26	00:00:00r	212	00:05:09r	133.2	54.4	degC
t/c5 topside laminate U42 csp	25	00:00:00r	233	00:04:44r	143.3	56.8	degC
t/c9 embedded U37 csp	25	00:00:00r	225	00:05:14r	139.4	59.5	degC

Figure 2 Example Reflow Oven Profile (SnPb)

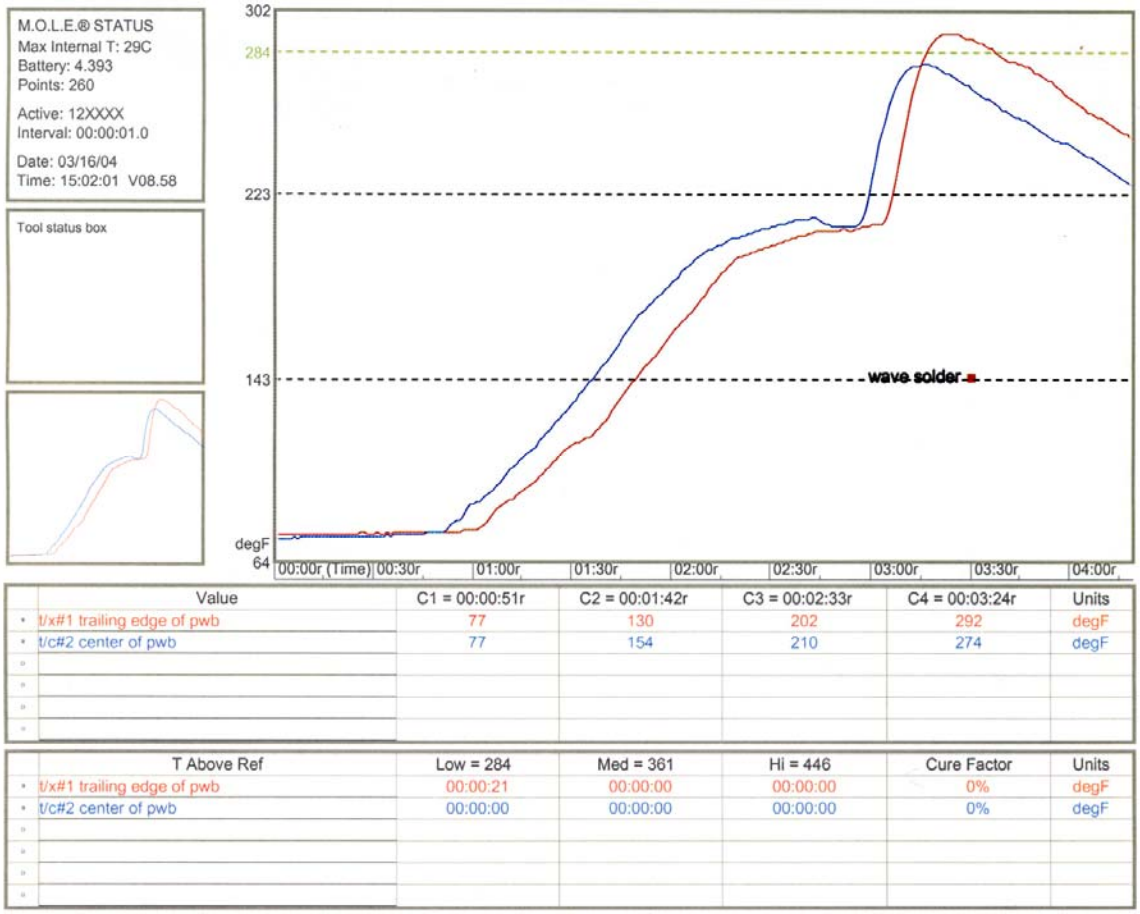


Figure 3 Example Wave Solder Profile (SnPb)

Lead-Free Manufactured (Batch E)

Printed Wiring Boards

- 12.75"X 9"X 0.09" (without break-off coupon)
- 6 layers of 0.5 ounce copper
- FR4 per IPC-4101/26 with a minimum Tg of 170°C
- Immersion Ag and ENIG surface finishes
- Serial Numbers received: 69, 70, 71, 72, 73 and 97*

*SN 97 (ENIG) was tested with the batch of rework test vehicles.

Table 5 Component Finish Matrix – Lead-Free Manufactured Test Vehicles (Batch E)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U02	BGA-225	SAC405	SAC305	
U05	BGA-225	SAC405	SAC305	
U21	BGA-225	SAC405	SAC305	
U44	BGA-225	SAC405	SAC305	
U56	BGA-225	SAC405	SAC305	
U18	BGA-225	SnPb	SAC305	
U43	BGA-225	SnPb	SAC305	
U04	BGA-225	SnPb	SAC305	
U06	BGA-225	SnPb	SAC305	
U55	BGA-225	SnPb	SAC305	
U10	CLCC-20	SAC305	SAC305	
U14	CLCC-20	SAC305	SAC305	
U17	CLCC-20	SAC305	SAC305	
U45	CLCC-20	SAC305	SAC305	
U52	CLCC-20	SAC305	SAC305	
U09	CLCC-20	SnPb	SAC305	

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U13	CLCC-20	SnPb	SAC305	
U22	CLCC-20	SnPb	SAC305	
U46	CLCC-20	SnPb	SAC305	
U53	CLCC-20	SnPb	SAC305	
U19	CSP-100	SAC105	SAC305	
U36	CSP-100	SAC105	SAC305	
U37	CSP-100	SAC105	SAC305	
U42	CSP-100	SAC105	SAC305	
U60	CSP-100	SAC105	SAC305	
U32	CSP-100	SnPb	SAC305	
U33	CSP-100	SnPb	SAC305	
U35	CSP-100	SnPb	SAC305	
U50	CSP-100	SnPb	SAC305	
U63	CSP-100	SnPb	SAC305	
U08	PDIP-20	NiPdAu		SN100C
U23	PDIP-20	NiPdAu		SN100C
U49	PDIP-20	NiPdAu		SN100C
U59	PDIP-20	NiPdAu		SN100C
U11	PDIP-20	Sn		SN100C
U30	PDIP-20	Sn		SN100C
U38	PDIP-20	Sn		SN100C
U51	PDIP-20	Sn		SN100C
U15	QFN	Matte Sn	SAC305	
U27	QFN	Matte Sn	SAC305	
U28	QFN	Matte Sn	SAC305	
U47	QFN	Matte Sn	SAC305	
U54	QFN	Matte Sn	SAC305	
U03	TQFP-144	Matte Sn	SAC305	
U31	TQFP-144	Matte Sn	SAC305	
U34	TQFP-144	Matte Sn	SAC305	
U48	TQFP-144	Matte Sn	SAC305	
U57	TQFP-144	Matte Sn	SAC305	
U01	TQFP-144	SnPb Dip	SAC305	
U07	TQFP-144	SnPb Dip	SAC305	
U20	TQFP-144	SnPb Dip	SAC305	
U41	TQFP-144	SnPb Dip	SAC305	
U58	TQFP-144	SnPb Dip	SAC305	
U16	TSOP-50	SnBi	SAC305	
U24	TSOP-50	SnBi	SAC305	
U26	TSOP-50	SnBi	SAC305	
U40	TSOP-50	SnBi	SAC305	
U62	TSOP-50	SnBi	SAC305	
U12	TSOP-50	SnPb	SAC305	
U25	TSOP-50	SnPb	SAC305	
U29	TSOP-50	SnPb	SAC305	
U39	TSOP-50	SnPb	SAC305	
U61	TSOP-50	SnPb	SAC305	

Assembly Note

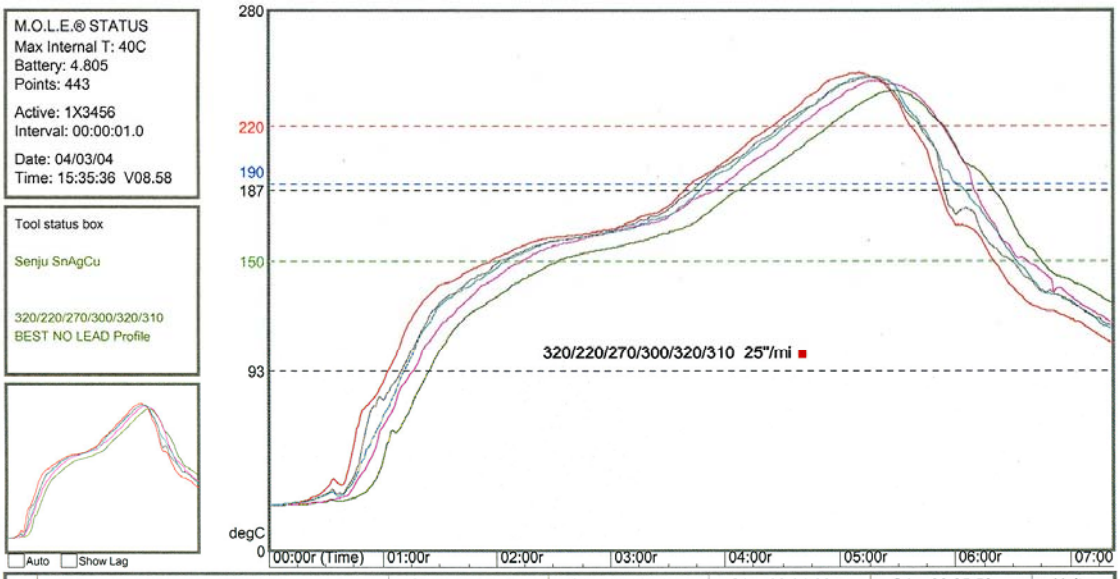
PDIP components of the Batch E test vehicles were assembled with the incorrect component finish. Table 6 shows the PDIP component finish alloy for Batch E. The second column indicates what the component finishes were meant to be. Cells highlighted in red indicate an incorrect component finish, while cells highlighted in green indicate the correct component finish. For Batch E, no action was taken and the test vehicles were tested as-received.

Table 6 PDIP Component Finishes – Lead-Free Manufactured Test Vehicles (Batch E)

Ref Des	Component Finish	Test Vehicle Serial Number					
		69	70	71	72	73	97
U8	NiPdAu	Sn	Sn	Sn	Sn	Sn	Sn
U23	NiPdAu	Sn	Sn	Sn	Sn	Sn	Sn
U49	NiPdAu	Sn	Sn	Sn	Sn	Sn	Sn
U59	NiPdAu	Sn	Sn	Sn	Sn	Sn	Sn
U11	Sn	Sn	Sn	NiPdAu	Sn	Sn	Sn
U30	Sn	Sn	Sn	NiPdAu	Sn	Sn	Sn
U38	Sn	Sn	Sn	NiPdAu	Sn	Sn	Sn
U51	Sn	Sn	Sn	Sn	Sn	Sn	Sn

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
    - Preheat = 60-120 seconds @150-190°C
    - Peak temperature target = 243°C
    - Reflow:~20 seconds above 230°C
    - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
    - Solder Pot Temperature = 265°C
    - Preheat Board T = 134°C
    - Peak Temperature = 157°C
    - Speed: 90 cm/min

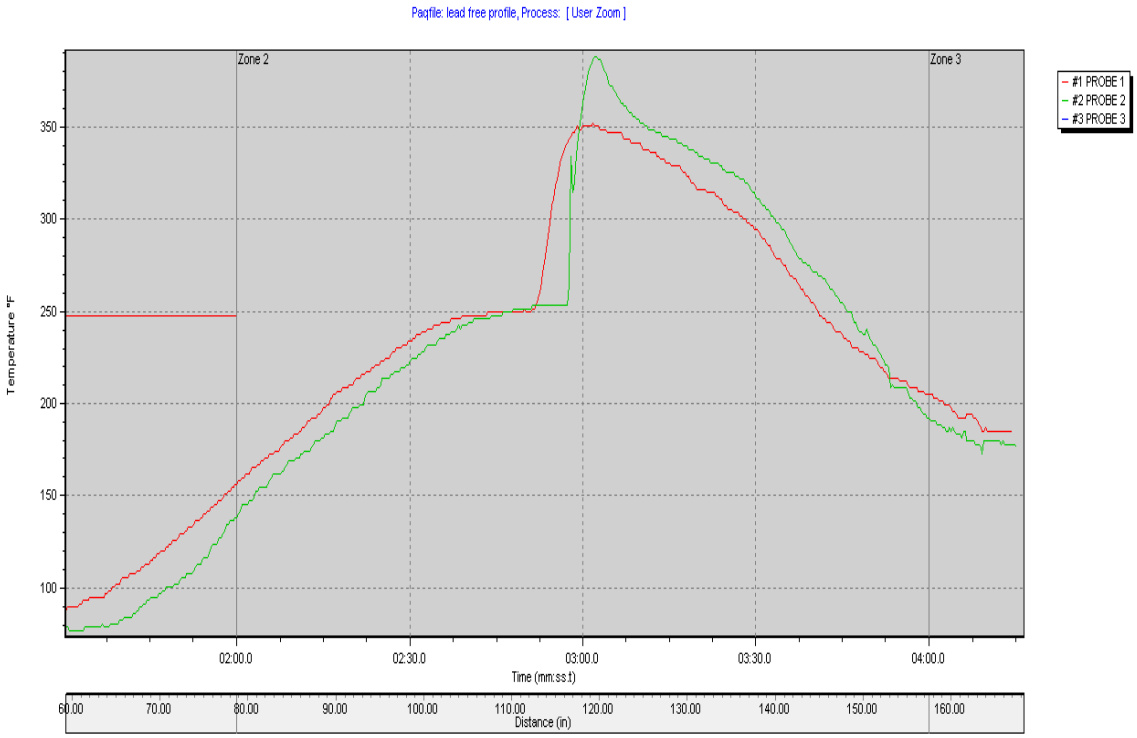


Value	C1 = 00:02:13r	C2 = 00:03:59r	C3 = 00:04:38r	C4 = 00:05:53r	Units
t/c11topside U41	158	201	230	183	degC
t/c2 under U44 BGA					
t/c24 topside U44	141	182	208	221	degC
t/c4 under U2 BGA	150	190	219	220	degC
t/c5 topside U57	154	197	225	198	degC
t/c6 topside U2	155	199	227	191	degC

T Above Ref	Low = 150	Med = 190	Hi = 220	Cure Factor	Units
t/c11topside U41	00:04:23	00:02:09	00:01:12	0%	degC
t/c2 under U44 BGA					
t/c24 topside U44	00:04:13	00:02:06	00:01:00	0%	degC
t/c4 under U2 BGA	00:04:25	00:02:10	00:01:15	0%	degC
t/c5 topside U57	00:04:27	00:02:11	00:01:11	0%	degC
t/c6 topside U2	00:04:29	00:02:08	00:01:13	0%	degC

Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
t/c11topside U41	23	00:00:00r	248	00:05:10r	155.4	60.2	degC
t/c2 under U44 BGA							
t/c24 topside U44	23	00:00:00r	238	00:05:26r	148.2	63.2	degC
t/c4 under U2 BGA	24	00:00:00r	243	00:05:15r	153.1	63.2	degC
t/c5 topside U57	24	00:00:00r	246	00:05:12r	154.1	62.0	degC
t/c6 topside U2	23	00:00:00r	245	00:05:13r	154.4	61.0	degC

Figure 4 Example Reflow Oven Profile - Lead-Free (SAC305)



Reflow Results

Probe	Positive Slope (°F/sec)	Positive Slope Time (mm:ss.t)	Time Above Liquidus (361.4°F) (mm:ss.t)	Peak Temperature (°F)	Delta T (°F)
#1 (°F)	12.98	02:54.6	00:00.0	352.4	36.0
#2 (°F)	18.46	02:58.5	00:07.8	388.4	
#3 (°F)	***	***	00:00.0	***	

Figure 5 Example Wave Solder Profile - Lead-Free (SN100C)

Lead-Free Manufactured (Batch G)

Printed Wiring Boards

- 12.75”X 9”X 0.09” (without break-off coupon)
- 6 layers of 0.5 ounce copper
- FR4 per IPC-4101/26 with a minimum Tg of 170°C
- Immersion Ag surface finish
- Serial Numbers received: 116, 117, 118, 119 and 120

Table 7 Component Finish Matrix – Lead-Free Manufactured Test Vehicles (Batch G)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U02	BGA-225	SAC405	SN100C	
U05	BGA-225	SAC405	SN100C	
U21	BGA-225	SAC405	SN100C	
U44	BGA-225	SAC405	SN100C	
U56	BGA-225	SAC405	SN100C	
U18	BGA-225	SnPb	SN100C	
U43	BGA-225	SnPb	SN100C	
U04	BGA-225	SnPb	SN100C	
U06	BGA-225	SnPb	SN100C	
U55	BGA-225	SnPb	SN100C	
U10	CLCC-20	SAC305	SN100C	
U14	CLCC-20	SAC305	SN100C	
U17	CLCC-20	SAC305	SN100C	
U45	CLCC-20	SAC305	SN100C	
U52	CLCC-20	SAC305	SN100C	

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U09	CLCC-20	SnPb	SN100C	
U13	CLCC-20	SnPb	SN100C	
U22	CLCC-20	SnPb	SN100C	
U46	CLCC-20	SnPb	SN100C	
U53	CLCC-20	SnPb	SN100C	
U19	CSP-100	SAC105	SN100C	
U36	CSP-100	SAC105	SN100C	
U37	CSP-100	SAC105	SN100C	
U42	CSP-100	SAC105	SN100C	
U60	CSP-100	SAC105	SN100C	
U32	CSP-100	SnPb	SN100C	
U33	CSP-100	SnPb	SN100C	
U35	CSP-100	SnPb	SN100C	
U50	CSP-100	SnPb	SN100C	
U63	CSP-100	SnPb	SN100C	
U08	PDIP-20	NiPdAu		SN100C
U23	PDIP-20	NiPdAu		SN100C
U49	PDIP-20	NiPdAu		SN100C
U59	PDIP-20	NiPdAu		SN100C
U11	PDIP-20	Sn		SN100C
U30	PDIP-20	Sn		SN100C
U38	PDIP-20	Sn		SN100C
U51	PDIP-20	Sn		SN100C
U15	QFN	Matte Sn	SN100C	
U27	QFN	Matte Sn	SN100C	
U28	QFN	Matte Sn	SN100C	
U47	QFN	Matte Sn	SN100C	
U54	QFN	Matte Sn	SN100C	
U03	TQFP-144	Matte Sn	SN100C	
U31	TQFP-144	Matte Sn	SN100C	
U34	TQFP-144	Matte Sn	SN100C	
U48	TQFP-144	Matte Sn	SN100C	
U57	TQFP-144	Matte Sn	SN100C	
U01	TQFP-144	SnPb Dip	SN100C	
U07	TQFP-144	SnPb Dip	SN100C	
U20	TQFP-144	SnPb Dip	SN100C	
U41	TQFP-144	SnPb Dip	SN100C	
U58	TQFP-144	SnPb Dip	SN100C	
U16	TSOP-50	SnBi	SN100C	
U24	TSOP-50	SnBi	SN100C	
U26	TSOP-50	SnBi	SN100C	
U40	TSOP-50	SnBi	SN100C	
U62	TSOP-50	SnBi	SN100C	
U12	TSOP-50	SnPb	SN100C	
U25	TSOP-50	SnPb	SN100C	
U29	TSOP-50	SnPb	SN100C	
U39	TSOP-50	SnPb	SN100C	
U61	TSOP-50	SnPb	SN100C	

Assembly Note

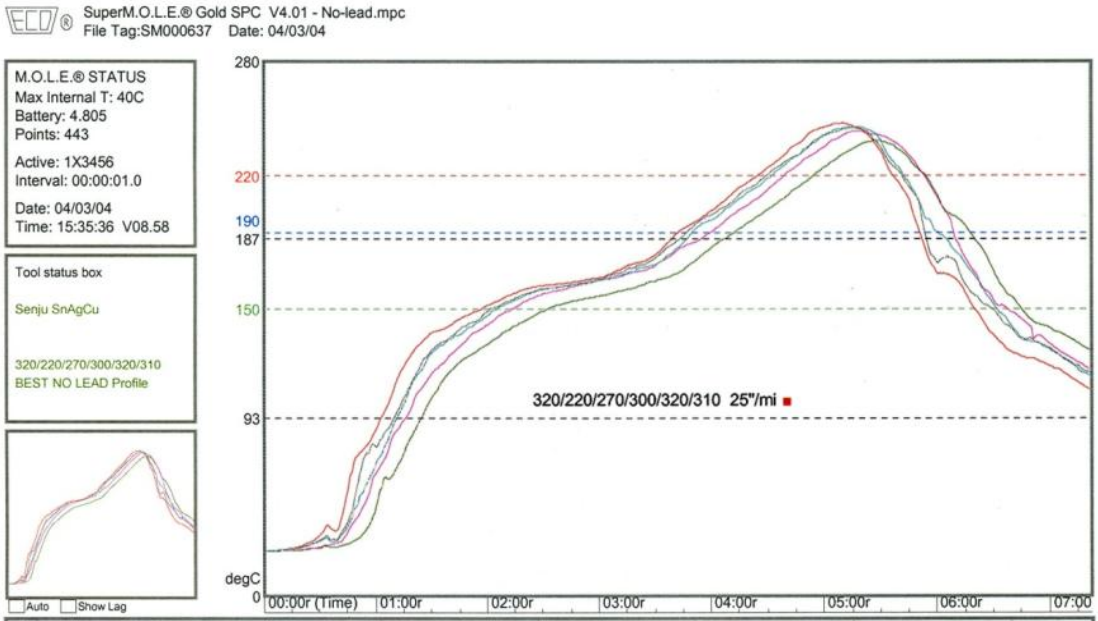
PDIP components from Batch G were assembled with the incorrect component finish. Table 8 shows the PDIP component finish alloy for Batch G. The second column shows what the component finishes were meant to be. Cells highlighted in red indicate the incorrect component finish, while cells highlighted in green indicate the correct component finish. For Batch G, no action was taken and the test vehicles were tested as-received.

Table 8 PDIP Component Finishes – Lead-Free Manufactured Test Vehicles (Batch G)

Ref Des	Component Finish	Test Vehicle Serial Number				
		116	117	118	119	120
U8	NiPdAu	NiPdAu	Sn	Sn	NiPdAu	Sn
U23	NiPdAu	NiPdAu	NiPdAu	Sn	NiPdAu	NiPdAu
U49	NiPdAu	NiPdAu	NiPdAu	Sn	Sn	NiPdAu
U59	NiPdAu	NiPdAu	NiPdAu	Sn	Sn	NiPdAu
U11	Sn	NiPdAu	NiPdAu	Sn	NiPdAu	NiPdAu
U30	Sn	NiPdAu	NiPdAu	Sn	Sn	NiPdAu
U38	Sn	NiPdAu	NiPdAu	Sn	Sn	NiPdAu
U51	Sn	NiPdAu	NiPdAu	Sn	Sn	NiPdAu

Assembly Details

- Reflow Profile = SN100C
- Location – BAE Systems Irving, Texas
  - Preheat = 60-120 seconds @150-190°C
  - Peak temperature target = 243°C
  - Reflow:~20 seconds above 230°C
  - ~30-90 seconds above 220°C
- Wave Soldering
- Wave Profile = SN100C
- Location – Scorpio Solutions
  - Solder Pot Temperature = 265°C
  - Preheat Board T = 134°C
  - Peak Temperature = 157°C
  - Speed: 90 cm/min

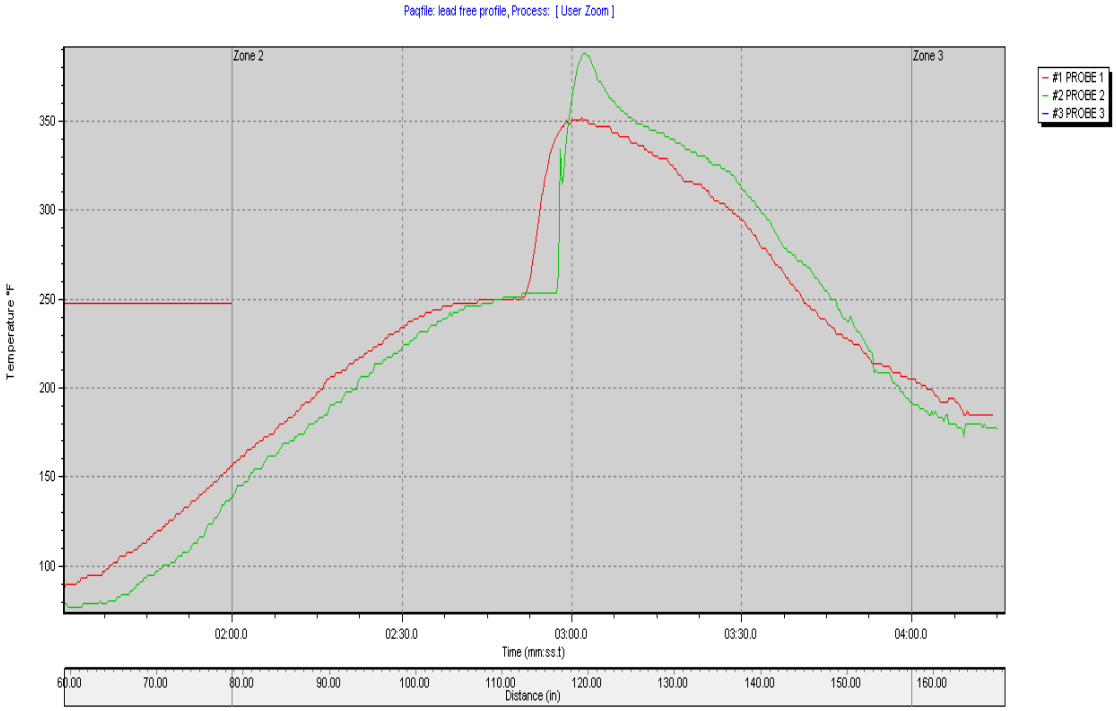


Value	C1 = 00:02:13r	C2 = 00:03:59r	C3 = 00:04:38r	C4 = 00:05:53r	Units
t/c11topside U41	158	201	230	183	degC
t/c2 under U44 BGA					
t/c24 topside U44	141	182	208	221	degC
t/c4 under U2 BGA	150	190	219	220	degC
t/c5 topside U57	154	197	225	198	degC
t/c6 topside U2	155	199	227	191	degC

T Above Ref	Low = 150	Med = 190	Hi = 220	Cure Factor	Units
t/c11topside U41	00:04:23	00:02:09	00:01:12	0%	degC
t/c2 under U44 BGA					
t/c24 topside U44	00:04:13	00:02:06	00:01:00	0%	degC
t/c4 under U2 BGA	00:04:25	00:02:10	00:01:15	0%	degC
t/c5 topside U57	00:04:27	00:02:11	00:01:11	0%	degC
t/c6 topside U2	00:04:29	00:02:08	00:01:13	0%	degC

Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
t/c11topside U41	23	00:00:00r	248	00:05:10r	155.4	60.2	degC
t/c2 under U44 BGA							
t/c24 topside U44	23	00:00:00r	238	00:05:26r	148.2	63.2	degC
t/c4 under U2 BGA	24	00:00:00r	243	00:05:15r	153.1	63.2	degC
t/c5 topside U57	24	00:00:00r	246	00:05:12r	154.1	62.0	degC
t/c6 topside U2	23	00:00:00r	245	00:05:13r	154.4	61.0	degC

Figure 6 Example Reflow Oven Profile – Lead-Free (SN100C)



Reflow Results

Probe	Positive Slope (°F/sec)	Positive Slope Time (mm:ss.t)	Time Above Liquidus (361.4°F) (mm:ss.t)	Peak Temperature (°F)	Delta T (°F)
#1 (°F)	12.98	02:54.6	00:00.0	352.4	36.0
#2 (°F)	18.46	02:58.5	00:07.8	388.4	
#3 (°F)	***	***	00:00.0	***	

Figure 7 Example Wave Solder Profile – Lead -Free (SN100C)

Rework Test Vehicles

Component Rework Procedure

NOTE:

- Contamination: Care needs to be taken not to contaminate the rework station used for SnPb and lead-free rework procedures. Cross contamination can cause decreased reliability of solder interconnects.
- Flux: In any solder removal/replacement sequence, use of external flux (ROLO) is allowed.
- Repair: If needed, repairs can be made during rework. Each location will document any repairs needed.
- BGA rework: Solder paste will be applied to the BGA not the board.
- CSP rework: Solder paste will be applied to the CSP not the board.
- Rework Sequence: For all component types:
    - Remove component
    - Cool
    - Replace

1.1 Component Preparation

1.1.1 Moisture bake-out per J-STD-033, Table 4-1

- Prior to rework, bake the components for 48 hours @ 125°C

1.2 Rework Procedure per IPC-7711

1.2.1 Moisture bake-out

- Prior to rework, bake boards for 4 hours @ 230°F and store in a dry environment until all rework is complete.

1.2.2 Cleaning
- In-line clean after rework (wash within shift), document multiple cleanings on traveler
- Clean as required per J-STD-001
- Document cleaning chemistry per rework location

1.2.3 Removal and Replacement

1.2.3.1 Removal of Leaded Through Hole Parts
- Remove components per IPC-7711, Number 3.1.1

1.2.3.2 Replacement of Leaded Through Hole Parts
- Per J-STD-001 certified soldering
- Use Metcal STTC-138, 700°F tips and rosin base flux

1.2.3.3 Removal and Replacement of Leaded Surface Mount Devices
- Remove using solder wick and replace per J-STD-001
- Hand procedure per IPC-7711
- Remove by using soldering iron method by removing excess solder using solder braid (wick). Heat and lift each lead from the pad surface using a dental pick or similar device.

1.2.3.4 Replacement of Leaded Surface Mount Devices
- Per J-STD-001 certified soldering
- Use Metcal STTC-125 or STTC-142, 700°F tips and rosin base flux

1.2.3.5 Removal and Replacement of area array components
- Removal per procedure IPC-7711, Number 3.9.1
- Replace per procedure IPC-7711 , Number 5.7.2; use paste / tacky flux
- Thermocouple map
- Drill center and polarity corner to place thermocouple in every BGA, name profile using ref designator for SnPb and lead-free
    - .032"drill bit with a .090" depth.

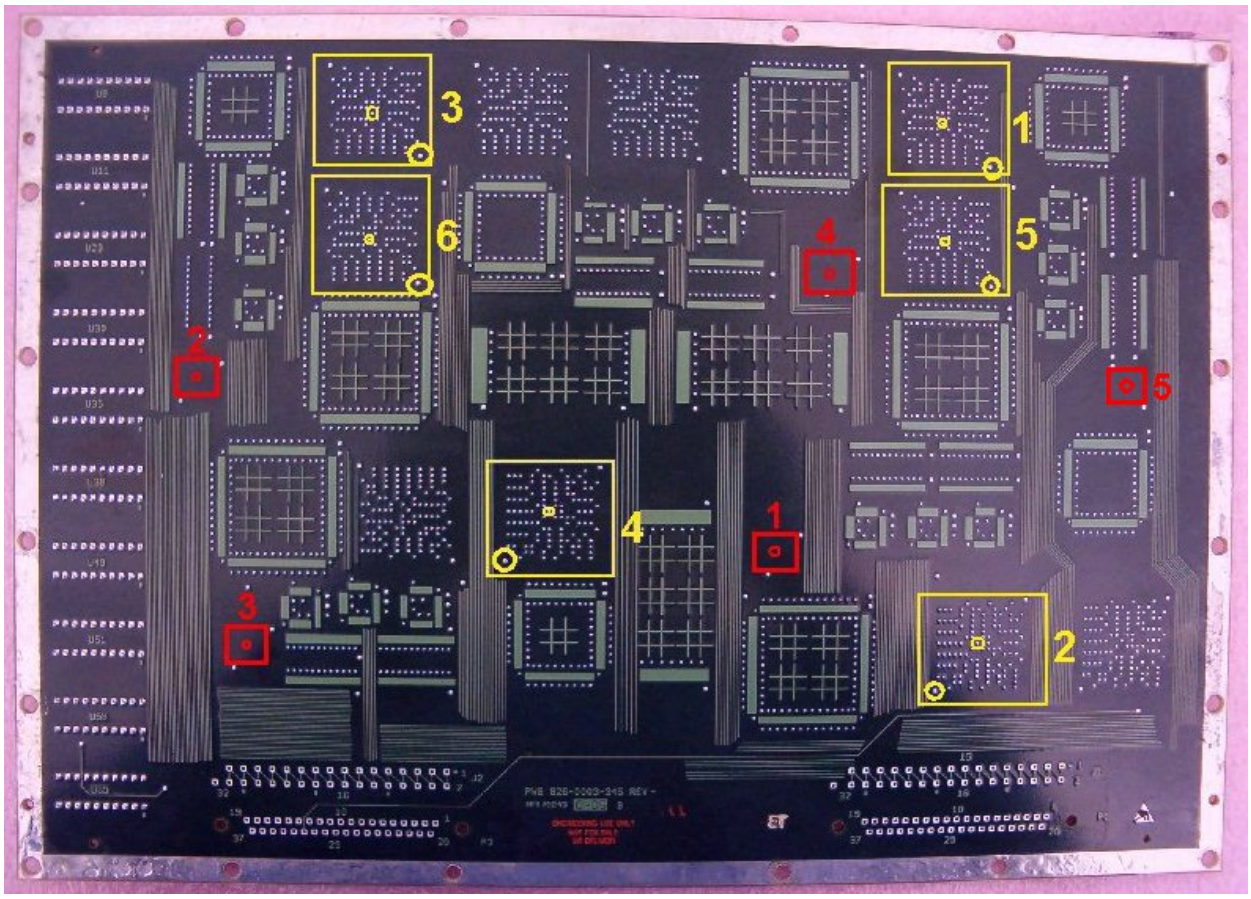


Figure 8 Thermocouple Map, Bottom Side of the Test Vehicle**

** A JCAA/JGPP test vehicle was used for the thermocouple map since this work was done prior to the NASA-DoD test vehicles being available

- Tape off all areas around the component being reworked
- Hot air rework station with nitrogen per IPC-7711, Number 3.9.1
    - Use regular or tacky flux, document type of flux
    - Nozzle table
    - Mini stencil
        - All 6 mil thick
        - Stainless steel
        - Laser cut
        - BGA = Standard mini stencil with 10% reduction
        - CSP = Standard mini stencil with 10% reduction

- SnPb rework profile for area array removal and replacement
    - Device joint target = 210°C ± 5°C
    - Device top max target = 250°C
    - Board max = as measured by the board trigger thermocouple; will be recorded
    - Reflow:
    - ~60 - 120 seconds @ 140-180 °C
    - ~60 - 120 seconds above 183 °C
    - Delta T from center to corner ball = 10°C
    - Ramp rate ≤ 4°C/sec

Lead-Free Rework (Batch A)

Printed Wiring Boards

- 12.75"X 9"X 0.09" (without break-off coupon)
- 6 layers of 0.5 ounce copper
- FR4 per IPC-4101/26 with a minimum Tg of 170°C
- Immersion Ag surface finish
- Serial Numbers received: 163, 180, 181, 182 and 183

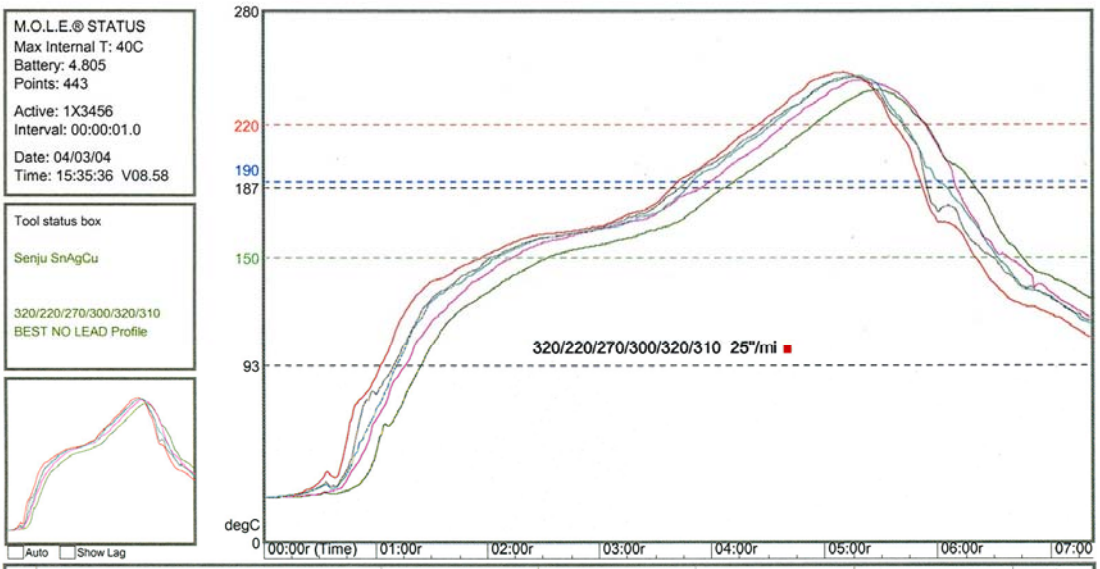
Table 9 Component Finish Matrix – Lead-Free Rework Test Vehicles (Batch A)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U18	BGA-225	SAC405	SAC305	
U43	BGA-225	SAC405	SAC305	
U06	BGA-225	SAC405	SAC305	
U02	BGA-225	SAC405	SAC305	
U21	BGA-225	SAC405	SAC305	
U56	BGA-225	SAC405	SAC305	
U04	BGA-225	SnPb	SAC305	
U55	BGA-225	SnPb	SAC305	
U05	BGA-225	SnPb	SAC305	
U44	BGA-225	SnPb	SAC305	
U09	CLCC-20	SnPb	SAC305	
U13	CLCC-20	SnPb	SAC305	
U22	CLCC-20	SnPb	SAC305	
U46	CLCC-20	SnPb	SAC305	
U53	CLCC-20	SnPb	SAC305	
U10	CLCC-20	SnPb	SAC305	
U14	CLCC-20	SnPb	SAC305	
U17	CLCC-20	SnPb	SAC305	
U45	CLCC-20	SnPb	SAC305	
U52	CLCC-20	SnPb	SAC305	
U33	CSP-100	SAC105	SAC305	
U50	CSP-100	SAC105	SAC305	
U19	CSP-100	SAC105	SAC305	
U37	CSP-100	SAC105	SAC305	
U42	CSP-100	SAC105	SAC305	
U60	CSP-100	SAC105	SAC305	
U36	CSP-100	SAC105	SAC305	
U32	CSP-100	SnPb	SAC305	
U35	CSP-100	SnPb	SAC305	
U63	CSP-100	SnPb	SAC305	
U08	PDIP-20	Sn		SN100C
U23	PDIP-20	Sn		SN100C
U49	PDIP-20	Sn		SN100C
U59	PDIP-20	Sn		SN100C
U30	PDIP-20	Sn		SN100C
U38	PDIP-20	Sn		SN100C
U11	PDIP-20	Sn		SN100C
U51	PDIP-20	Sn		SN100C
U15	QFN	SnPb	SAC305	
U27	QFN	SnPb	SAC305	
U28	QFN	SnPb	SAC305	
U47	QFN	SnPb	SAC305	
U54	QFN	SnPb	SAC305	
U03	TQFP-144	NiPdAu	SAC305	
U31	TQFP-144	NiPdAu	SAC305	
U34	TQFP-144	NiPdAu	SAC305	
U48	TQFP-144	NiPdAu	SAC305	
U57	TQFP-144	NiPdAu	SAC305	
U01	TQFP-144	SAC 305 Dip	SAC305	
U07	TQFP-144	SAC 305 Dip	SAC305	
U20	TQFP-144	SAC 305 Dip	SAC305	
U41	TQFP-144	SAC 305 Dip	SAC305	
U58	TQFP-144	SAC 305 Dip	SAC305	
U12	TSOP-50	Sn	SAC305	
U25	TSOP-50	Sn	SAC305	
U29	TSOP-50	SnBi	SAC305	
U39	TSOP-50	SnBi	SAC305	
U61	TSOP-50	SnBi	SAC305	
U24	TSOP-50	SnBi	SAC305	
U26	TSOP-50	SnBi	SAC305	

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U16	TSOP-50	SnPb	SAC305	
U40	TSOP-50	SnPb	SAC305	
U62	TSOP-50	SnPb	SAC305	

Assembly Details

- Reflow Soldering
- Location – BAE Systems Irving, Texas
- Reflow Profile = SAC305
    - Preheat = 60-120 seconds @150-190°C
    - Peak temperature target = 243°C
    - Reflow:~20 seconds above 230°C
    - ~30-90 seconds above 220°C
- Wave Soldering
- Location – Scorpio Solutions
- Wave Profile = SN100C
    - Solder Pot Temperature = 265°C
    - Preheat Board T = 134°C
    - Peak Temperature = 155°C to 175°C
    - Speed: 90 cm/min

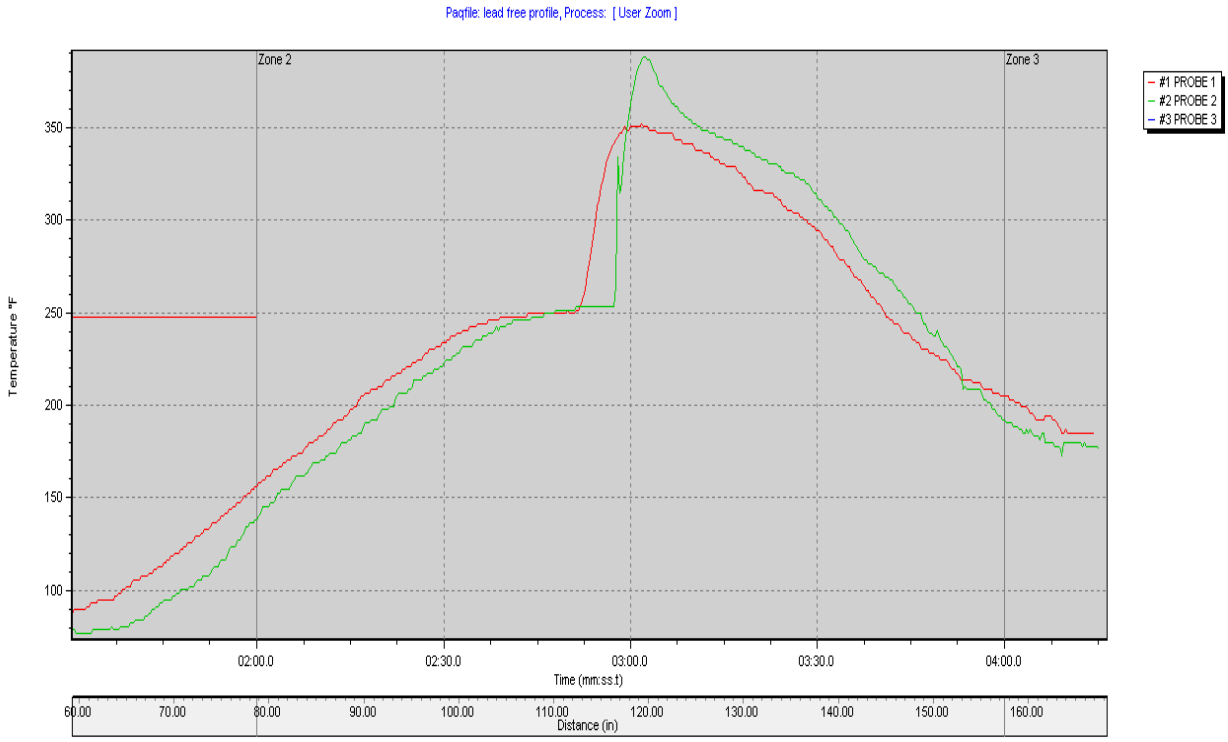


	Value	C1 = 00:02:13r	C2 = 00:03:59r	C3 = 00:04:38r	C4 = 00:05:53r	Units
•	t/c11topside U41	158	201	230	183	degC
◦	t/c2 under U44 BGA					
•	t/c24 topside U44	141	182	208	221	degC
•	t/c4 under U2 BGA	150	190	219	220	degC
•	t/c5 topside U57	154	197	225	198	degC
•	t/c6 topside U2	155	199	227	191	degC

	T Above Ref	Low = 150	Med = 190	Hi = 220	Cure Factor	Units
•	t/c11topside U41	00:04:23	00:02:09	00:01:12	0%	degC
◦	t/c2 under U44 BGA					
•	t/c24 topside U44	00:04:13	00:02:06	00:01:00	0%	degC
•	t/c4 under U2 BGA	00:04:25	00:02:10	00:01:15	0%	degC
•	t/c5 topside U57	00:04:27	00:02:11	00:01:11	0%	degC
•	t/c6 topside U2	00:04:29	00:02:08	00:01:13	0%	degC

	Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
•	t/c11topside U41	23	00:00:00r	248	00:05:10r	155.4	60.2	degC
◦	t/c2 under U44 BGA							
•	t/c24 topside U44	23	00:00:00r	238	00:05:26r	148.2	63.2	degC
•	t/c4 under U2 BGA	24	00:00:00r	243	00:05:15r	153.1	63.2	degC
•	t/c5 topside U57	24	00:00:00r	246	00:05:12r	154.1	62.0	degC
•	t/c6 topside U2	23	00:00:00r	245	00:05:13r	154.4	61.0	degC

Figure 9 Example Reflow Oven Profile - Lead-Free (SAC305)



Reflow Results

Probe	Positive Slope (°F/sec)	Positive Slope Time (mm:ss.t)	Time Above Liquidus (361.4°F) (mm:ss.t)	Peak Temperature (°F)	Delta T (°F)
#1 (°F)	12.98	02:54.6	00:00.0	352.4	36.0
#2 (°F)	18.46	02:58.5	00:07.8	388.4	
#3 (°F)	***	***	00:00.0	***	

Figure 10 Example Wave Solder Profile - Lead-Free (SN100C)

Table 10 Component Finish Matrix – Lead-Free Rework (Batch A)

RefDes	Component	Original Component Finish	Reflow Solder	Wave Solder	New Component Finish	Rework Solder	Rework Profile
U18	BGA-225	SAC405	SAC305		SAC405	SnPb	Lead-Free
U43	BGA-225	SAC405	SAC305		SAC405	SnPb	
U06	BGA-225	SAC405	SAC305		SAC405	SnPb	
U02	BGA-225	SAC405	SAC305		SAC405	Flux Only	
U21	BGA-225	SAC405	SAC305		SAC405	Flux Only	
U56	BGA-225	SAC405	SAC305		SAC405	Flux Only	
U33	CSP-100	SAC105	SAC305		SAC105	SnPb	
U50	CSP-100	SAC105	SAC305		SAC105	Flux Only	
U19	CSP-100	SAC105	SAC305		SAC105	Flux Only	
U37	CSP-100	SAC105	SAC305		SAC105	Flux Only	
U42	CSP-100	SAC105	SAC305		SAC105	SnPb	
U60	CSP-100	SAC105	SAC305		SAC105	SnPb	
U11	PDIP-20	Sn		SN100C	Sn	SN100C	
U51	PDIP-20	Sn		SN100C	Sn	SN100C	
U12	TSOP-50	Sn	SAC305		Sn	SnPb	
U25	TSOP-50	Sn	SAC305		Sn	SnPb	
U24	TSOP-50	SnBi	SAC305		SnBi	SAC305	
U26	TSOP-50	SnBi	SAC305		SnBi	SAC305	

Reworked components are grouped by rework solder alloy and material (SnPb, Flux only, SAC305 and SN100C). The location performing the rework choose what order to rework the solder alloy and material groups, but must use the order indicated in Figure 11 for specific component locations within the solder alloy and material group. When reworking a component, the component was removed and replaced before moving on to the next component.

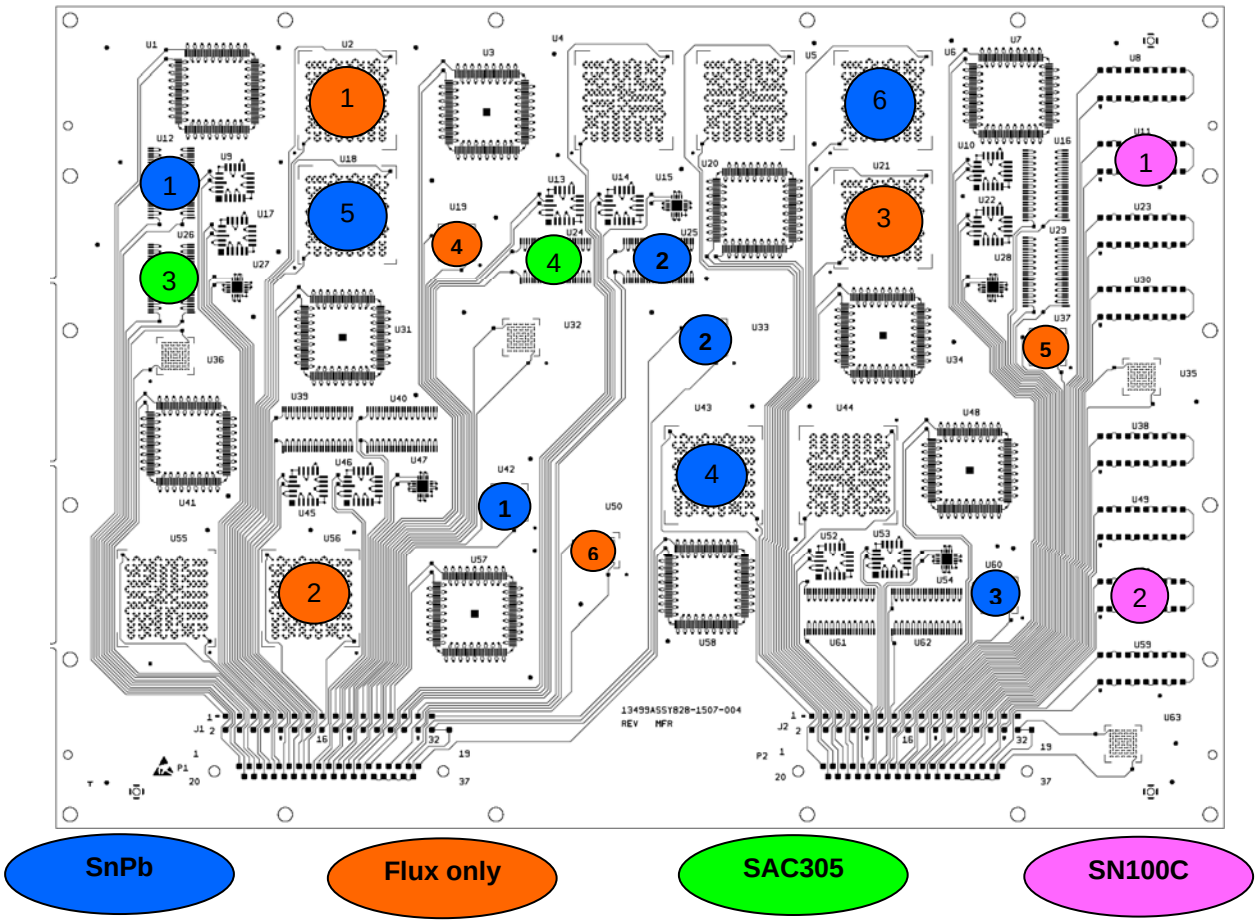
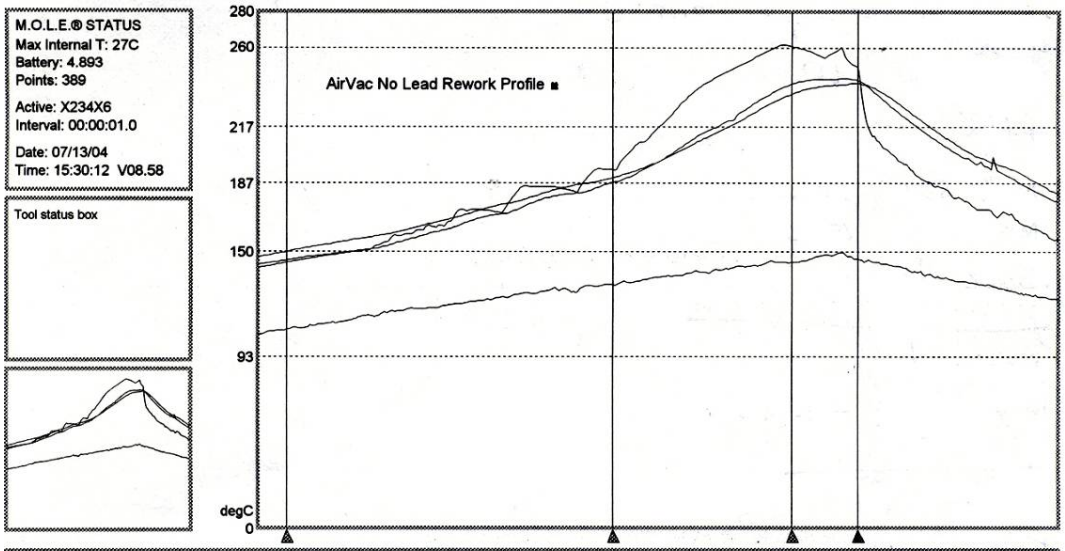


Figure 11 Rework Order = Batch A



	Value	C1 = 00:00:14r	C2 = 00:02:52r	C3 = 00:04:19r	C4 = 00:04:50r	Units
▫	open					
▪	t/c2 top of U2 body	146	194	261	249	degC
▪	board surface	108	132	144	146	degC
▪	t/c4 under U2 BGA in pad	150	190	235	241	degC
▫	open					
▪	t/c6 topside under U2	144	187	241	242	degC

	T Above Ref	Low = 150	Med = 217	Hi = 260	Cure Factor	Units
▫	open					
▪	t/c2 top of U2 body	00:05:44	00:01:41	00:00:14	0%	degC
▪	board surface	00:00:00	00:00:00	00:00:00	0%	degC
▪	t/c4 under U2 BGA in pad	00:06:14	00:01:37	00:00:00	0%	degC
▫	open					
▪	t/c6 topside under U2	00:05:43	00:01:36	00:00:00	0%	degC

	Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
▫	open							
▪	t/c2 top of U2 body	143	00:00:00r	262	00:04:13r	192.7	37.1	degC
▪	board surface	105	00:00:00r	149	00:04:41r	129.9	11.7	degC
▪	t/c4 under U2 BGA in pad	147	00:00:00r	241	00:04:46r	193.3	28.4	degC
▫	open							
▪	t/c6 topside under U2	141	00:00:00r	243	00:04:41r	190.9	31.4	degC

Figure 12 Example Lead-Free Rework Profile for area array components, removal and replacement

Tin-Lead Rework (Batch B)

Printed Wiring Boards

- 12.75”X 9”X 0.09” (without break-off coupon)
- 6 layers of 0.5 ounce copper
- FR4 per IPC-4101/26 with a minimum Tg of 170°C
- Immersion Ag and ENIG surface finishes
- Serial Numbers received: 139, 140, 141, 142, 143 and 158

Table 11 Component Finish Matrix – SnPb Rework Test Vehicles (Batch B)

RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U04	BGA-225	SAC405	SnPb	
U55	BGA-225	SAC405	SnPb	
U05	BGA-225	SAC405	SnPb	
U44	BGA-225	SAC405	SnPb	
U18	BGA-225	SnPb	SnPb	
U43	BGA-225	SnPb	SnPb	
U06	BGA-225	SnPb	SnPb	
U02	BGA-225	SnPb	SnPb	
U21	BGA-225	SnPb	SnPb	
U56	BGA-225	SnPb	SnPb	
U09	CLCC-20	SAC305	SnPb	
U13	CLCC-20	SAC305	SnPb	
U22	CLCC-20	SAC305	SnPb	
U46	CLCC-20	SAC305	SnPb	

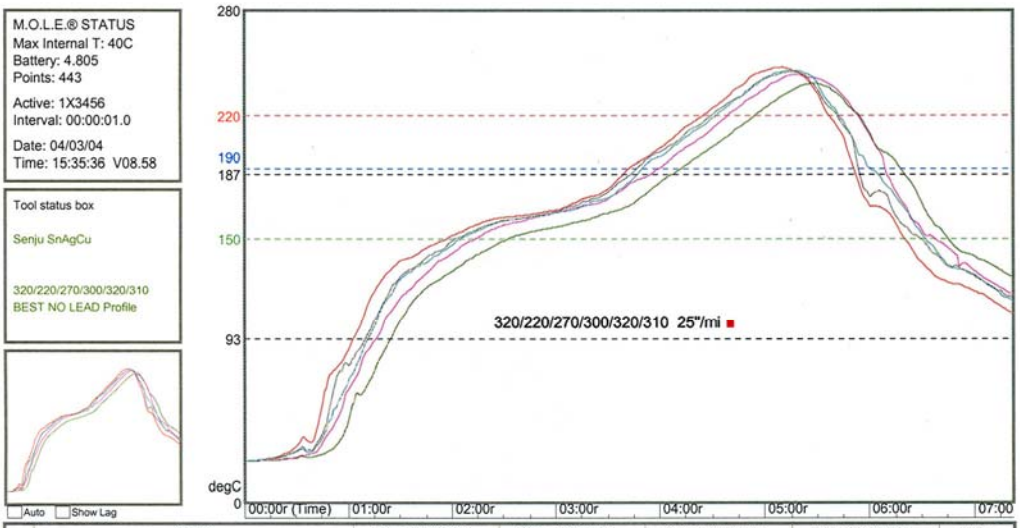
RefDes	Component	Component Finish	Reflow Solder Alloy	Wave Solder Alloy
U53	CLCC-20	SAC305	SnPb	
U10	CLCC-20	SAC305	SnPb	
U14	CLCC-20	SAC305	SnPb	
U17	CLCC-20	SAC305	SnPb	
U45	CLCC-20	SAC305	SnPb	
U52	CLCC-20	SAC305	SnPb	
U32	CSP-100	SAC105	SnPb	
U35	CSP-100	SAC105	SnPb	
U63	CSP-100	SAC105	SnPb	
U36	CSP-100	SAC105	SnPb	
U33	CSP-100	SnPb	SnPb	
U50	CSP-100	SnPb	SnPb	
U19	CSP-100	SnPb	SnPb	
U37	CSP-100	SnPb	SnPb	
U42	CSP-100	SnPb	SnPb	
U60	CSP-100	SnPb	SnPb	
U08	PDIP-20	NiPdAu		SnPb
U23	PDIP-20	NiPdAu		SnPb
U49	PDIP-20	NiPdAu		SnPb
U59	PDIP-20	Sn		SnPb
U30	PDIP-20	Sn		SnPb
U38	PDIP-20	Sn		SnPb
U11	PDIP-20	SnPb		SnPb
U51	PDIP-20	SnPb		SnPb
U15	QFN	Matte Sn	SnPb	
U27	QFN	Matte Sn	SnPb	
U28	QFN	Matte Sn	SnPb	
U47	QFN	Matte Sn	SnPb	
U54	QFN	Matte Sn	SnPb	
U03	TQFP-144	NiPdAu	SnPb	
U31	TQFP-144	NiPdAu	SnPb	
U34	TQFP-144	NiPdAu	SnPb	
U48	TQFP-144	NiPdAu	SnPb	
U57	TQFP-144	NiPdAu	SnPb	
U01	TQFP-144	SnPb Dip	SnPb	
U07	TQFP-144	SnPb Dip	SnPb	
U20	TQFP-144	SnPb Dip	SnPb	
U41	TQFP-144	SnPb Dip	SnPb	
U58	TQFP-144	SnPb Dip	SnPb	
U29	TSOP-50	Sn	SnPb	
U39	TSOP-50	Sn	SnPb	
U61	TSOP-50	Sn	SnPb	
U16	TSOP-50	SnBi	SnPb	
U40	TSOP-50	SnBi	SnPb	
U62	TSOP-50	SnBi	SnPb	
U12	TSOP-50	SnPb	SnPb	
U25	TSOP-50	SnPb	SnPb	
U24	TSOP-50	SnPb	SnPb	
U26	TSOP-50	SnPb	SnPb	

Assembly Details

Project consortia members agreed to use higher temperature lead-free reflow and wave soldering profiles in conjunction with tin-lead solder alloys for the tin-lead Rework Test Vehicles only. The intention of the higher temperature was to ensure complete mixing of the tin-lead solder paste with the tin-silver-copper BGA balls. Theoretically, this maximizes reliability. Incomplete solder mixing with lead-free solder balls attached with tin-lead solder using a tin-lead reflow profile is known to result in reduced reliability for area array components.

- Reflow Soldering
- Location - BAE Systems Irving, Texas
- Reflow Profile = SAC305
  - Preheat = 60-120 seconds @150-190°C
  - Peak temperature target = 243°C
  - Reflow:~20 seconds above 230°C
  - ~30-90 seconds above 220°C
- Wave Soldering
- Location - BAE Systems Irving, Texas

- Wave Profile = SN100C
  - Solder Pot Temperature = 265°C
  - Preheat Board T = 134°C
  - Peak Temperature = 157°C
  - Speed: 90 cm/min

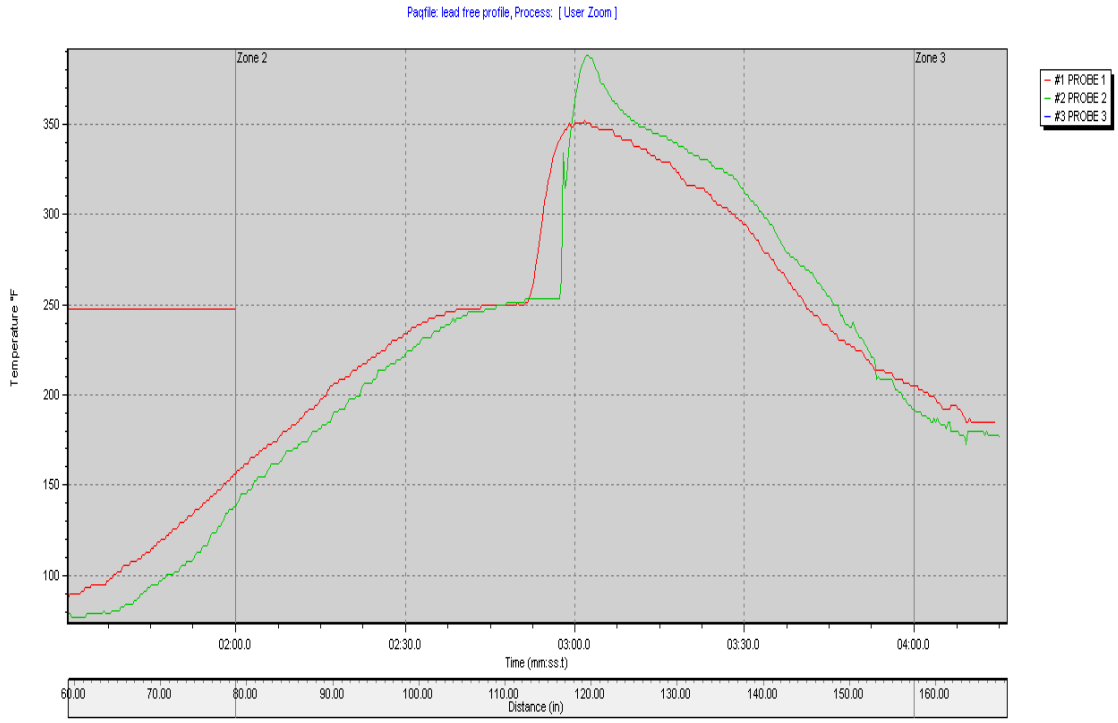


Value	C1 = 00:02:13r	C2 = 00:03:59r	C3 = 00:04:38r	C4 = 00:05:53r	Units
t/c11topside U41	158	201	230	183	degC
t/c2 under U44 BGA					
t/c24 topside U44	141	182	208	221	degC
t/c4 under U2 BGA	150	190	219	220	degC
t/c5 topside U57	154	197	225	198	degC
t/c6 topside U2	155	199	227	191	degC

T Above Ref	Low = 150	Med = 190	Hi = 220	Cure Factor	Units
t/c11topside U41	00:04:23	00:02:09	00:01:12	0%	degC
t/c2 under U44 BGA					
t/c24 topside U44	00:04:13	00:02:06	00:01:00	0%	degC
t/c4 under U2 BGA	00:04:25	00:02:10	00:01:15	0%	degC
t/c5 topside U57	00:04:27	00:02:11	00:01:11	0%	degC
t/c6 topside U2	00:04:29	00:02:08	00:01:13	0%	degC

Statistics	Minimum	Minimum X	Maximum	Maximum X	Average	Std Deviation	Units
t/c11topside U41	23	00:00:00r	248	00:05:10r	155.4	60.2	degC
t/c2 under U44 BGA							
t/c24 topside U44	23	00:00:00r	238	00:05:26r	148.2	63.2	degC
t/c4 under U2 BGA	24	00:00:00r	243	00:05:15r	153.1	63.2	degC
t/c5 topside U57	24	00:00:00r	246	00:05:12r	154.1	62.0	degC
t/c6 topside U2	23	00:00:00r	245	00:05:13r	154.4	61.0	degC

Figure 13 Example Reflow Oven Profile – Lead-Free (SAC305), being used for SnPb Rework Assemblies



Reflow Results

Probe	Positive Slope (°F/sec)	Positive Slope Time (mm:ss.t)	Time Above Liquidus (361.4°F) (mm:ss.t)	Peak Temperature (°F)	Delta T (°F)
#1 (°F)	12.98	02:54.6	00:00.0	352.4	36.0
#2 (°F)	18.46	02:58.5	00:07.8	388.4	
#3 (°F)	***	***	00:00.0	***	

Figure 14 Example Wave Solder Profile – Lead-Free (SN100C), being used for SnPb Rework Assemblies

Table 12 Component Finish Matrix – SnPb Rework (Batch B)

Ref-Des	Compo-nent	Original Compo-nent Finish	Reflow Solder	Wave Solder	New Component Finish	Rework Solder	Rework Profile
U18	BGA-225	SnPb	SnPb		SAC405	SnPb	SnPb
U43	BGA-225	SnPb	SnPb		SAC405	SnPb	
U06	BGA-225	SnPb	SnPb		SAC405	SnPb	
U02	BGA-225	SnPb	SnPb		SnPb	Flux Only	
U21	BGA-225	SnPb	SnPb		SnPb	Flux Only	
U56	BGA-225	SnPb	SnPb		SnPb	Flux Only	
U33	CSP-100	SnPb	SnPb		SAC105	SnPb	
U50	CSP-100	SnPb	SnPb		SnPb	Flux Only	
U19	CSP-100	SnPb	SnPb		SnPb	Flux Only	
U37	CSP-100	SnPb	SnPb		SnPb	Flux Only	
U42	CSP-100	SnPb	SnPb		SAC105	SnPb	
U60	CSP-100	SnPb	SnPb		SAC105	SnPb	
U11	PDIP-20	SnPb		SnPb	Sn	SnPb	
U51	PDIP-20	SnPb		SnPb	Sn	SnPb	
U12	TSOP-50	SnPb	SnPb		SnPb	SnPb	
U25	TSOP-50	SnPb	SnPb		SnPb	SnPb	
U24	TSOP-50	SnPb	SnPb		Sn	SnPb	
U26	TSOP-50	SnPb	SnPb		Sn	SnPb	

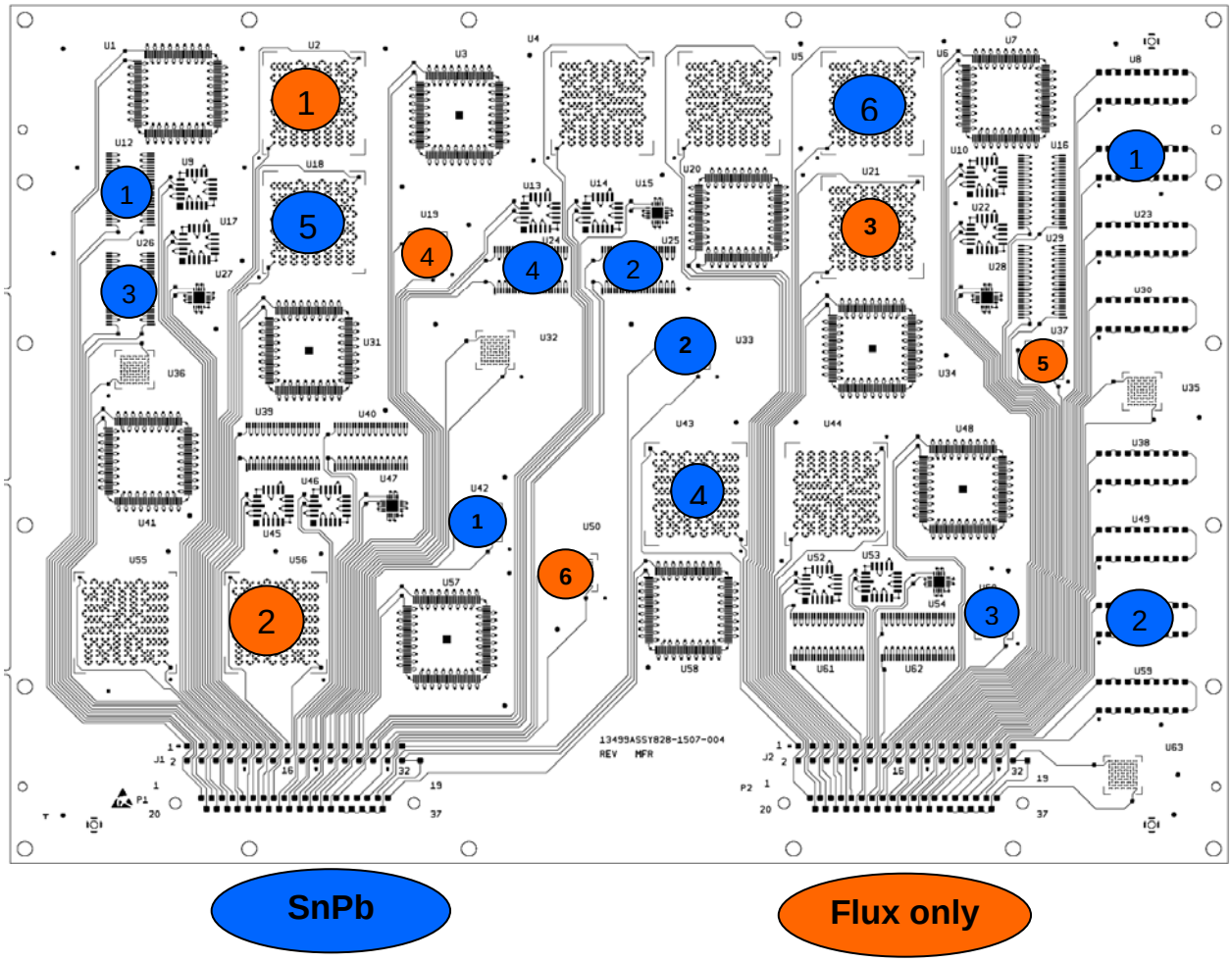
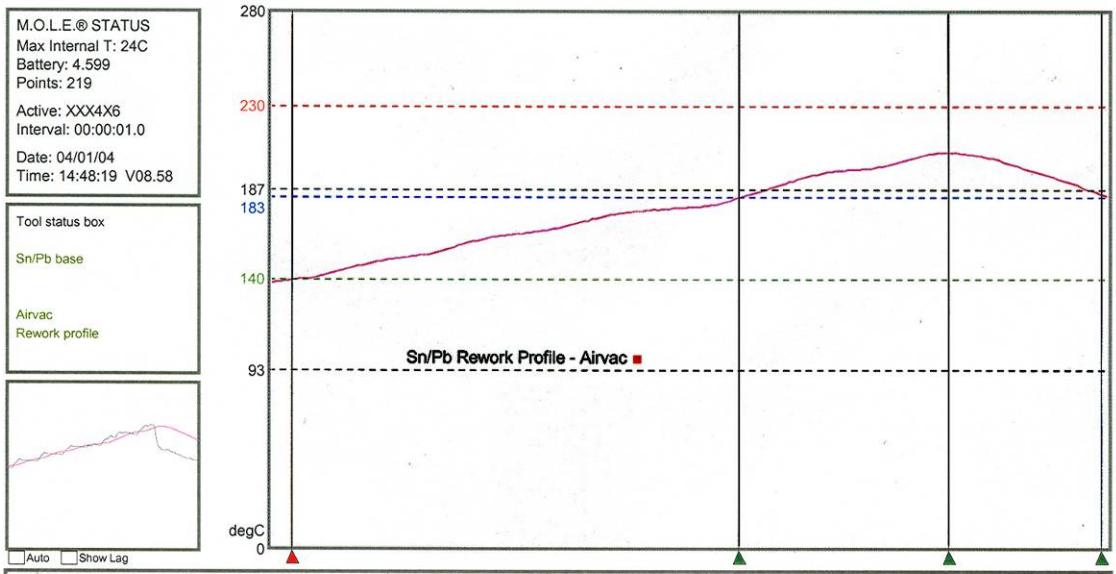


Figure 15 Rework Order = Batch B



	Value	C1 = 00:00:06r	C2 = 00:02:02r	C3 = 00:02:56r	C4 = 00:03:35r	Units
	open					
	open					
	open					
	t/c4 under U2 BGA	140	183	206	184	degC
	open					
	t/c6 topside U2					

	T Above Ref	Low = 140	Med = 183	Hi = 230	Cure Factor	Units
	open					
	open					
	open					
	t/c4 under U2 BGA	00:03:32	00:01:36	00:00:00	0%	degC
	open					
	t/c6 topside U2					

Figure 16 Example SnPb Rework Profile for area array components, removal and replacement

- Lead-Free rework profile for area array removal and replacement
  - Device joint target = 240°C ± 5°C
  - Device top max target = 260°C
  - Board max = as measured by the board trigger thermocouple; will be recorded
  - Reflow:
  - ~60 - 120 seconds @ 170-205°C
  - ~60 - 120 seconds above liquidus of alloy
  - Delta T from center to corner ball = 10°C
  - Ramp rate ≤ 4°C/sec

Thermal Aging, 100°C for 24 hours

A thermal aging procedure was selected to establish a common starting "state" for the test vehicles in terms of solder joint microstructure, printed wiring board stress state, surface finish oxidation condition, and intermetallic phase formation/thickness. Project consortia members preferred to have the test vehicles begin the various testing procedures with a common starting "state" in order to eliminate potential assembly differences which could inadvertently affect the test results. The chosen thermal aging procedure was not intended to represent the various burn-in, bake-out, operational field life or other environmental stress screening (ESS) procedures that are used to evaluate electronics hardware. Several ESS procedures and operational field expectations exist in the high performance electronics industry; meaning, a "standard" thermal aging procedure does not exist that would suit all electronic applications. Therefore, this is not a true life test for all consumer or military electronics.

Assembly Irregularities

Chip Scale Package (CSP-100)

Prior to test execution a drafting error in the CSP components was revealed that would affect continuity readings and data collection. The wrong component configuration was implemented during test vehicle drafting. Please note that all CSP components on the test vehicles only have continuity in the outside solder balls. The traces needed to interconnect internal rows of balls to the outside row of balls were not implemented on the test vehicles, Figure 17. A solder joint failure on a CSP component having this configuration will not be recorded by an event detector until both sides of the continuity loop break to record the "event", see Figure 17. Data collected for these components will be analyzed separately

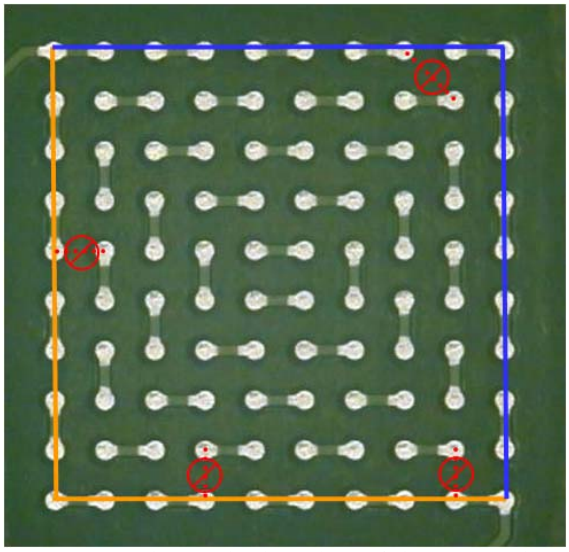


Figure 17 Shows the location of the traces that are missing for the CSP component.

Quad Flat No Leads (QFN-20), Location U15

Prior to test execution another drafting error was revealed. A QFN-20, board location U15, was missing the wire trace, see Figure 18. During drafting, the trace was not included on the test vehicle drawing. Test data cannot be collected for this component; therefore, no conclusions or comparable data can be used regarding lead-free solder reliability for this component. Jumper wires were considered for thermal cycle testing. The project consortia decided installing a jumper wire to the U15 component was not feasible for combined environments testing or for some of the other testing in the lead-free solder test plan.

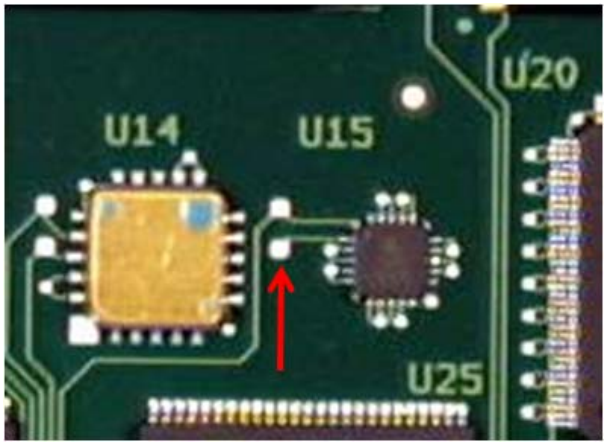


Figure 18 Missing trace of QFN-20, component U15

Test Plan

Electrical Continuity Test

An event detector (Anatech or equivalent conforming to IPC-SM-785) was used to monitor the electrical continuity of each channel on the test vehicles. The Anatech detects solder joint failures that occur during testing and records it as an "event". The failure criteria measured by the event detector will be 10 events per channel with an interruption of electrical continuity (≥ 1,000Ω) for periods greater than 0.2 μsec per IPC-SM-785.

Combined Environments Test

The combined environments test (CET) was based on MIL-STD-810F, Method 520.2 and a modified Highly Accelerated Life Test (HALT), a process that subjects products to accelerated environments to find weak links in the design and/or manufacturing process. The purpose of the CET was to determine the reliability of solder alloys subjected to combined thermal cycle and vibration environmental exposures. The limits identified in CET will be used to compare performance differences in the lead-free test alloys vs. the baseline standard tin-lead alloy. The project stakeholders felt that combined environments testing would provide comparative potential reliability differences in the test alloys versus the tin-lead baseline in a shorter period of time.

HALT Chamber

The CET was conducted using a QualMark Model OVS-4 HALT/HASS chamber. The chamber is located in the Raytheon Environmental Test Laboratory (ETL) in McKinney, Texas. A photograph of the chamber is provided in Figure 19. The chamber utilizes liquid nitrogen for cooling and nichrome heater elements for heating. The chamber has a thermal capability range from -100 to 200 degrees Celsius with ramp rates up to 60 degrees Celsius per minute. The pseudorandom vibration spectra are generated by pneumatically driven vibrators attached to the bottom of the table with a maximum level of approximately 60 g_{rms}. The thermal and vibration environments can be applied separately or combined. Refer to page 238 for the vibration profiles between 10 g_{rms} and 55 g_{rms}.

Test Profile

The combined environments test was performed utilizing a temperature range of -55 to 125 degrees Celsius with 20 degree Celsius per minute ramps. The dwell times at each temperature extreme are the times required to stabilize the test sample plus a 15-minute soak. Pseudorandom vibration began at 10 g_{rms} and was applied during the entire thermal cycle for the first 50 cycles, the vibration levels were incremented by 5 g_{rms} until a maximum of 55 g_{rms} was reached or 50 to 63% of total components had failed, which ever occurred first. The test profile is graphically represented in Figure 20. This process was repeated until a significant number of solder joints failed 500 cycles was reached. After 500 cycles, testing continued for an additional 150 cycles at 55 g_{rms} because 50 to 63% failures were not achieved. Testing was stopped after 650 cycles for both runs of testing. The additional cycles helped obtain statistically significant Weibull plots indicating relative solder joint reliability.

Figure 19 QualMark Model OVS-4 HALT/HASS Chamber

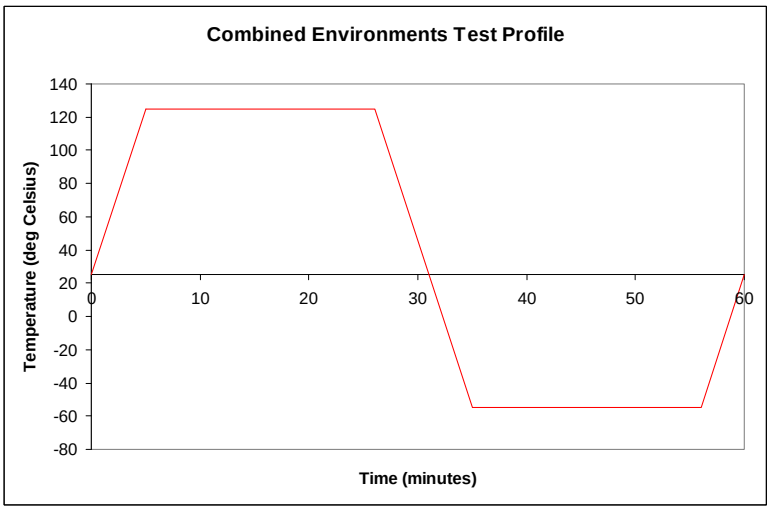


Figure 20 Initial Combined Environments Test Profile

Test Execution

The test vehicles were inspected by a Materials and Process Engineer. Ribbon cables were manually soldered to the test vehicle ports, P1 and P2, plated-through holes using eutectic tin-lead solder. Epoxy adhesive was used to bond the ribbon cables to the test vehicles to provide strain relief to the ribbon cable solder joints.

ETL personnel can run 15 test vehicles in the chamber at once. The test vehicles were tested in two groups: manufactured and rework test vehicles. The manufactured test vehicles were tested first followed by twelve rework test vehicles. The rework set included one manufactured test vehicle, SN 97, which is one of two ENIG board finish test vehicles. ETL fabricated aluminum holding fixtures that hold nine test vehicles in the first level and six test vehicles on the second level, Figure 21. The test vehicles were loaded onto the fixtures in random order, documented by Figure 22.

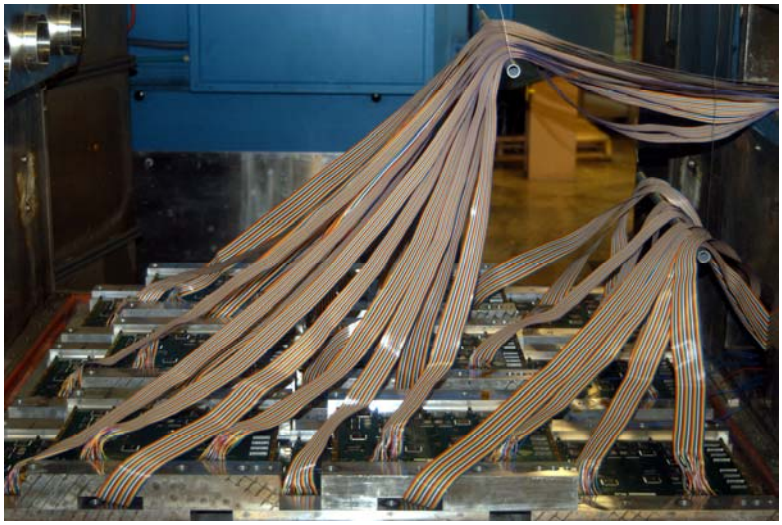


Figure 21 Photograph of Test Vehicles in Test Chamber

Manufactured Test Set-up		
Bottom Layer		
23	69	71
118	22	120
73	20	24

Rework Test Set-up		
Bottom Layer		
181	140	142
158	139	183
163	143	97

Top Layer	
116	72
21	70
119	117

Top Layer	
180	N/A
182	N/A
141	N/A

Monitored with accelerometer
Monitored with Anatechs' thermocouple

Figure 22 Manufactured and Rework Test Chamber Set-up

Results and Discussion

Pretest Inspection

The manufactured and rework test vehicles were inspected per J-STD-001, Class 3 requirements by a Materials and Process Engineer. Overall, the manufactured test vehicles did not have any significant quality issues or concerns. The solder joint appearance was acceptable and did not have the grainy appearance documented in the previous JCAA/JGPP testing. Similarly, the rework test vehicles solder joints were acceptable. The difference between the rework test vehicles and manufactured test vehicles was the physical damage to a few of the reworked test vehicles. For example, one test vehicle had a burned area on the PWB laminate from the thermal cycling process applied to the test vehicles prior to combined environments testing. The inspector's findings and comments were documented in the Pretest Inspection Logs found in page 140.

Manufactured Test Vehicles

The manufactured test vehicles were found to have acceptable solder wetting, sufficient solder, and proper part alignment. No test vehicle was found to have solder balls or bridging. The test vehicles were free of flux residue and the solder appearance and PTH wetting and fillet appearance were acceptable.

The following anomalies were noted:

- SN 23 – Board warped by 0.277 inch off the table from the bottom right corner.
- SN 97 – Board warped at the bottom left, not measured.
- SN 120 – Board warped by 0.350 inch off the table from the bottom right corner.

Rework Test Vehicles

Due to the complexity of the multiple rework performed on the test vehicles there are additional observations recorded on the Pretest Inspection forms than with the manufactured pretest inspection. Some of the rework test vehicles were found to have solder balls on the back side of components near the rework locations. And some test vehicles were found to have small areas of delamination near rework sites as well.

The following anomalies were noted:

- SN 139 – Board was cut beyond the dimensions along the left side, some hardware holes were sliced.
- SN 141 – Board was cut beyond the dimensions along the left side, some hardware holes were sliced.
- SN 142 – Board was cut beyond the dimensions along the left side, some hardware holes were sliced.
- SN 180 – Vias were completely filled in ports P1 and P2.
- SN 182 – Board warped at the bottom left, not measured, very minor.
- SN 183 – Board warped at the bottom left, not measured

Please refer to the Pretest Inspections logs on page 140 for detailed notes of the rework test vehicles.

Manufactured Test Vehicles Results and Discussion

The manufactured test vehicles were tested for a total of 650 cycles. The raw data is tabulated on page 112. Events or failures logged at ten cycles or less were deemed outliers by a team consensus and were excluded in the data analysis. The team decided that early life failures were due to a manufacturing or test anomaly. Therefore, the outliers were removed to prevent skewing the data analysis results, but a second Weibull plot was used to compare the changes between the charts including the outliers. All test vehicles were inspected for lead damage and broken wires at the conclusion of testing.

The data was compiled by test vehicle serial number, component type, and component finish, see Table 13. The data suggests test vehicles 23, 97, 116 and 69 exhibited less than twenty (20) failed components compared to the other test vehicles. This observation suggests these test vehicles may have experienced lower thermal and/or vibration stresses during testing due to the location of the test vehicles in the chamber. See Figure 22 for the manufactured and rework test chamber set-up.

Table 13 Number of Failed Components by Manufactured Test Vehicle

Board Finish	Compo-nent	Finish	Solder	20	21	22	23	24	69	70	71	72	73	97	116	117	118	119	120	Total
ENIG	BGA-225	SAC405	SAC305											0						**0**
		SnPb	SAC305											5						**5**
	CLCC-20	SAC305	SAC305											3						**3**
		SnPb	SAC305											3						**3**
	CSP-100	SAC105	SAC305											0						**0**
		SnPb	SAC305											0						**0**
	PDIP-20	Sn	SN100C											0						**0**
	PTH	ENIG	SN100C											0						**0**
	QFN-20	Matte Sn	SAC305											1						**1**
	TQFP-144	Matte Sn	SAC305											0						**0**
		SnPb Dip	SAC305											0						**0**
	TSOP-50	SnBi	SAC305											1						**1**
		SnPb	SAC305											1						**1**
ENIG Total														**14**						**14**
ImAg	BGA-225	SAC405	SAC305						1	3	0	0	5							**9**
			SN100C												1	5	3	5	5	**19**
			SnPb	5	4	5	4	5												**23**
		SnPb	SAC305						1	5	5	5	5							**21**
			SN100C												2	5	5	5	5	**22**
			SnPb	5	1	3	1	5												**15**
	CLCC-20	SAC305	SAC305						5	5	4	5	5							**24**
			SN100C												4	5	5	5	5	**24**
			SnPb	5	5	5	3	5												**23**
		SnPb	SAC305						5	5	5	5	5							**25**
			SN100C												4	4	4	5	5	**22**
			SnPb	5	5	5	2	4												**21**
	CSP-100	SAC105	SAC305						0	1	3	1	3							**8**
			SN100C												0	4	2	4	1	**11**
			SnPb	3	4	5	1	4												**17**
		SnPb	SAC305						0	0	1	2	2							**5**
			SN100C												0	3	1	0	3	**7**
			SnPb	1	1	0	0	2												**4**
	PDIP-20	NiPdAu	SN100C												0	0	0	0	0	**0**
			SnPb	0	0	0	0	0												**0**
		Sn	SN100C						0	0	0	0	0		0	0	4	1	0	**5**
			SnPb	0	0	0	0	0												**0**
	PTH	ImAg	SN100C						0	0	0	0	0		0	0	0	0	0	**0**
			SnPb	0	0	0	0	0												**0**
	QFN-20	Matte Sn	SAC305						1	1	1	1	1							**5**
			SN100C												1	2	1	4	2	**10**
			SnPb	1	1	1	1	1												**5**
	TQFP-144	Matte Sn	SAC305						0	3	0	0	3							**6**
			SN100C												0	3	3	4	3	**13**
			SnPb	2	2	1	1	2												**8**
		SnPb Dip	SAC305						0	0	0	0	0							**0**
			SN100C												0	2	5	5	3	**15**
			SnPb	0	2	0	0	0												**2**
	TSOP-50	SnBi	SAC305						3	5	5	5	5							**23**
			SN100C												3	5	5	5	5	**23**
			SnPb	4	3	5	0	4												**16**
		SnPb	SAC305						2	3	3	3	4							**15**
			SN100C												1	5	5	5	5	**21**
			SnPb	4	4	2	1	5												**16**
ImAg Total				**35**	**32**	**32**	**14**	**37**	**18**	**31**	**32**	**32**	**38**		**16**	**43**	**43**	**53**	**42**	**498**
Grand Total				**35**	**32**	**32**	**14**	**37**	**18**	**31**	**32**	**32**	**38**	**14**	**16**	**43**	**43**	**53**	**42**	**512**

The data was also segregated by component type, component finish and solder alloy, see Table 14. Test vehicles soldered with tin-lead solder had the fewest solder joint failures overall. Test vehicles soldered with tin-silver-copper solder were second best. Lastly, the test vehicles soldered with tin-copper solder paste had the worst performance.

Table 14 Number of Failed Components by Board Finish, Component, Component Finish and Solder Alloy on Manufactured Test Vehicles

Board Finish	Component	Finish	Solder	Number of Failed Components
ENIG	BGA-225	SAC405	SAC305	0% (0 of 5)
		SnPb	SAC305	100% (5 of 5)
	CLCC-20	SAC305	SAC305	60% (3 of 5)
		SnPb	SAC305	60% (3 of 5)
	CSP-100	SAC105	SAC305	0% (0 of 5)
		SnPb	SAC305	0% (0 of 5)
	PDIP-20	Sn	SN100C	0% (0 of 8)
	PTH	ENIG	SN100C	0% (0 of 1)
	QFN-20	Matte Sn	SAC305	20% (1 of 5)
	TQFP-144	Matte Sn	SAC305	0% (0 of 5)
		SnPb Dip	SAC305	0% (0 of 5)
	TSOP-50	SnBi	SAC305	20% (1 of 5)
		SnPb	SAC305	20% (1 of 5)
ENIG Total				**22% (14 of 64)**
ImAg	BGA-225	SAC405	SAC305	76% (19 of 25)
			SN100C	76% (19 of 25)
			SnPb	92% (23 of 25)
		SnPb	SAC305	84% (21 of 25)
			SN100C	88% (22 of 25)
			SnPb	60% (15 of 25)
	CLCC-20	SAC305	SAC305	96% (24 of 25)
			SN100C	96% (24 of 25)
			SnPb	92% (23 of 25)
		SnPb	SAC305	100% (25 of 25)
			SN100C	88% (22 of 25)
			SnPb	84% (21 of 25)
	CSP-100	SAC105	SAC305	32% (8 of 25)
			SN100C	44% (11 of 25)
			SnPb	68% (17 of 25)
		SnPb	SAC305	20% (5 of 25)
			SN100C	48% (12 of 25)
			SnPb	16% (4 of 25)
	PDIP-20	NiPdAu	SN100C	0% (0 of 28)
			SnPb	0% (0 of 20)
		Sn	SN100C	10% (5 of 52)
			SnPb	0% (0 of 20)
	PTH	ImAg	SN100C	0% (0 of 10)
			SnPb	0% (0 of 5)
	QFN-20	Matte Sn	SAC305	20% (5 of 25)
			SN100C	40% (10 of 25)
			SnPb	20% (5 of 25)
	TQFP-144	Matte Sn	SAC305	24% (6 of 25)
			SN100C	52% (13 of 25)
			SnPb	32% (8 of 25)
		SnPb Dip	SAC305	0% (0 of 25)
			SN100C	60% (15 of 25)
			SnPb	8% (2 of 25)
	TSOP-50	SnBi	SAC305	92% (23 of 25)
			SN100C	92% (23 of 25)
			SnPb	64% (16 of 25)
		SnPb	SAC305	60% (15 of 25)
			SN100C	84% (21 of 25)
			SnPb	64% (16 of 25)
ImAg Total				**52% (498 of 960)**
Grand Total				**50% (512 of 1024)**

The number of failed components by solder alloy on manufactured test vehicles, excluding ENIG data, is shown in Table 15. This shows the difference in solder joint reliability between surface mount technology and plated-through-hole technology; PTH components are more reliable.

Table 15 Number of Failed Components by Solder Alloy on Manufactured Test Vehicles excluding ENIG

Solder Alloy	Number of Failed SMT Components	Number of Failed PTH Components
SAC305	54.9% (151 of 275)	
SN100C	69.8% (192 of 275)	6.3% (5 of 80)
SnPb	54.5% (150 of 275)	0% (0 of 40)

The following sections provide the Weibull analysis for each component type.

BGA-225 Results and Discussion

The Weibull plot for tin-silver-copper 405 BGA-225 components soldered with tin-silver copper 305 solder paste is shown in Figure 23. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a poor fit of the data given some data points fall outside the confidence limits and the fitted line has a ρ (rho) value less than the desired 95-percent. There also appears to be a "stair step" in the data, approximately at 500 cycles, indicating possible changes in stresses applied to the test vehicle or multiple failure modes in the solder joint failures. The test logs were reviewed for potential chamber problems or test procedural issues. Yet, no common cause for the stair step could be identified. A similar stair step phenomena occurred in the previous JCAA/JG-PP Lead-Free Electronics study in 2005, where other project members reported observing this stair step in thermal cycle testing.

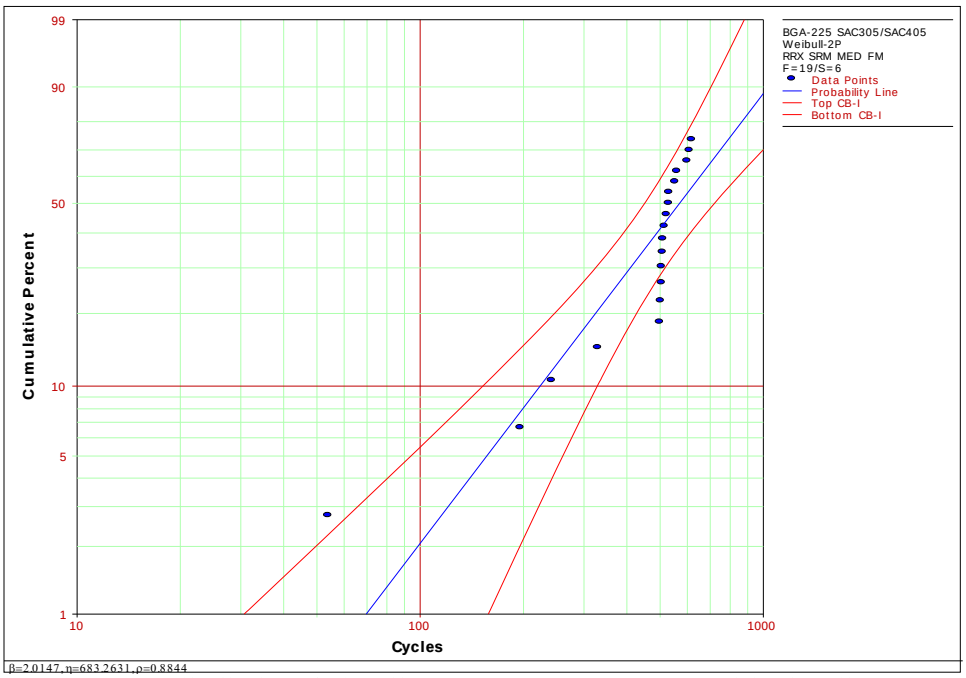


Figure 23 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-silver-copper 405 BGA-225 components soldered with tin-copper solder paste is shown in Figure 24. The 2-paramater Weibull plot is a good fit of the data since only two data points fall outside of the confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be a "stair step" in the data.

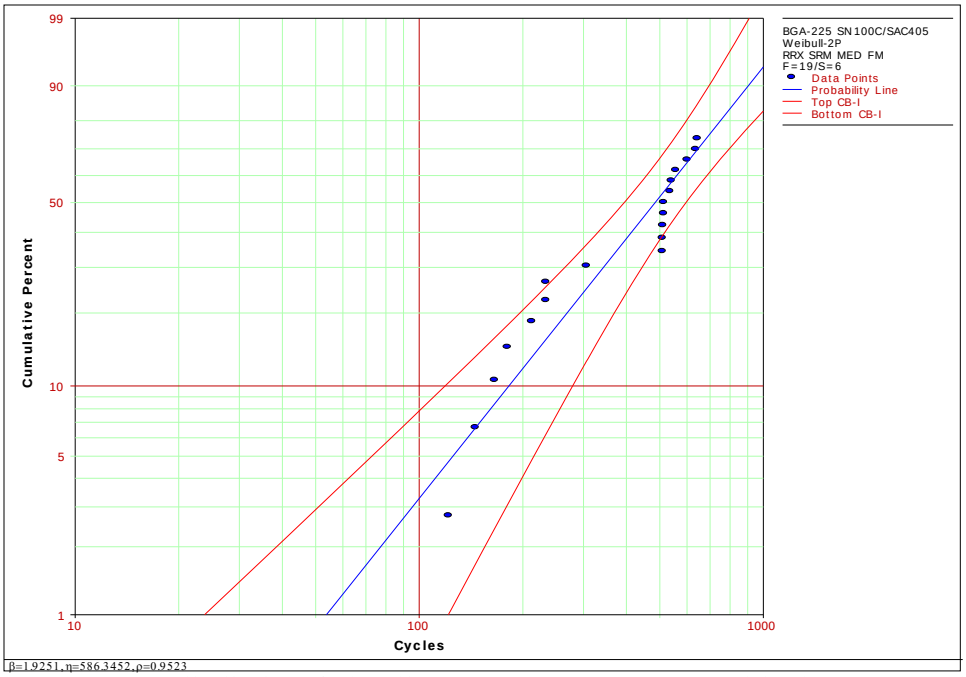


Figure 24 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste is shown in Figure 25. The 2-paramater Weibull plot is a good fit of the data since only one data point falls on the edge of the confidence limits approximately at 250 cycles. The fitted line has a ρ (rho) value of 95-percent. This plot also appears to have a "stair step" approximately at 150 cycles. There are no failures beyond 250 cycles for this data.

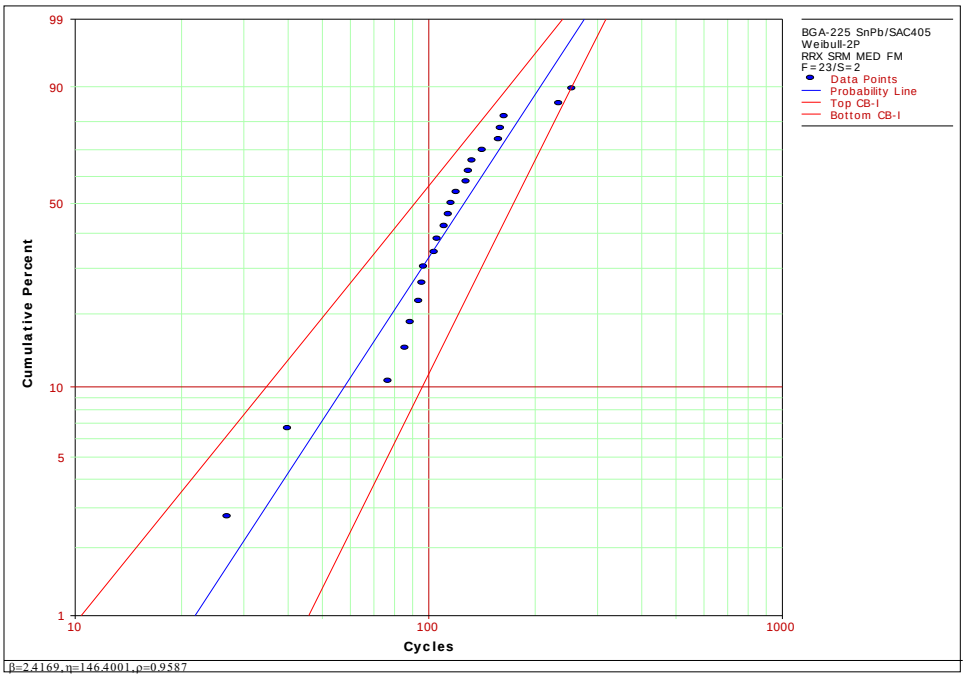


Figure 25 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead BGA-225 components soldered with tin-silver-copper 305 solder paste is shown in Figure 26. The 2-paramater Weibull plot is a good fit of the data since only two data points fall outside of the confidence limits. The fitted line has a ρ (rho) value of 97-percent. There also appears to be a "stair step" in the data.

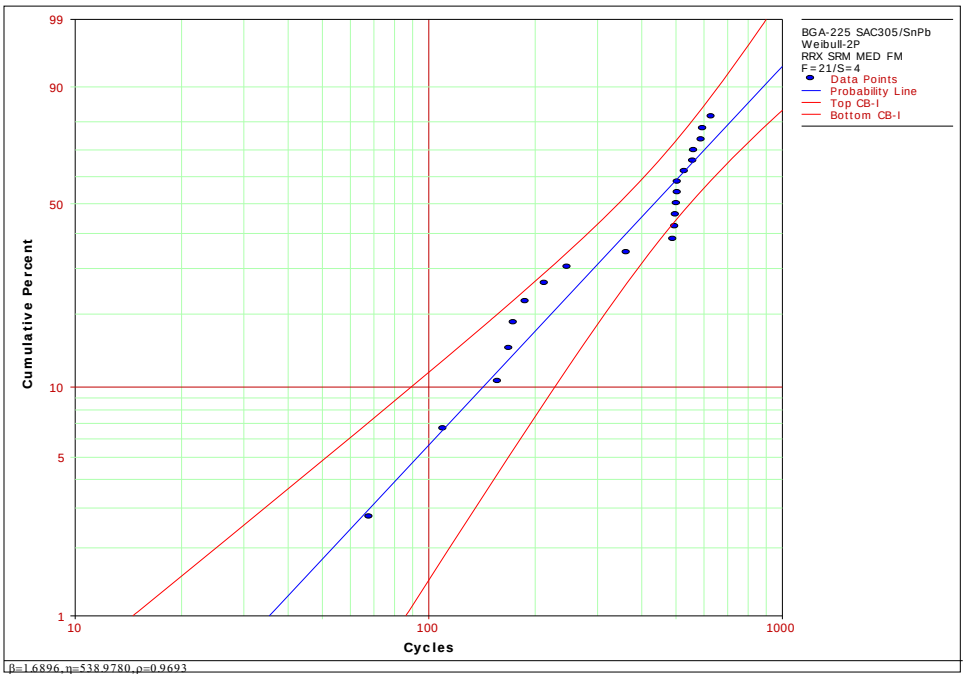


Figure 26 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead BGA-225 components soldered with tin-copper solder paste is shown in Figure 27. The 2-paramater Weibull plot is a good fit of the data, no one data point falls outside of the confidence limits. The fitted line has a ρ (rho) value of 96-percent. There also appears to be a "stair step" in the data. This data has an outlier which was removed and re-plotted in Figure 29 to show the change in slope of the probability line to the data. The same scale was used for both Weibull plots in Figure 27 and Figure 28 for comparative purposes.

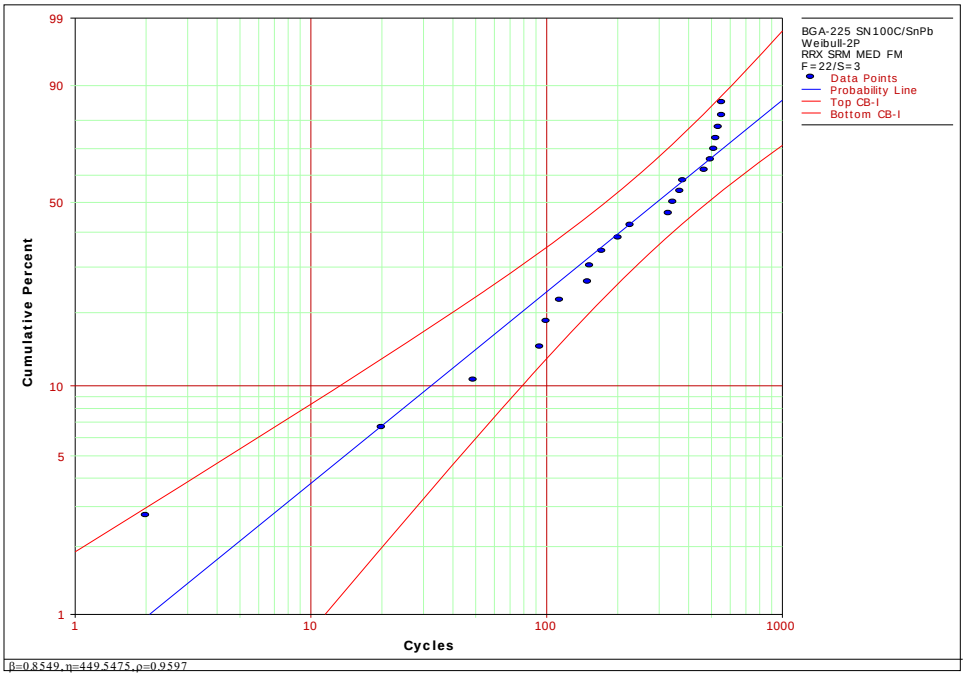


Figure 27 Weibull Plot of Tin-Lead BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The second Weibull plot for tin-lead BGA-225 components soldered with tin-copper solder paste is shown in Figure 28 less the outlier. This 2-paramater Weibull plot is an excellent fit of the data, no one data point falls outside of the confidence limits. The fitted line has a ρ (rho) value of 99-percent. There also appears to be two "stair steps" in the data.

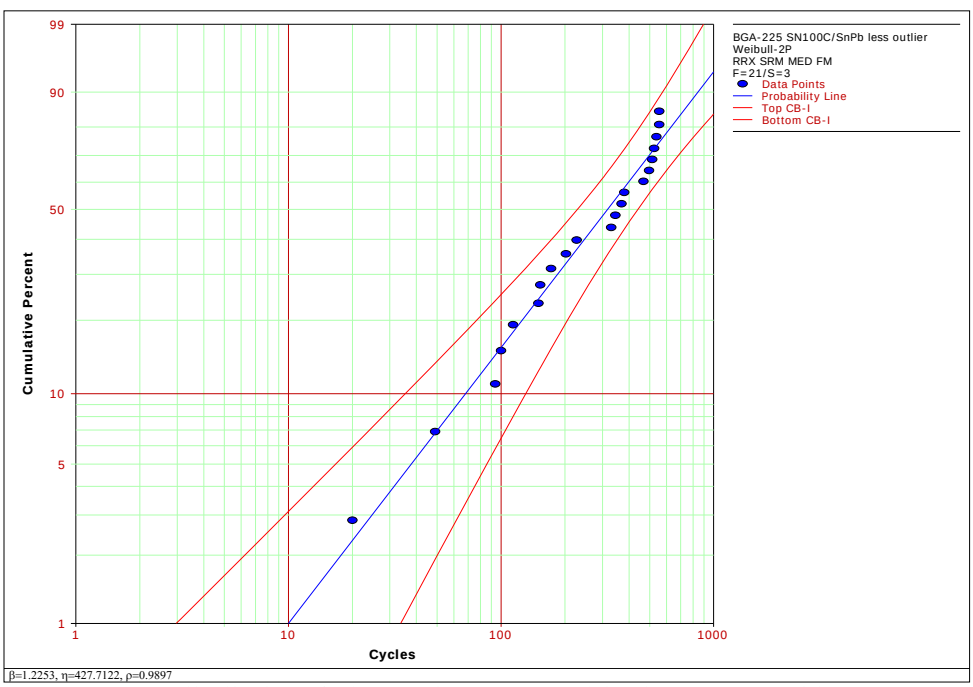


Figure 28 Weibull Plot of Tin-Lead BGA-225 with Tin-Copper Solder Paste on Manufactured Test Vehicles less one outlier

The Weibull plot of tin-lead BGA-225 components soldered with tin-lead solder paste is shown in Figure 29. This 2-paramater Weibull plot is an excellent fit of the data, no one data point falls outside of the confidence limits. The fitted line has a ρ (rho) value of 97-percent. There also appears to be a "stair step" in the data. This plot is also our baseline component behavior.

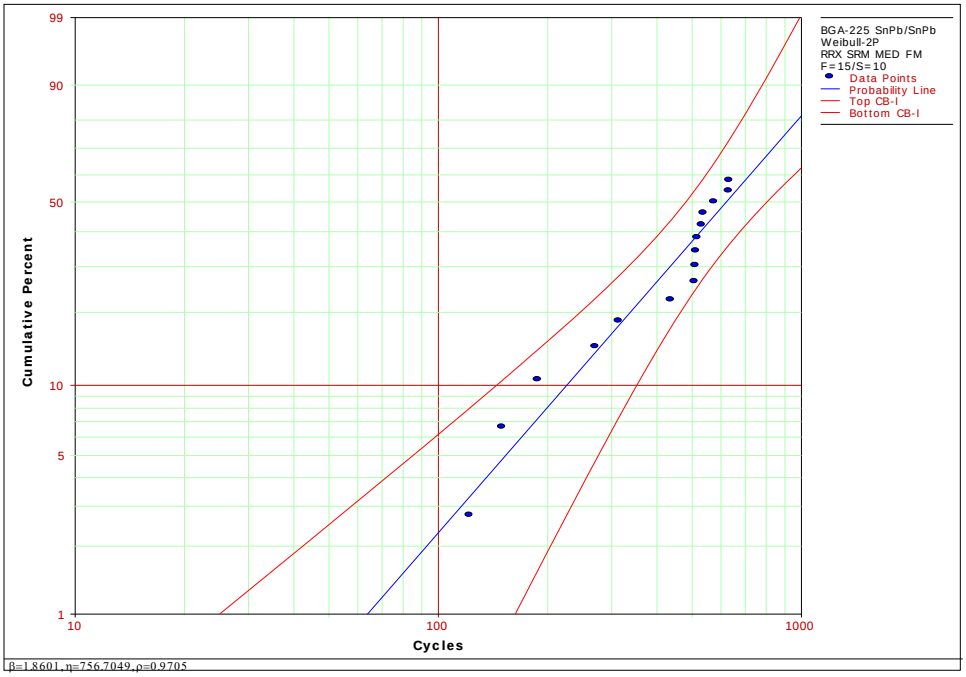


Figure 29 Weibull Plot of Tin-Lead BGA-225 with Tin-Lead Solder Paste on Manufactured Test Vehicles

Figure 30 shows all the combinations of component finish and solder alloy for BGA-225 components on the manufactured test vehicles. Overall, tin-lead BGA-225 components soldered with tin-lead solder paste were the most reliable. It can be determined that tin-silver-copper 405 BGA-225 components soldered with tin-silver-copper 305 solder paste combination and the tin-lead BGA-225 components soldered with tin-lead solder paste combination are almost equivalent based on these Weibull probability plots. The tin-silver-copper 405 BGA-225 components soldered with tin-copper solder paste combination came in second best and the tin-lead BGA-225 components soldered with tin-lead-copper 305 solder paste combination came in third.

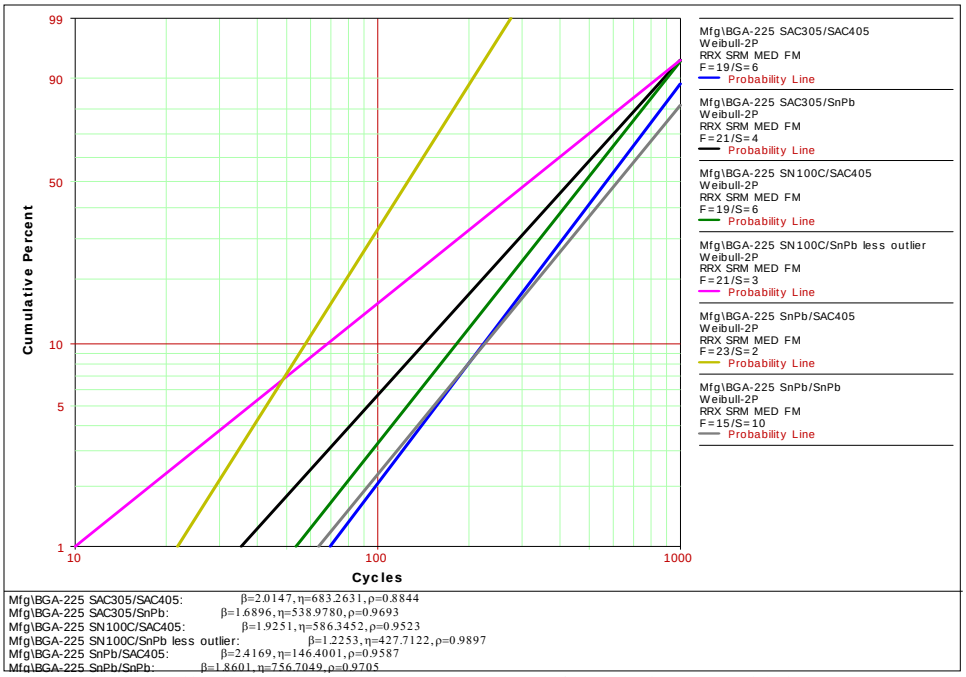


Figure 30 Weibull Plots of BGA-225 on Manufactured Test Vehicles

The effect of tin-lead contamination on tin-copper soldered BGA-225 components is shown in Figure 31. The plots show tin-lead degrades the early life performance of tin-copper solder. Both fitted lines have a ρ (rho) value above the desired 95-percent.

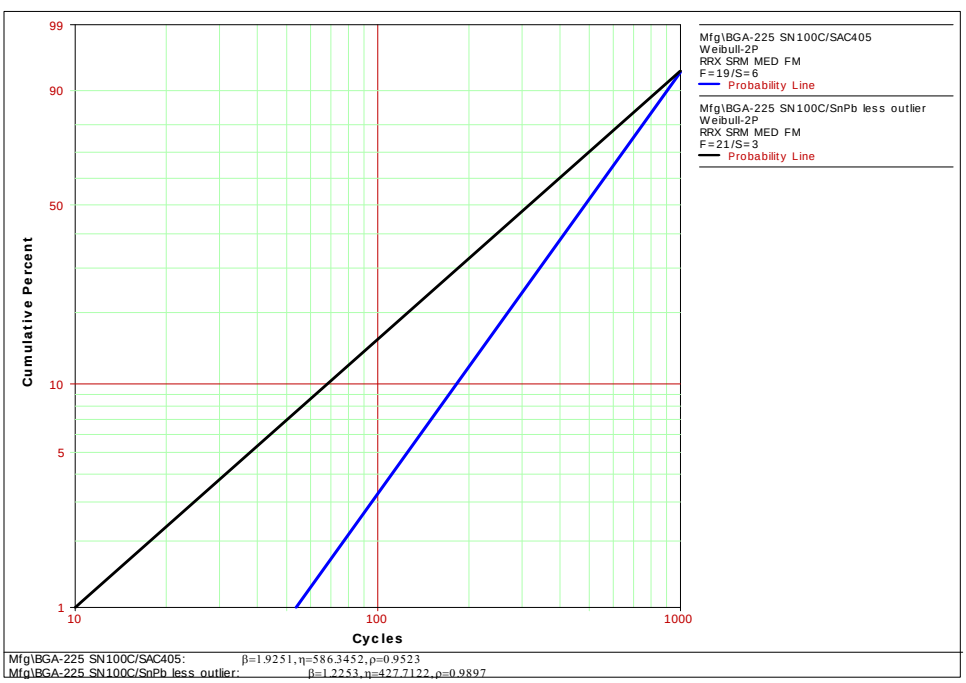


Figure 31 Effect of Tin-Lead Contamination on Tin-Copper Soldered BGA-225 on Manufactured Test Vehicles

The effect of tin-lead contamination on tin-silver-copper 305 soldered BGA-225 components is shown in Figure 32. The plots show tin-lead degrades the early life performance of tin-silver-copper solder. Though, it performs

slightly better than tin-lead contamination on tin-copper soldered BGA-225 components (Figure 31). The fitted lines have ρ (rho) values above and below the desired 95-percent.

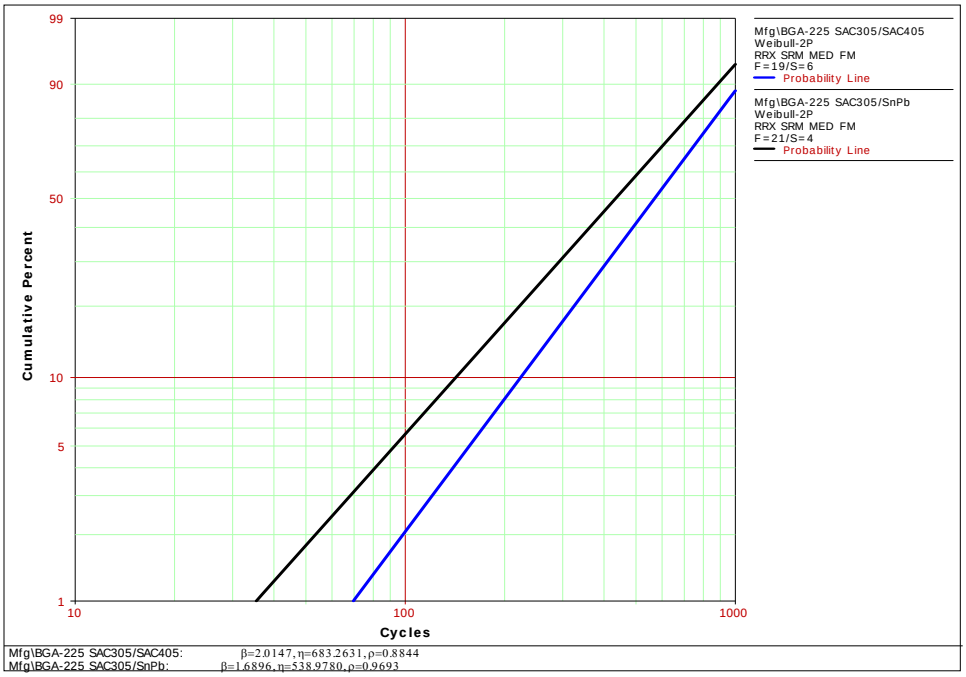


Figure 32 Effect of Tin-Lead Contamination on Tin-Silver-Copper 305 Soldered BGA-225 on Manufactured Test Vehicles

CLCC-20 Results and Discussion

The Weibull plot for tin-silver-copper 305 CLCC-20 components soldered with tin-silver copper 305 solder paste is shown in Figure 33. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a good fit of the data, given two data points fall outside the confidence limits. The fitted line has a ρ (rho) value of 97-percent. There also appears to be a "stair step" in the data, approximately at 500 cycles, indicating possible changes in stresses applied to the test vehicle or multiple failure modes in the solder joint failures. The test logs were reviewed for potential chamber problems or test procedural issues. Yet, no common cause for the stair step could be identified. A similar stair step phenomena occurred in the previous JCAA/JG-PP Lead-Free Electronics study in 2005, where other project members reported observing this stair step in thermal cycle testing.

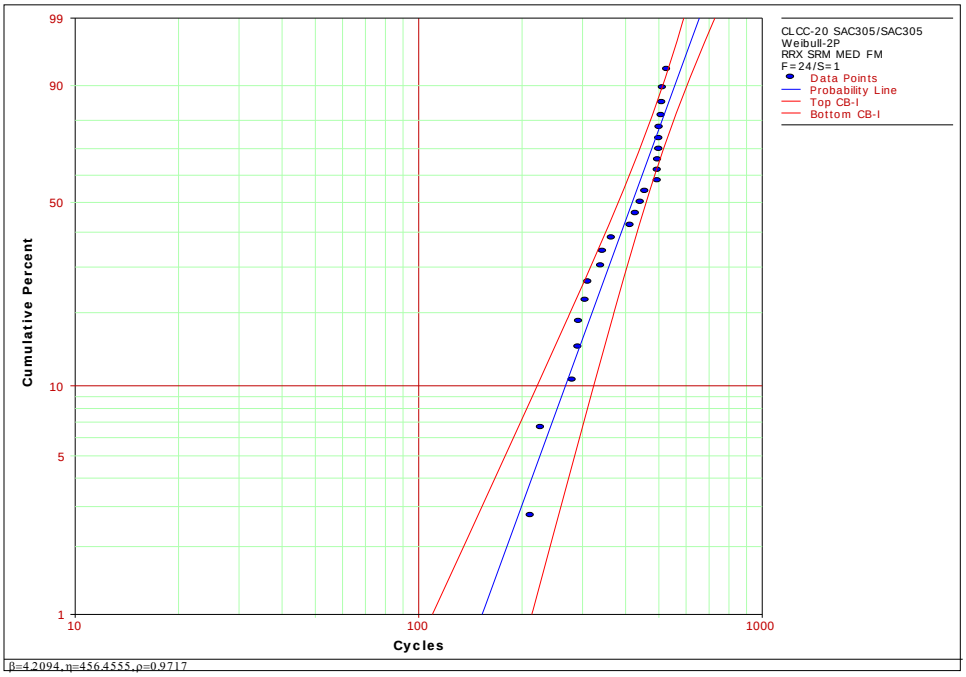


Figure 33 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-silver-copper 305 CLCC-20 components soldered with tin-copper solder paste is shown in Figure 34. The 2-parameter Weibull plot is a fair fit of the data, given two data points fall outside the confidence limits. The fitted line has a ρ (rho) value of 94-percent. The data point to the far left may be influencing the slope of the probability plot, therefore, skewing the resulting probability result. That data point may be removed as an outlier, but it is not an outlier based on the consortia's definition, therefore it stays. There also appears to be a "stair step" in the data.

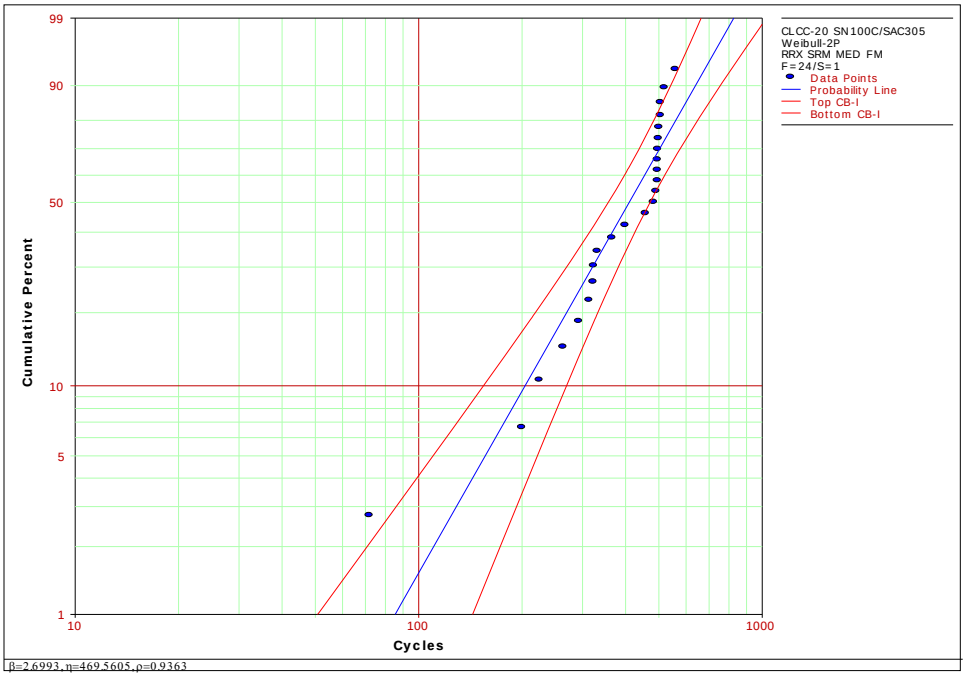


Figure 34 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste is shown in Figure 35. The 2-parameter Weibull plot is an excellent fit of the data, no one data point falls outside the confidence limits. The fitted line has a ρ (rho) value of 97-percent. There also appears to be a "stair step" in the data.

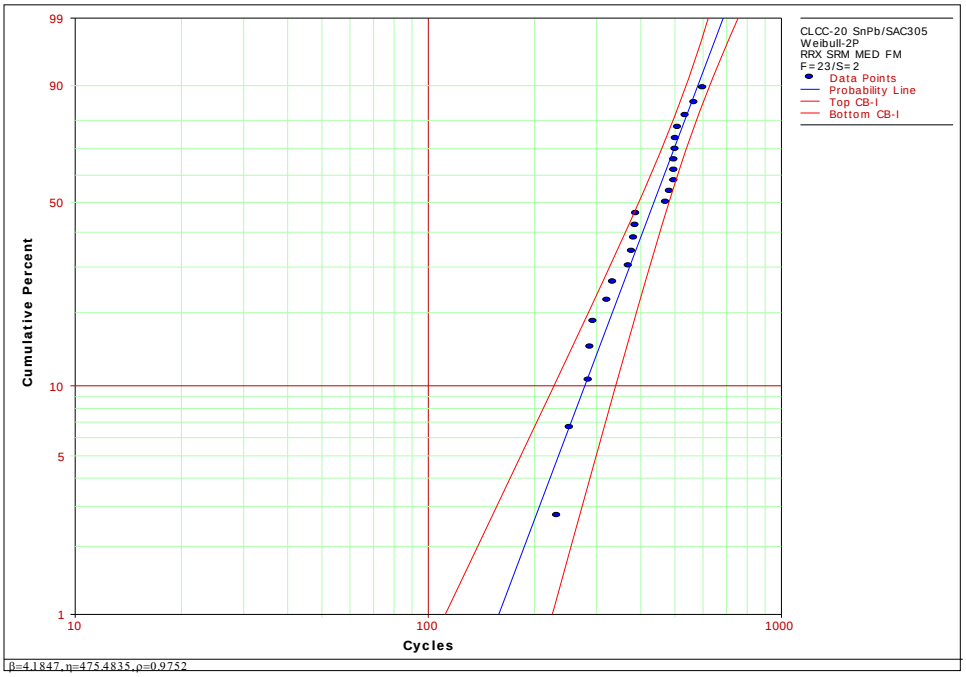


Figure 35 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste is shown in Figure 36. The 2-parameter Weibull plot is a good fit of the data only a few data points fall outside the confidence limits. The fitted line has a ρ (rho) value of 96-percent. There also appears to be a "stair step" in the data.

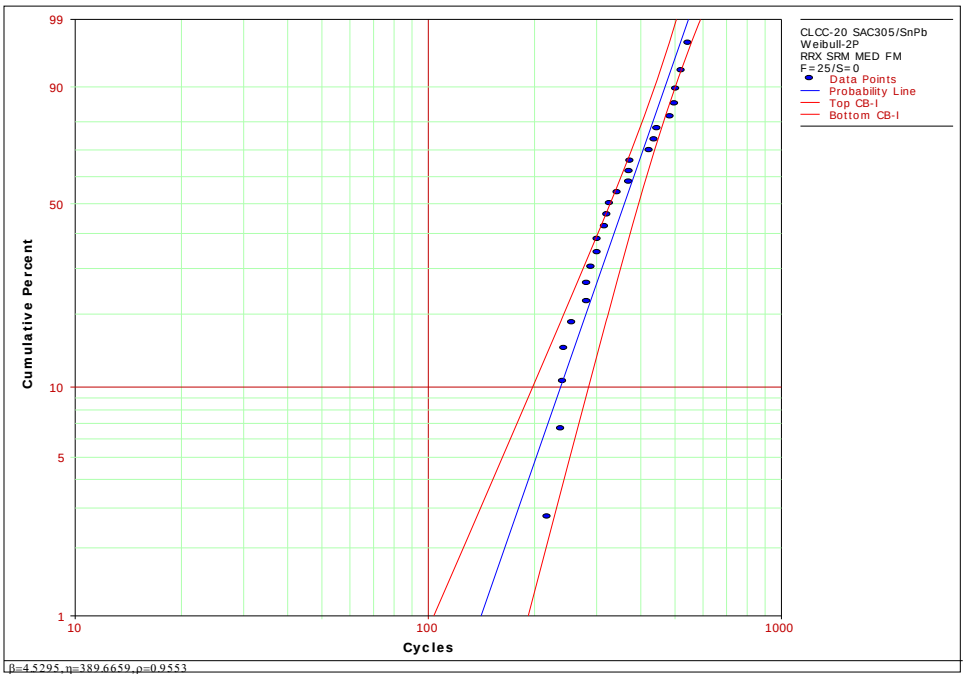


Figure 36 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-lead CLCC-20 components soldered with tin-copper solder paste is shown in Figure 37. The 2-parameter Weibull plot is an excellent fit of the data, not one data point falls outside the confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be a "stair step" in the data.

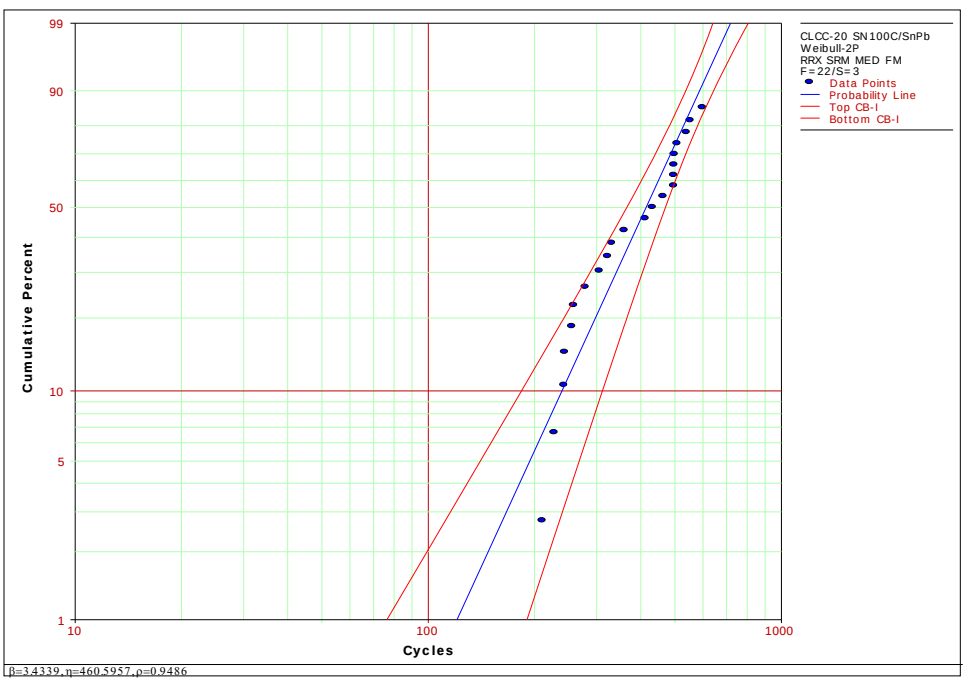


Figure 37 Weibull Plot of Tin-Lead CLCC-20 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-lead CLCC-20 components soldered with tin-lead solder paste is shown in Figure 38. The 2-parameter Weibull plot is an excellent fit of the data. No one data point falls outside of the confidence limits. The fitted line has a ρ (rho) value of 98-percent. There also appears to be a slight "stair step" in the data at 500 cycles. This plot is also our baseline component behavior.

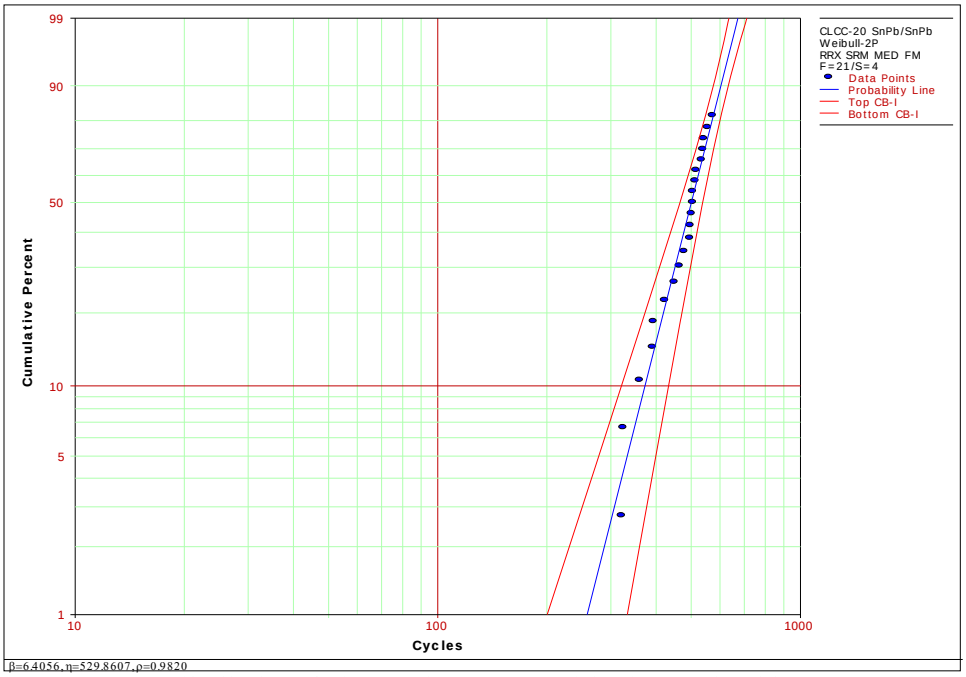


Figure 38 Weibull Plot of Tin-Lead CLCC-20 with Tin-Lead Solder Paste on Manufactured Test Vehicles

Figure 39 shows all the combinations of component finish and solder alloy for CLCC-20 components on the manufactured test vehicles. Overall, tin-lead CLCC-20 components soldered with tin-lead solder paste were the most reliable. When comparing the CLCC-20 component Weibull plots, one can see how the tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste (beige line) and tin-silver-copper 305 CLCC-20 components soldered with tin-silver-copper 305 solder paste (blue line) are statistically equivalent, but these two options lead-free options do not meet the reliability achieved with the baseline tin-lead CLCC-20 component soldered with tin-lead solder paste (gray line).

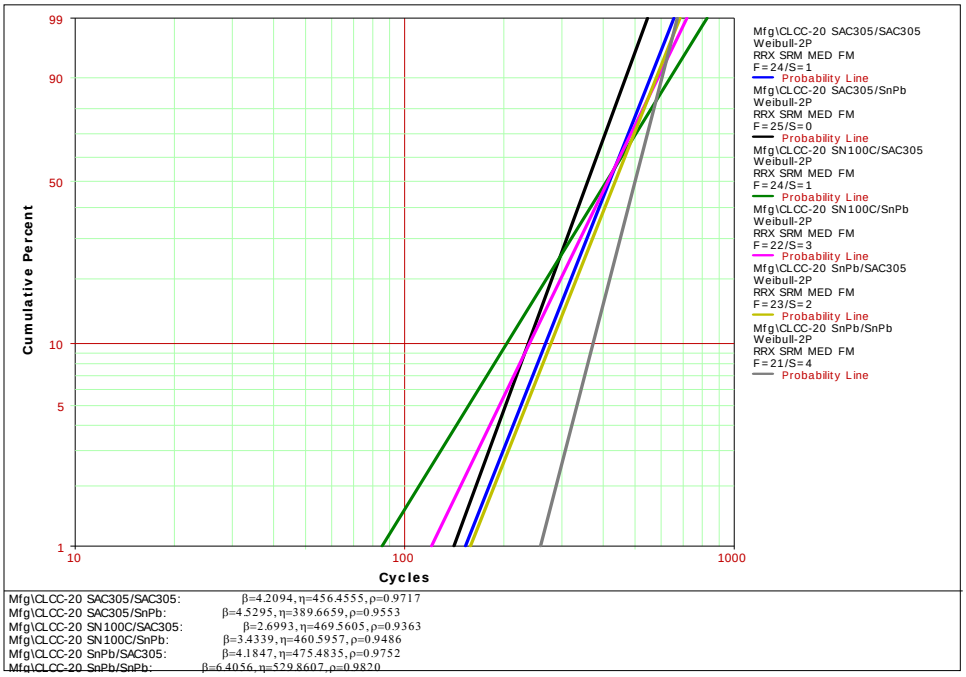


Figure 39 Weibull Plots of CLCC-20 on Manufactured Test Vehicles

CSP-100 Results and Discussion

The Weibull plot for tin-silver-copper 105 CSP-100 components soldered with tin-silver-copper 305 solder paste is shown in Figure 40. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is an excellent fit of the data given that no one data point falls outside the confidence limits. The fitted line has a ρ (rho) value of 98-percent. There also appears to be a slight "stair step" in the data, approximately at 500 cycles, indicating possible changes in stresses applied to the test vehicle or multiple failure modes in the solder joint failures. A similar stair step phenomena occurred in the previous JCAA/JG-PP Lead-Free Electronics study in 2005, where other project members reported observing this stair step in thermal cycle testing.

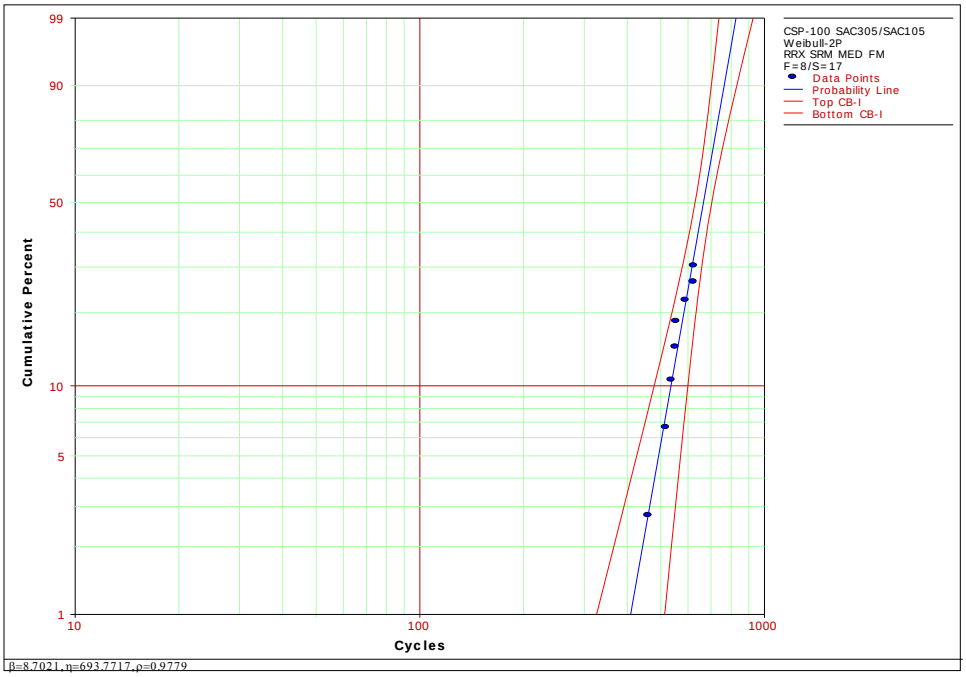


Figure 40 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-silver-copper 105 CSP-100 components soldered with tin-copper solder paste is shown in Figure 41. The 2-parameter Weibull plot is a fair fit of the data given that no one data point falls outside the confidence limits but the fitted line has a ρ (rho) value of 89-percent. There also appears to be a "stair step" in the data.

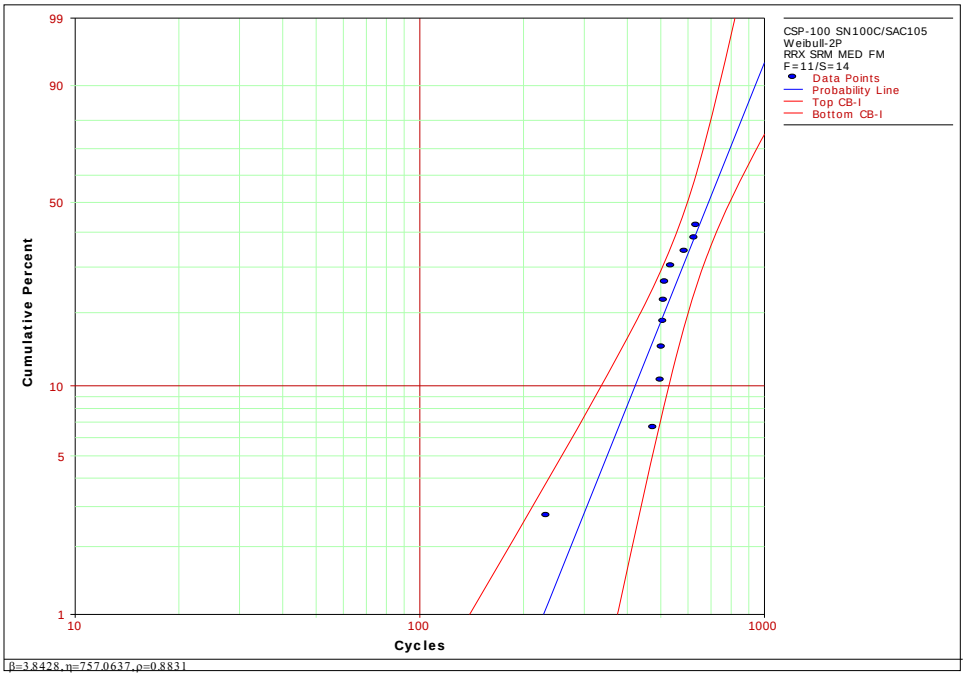


Figure 41 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-silver-copper 105 CSP-100 components soldered with tin-lead solder paste is shown in Figure 42. The 2-parameter Weibull plot is a good fit of the data given that no one data point falls outside the confidence limits. The fitted line has a ρ (rho) value of 96-percent. There also appears to be a "stair step" in the data.

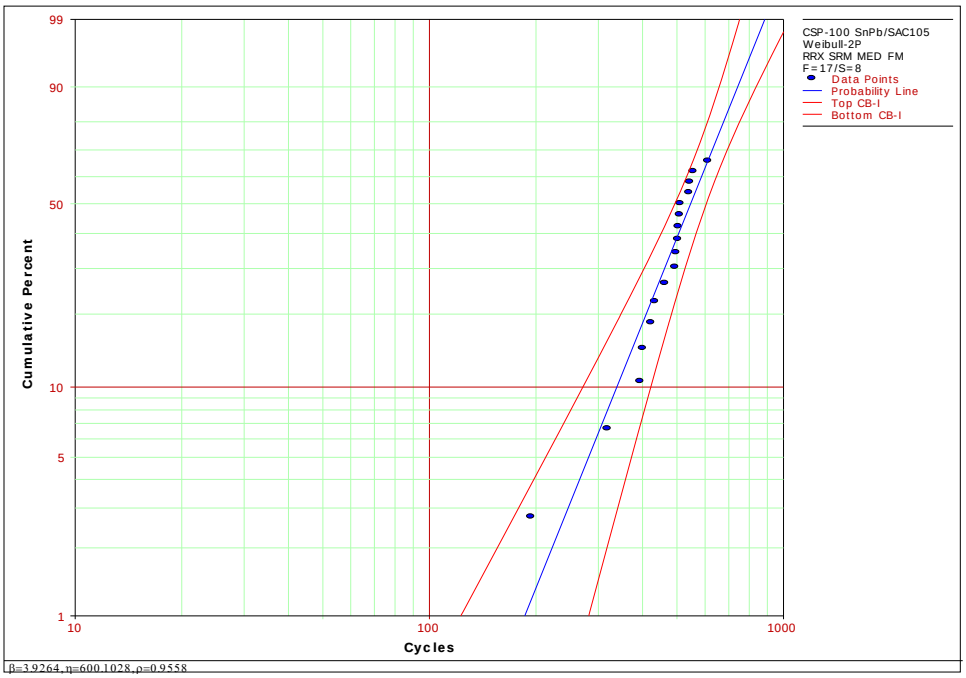


Figure 42 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead CSP-100 components soldered with tin-silver-copper 305 solder paste is shown in Figure 43. The 2-parameter Weibull plot is an excellent fit of the data. The fitted line has a ρ (rho) value of 99-percent.

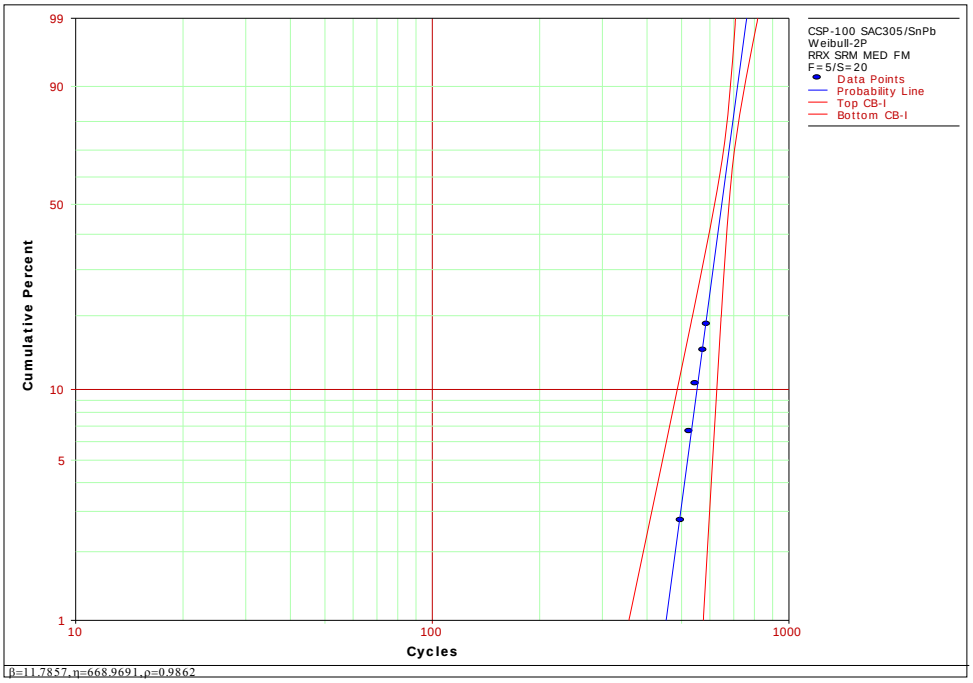


Figure 43 Weibull Plot of Tin-Lead CSP-100 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead CSP-100 components soldered with tin-copper solder paste is shown in Figure 44. The 2-parameter Weibull plot is a good fit of the data given that no one data point falls outside the confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be a "stair step" in the data.

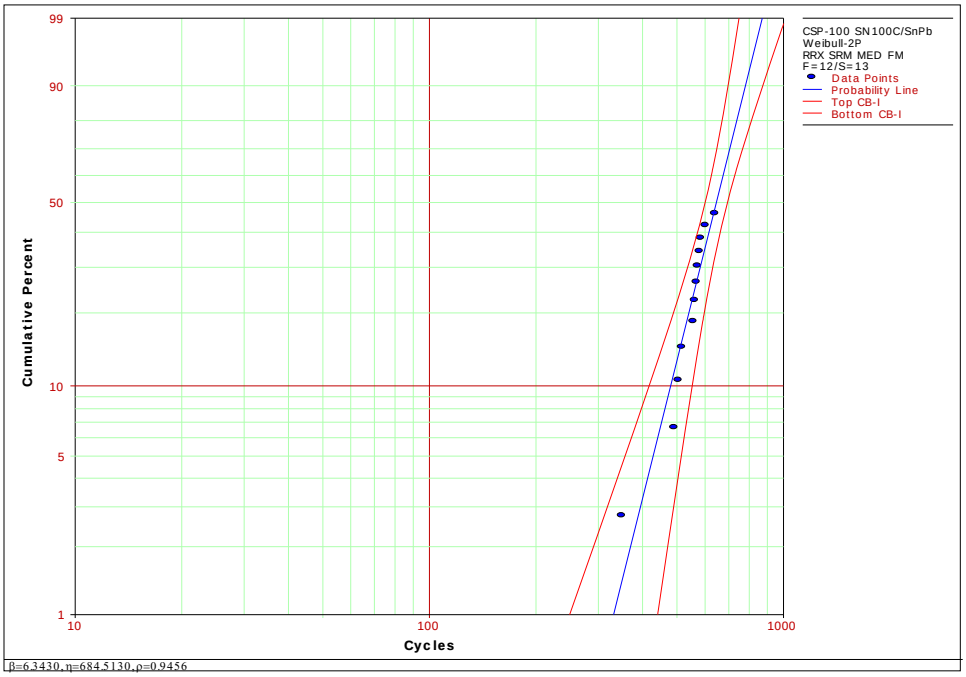


Figure 44 Weibull Plot of Tin-Lead CSP-100 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead CSP-100 components soldered with tin-lead solder paste is shown in Figure 45. The 2-parameter Weibull plot is an excellent fit of the data and the fitted line has a ρ (rho) value of 96-percent. This plot represents the baseline reliability result for CSP-100 components.

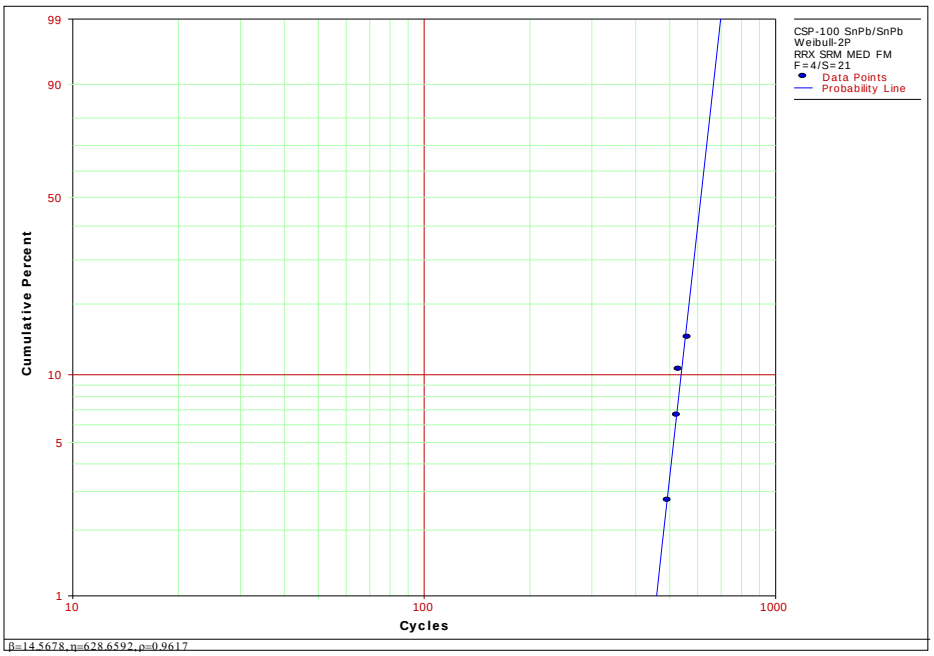


Figure 45 Weibull Plot of Tin-Lead CSP-100 with Tin-Lead Solder Paste on Manufactured Test Vehicles

Figure 46 shows all the combinations of component finish and solder alloy for CSP-100 components on the manufactured test vehicles. Overall, tin-lead CSP-100 components soldered with tin-lead solder paste were not the most reliable, but it is very close. When comparing the Weibull plots for the CSP-100 components, the tin-lead CSP-100 components soldered with tin-silver-copper 305 solder paste resulted as statistically equivalent, and slightly better than tin-lead CSP-100 components soldered with tin-lead solder paste.

The reason for this result maybe the effect of the incorrect chip scale package (CSP)-100 component configuration used during the drafting of the test vehicles. Traces interconnecting internal rows of balls to the outside row of balls do not exist. Therefore, both sides of the continuity box must break in order for a failure or an "event" to record, see Figure 17. This also explains the high cycles to failure observed during testing. CSP-100 components were expected to fail early, but this was not the case due to the drafting error.

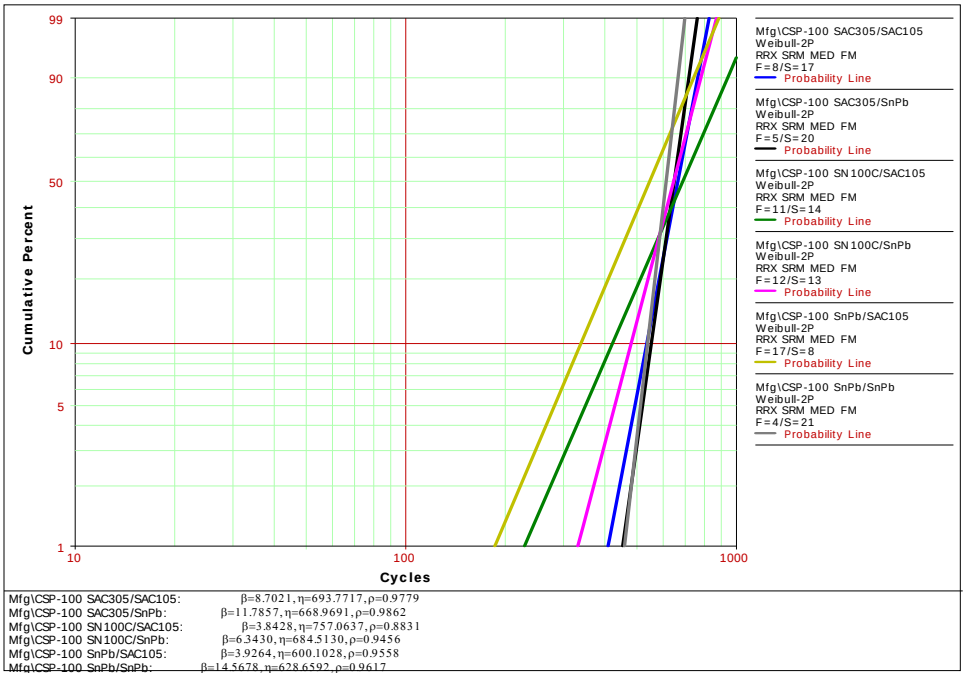


Figure 46 Weibull Plots of CSP-110 on Manufactured Test Vehicles

PDIP-20 Results and Discussion

The Weibull plot for tin PDIP-20 components soldered with tin-copper solder paste for manufactured test vehicles is shown in Figure 47. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a good fit of the data, no one data point falls outside of the confidence limits and the fitted line has a ρ (rho) value of 94-percent, slightly below the desired 95-percent.

There is not sufficient data to compare Weibull plot data for any other combination of PDIP-20 components soldered with tin-lead or lead-free solder, only 10% of the total PDIP-20 components failed, Figure 48. Consortia members performing thermal cycle testing have experienced early life failures of PDIP-20 components, but Raytheon's combined environments testing did not experience the same issue; the reason is not known.

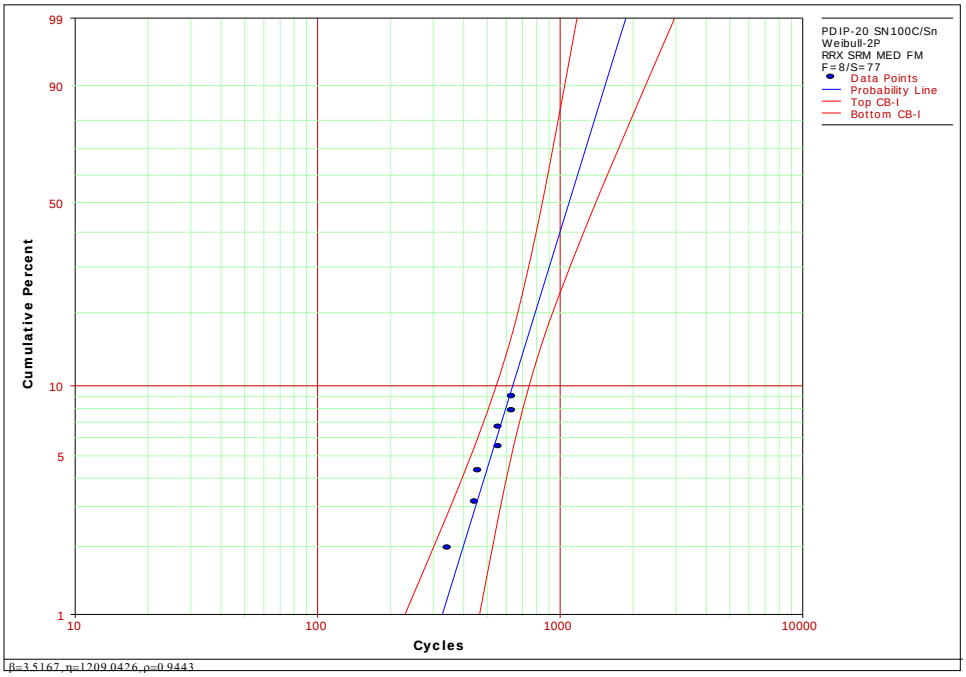


Figure 47 Weibull Plot of Tin PDIP-20 with Tin-Copper Solder on Manufactured Test Vehicles

PDIP-20 components on manufactured test vehicles results can be summarized by the chart in Figure 48. Only tin PDIP-20 components soldered with SN100C recorded failures, 10% of that total population failed. No other failures were recorded for the other combinations of solder alloy and finish for the PDIP-20 component.

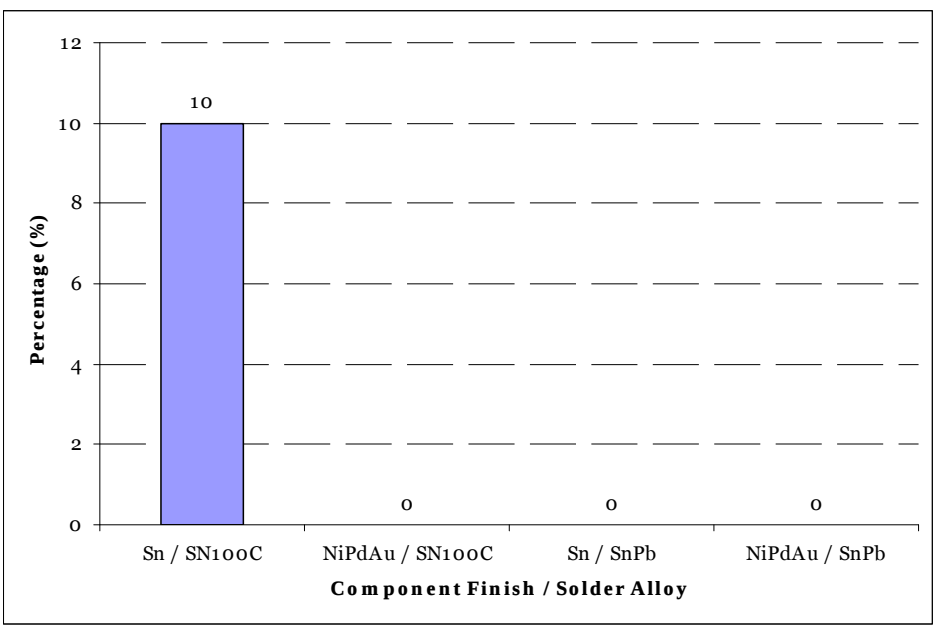


Figure 48 Percentage of Manufactured PDIP Failures by Wave Solder

TQFP-144 Results and Discussion

The Weibull plot for matte tin TQFP-144 components soldered with tin-silver-copper 305 solder paste is shown in Figure 49. The plot includes the fitted line to the data but the 95-percent confidence limits are not shown. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a

good fit of the data but the fitted line has a ρ (rho) value of 90-percent. There appears to be a "stair step" in the data approximately at 500 cycles, indicating possible changes in stresses applied to the test vehicle or multiple failure modes in the solder joint failures. No common cause for the stair step could be identified.

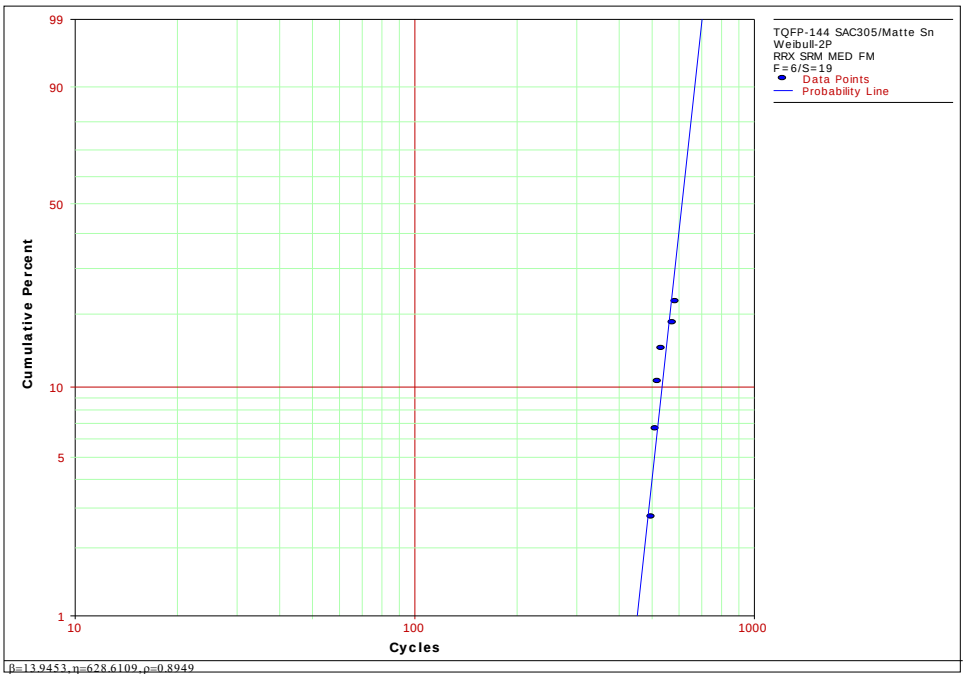


Figure 49 Weibull Plot of Matte Tin TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot for matte tin TQFP-144 components soldered with tin-copper solder paste is shown in Figure 51. The 2-parameter Weibull plot is an excellent fit of the data, no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be a "stair step" in the data.

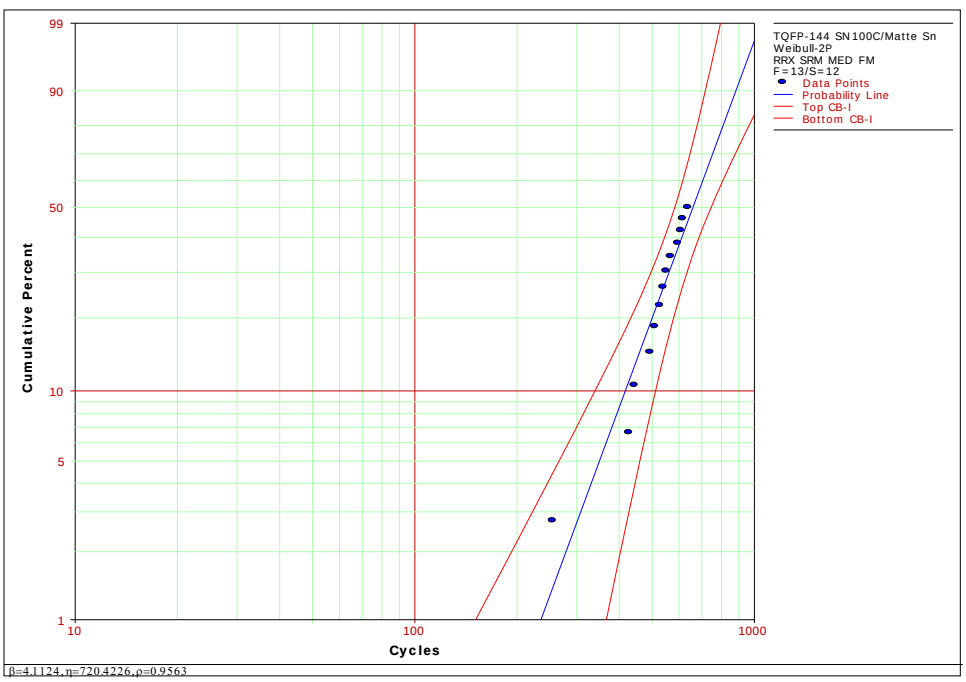


Figure 50 Weibull Plot of Matte Tin TQFP-144 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot for matte tin TQFP-144 components soldered with tin-lead solder paste in shown in Figure 51. The 2-parameter Weibull plot is an excellent fit of the data where no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 94-percent. There also appears to be a "stair step" in the data.

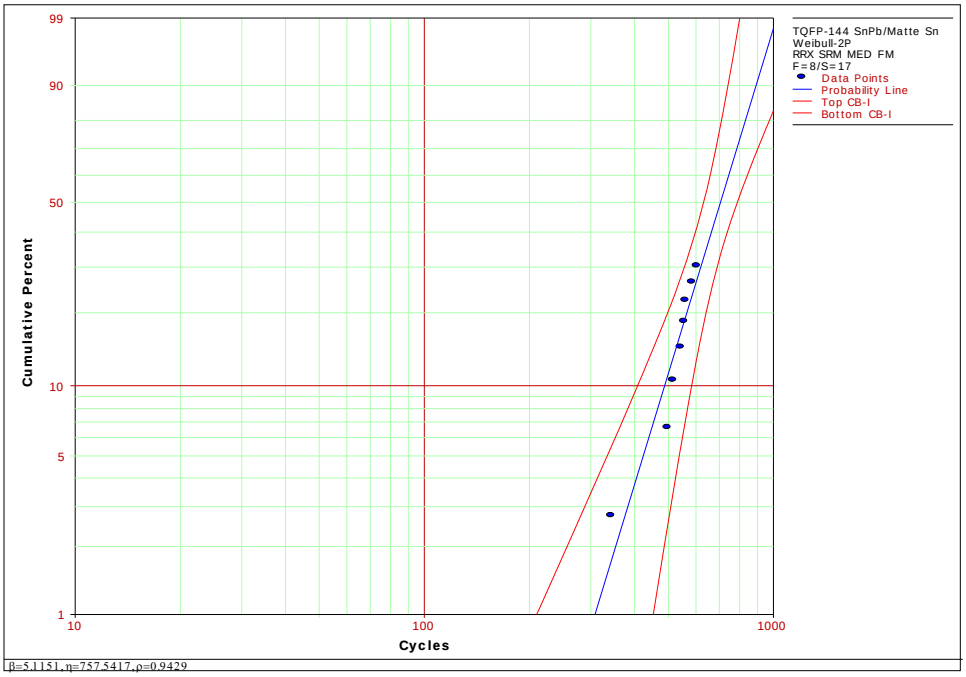


Figure 51 Weibull Plot of Matte Tin TQFP-144 with Tin-Lead Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead dipped TQFP-144 components soldered with tin-copper solder paste in shown in Figure 52. The 2-parameter Weibull plot is an excellent fit of the data where no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 100-percent. There also appears to be a "stair step" in the data, although, slightly difficult to see.

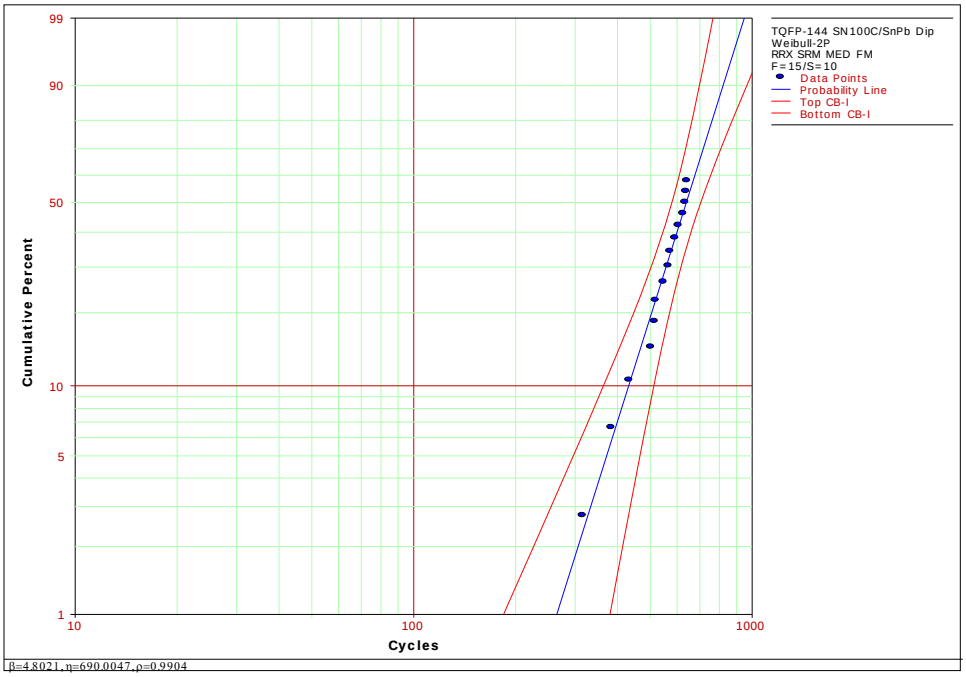


Figure 52 Weibull Plot of Tin-Lead Dipped TQFP-144 with Tin-Copper Solder Paste on Manufactured Test Vehicles

Figure 53 shows all the combinations of component finish and solder alloy for TQFP-144 components on the manufactured test vehicles. Overall, the matte tin TQFP-144 components soldered with tin-lead solder paste were the most reliable and can be used as the baseline reliability result. The plot shows that tin-lead dipped TQFP-144 components soldered with tin-copper solder paste and matte tin TQFP-144 components soldered with tin-copper solder paste performed nearly equal to tin-lead solder. The plot for matte tin TQFP-144 components soldered with tin-silver-copper 305 solder paste (shown in blue) performs slightly better than tin-lead when comparing first cycle to failure, but the overall solder joint life reliability fails before the baseline tin-lead solder.

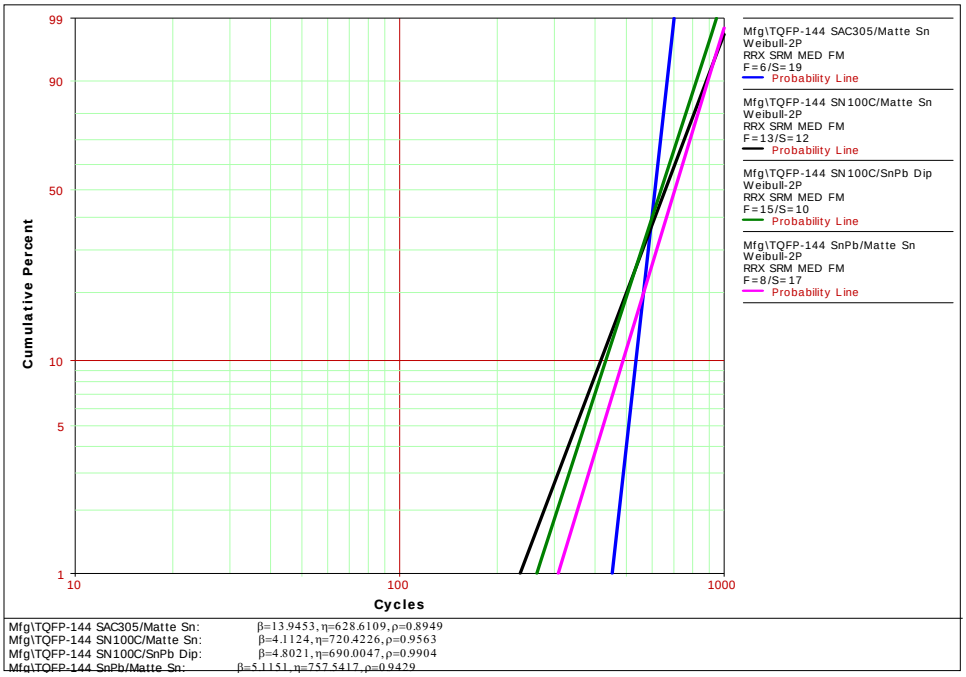


Figure 53 Weibull Plots of Tin TQFP-144 on Manufactured Test Vehicles

TSOP-50 Results and Discussion

The Weibull plot of tin-bismuth TSOP-50 components soldered with tin-silver-copper 305 solder paste is shown in Figure 54. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a fair fit of the data given some of the data points fall outside of the confidence limits. The fitted line has a ρ (rho) value of 93-percent, slightly less than the desired 95-perecent. There also appears to be a “stair step” in the data. The test logs were reviewed for potential chamber problems or test procedural issues. No common cause for the stair step could be identified. This is a similar finding across the other project members performing thermal cycling.

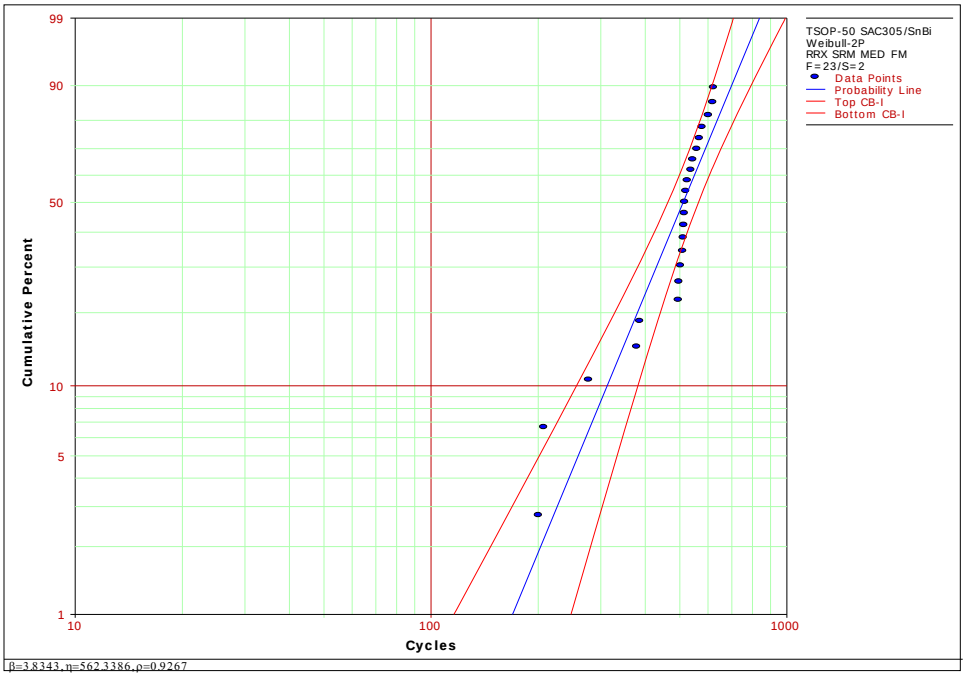


Figure 54 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-bismuth TSOP-50 components soldered with tin-copper solder paste is shown in Figure 55. The 2-parameter Weibull plot is a fair fit of the data given some data points fall outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 93-percent. There also appears to be a "stair step" in two locations of the data.

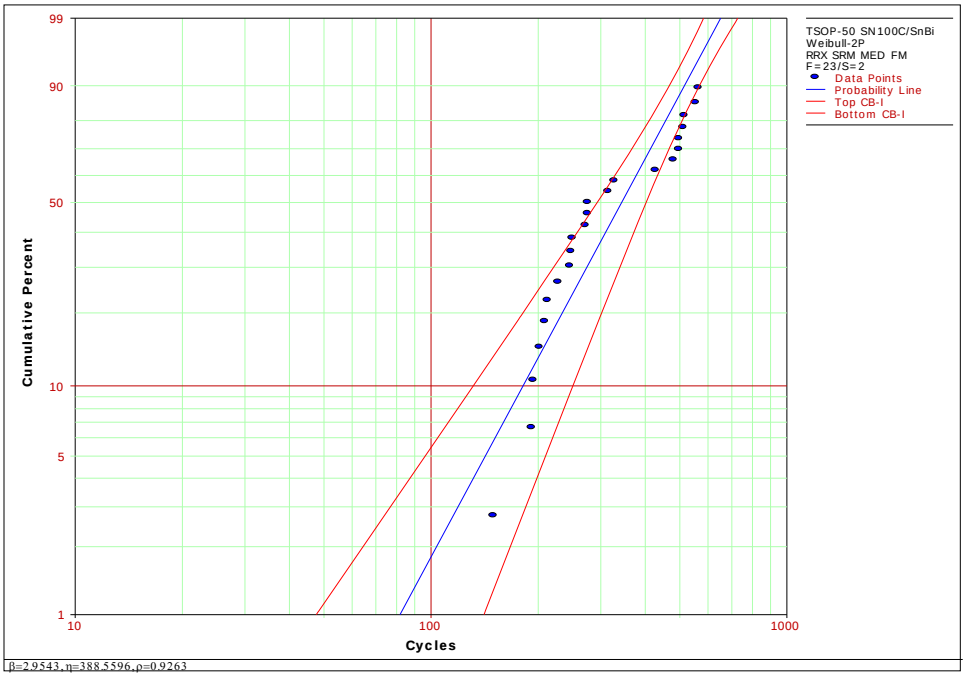


Figure 55 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-bismuth TSOP-50 components soldered with tin-lead solder paste is shown in Figure 56. The 2-parameter Weibull plot is a good fit of the data, no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be a "stair step" in two locations of the data.

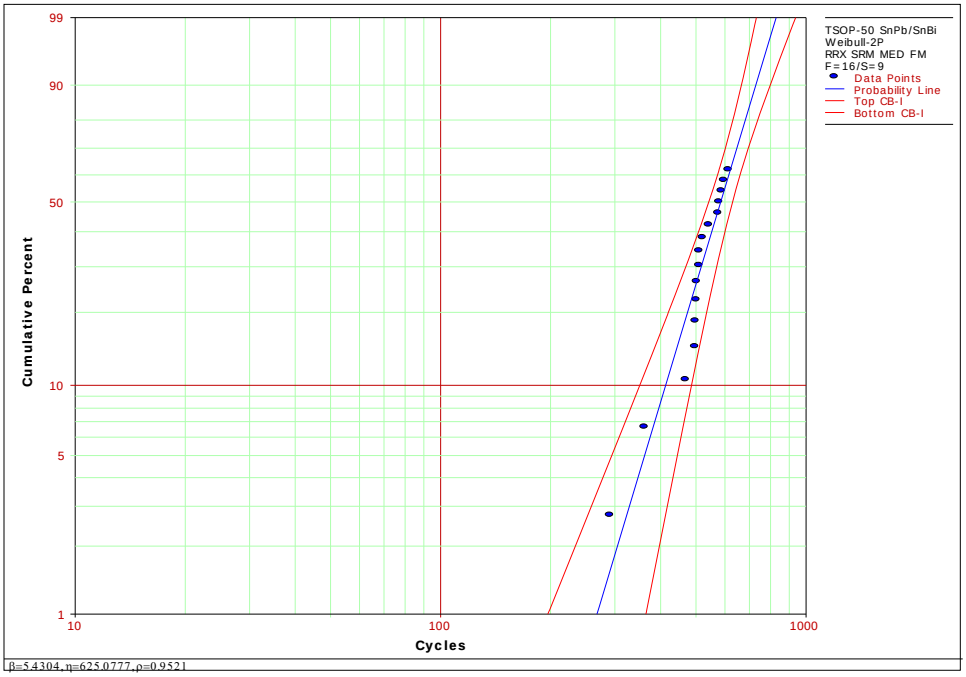


Figure 56 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Lead Solder Paste on Manufactured Test Vehicles

The Weibull plot for tin-lead TSOP-50 components soldered with tin-silver-copper 305 solder paste is shown in Figure 57. The 2-parameter Weibull plot is a fair fit of the data given some of the data points fall outside of the 95-percent confidence limits. It's possible the two data points to the far left of the graph are outliers, but those data points do not fall into the group consortia definition of an outlier, therefore the data points remain. If those data points were removed, the fitted line would probably shift to the right and the slope would change. The current fitted line has a ρ (rho) value of 88-percent, less than the desired 95-percent. There also appears to be a "stair step" in the data.

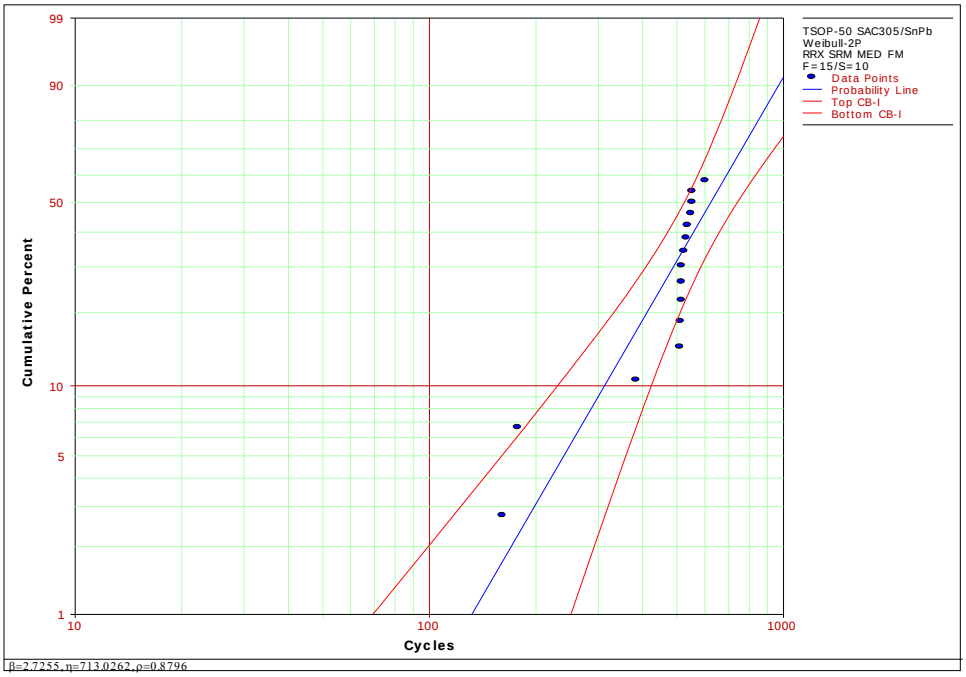


Figure 57 Weibull Plot of Tin-Lead TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-lead TSOP-50 components soldered with tin-copper solder paste is shown in Figure 58. The 2-parameter Weibull plot is a good fit of the data given some of the data points fall outside of the confidence limits. The fitted line has a ρ (rho) value of 95-percent. There also appears to be more than one "stair step" in the data.

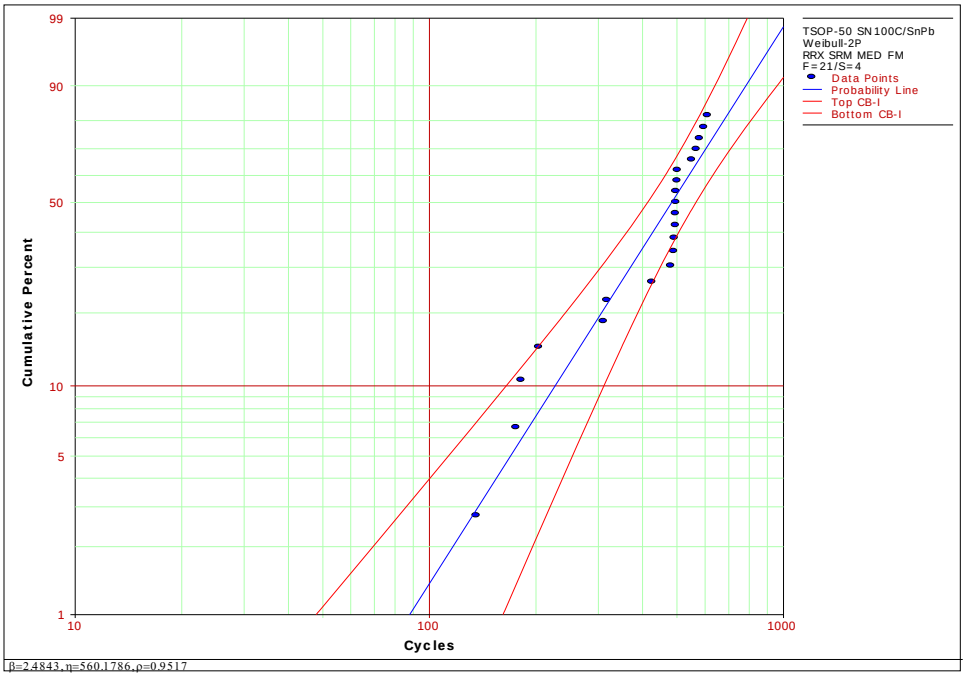


Figure 58 Weibull Plot of Tin-Lead TSOP-50 with Tin-Copper Solder Paste on Manufactured Test Vehicles

The Weibull plot of tin-lead TSOP-50 components soldered with tin-lead solder paste is shown in Figure 59. The 2-parameter Weibull plot is a fair fit of the data given two data points fall outside of the confidence limits. The single data point to the far left may be an outlier; but it does not meet the team's definition of an outlier, therefore that data point remains. This affects the fitted line with a ρ (rho) value of 87-percent. There also appears to be a "stair step" in the data.

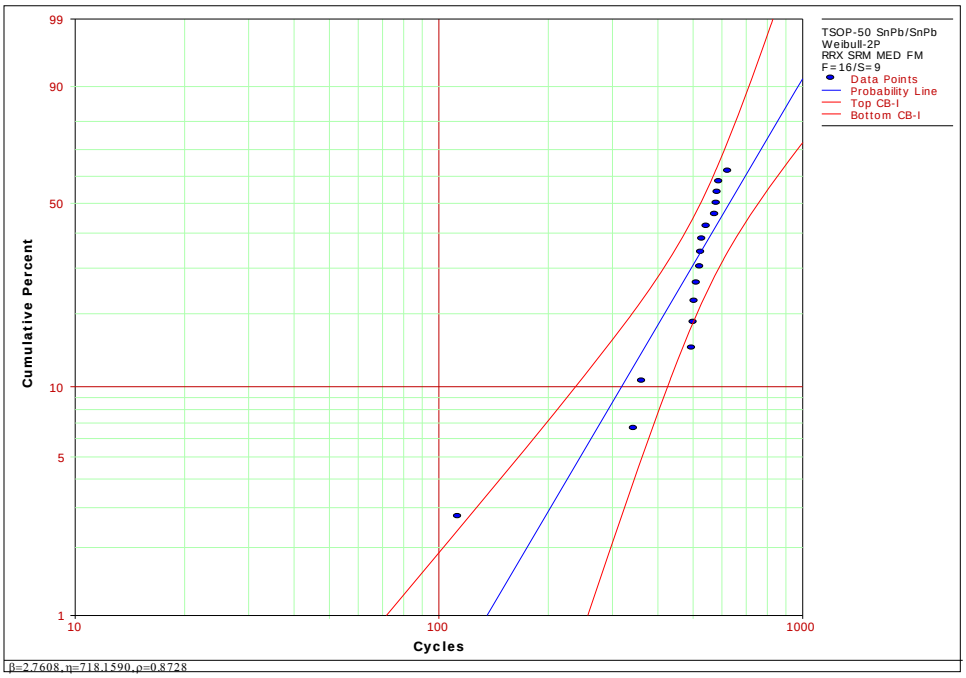


Figure 59 Weibull Plot of Tin-Lead TSOP-50 with Tin-Lead Solder Paste on Manufactured Test Vehicles

Figure 60 shows all the combinations of component finish and solder alloy for TSOP-50 components on the manufactured test vehicles. Overall, the tin-lead TSOP-50 components soldered with tin-lead solder paste were the most reliable and can be used as the baseline reliability result. The plot shows that tin-lead TSOP-50 components soldered with tin-silver-copper 305 solder performed the same as tin-lead solder.

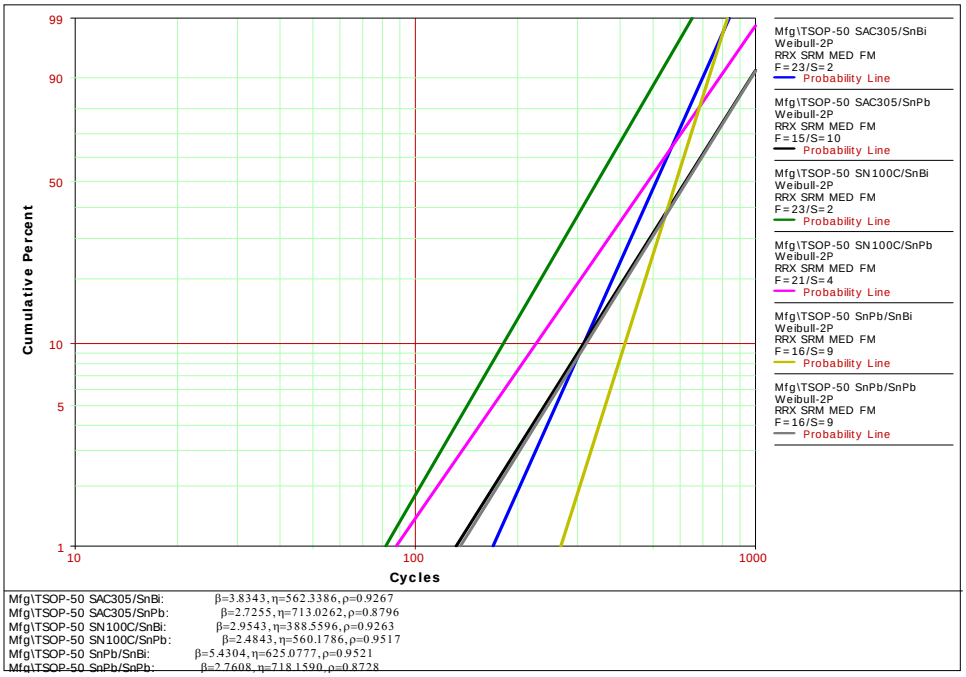


Figure 60 Weibull Plots of TSOP-50 on Manufactured Test Vehicles

Electroless Nickel Immersion Gold (ENIG) Manufactured Test Vehicle Results and Discussion

The Weibull plot for tin-lead BGA-225 components soldered with tin-silver-copper 305 solder paste onto an electroless nickel immersion gold finished board is shown in Figure 61. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates the solder alloy then component finish. The 2-parameter Weibull plot is a fair fit of the data, no one data point falls outside of the confidence limits. The fitted line has a ρ (rho) value of 92-percent, slightly less than the desired 95-percent value. The results from ENIG manufactured test vehicles will not be included in the data analysis of the manufactured test vehicles, because the ENIG sample size was too small to draw solder joint reliability conclusions.

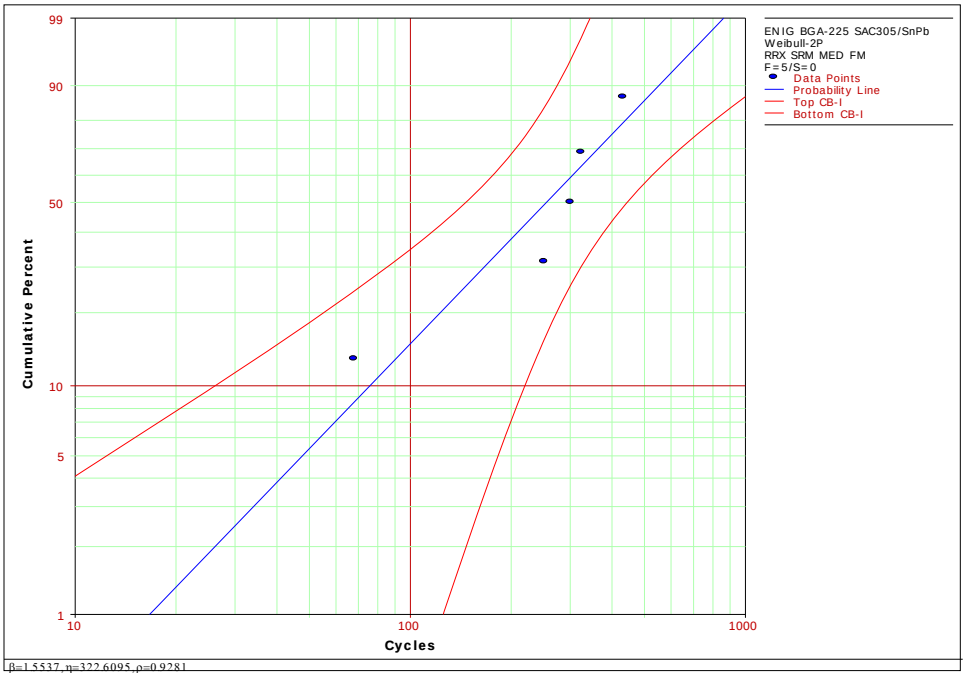


Figure 61 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle

The Weibull plot comparing ENIG and immersion silver board finish for tin-lead BGA-225 components soldered with tin-silver-copper 305 solder paste is shown in Figure 62. The probability that manufactured tin-lead BGA-225 components soldered with tin-silver-copper 305 solder paste onto immersion silver board finish will last longer than tin-lead BGA-225 components soldered onto an ENIG board finish is 70%.

Figure 62 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste. Mfg/BGA-225 SAC305/SnPb will last longer with probability of 70%. Convergence Delta at Solution is 0.00000577%.

The Weibull plot for tin-silver-copper 305 CLCC-20 components soldered with tin-silver-copper 305 solder paste on ENIG board finish is shown in Figure 63. The 2-parameter Weibull plot is a fair fit of the data, no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 83-percent, which is below the desired 95-percent value.

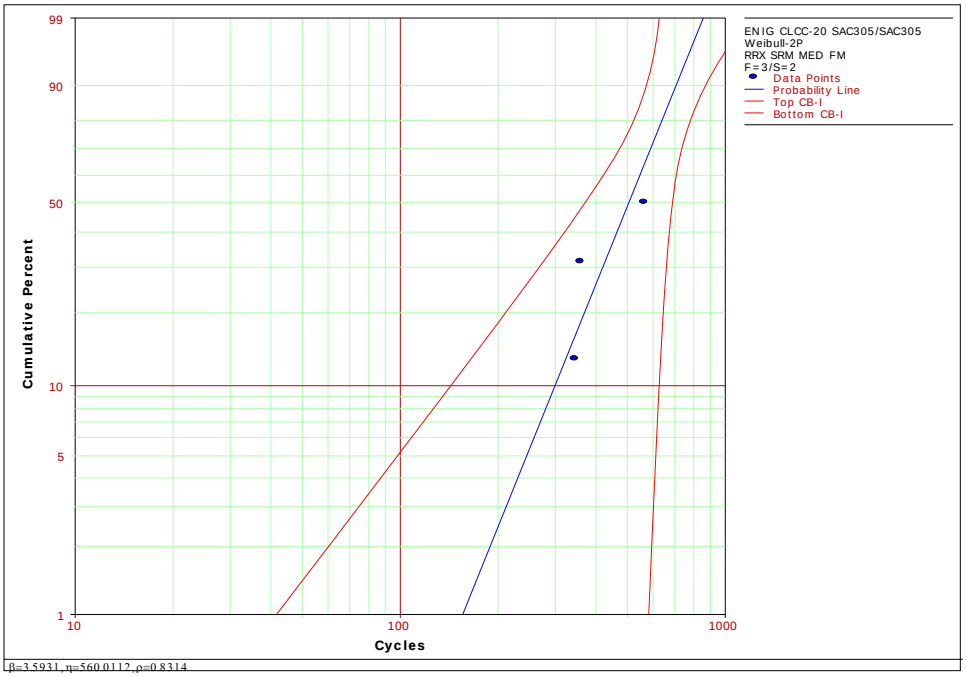


Figure 63 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle

The Weibull plot comparing ENIG and immersion silver board finish for tin-silver-copper 305 CLCC-20 components soldered with tin-silver-copper 305 solder paste is shown in Figure 64. The probability that manufactured tin-silver-copper 305 CLCC-20 components soldered with tin-silver-copper 305 solder paste onto ENIG board finish will last longer than tin-silver-copper 305 BGA-225 components soldered onto immersion silver board finish is 68%.

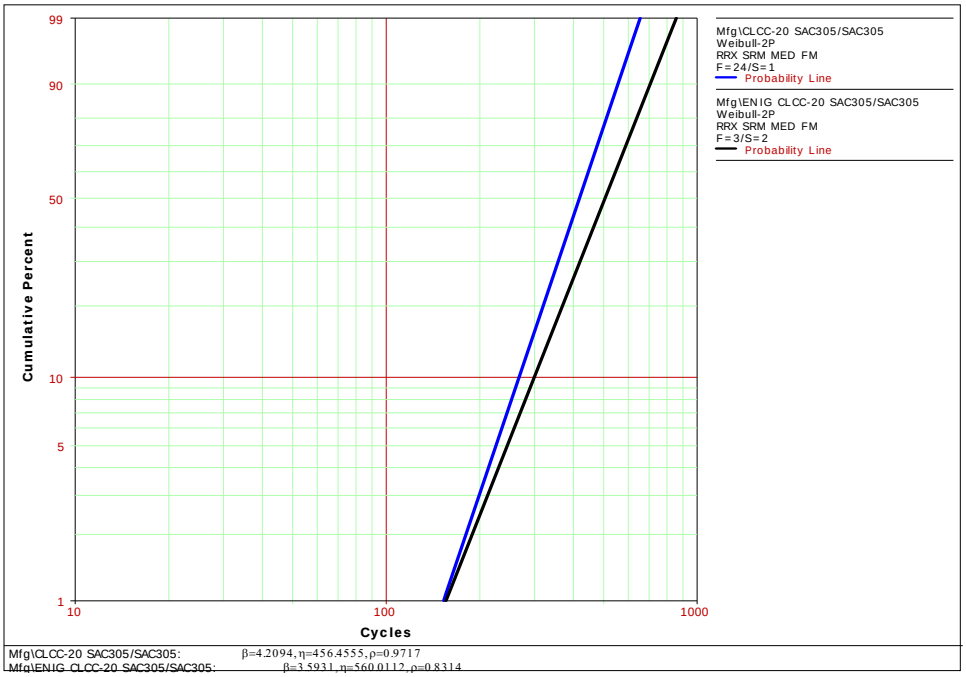


Figure 64 Comparison of ENIG and Immersion Silver Board Finish for Tin-Silver-Copper 305 CLCC-20 with Tin-Silver-Copper Solder Paste. Mfg/ENIG CLCC-20 SAC305/SAC305 will last longer with probability of 68%. Convergence Delta at Solution is 0.00000058%

The Weibull plot for tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste on an ENIG board finish is shown in Figure 65. The 2-parameter Weibull plot is an excellent fit of the data. The fitted line has a ρ (rho) value of 96-percent.

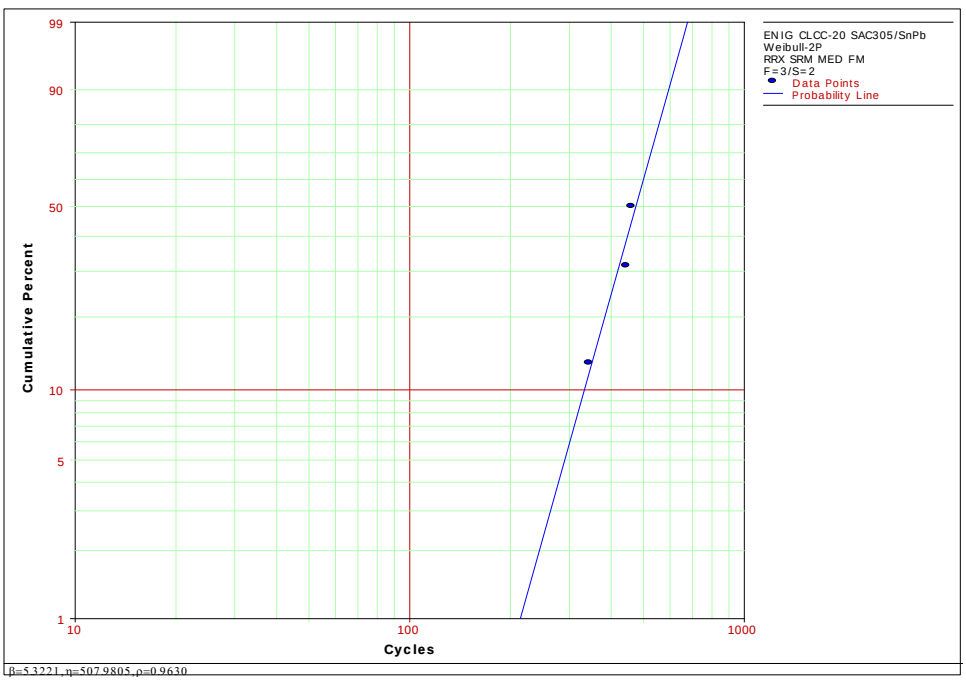


Figure 65 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on ENIG Manufactured Test Vehicle

The Weibull plot comparing ENIG and immersion silver board finish for tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste is shown in Figure 66. The probability that manufactured tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste onto ENIG board finish will last longer than tin-lead BGA-225 components soldered onto immersion silver board finish is 80%.

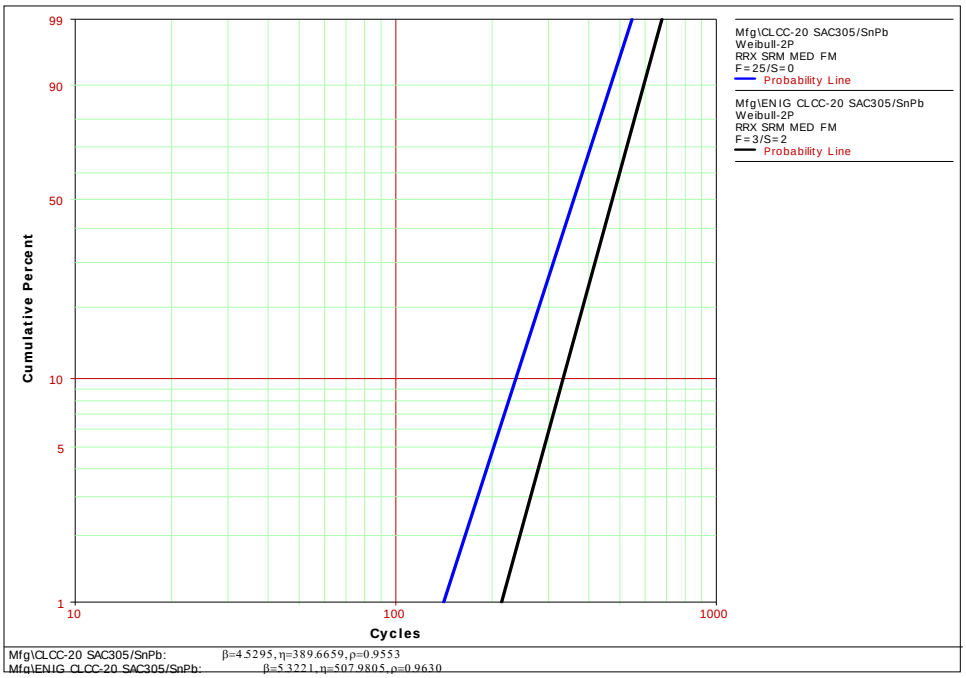


Figure 66 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste. Mfg/ENIG CLCC-20 SAC305/SnPb will last longer with probability of 80%. Convergence Delta at Solution is 0.00000060%

A summary of the manufactured test vehicle test results is show in Table 16. Plated-through-hole components and lead components performed better than the surface mount technology components.

Table 16 Summary of Manufactured Test Vehicle Test Results

Board Finish	Component	Alloy	Finish	β	η	ρ	Nf (1%)	Nf (10%)	Nf (63.2%)	Comments
ENIG	BGA-225	SAC305	SAC405							
ENIG	BGA-225	SAC305	SnPb	1.5537	322.6095	0.9281	17	76	323	
ENIG	CLCC-20	SAC305	SAC305	3.5931	560.0112	0.8314	156	299	560	
ENIG	CLCC-20	SAC305	SnPb	5.3221	507.9805	0.9630	214	333	508	
ENIG	CSP-100	SAC305	SAC105							
ENIG	CSP-100	SAC305	SnPb							
ENIG	PDIP-20	SN100C	Sn							
ENIG	PTH	SN100C	ENIG							
ENIG	QFN-20	SAC305	Matte Sn							
ENIG	TQFP-144	SAC305	Matte Sn							
ENIG	TQFP-144	SAC305	SnPb Dip							
ENIG	TSOP-50	SAC305	SnBi							
ENIG	TSOP-50	SAC305	SnPb							
ImAg	BGA-225	SAC305	SAC405	2.0147	683.2631	0.8844	70	224	683	
ImAg	BGA-225	SN100C	SAC405	1.9251	586.3452	0.9523	54	182	586	
ImAg	BGA-225	SnPb	SAC405	2.4169	146.4001	0.9587	22	58	146	
ImAg	BGA-225	SAC305	SnPb	1.6896	538.9780	0.9693	35	142	539	
ImAg	BGA-225	SN100C	SnPb	1.2253	427.7122	0.9897	10	68	428	Outlier
ImAg	BGA-225	SnPb	SnPb	1.8601	756.7049	0.9705	64	226	757	
ImAg	CLCC-20	SAC305	SAC305	4.2094	456.4555	0.9717	153	267	456	
ImAg	CLCC-20	SN100C	SAC305	2.6993	469.5605	0.9363	85	204	470	
ImAg	CLCC-20	SnPb	SAC305	4.1847	475.4835	0.9752	158	278	475	
ImAg	CLCC-20	SAC305	SnPb	4.5295	389.6659	0.9553	141	237	390	
ImAg	CLCC-20	SN100C	SnPb	3.4339	460.5957	0.9486	121	239	461	
ImAg	CLCC-20	SnPb	SnPb	6.4056	529.8607	0.9820	258	373	530	
ImAg	CSP-100	SAC305	SAC105	8.7021	693.7717	0.9779	409	536	694	
ImAg	CSP-100	SN100C	SAC105	3.8428	757.0637	0.8831	229	422	757	
ImAg	CSP-100	SnPb	SAC105	3.9264	600.1028	0.9558	186	338	600	
ImAg	CSP-100	SAC305	SnPb	11.7857	668.9691	0.9862	453	553	669	
ImAg	CSP-100	SN100C	SnPb	6.3430	684.5130	0.9456	331	480	684	
ImAg	CSP-100	SnPb	SnPb	14.5678	628.6592	0.9617	458	539	629	
ImAg	PDIP-20	SN100C	NiPdAu							
ImAg	PDIP-20	SnPb	NiPdAu							
ImAg	PDIP-20	SN100C	Sn	3.5167	1209.0426	0.9443	327	638	1209	
ImAg	PDIP-20	SnPb	Sn							
ImAg	PTH	SN100C	ImAg							
ImAg	PTH	SnPb	ImAg							
ImAg	QFN-20	SAC305	Matte Sn							
ImAg	QFN-20	SN100C	Matte Sn	27.8552	563.9829	0.8487	478	520	564	
ImAg	QFN-20	SnPb	Matte Sn							
ImAg	TQFP-144	SAC305	Matte Sn	13.9453	628.6109	0.8949	452	535	629	
ImAg	TQFP-144	SN100C	Matte Sn	4.1124	720.4226	0.9563	235	417	720	
ImAg	TQFP-144	SnPb	Matte Sn	5.1151	757.5417	0.9429	308	488	757	
ImAg	TQFP-144	SAC305	SnPb Dip							
ImAg	TQFP-144	SN100C	SnPb Dip	4.8021	690.6047	0.9904	265	432	691	
ImAg	TQFP-144	SnPb	SnPb Dip							
ImAg	TSOP-50	SAC305	SnBi	3.8343	562.3386	0.9267	169	313	562	
ImAg	TSOP-50	SN100C	SnBi	2.9543	388.5596	0.9263	82	181	389	
ImAg	TSOP-50	SnPb	SnBi	5.4304	625.0777	0.9521	268	413	625	
ImAg	TSOP-50	SAC305	SnPb	2.7255	713.0262	0.8796	132	312	713	
ImAg	TSOP-50	SN100C	SnPb	2.4843	560.1786	0.9517	88	226	560	
ImAg	TSOP-50	SnPb	SnPb	2.7608	718.1590	0.8728	136	318	718	

Rework Test Vehicle Results and Discussion

The reworked test vehicles were tested for 650 cycles. The rework raw data is tabulated on page 128. Events or failures that were ten cycles or less were deemed as outliers and the data points were excluded from the formal data analysis. The team decided that early life failures were caused by manufacturing, rework process issues or a test anomaly. Therefore, the outliers were removed to prevent skewing the data analysis results, but Weibull plots were still created to compare the shift of the probability slope between the two charts by including the outliers in one of the charts. All reworked test vehicles were inspected for lead damage and broken wires at the conclusion of testing. The notes and observations from the post test inspections can be found on page 206.

The data was compiled by test vehicle serial number, component type, and component finish, see Table 17. The data suggests reworked test vehicles 142 and 183 exhibited twenty (20) or fewer failed components than the other rework test vehicles. This observation suggests these reworked test vehicles may have experienced lower thermal and/or vibration stresses during testing due to the location of the test vehicles in the chamber. See Figure 22 for the manufactured and rework test chamber set-up.

Table 17 Number of Failed Components by Rework Test Vehicle

Board Finish	Component	Finish	Solder	New Component Finish	Rework Solder	139	140	141	142	143	158	163	180	181	182	183	Total
ENIG	BGA-225	SAC405	SnPb								3						**3**
		SnPb	SnPb	SAC405	SnPb						3						**3**
		SnPb	SnPb	SnPb	Flux Only						1						**1**
	CLCC-20	SAC305	SnPb								10						**10**
	CSP-100	SAC105	SnPb								1						**1**
		SnPb	SnPb	SAC105	SnPb						1						**1**
		SnPb	SnPb	SnPb	Flux Only						0						**0**
	PDIP-20	NiPdAu	SnPb								0						**0**
		Sn	SnPb								1						**1**
		SnPb	SnPb	Sn	SnPb						0						**0**
	PTH	ENIG	SnPb								0						**0**
	QFN-20	Matte Sn	SnPb								1						**1**
	TQFP-144	NiPdAu	SnPb								1						**1**
		SnPb Dip	SnPb								3						**3**
	TSOP-50	Sn	SnPb								1						**1**
		SnBi	SnPb								1						**1**
		SnPb	SnPb	Sn	SnPb						2						**2**
		SnPb	SnPb	SnPb	SnPb						2						**2**
ENIG Total											**31**						**31**
ImAg	BGA-225	SAC405	SAC305	SAC405	Flux Only							2	3	3	1	0	**9**
					SnPb							1	3	1	0	0	**5**
			SnPb			4	1	2	0	3							**10**
		SnPb	SAC305									3	4	3	2	1	**13**
			SnPb	SAC405	SnPb	3	2	2	2	3							**12**
				SnPb	Flux Only	1	0	1	0	1							**3**
	CLCC-20	SAC305	SnPb			10	10	10	9	10							**49**
		SnPb	SAC305									10	10	10	10	10	**50**
	CSP-100	SAC105	SAC305	SAC105	Flux Only							0	2	0	1	0	**3**
					SnPb							2	3	3	3	3	**14**
												1	1	1	0	0	**3**
			SnPb			4	1	3	0	3							**11**
		SnPb	SAC305									0	0	0	0	0	**0**
			SnPb	SAC105	SnPb	1	0	0	0	0							**1**
				SnPb	Flux Only	0	0	0	0	0							**0**
	PDIP-20	NiPdAu	SnPb			1	0	0	0	0							**1**
		Sn	SN100C	Sn	SN100C							1	0	1	0	0	**2**
												1	0	0	1	0	**2**
			SnPb			2	0	0	0	0							**2**
		SnPb	SnPb	Sn	SnPb	2	1	0	0	1							**4**
	PTH	ImAg	SN100C									0	0	0	0	0	**0**
			SnPb			0	0	0	0	0							**0**
	QFN-20	Matte Sn	SnPb			1	1	1	1	1							**5**
		SnPb	SAC305									1	1	2	1	1	**6**
	TQFP-144	NiPdAu	SAC305									0	0	0	0	0	**0**
			SnPb			0	0	0	0	0							**0**
		SAC305	SAC305									0	2	3	2	4	**11**
		SnPb Dip	SnPb			1	1	1	0	0							**3**
	TSOP-50	Sn	SAC305	Sn	SnPb							1	2	2	1	0	**6**
			SnPb			1	1	0	0	1							**3**
		SnBi	SAC305	SnBi	SAC305							2	2	2	2	1	**9**
												2	3	3	2	0	**10**
			SnPb			1	1	1	1	1							**5**
		SnPb	SAC305									1	3	0	1	0	**5**
			SnPb	Sn	SnPb	1	1	1	0	2							**5**
				SnPb	SnPb	1	1	1	2	1							**6**
ImAg Total						**34**	**21**	**23**	**15**	**27**		**28**	**39**	**34**	**27**	**20**	**268**
Grand Total						**34**	**21**	**23**	**15**	**27**	**31**	**28**	**39**	**34**	**27**	**20**	**299**

The data was also segregated by component type, component finish and solder alloy, see Table 18. Test vehicles soldered with or reworked with tin-lead solder had the fewest solder joint failures. Test vehicles soldered with tin-silver-copper solder were second best. Lastly, the test vehicles soldered with tin-copper solder had the worst performance.

Table 18 Number of Failed Components by Board Finish, Component, Component Finish, Solder Alloy, New Component Finish and Rework Solder on Rework Test Vehicles

Board Finish	Component	Finish	Solder	New Component Finish	Rework Solder	Number of Failed Components
ENIG	BGA-225	SAC405	SnPb			75% (3 of 4)
		SnPb	SnPb	SAC405	SnPb	100% (3 of 3)
		SnPb	SnPb	SnPb	Flux Only	33% (1 of 3)
	CLCC-20	SAC305	SnPb			100% (10 of 10)
	CSP-100	SAC105	SnPb			25% (1 of 4)
		SnPb	SnPb	SAC105	SnPb	33% (1 of 3)
		SnPb	SnPb	SnPb	Flux Only	0% (0 of 3)
	PDIP-20	NiPdAu	SnPb			0% (0 of 3)
		Sn	SnPb			33% (1 of 3)
		SnPb	SnPb	Sn	SnPb	0% (0 of 2)
	PTH	ENIG	SnPb			0% (0 of 1)
	QFN-20	Matte Sn	SnPb			20% (1 of 5)
	TQFP-144	NiPdAu	SnPb			20% (1 of 5)
		SnPb Dip	SnPb			60% (3 of 5)
	TSOP-50	Sn	SnPb			33% (1 of 3)
		SnBi	SnPb			33% (1 of 3)
		SnPb	SnPb	Sn	SnPb	100% (2 of 2)
		SnPb	SnPb	SnPb	SnPb	100% (2 of 2)
ENIG Total						48% (31 of 64)
ImAg	BGA-225	SAC405	SAC305	SAC405	Flux Only	60% (9 of 15)
					SnPb	33% (5 of 15)
			SnPb			50% (10 of 20)
		SnPb	SAC305			65% (13 of 20)
			SnPb	SAC405	SnPb	80% (12 of 15)
				SnPb	Flux Only	20% (3 of 15)
	CLCC-20	SAC305	SnPb			98% (49 0f 50)
		SnPb	SAC305			100% (50 of 50)
	CSP-100	SAC105	SAC305	SAC105	Flux Only	20% (3 of 15)
					SnPb	93% (14 of 15)
						60% (3 of 5)
			SnPb			55% (11 of 20)
		SnPb	SAC305			0% (0 of 15)
			SnPb	SAC105	SnPb	7% (1 of 15)
				SnPb	Flux Only	0% (0 of 15)
	PDIP-20	NiPdAu	SnPb			7% (1 of 15)
		Sn	SN100C	Sn	SN100C	20% (2 of 10)
						7% (2 of 30)
			SnPb			13% (2 of 15)
		SnPb	SnPb	Sn	SnPb	40% (4 of 10)
	PTH	ImAg	SN100C			0% (0 of 5)
			SnPb			0% (0 of 5)
	QFN-20	Matte Sn	SnPb			20% (5 of 25)
		SnPb	SAC305			24% (6 of 25)
	TQFP-144	NiPdAu	SAC305			0% (0 of 25)
			SnPb			0% (0 of 25)
		SAC305	SAC305			44% (11 of 25)
		SnPb Dip	SnPb			12% (3 of 25)
	TSOP-50	Sn	SAC305	Sn	SnPb	60% (6 of 10)
			SnPb			20% (3 of 15)
		SnBi	SAC305	SnBi	SAC305	90% (9 of 10)
						67% (10 of 15)
			SnPb			33% (5 of 15)
		SnPb	SAC305			33% (5 of 15)
			SnPb	Sn	SnPb	50% (5 of 10)
				SnPb	SnPb	60% (6 of 10)
ImAg Total						42% (268 of 640)
Grand Total						42% (299 of 704)

BGA-225 Results and Discussion

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components reworked with flux only on a reworked test vehicle is shown in Figure 67. The plot includes the fitted line and 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is not a good fit of the data given there are several early life failures to

the far right of the chart. The fitted line has a ρ (rho) value of 85-percent, less than the desired 95-percent. The Weibull plot will have to be plotted again excluding the early life failures. Figure 69, shows how the reliability plot changes after the outliers are removed.

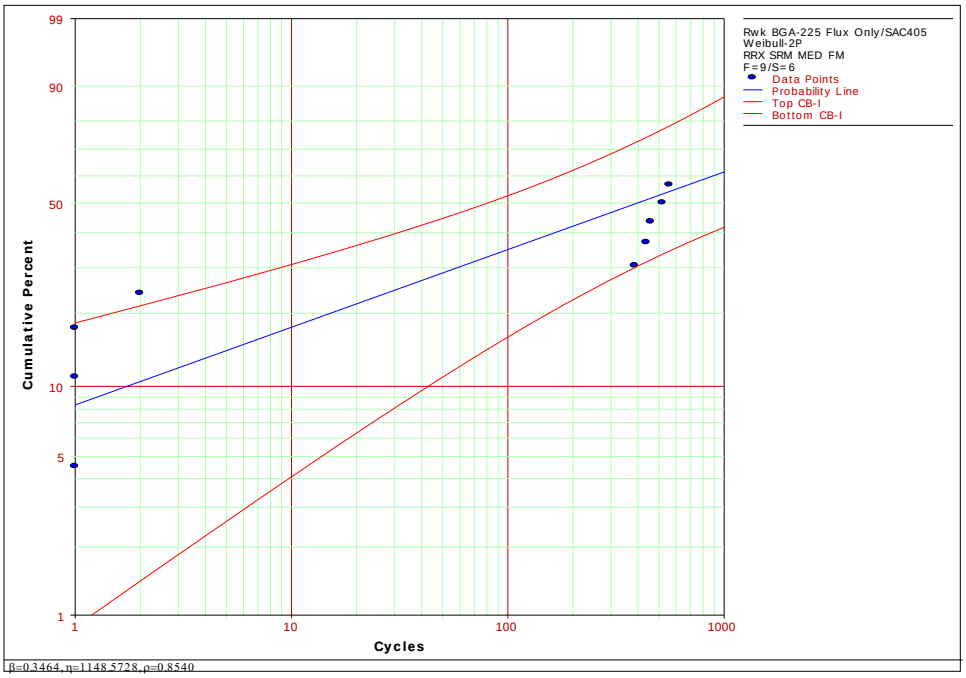


Figure 67 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Flux Only on Rework Test Vehicles

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components reworked with flux only on a rework test vehicle less the outliers is shown in Figure 68. The 2-parameter Weibull plot is an excellent fit of the data, no one data point falls outside of the 95-percent confidence limits. The fitted line has improved to a ρ (rho) value of 97-percent by removing the outliers and redrawing the slope. The changed dramatically, compare this plot to Figure 67.

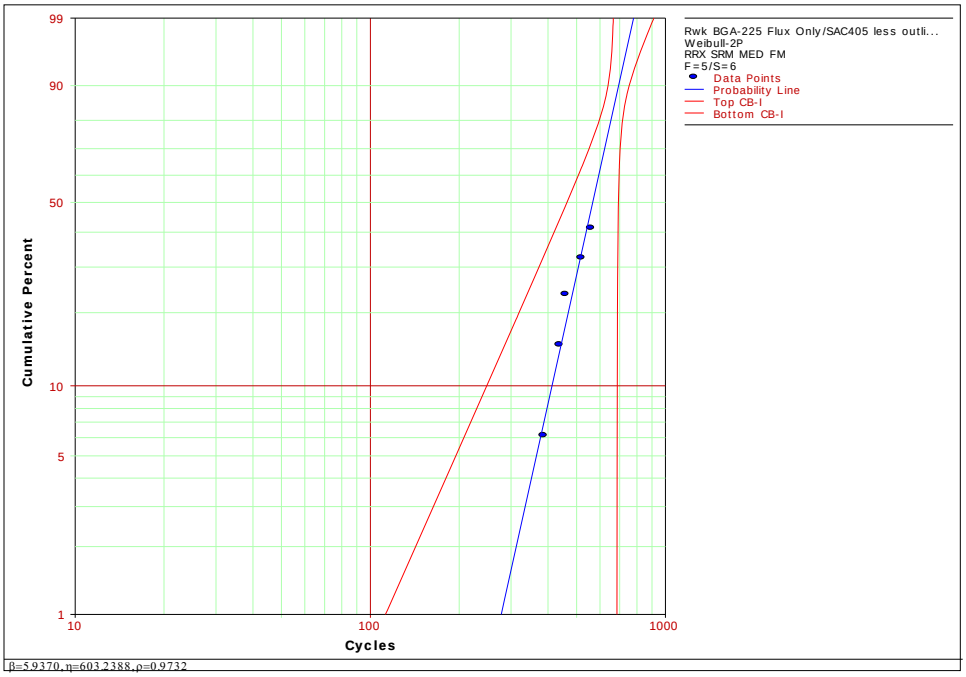


Figure 68 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Flux Only on Rework Test Vehicles less outliers

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components reworked with tin-lead solder paste, Batch A, on a reworked test vehicle is shown in Figure 69. The 2-parameter Weibull plot is a poor fit of the data given the fitted line does not pass through any data points. This fitted line has a ρ (rho) value of 89-percent. There's an outlier in the data. Figure 70 shows how the reliability plot changes after the outlier is removed.

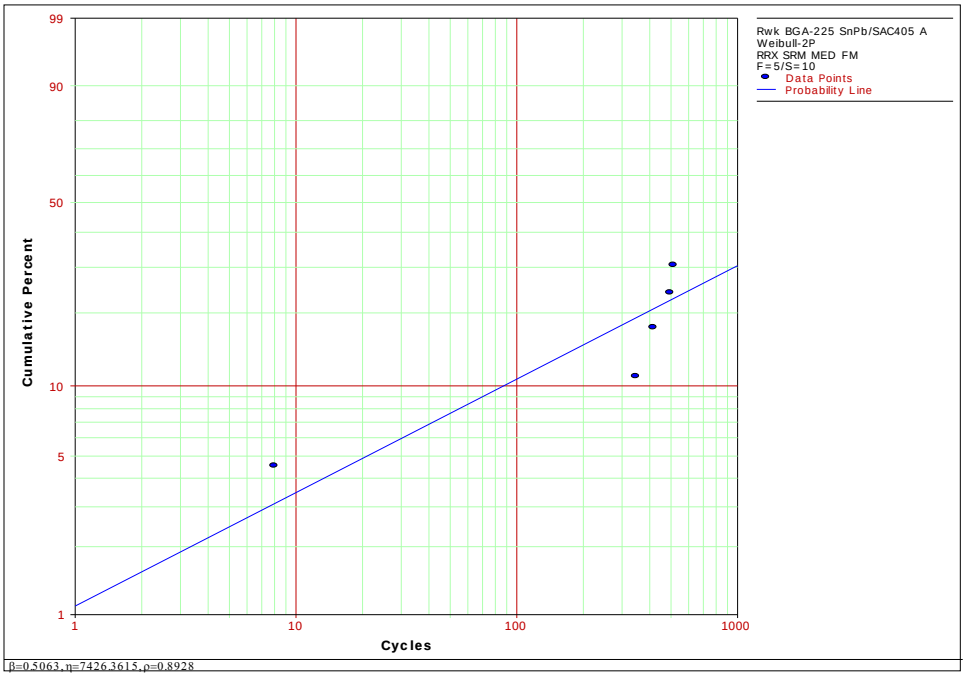


Figure 69 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Batch A Rework Test Vehicles

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components reworked with tin-lead solder paste, Batch A, on a reworked test vehicle less the outlier is shown in Figure 70. The 2-parameter Weibull plot is an excellent fit of the data. The fitted line has improved to a ρ (rho) value of 99-percent. Removing the outlier changes the slope of the fitted line dramatically.

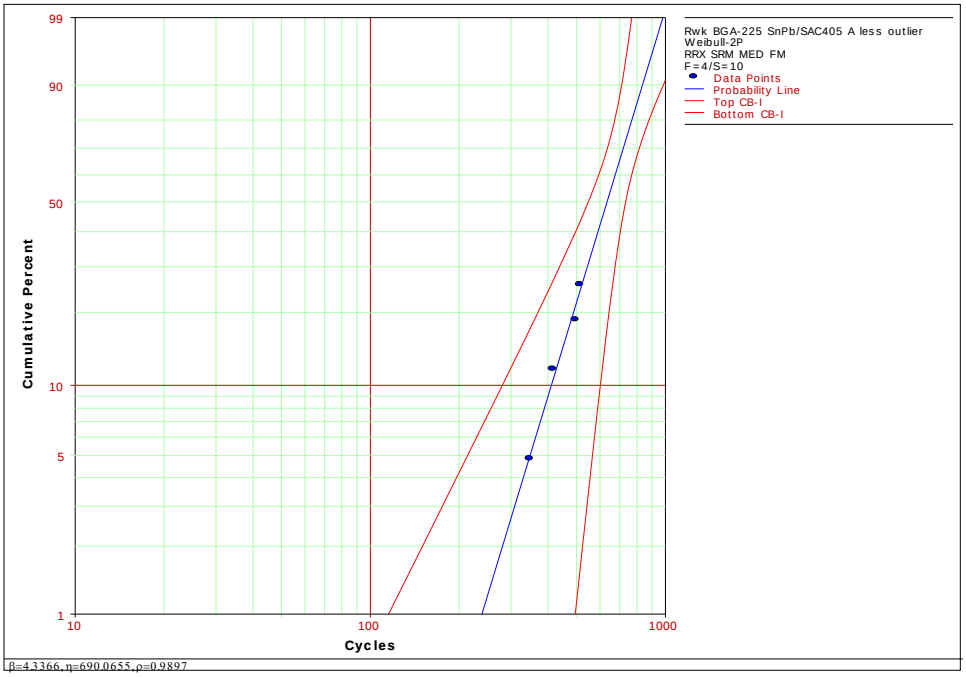


Figure 70 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Batch A Rework Test Vehicles less outlier

The Weibull plot for tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste in the rework test vehicle group is shown in Figure 71. The 2-paramater Weibull plot is a good fit of the data given no one data point falls outside of the 95-percent confidence limits. The fitted line has a ρ (rho) value of 94-percent. There appears to be a “stair step” in the data.

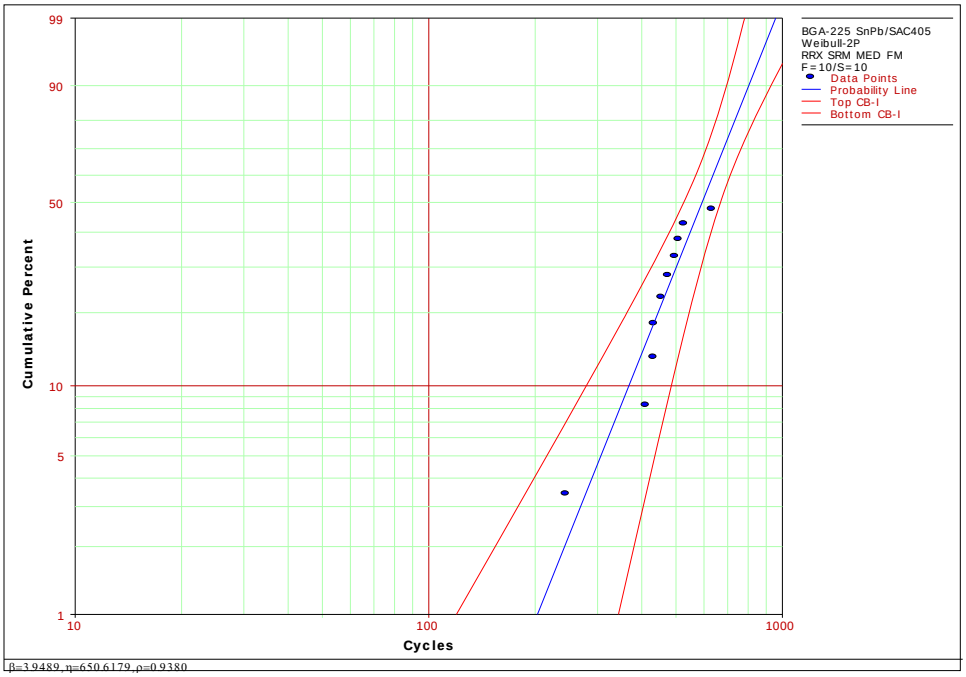


Figure 71 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Rework Test Vehicles

The Weibull plot for tin-lead BGA-225 components soldered with tin-silver-copper 305 solder paste in the rework test vehicle group is shown in Figure 72. The 2-parameter Weibull plot is a fair fit of the data. There are a few data points to the far left that appear to pull the slope of the reliability plot to the left, therefore, skewing the results. The fitted line has a ρ (rho) value of 87-percent. There appears to be a "stair step" in the data.

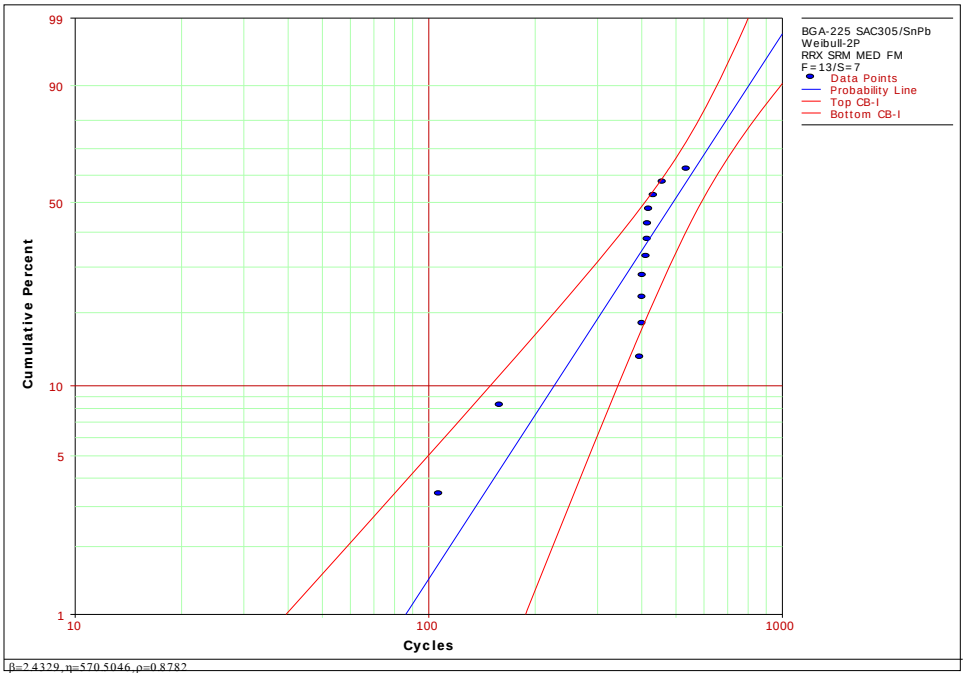


Figure 72 Weibull Plot of Tin-Lead BGA-225 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste, Batch B, in the rework test vehicle group is shown in Figure 73. The 2-parameter Weibull plot is an excellent fit of the data. The fitted line has a ρ (rho) value of 99-percent.

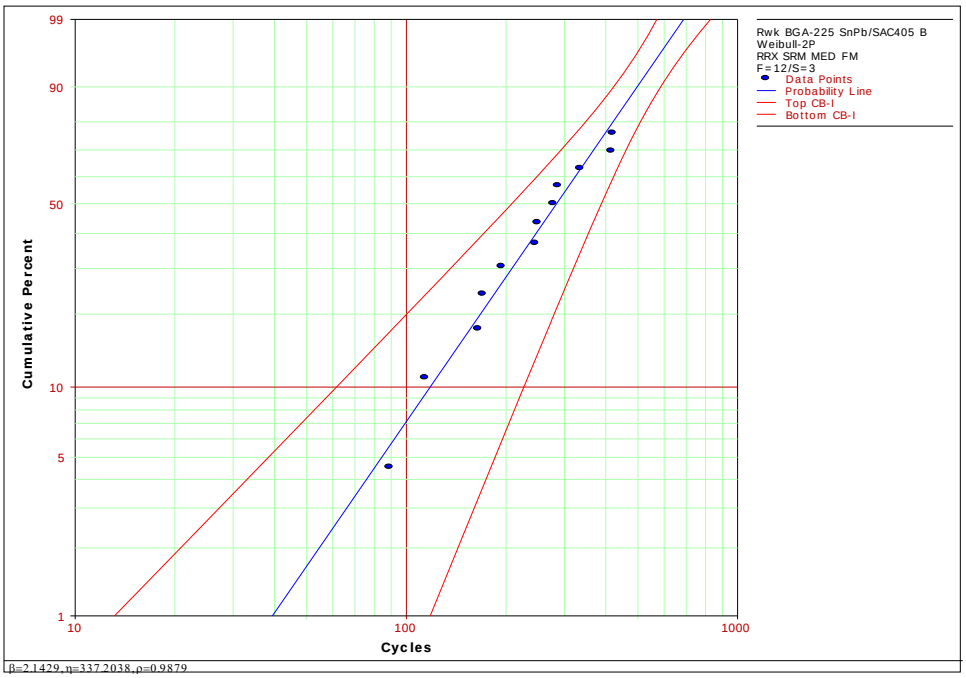


Figure 73 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder on Batch B Rework Test Vehicles

The Weibull plot for reworked tin-lead BGA-225 components reworked with flux only is shown in Figure 74. The 2-parameter Weibull plot is a fair fit of the data, considering there are three data points. The fitted line has a ρ (rho) value of 91-percent, which is slightly less than the desired 95-percent.

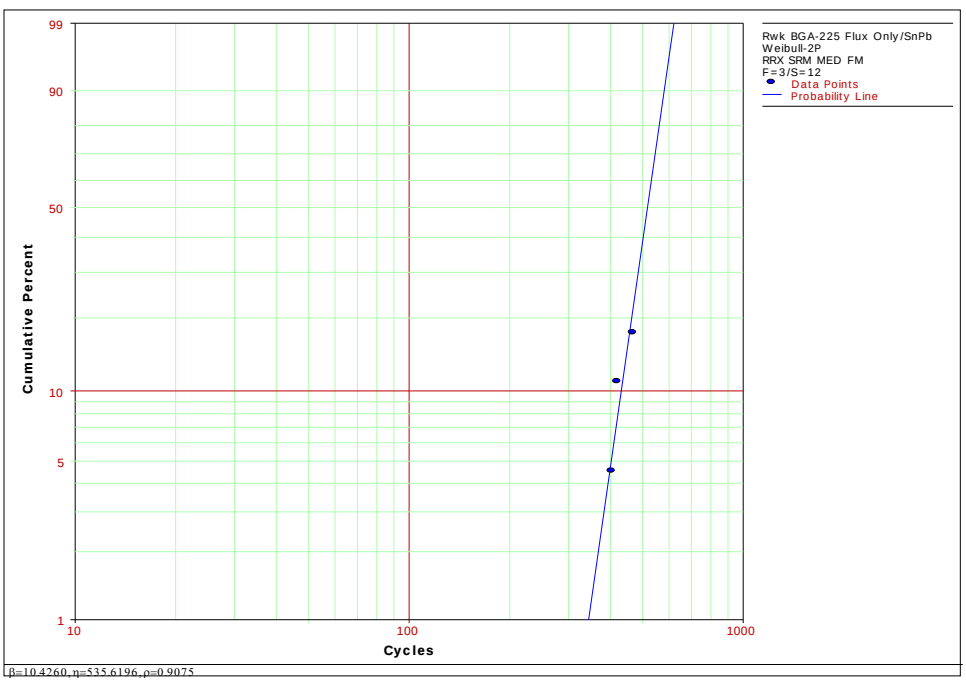


Figure 74 Weibull Plot of Reworked Tin-Lead BGA-225 with Flux Only on Rework Test Vehicles

Figure 75 shows all the combinations of rework component finish and solder alloy for BGA-225 components on the rework test vehicles. Overall, the reworked tin-silver-copper 405 BGA-225 components reworked with tin-lead solder paste, Batch A, less the outlier was the most reliable. The plot also shows that tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste performed the same as tin-silver-copper 405 BGA-225 components reworked with tin-lead solder paste.

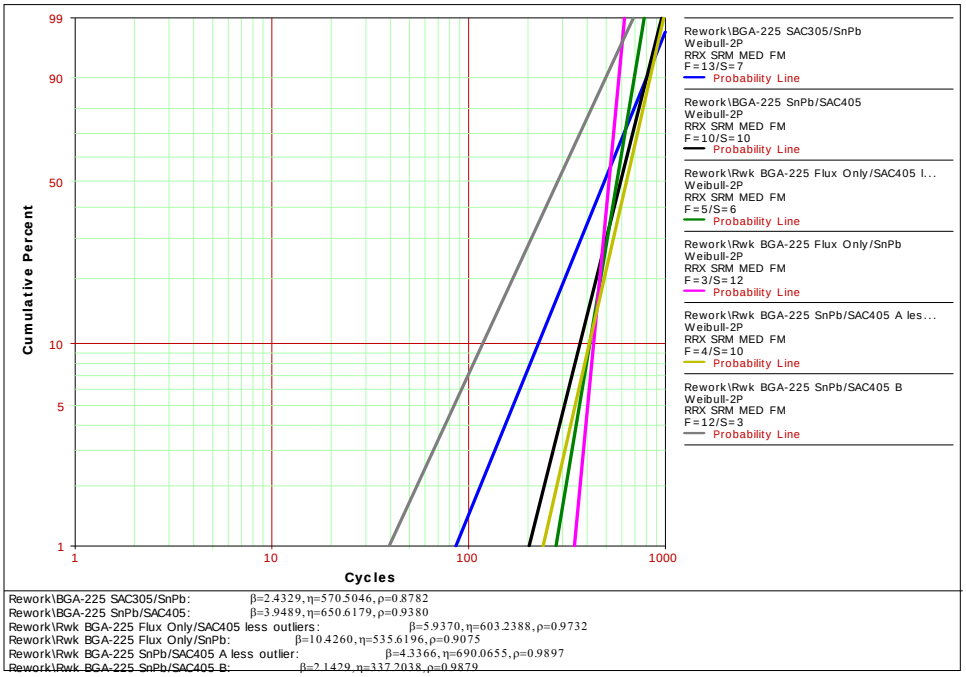


Figure 75 Weibull Plots of BGA-225 on Rework Test Vehicle

Figure 76 shows the Weibull plot comparing the reworked BGA-225 components on rework test vehicles. Overall, reworked tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste less the outlier perform the best of all the reliability plots on the chart.

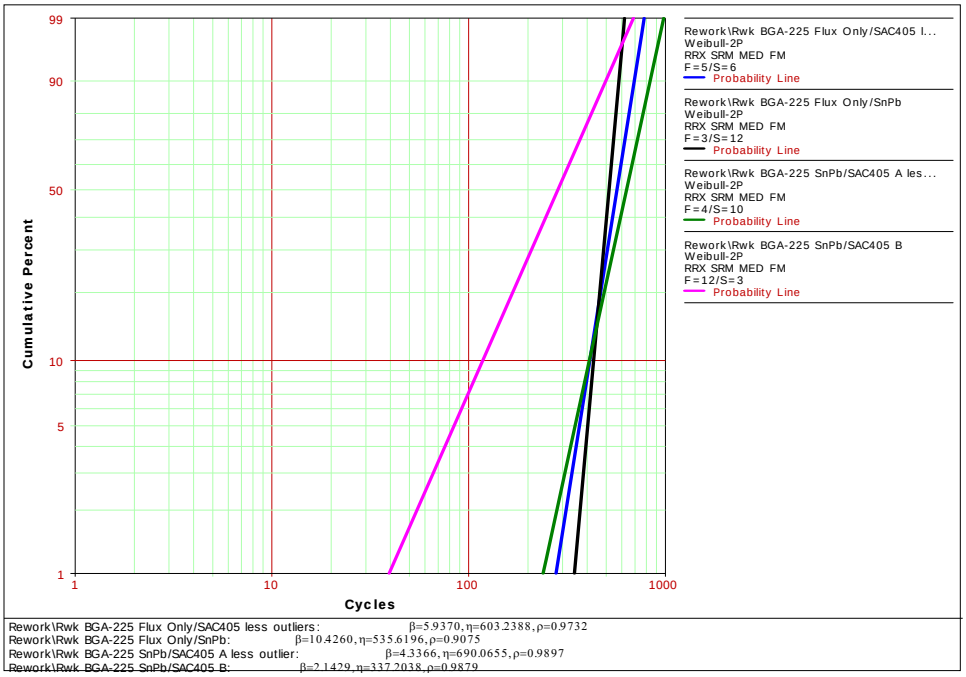


Figure 76 Weibull Plots of Reworked BGA-225 on Rework Test Vehicle

CLCC-20 Results and Discussion

The Weibull plot for reworked tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste on reworked test vehicles is shown in Figure 77. The plot includes the fitted line and 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is an excellent fit of the data only a few data points fall outside of the confidence limits. This fitted line has a ρ (rho) value of 98-percent. There appears to be a "stair step" in the data indicating possible changes in stresses applied to the test vehicle or multiple failure modes in the solder joint failures. The test logs were reviewed fro potential chamber problems or test procedural issues. No common cause for the stair step has been identified.

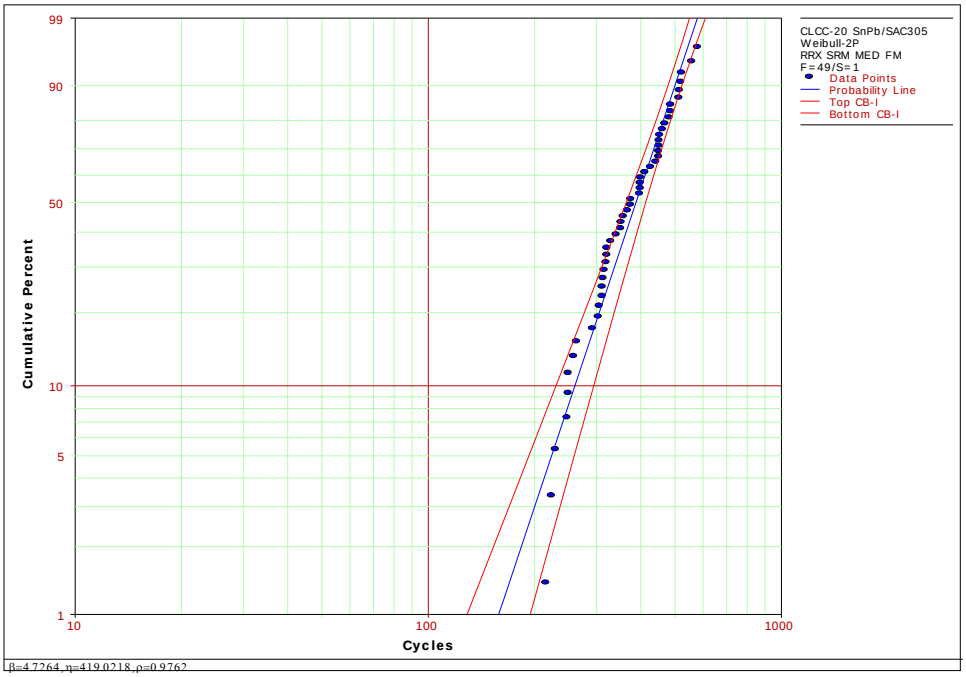


Figure 77 Weibull Plot of Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Rework Test Vehicles

The Weibull plot for tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 78. The 2-parameter Weibull plot is an excellent fit of the data only a few data points fall outside of the confidence limits. The fitted line has a ρ (rho) value of 98-percent. There appears to be two "stair steps" in the data.

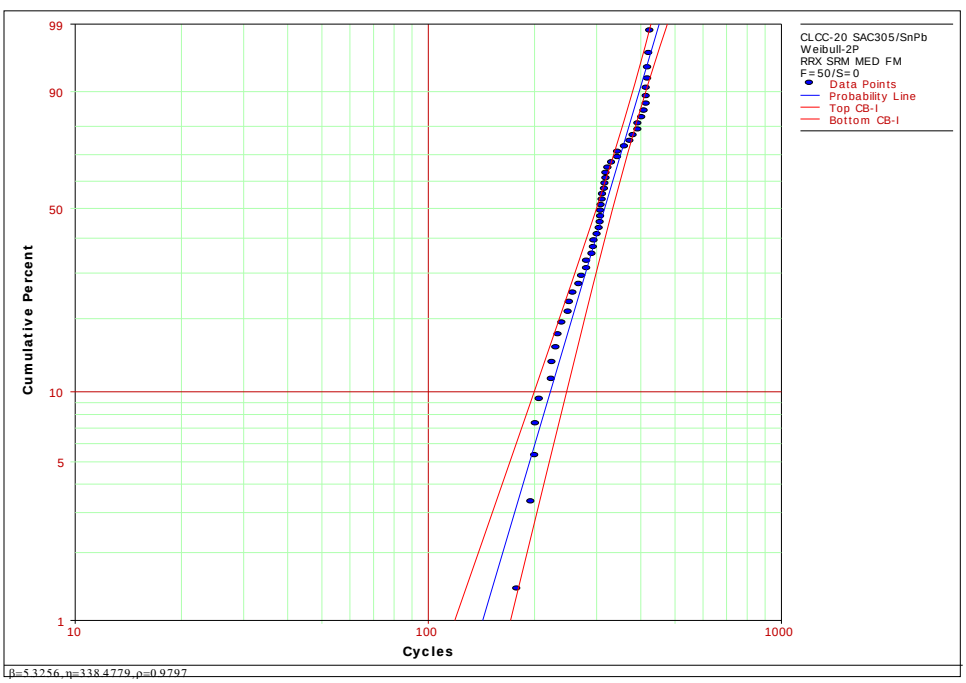


Figure 78 Weibull Plot of Tin-Lead CLCC-20 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plots from Figure 77 and Figure 78 have been combined in Figure 79 for comparative purposes. Overall, tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste has better solder joint

reliability performance than tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste on reworked test vehicles.

Figure 79 Weibull Plots of CLCC-20 on Rework Test Vehicles

CSP-100 Results and Discussion

The Weibull plot for reworked tin-silver-copper 105 CSP-100 components reworked with flux only on rework test vehicles is shown in Figure 80. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is an excellent fit of the data where the fitted line has a ρ (rho) value of 99-percent.

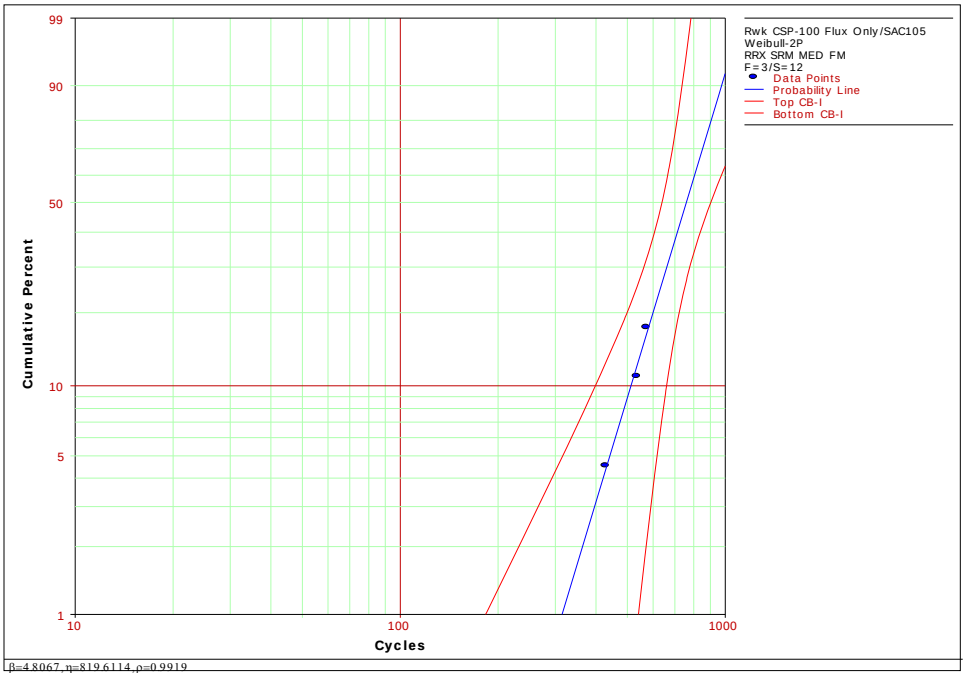


Figure 80 Weibull Plot of Reworked Tin-Silver-Copper 105 CSP-100 with Flux Only on Rework Test Vehicles

The Weibull plot for reworked tin-silver-copper 105 CSP-100 components soldered with tin-lead solder paste on Batch A rework test vehicles is shown in Figure 81. The 2-parameter Weibull plot is an excellent fit of the data where the fitted line has a ρ (rho) value of 98-percent. There appears to be more than one "stair steps" in the data.

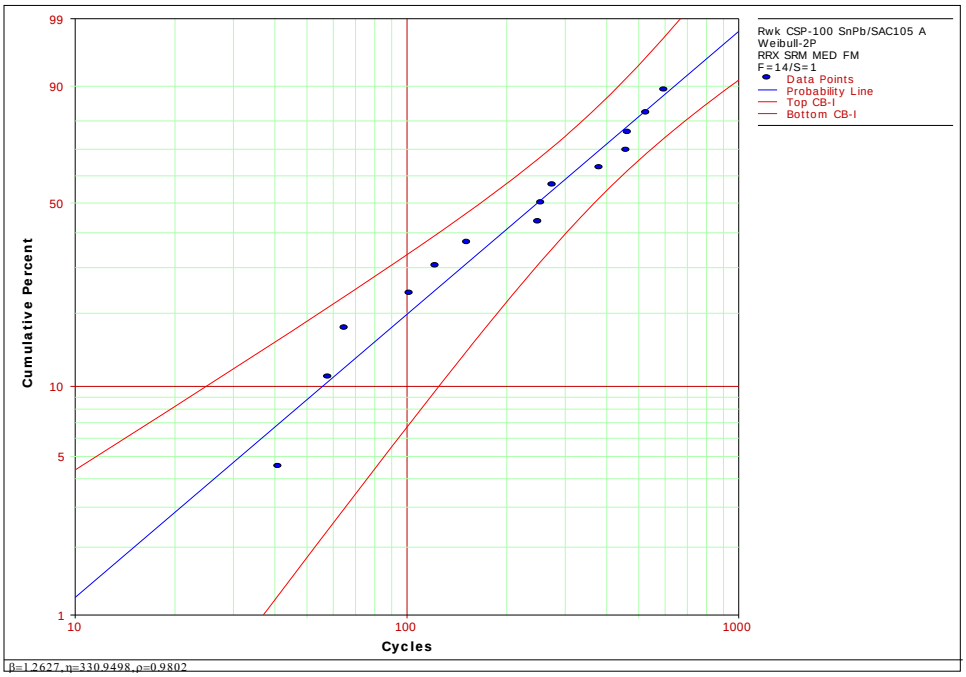


Figure 81 Weibull Plot of Reworked Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Batch A Rework Test Vehicles

The Weibull plot for tin-silver-copper 105 CSP-100 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 83. The 2-parameter Weibull plot is a good fit of the data where the fitted line has a ρ (rho) value of 94-percent.

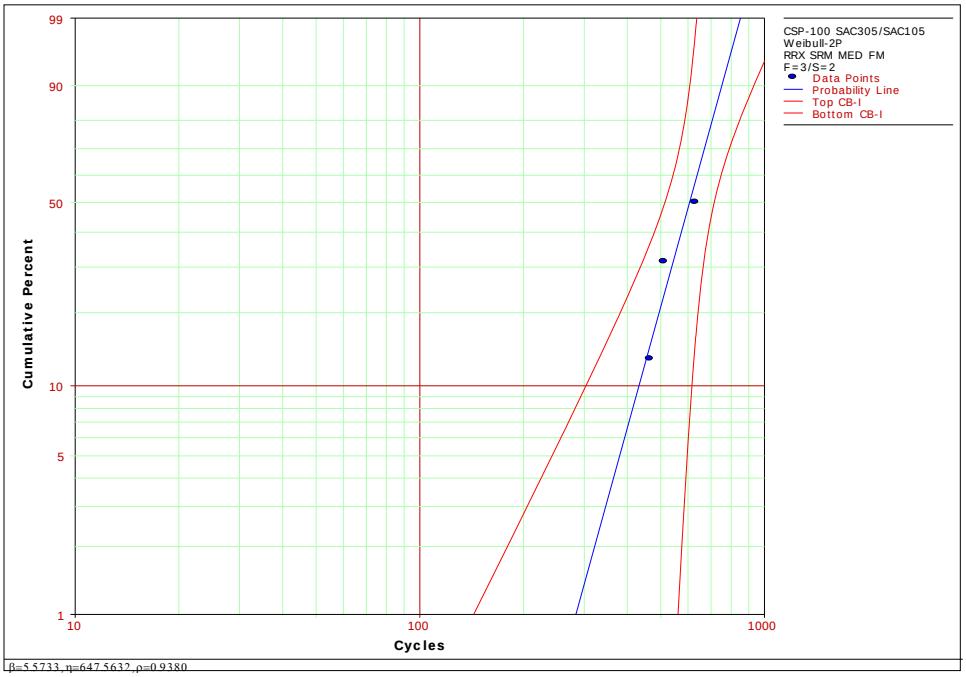


Figure 82 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plot for tin-silver-copper 105 CSP-100 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 83. The 2-parameter Weibull plot is an excellent fit of the data where the fitted line has a ρ (rho) value of 97-percent. There appears to be a "stair step" in the data.

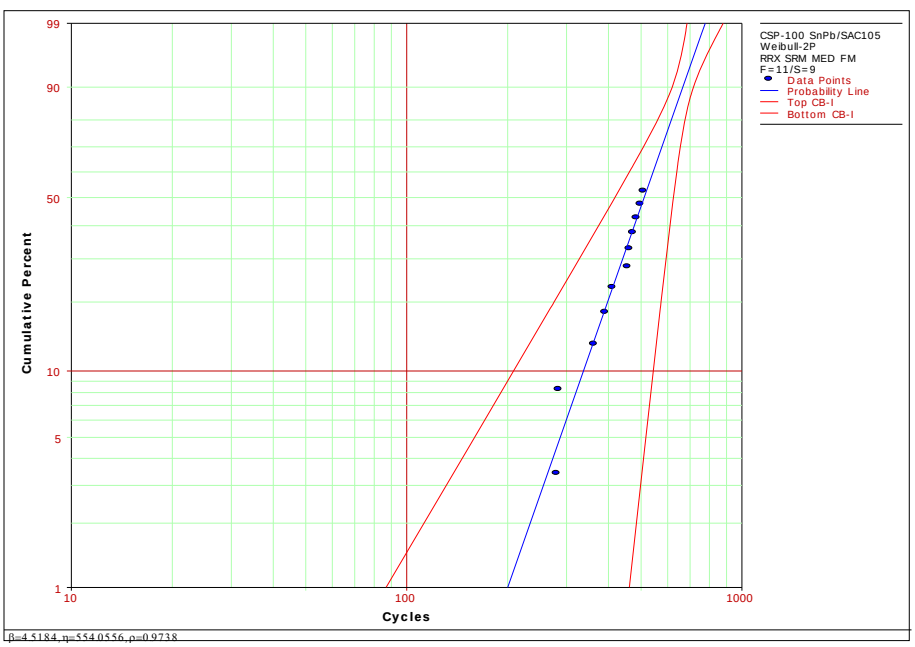


Figure 83 Weibull Plot of Tin-Silver-Copper 105 CSP-100 with Tin-Lead Solder Paste on Rework Test Vehicles

Figure 84 combines all the rework CSP-100 component Weibull results on rework test vehicles. Overall, reworked tin-silver-copper 105 CSP-100 components reworked with flux only performed the best in solder joint reliability.

Solder joint reliability of tin-silver-copper 105 CSP-100 components soldered with tin-silver-copper 305 solder paste performed second best.

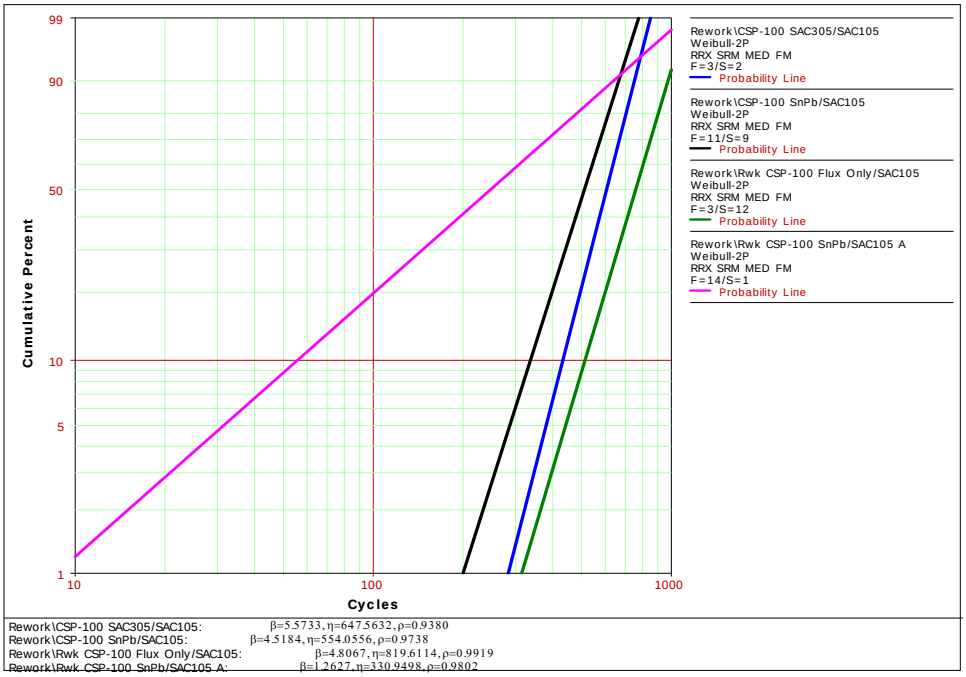


Figure 84 Weibull Plot of CSP-100 on Rework Test Vehicles

PDIP-20 Results and Discussion

The Weibull plot for reworked tin PDIP-20 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 85. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is a fair fit of the data where the fitted line has a ρ (rho) value of 89-percent, which is less than the desired 95-percent. No other test data was collected for PDIP-20 components on reworked test vehicles.

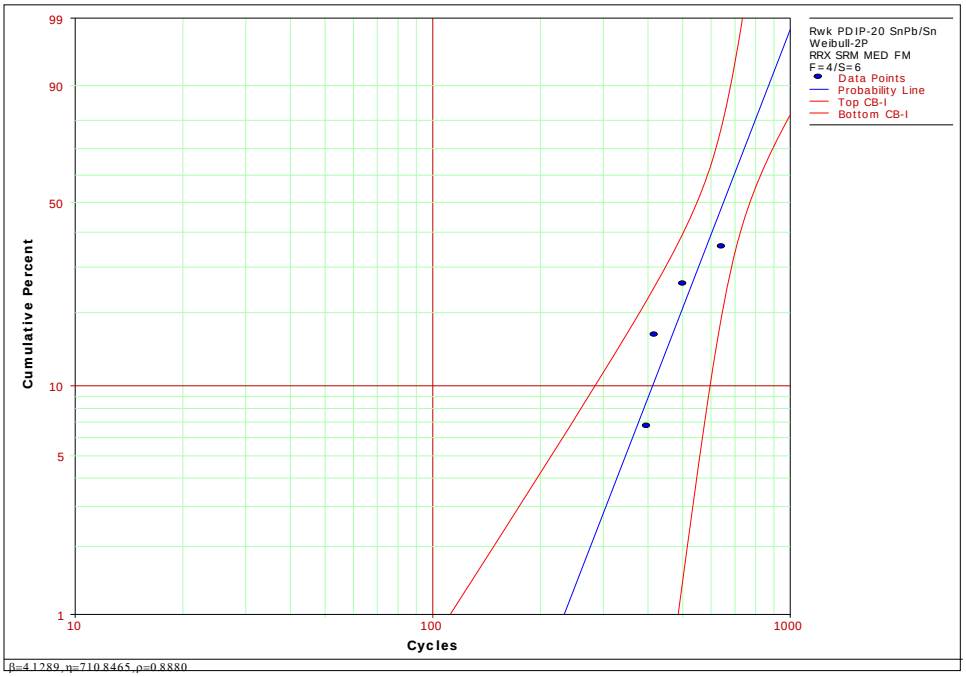


Figure 85 Weibull Plot of Reworked Tin PDIP-20 with Tin-Lead Solder on Rework Test Vehicles

TQFP-144 Results and Discussion

The Weibull plot for tin-silver-copper 305 TQFP-144 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 86. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is not a good fit of the data because there are several early life failures, less than 10 cycles, on the plot. The data will have to be plotted again without the outliers, Figure 87, to show the affect of the outliers on the fitted line's slope.

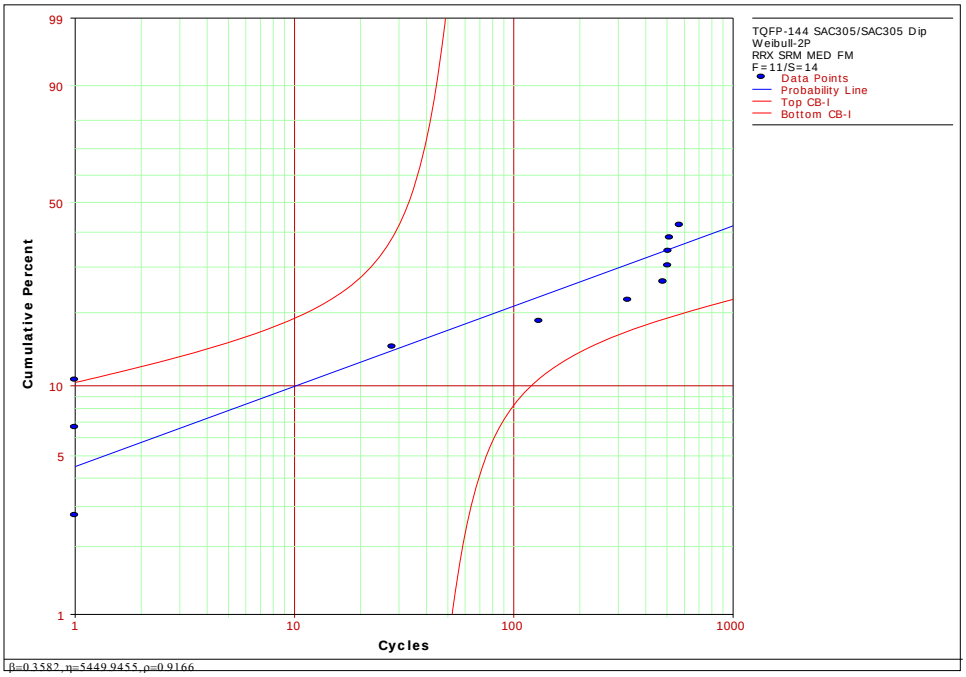


Figure 86 Weibull Plot of Tin-Silver-Copper 305 TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plot for tin-silver-copper 305 TQFP-144 components soldered with tin-silver-copper 305 solder paste less the outliers on rework test vehicles is shown in Figure 87. The 2-parameter Weibull plot is a fair fit of the data after the outliers were removed. The fitted line has a ρ (rho) value of 94-percent, but there is a data point to the far right that is influencing the slope of the fitted line. Please note Figure 86 and Figure 87 do not have the same scale.

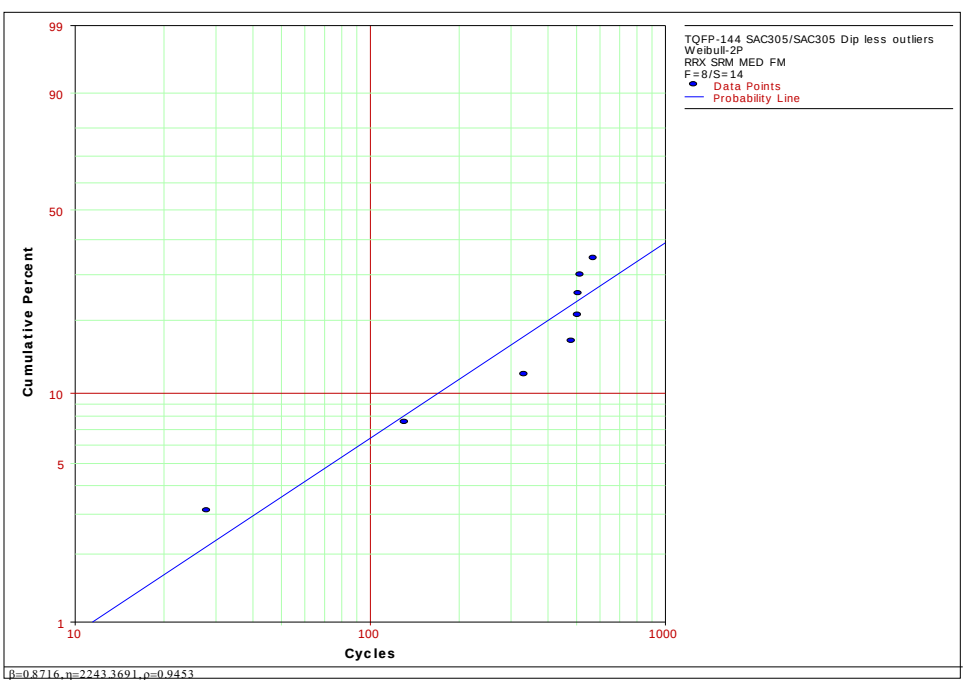


Figure 87 Weibull Plot of Tin-Silver-Copper 305 TQFP-144 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles less outliers

The Weibull plot for tin-lead dipped TQFP-144 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 88. The 2-parameter Weibull plot is an excellent fit of the data. The fitted line has a ρ (rho) value of 99-percent.

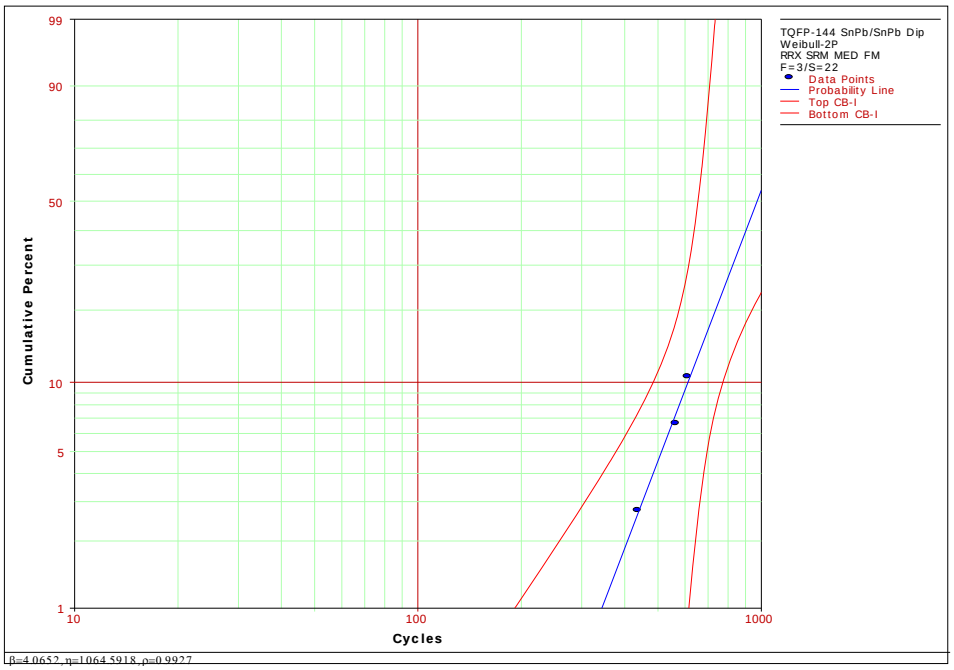


Figure 88 Weibull Plot of Tin-Lead Dipped TQFP-144 with Tin-Lead Solder Paste on Rework Test Vehicles

Figure 87 and Figure 88 are plotted together in Figure 89 for comparative purposes. It can be determined that tin-lead dipped TQFP-144 components soldered with tin-lead solder paste performed better than tin-silver-copper 305 dipped TQFP-144 components soldered with tin-silver-copper 305 solder paste less the outliers on rework test vehicles.

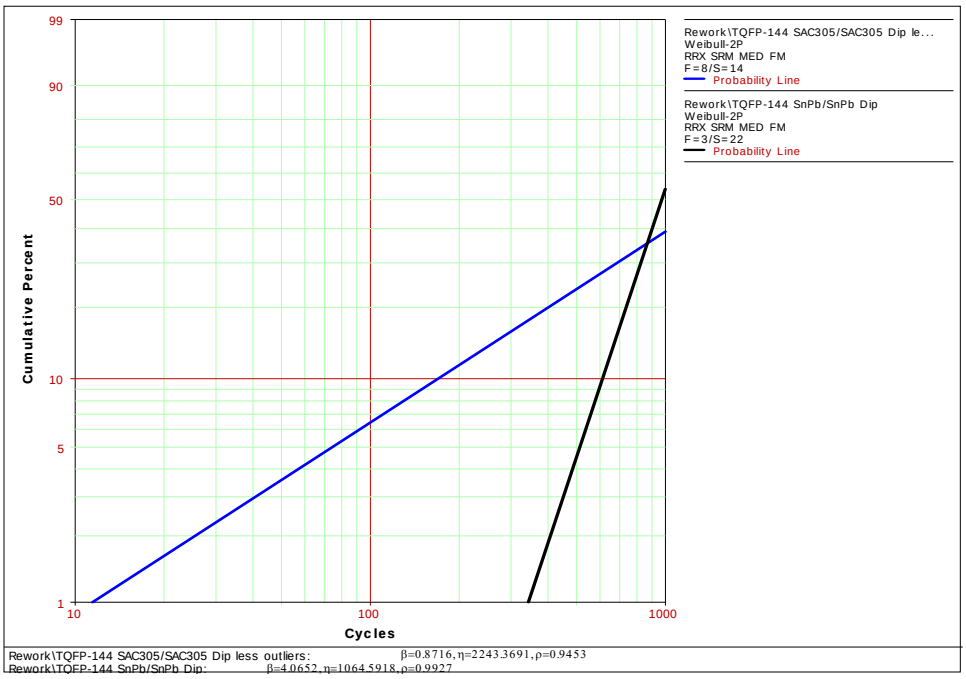


Figure 89 Weibull Plots of TQFP-144 on Rework Test Vehicles

TSOP-50 Results and Discussion

The Weibull plot for reworked tin TSOP-50 components reworked with tin-lead solder paste, Batch A, on rework test vehicles is shown in Figure 90. The plot includes the fitted line only. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is not a good fit of the data because there is an early life failure to the far right of the plot. The data will have to be plotted again minus the outlier, Figure 92, to show the affect of the outlier on the reliability slope.

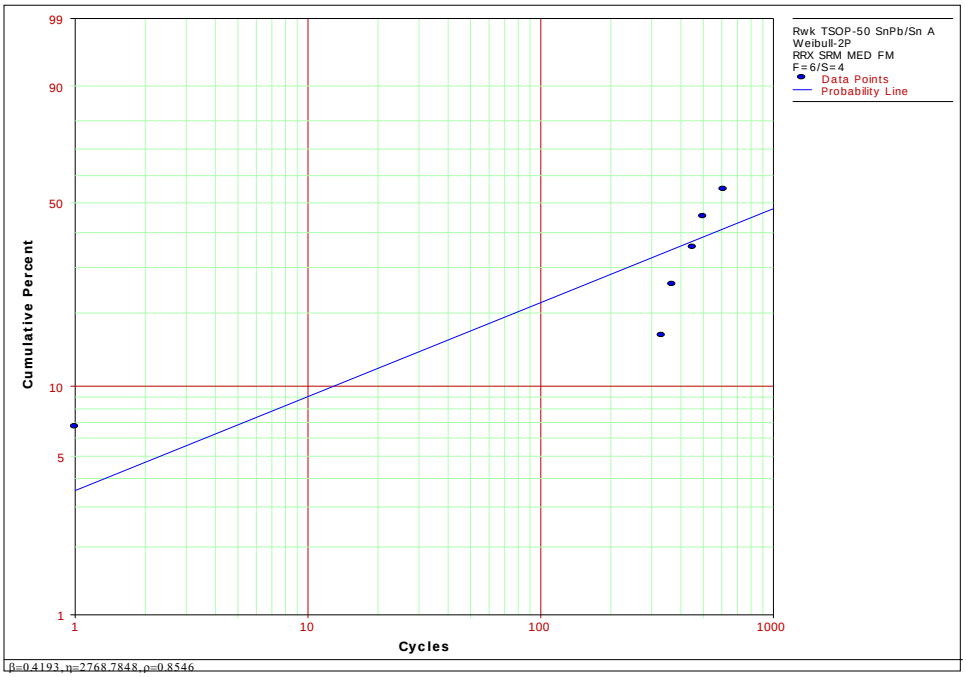


Figure 90 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch A Rework Test Vehicles

The Weibull plot for reworked tin TSOP-50 components reworked with tin-lead solder paste less the outlier, Batch A, on rework test vehicles is shown in Figure 91. The slope of the reliability plot shifted dramatically to the left to fit the data better, this is also shown through the 95-percent confidence limits, as well. Therefore, the 2-parameter Weibull plot is now a good fit of the data. The fitted line has a ρ (rho) value of 96-percent.

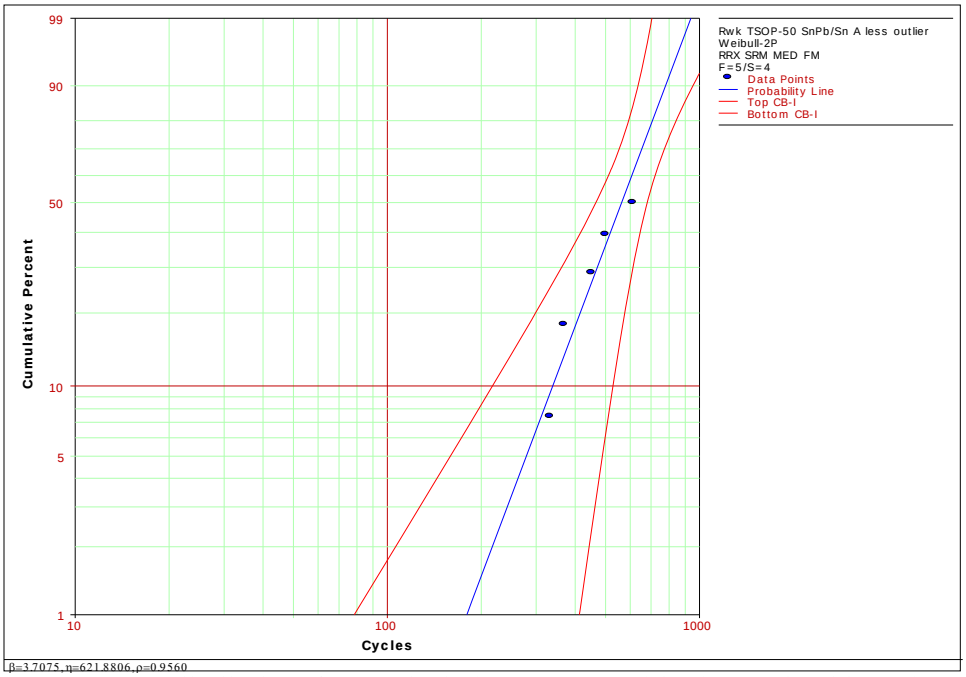


Figure 91 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch A Rework Test Vehicles less outlier

The Weibull plot for tin TSOP-50 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 92. The 2-parameter Weibull plot is a fair fit of the data, where the fitted line has a ρ (rho) value of 90-percent, which is less than the desired 95-percent.

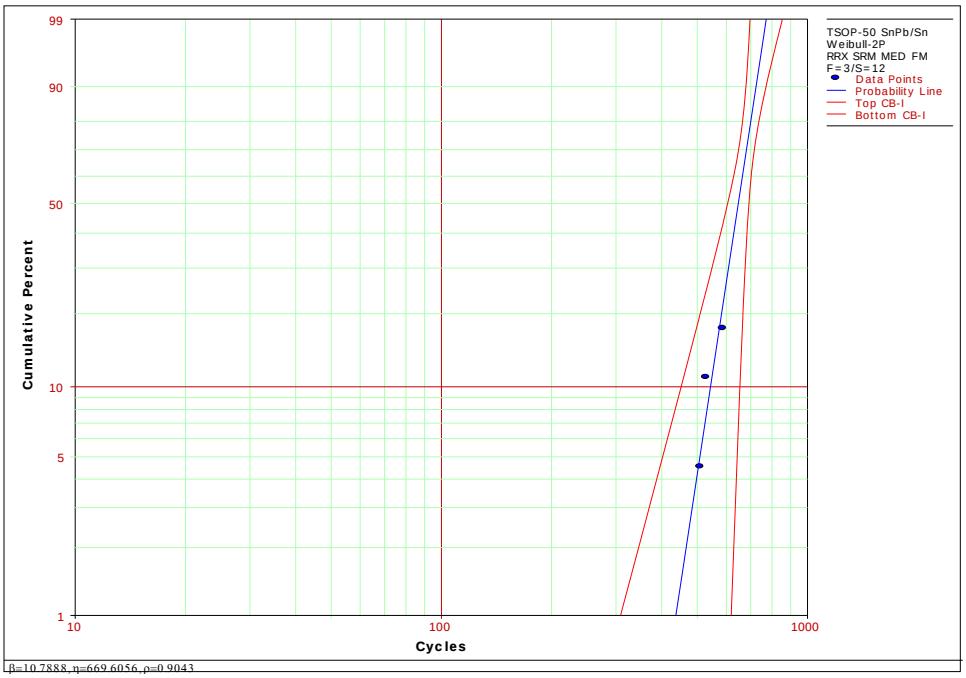


Figure 92 Weibull Plot of Tin TSOP-50 with Tin-Lead Solder Paste on Rework Test Vehicles

The Weibull plot for reworked tin-bismuth TSOP-50 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 93. The 2-parameter Weibull plot is a good fit of the data, where the fitted line has a ρ (rho) value of 97-percent. There appears to be a "stair step" approximately at 500 cycles.

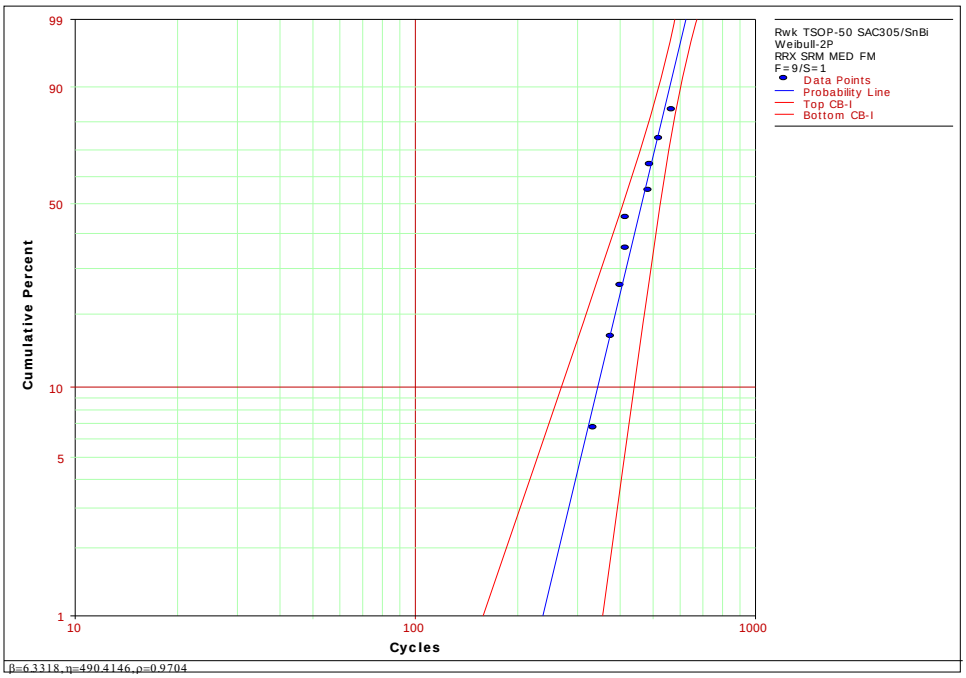


Figure 93 Weibull Plot of Reworked Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Wire on Rework Test Vehicles

The Weibull plot for tin-bismuth TSOP-50 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 94. The 2-parameter Weibull plot is a good fit of the data, where the fitted line has a ρ (rho) value of 95-percent. There appears to be two "stair steps" in the data.

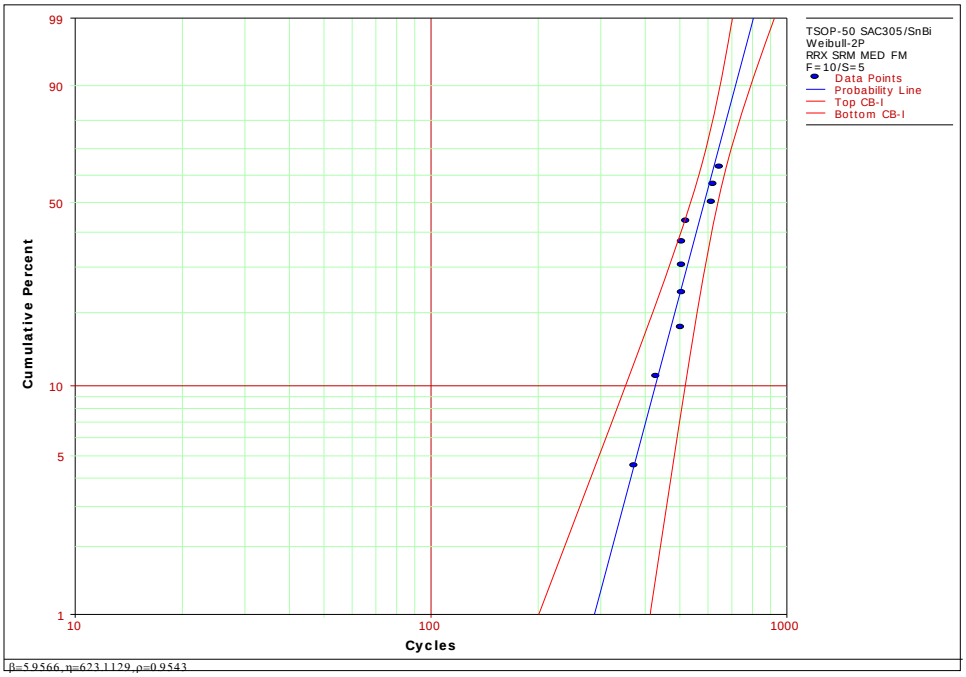


Figure 94 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plot for tin-bismuth TSOP-50 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 95. The 2-parameter Weibull plot is an excellent fit of the data, where the fitted line has a ρ (rho) value of 98-percent.

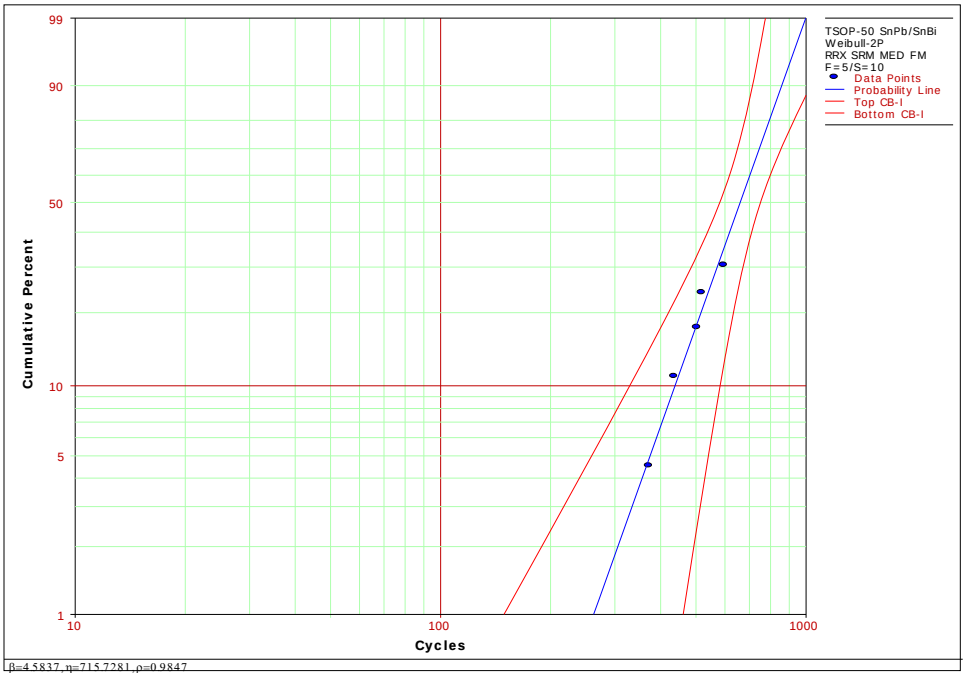


Figure 95 Weibull Plot of Tin-Bismuth TSOP-50 with Tin-Lead Solder Paste on Rework Test Vehicles

The Weibull plot for tin-lead TSOP-50 components soldered with tin-silver-copper 305 solder paste on rework test vehicles is shown in Figure 96. The 2-parameter Weibull plot is a good fit of the data, where the fitted line has a ρ (rho) value of 92-percent, slightly less than the desired 95-percent.

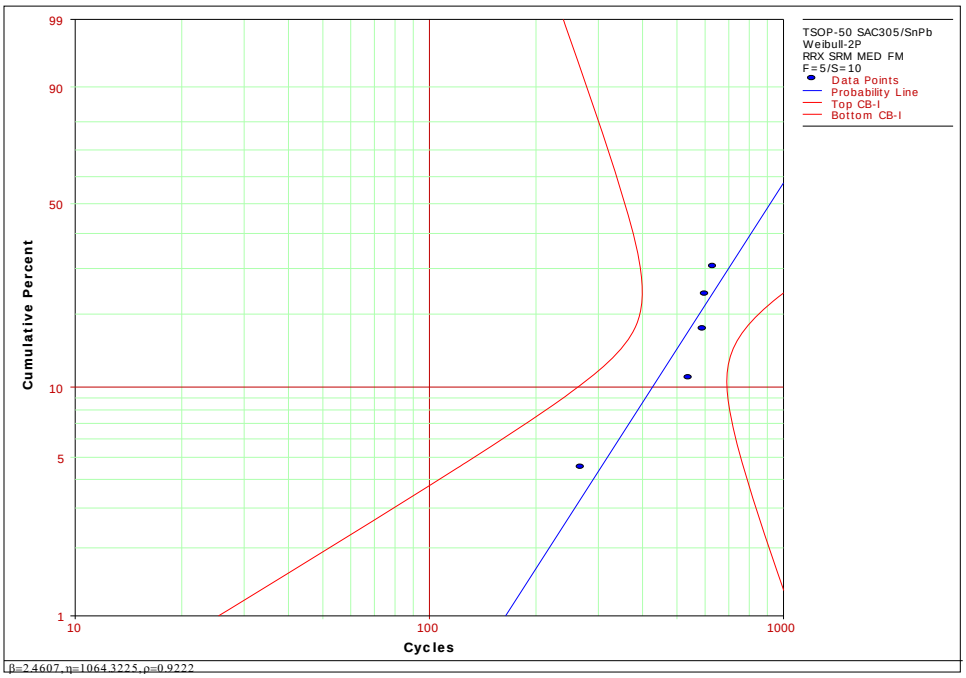


Figure 96 Weibull Plot of Tin-Lead TSOP-50 with Tin-Silver-Copper 305 Solder Paste on Rework Test Vehicles

The Weibull plot for reworked tin TSOP-50 components reworked with tin-lead solder paste, Batch B, on rework test vehicles is shown in Figure 97. The 2-parameter Weibull plot is an excellent fit of the data, where the fitted line has a ρ (rho) value of 98-percent.

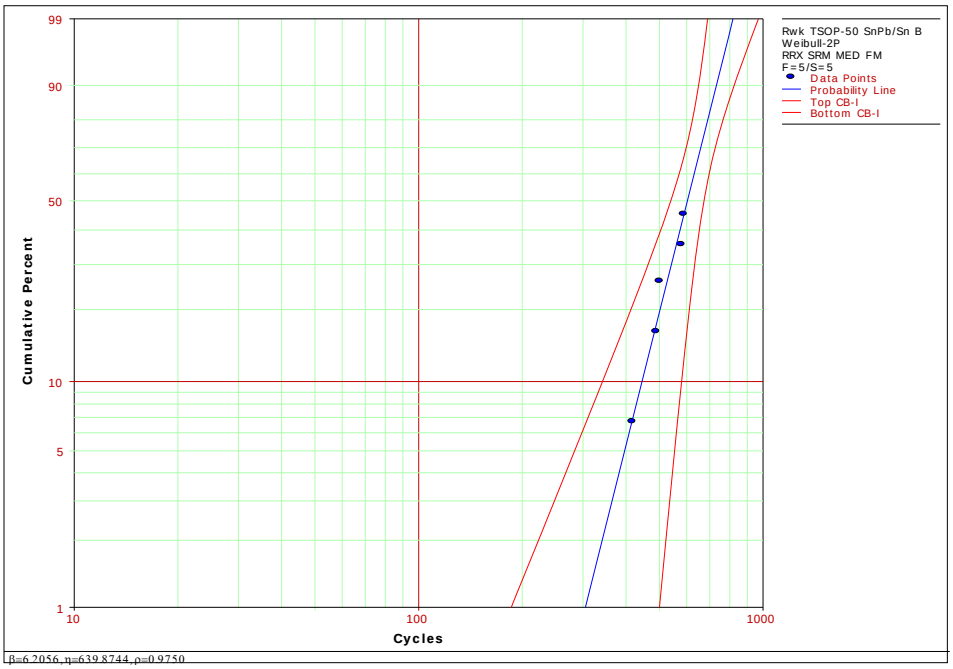


Figure 97 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Batch B Rework Test Vehicles

The Weibull plot for reworked tin-lead TSOP-50 components reworked with tin-lead solder paste on rework test vehicles is shown in Figure 98. The 2-parameter Weibull plot is an excellent fit of the data, where the fitted line has a ρ (rho) value of 97-percent.

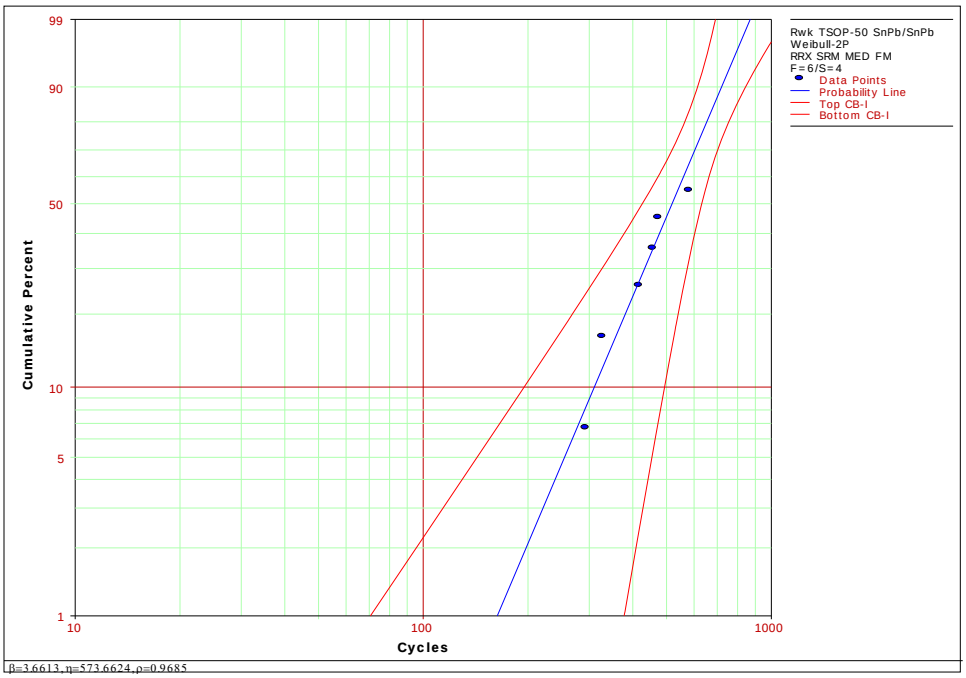


Figure 98 Weibull Plot of Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles

Figure 99 shows all the different Weibull plots generated for the TSOP-50 component on reworked test vehicles. It can be determined that tin TSOP-50 components soldered with tin-lead solder paste on rework test vehicles performed better than any other combination of solder alloy and rework for the TSOP-50 component.

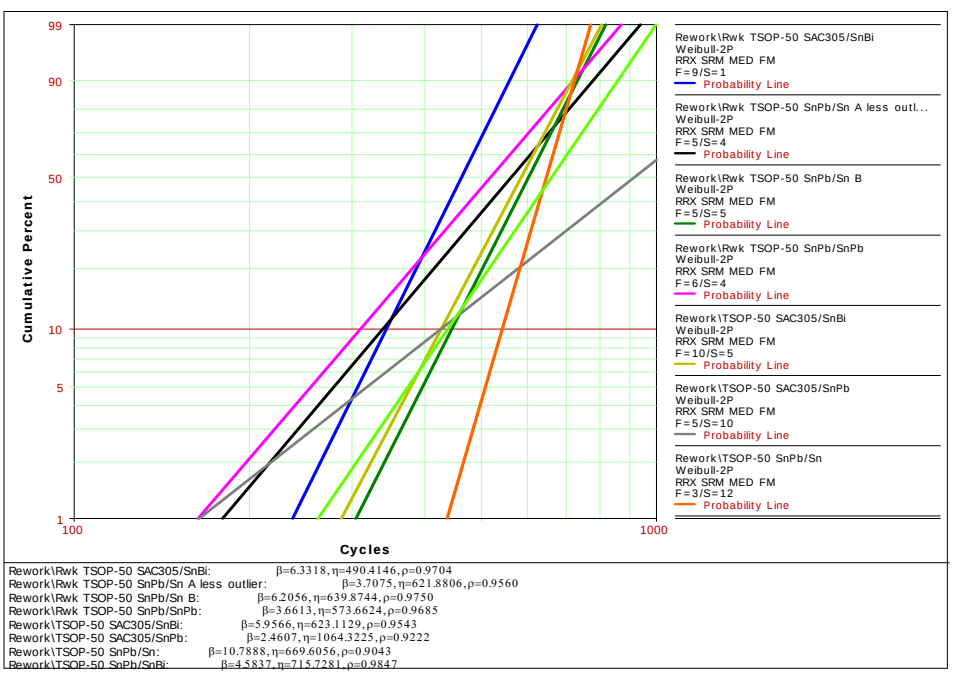


Figure 99 Weibull Plots of TSOP-50 on Rework Test Vehicles

Figure 100 shows the different Weibull plots generated for the reworked TSOP-50 components on reworked test vehicles. It can be determined that reworked tin TSOP-50 components reworked with tin-lead solder paste, Batch B, on rework test vehicles performed better than the other combinations.

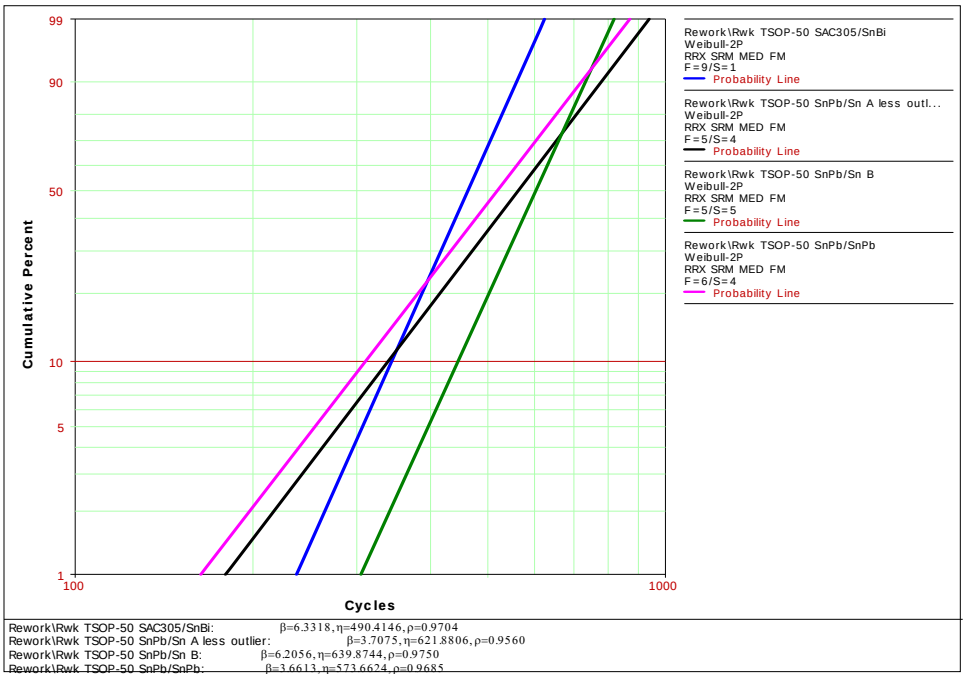


Figure 100 Weibull Plots of Reworked TSOP-50 on Rework Test Vehicles

Electroless Nickel Immersion Gold (ENIG) Rework Test Vehicle Results and Discussion

The Weibull plot for tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste on ENIG board finish reworked test vehicle is shown in Figure 101. The plot includes the fitted line and the 95-percent confidence limits. The legend on the right of the chart indicates components that have been reworked or are on a reworked test vehicle. The "Rwk" identifies reworked components, data without the "Rwk" label identifies the build solder alloy and original component finish. The 2-parameter Weibull plot is a poor fit of the data, where the fitted line has a ρ (rho) value of 81-percent, less than the desired 95-percent.

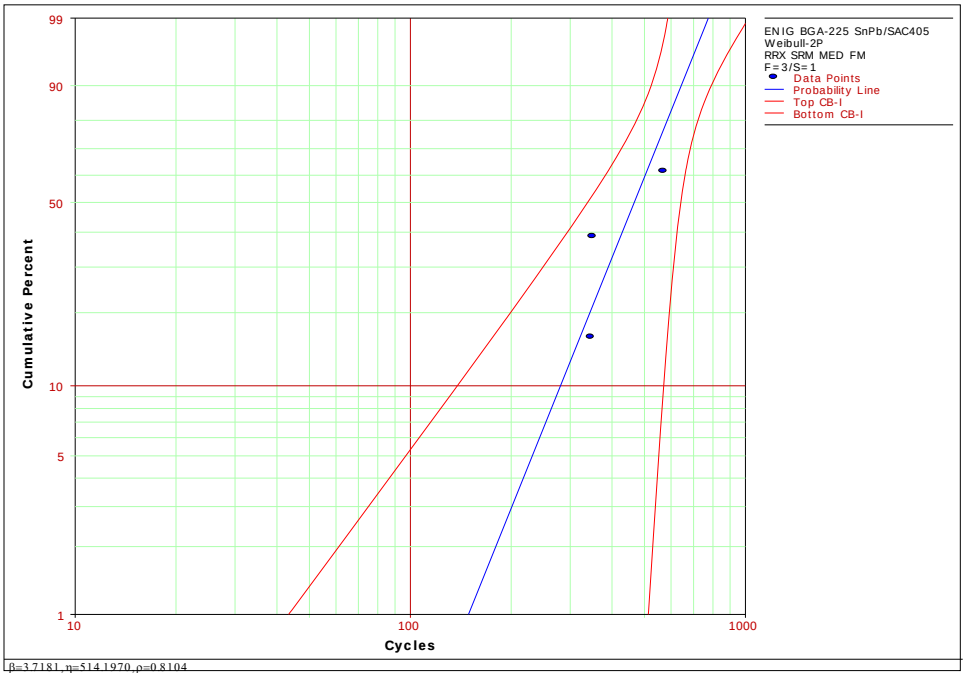


Figure 101 Weibull Plot of Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste is shown in Figure 102. Overall, the probability that immersion silver board finish performs better than the ENIG board finish is 72-precent.

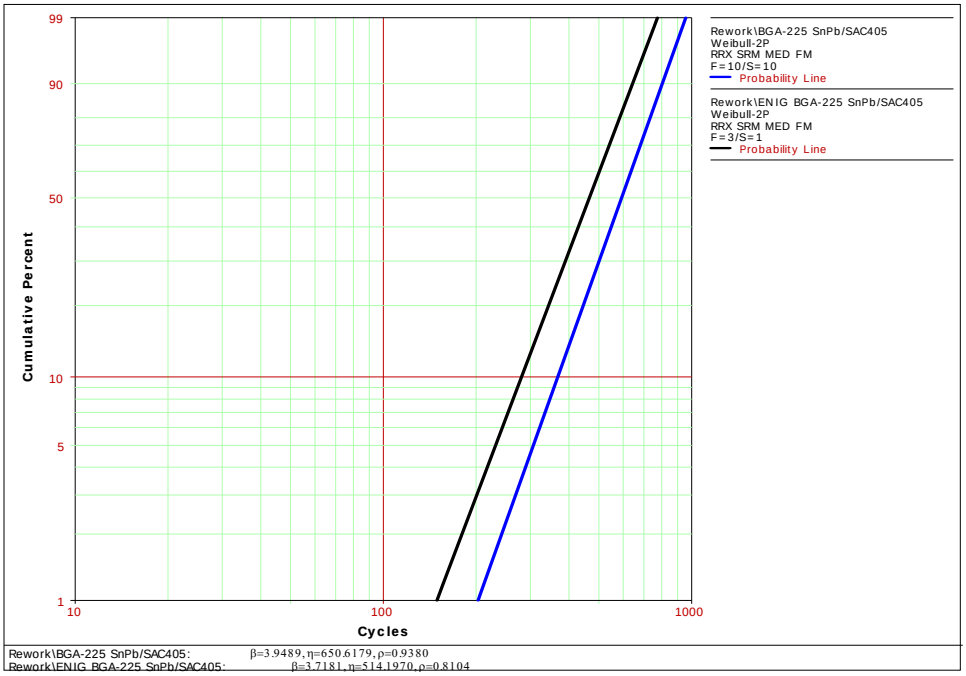


Figure 102 Comparison of ENIG and Immersion Silver Board Finish on Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Rework Test Vehicles. Rework/BGA-225 SnPb/SAC405 will last longer with probability of 72%. Convergence Delta at Solution is 0.00000003%

The Weibull plot for reworked tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste on ENIG board finish reworked test vehicle less the outlier is shown in Figure 103. The 2-parameter Weibull plot is an excellent fit of the data because there are only two data points. The fitted line has a ρ (rho) value of 100-percent.

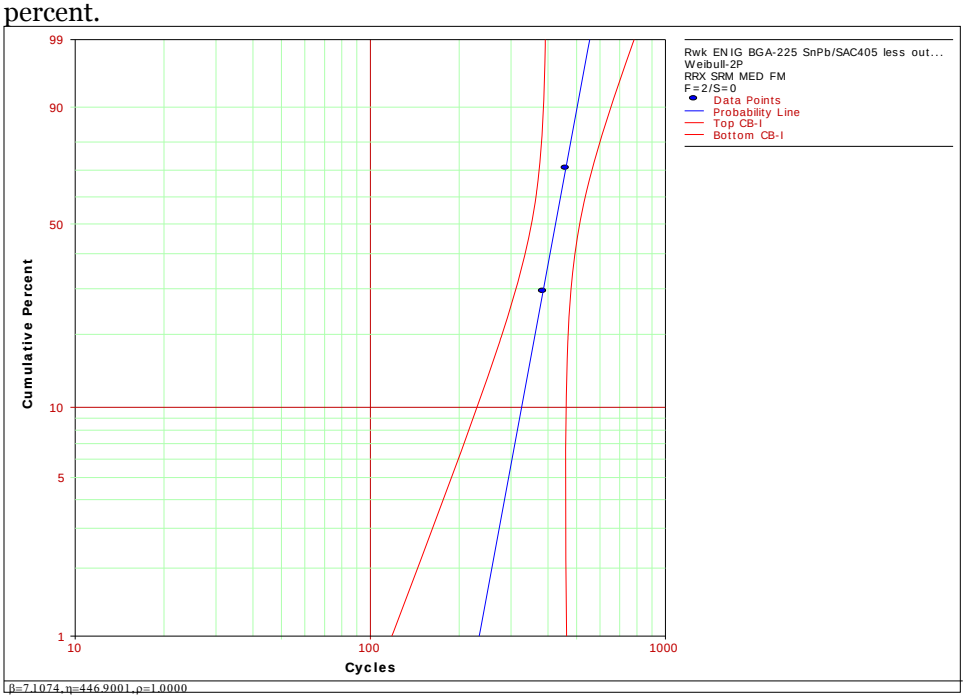


Figure 103 Weibull Plot of Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle less outlier

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for reworked tin-silver-copper 405 BGA-225 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 104. Overall, the probability that ENIG board finish less the outlier performs better than the immersion silver board finish is 78-percent.

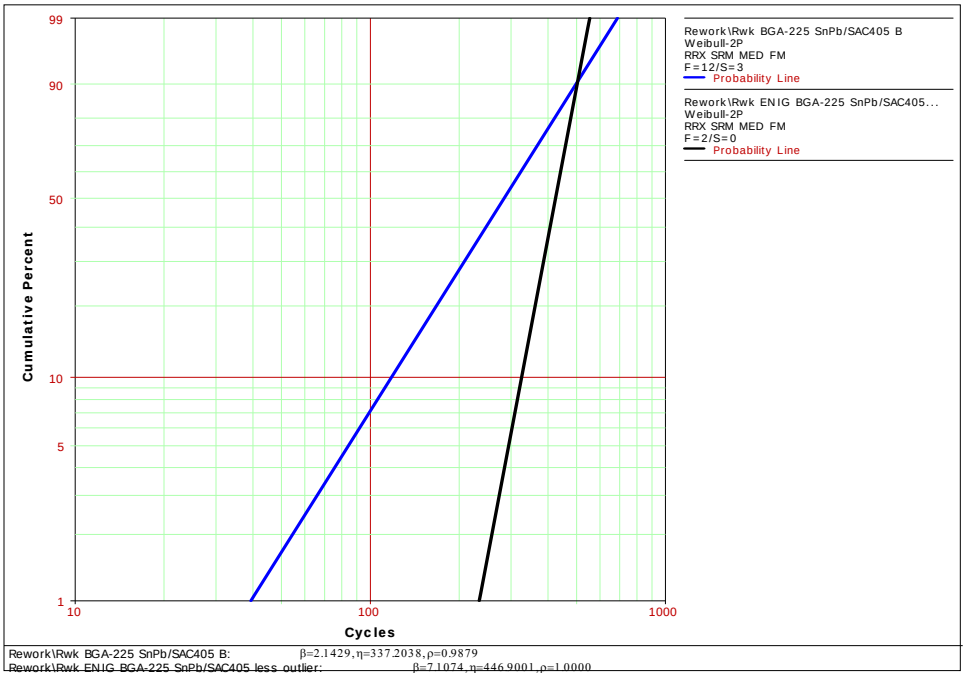


Figure 104 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin-Silver-Copper 405 BGA-225 with Tin-Lead Solder Paste on Rework Test Vehicles. Rework/Rwk ENIG BGA-225 SnPb/SAC405 less outlier will last longer with probability of 78%. Convergence Delta at Solution is 0.00000010%

The Weibull plot for tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste on ENIG board finished reworked test vehicle is shown in Figure 105. The 2-parameter Weibull plot is an excellent fit of the data, where the fitted line has a ρ (rho) value of 99-percent.

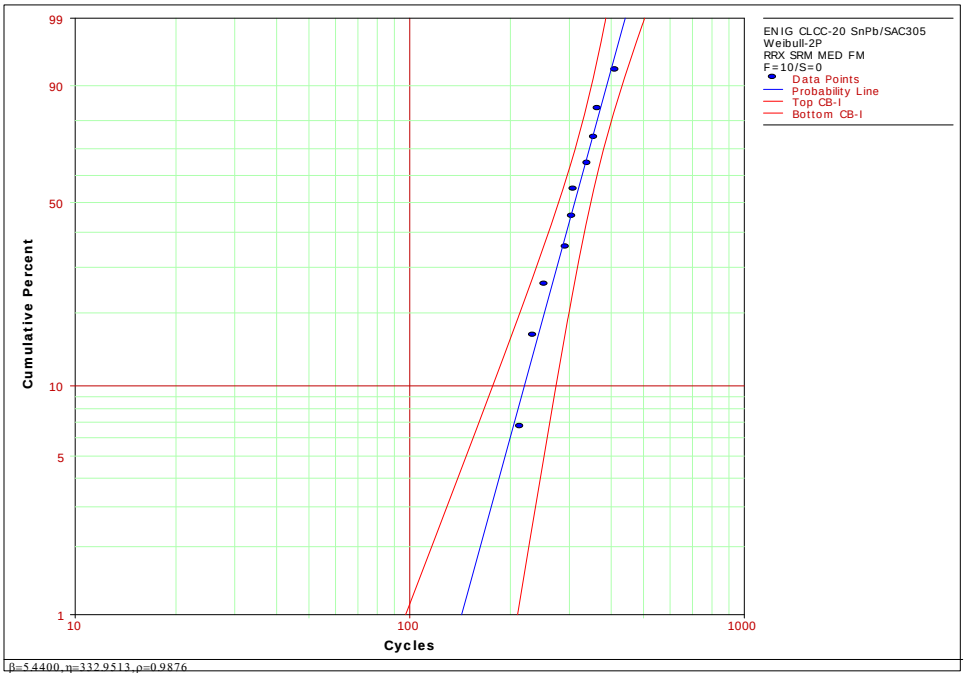


Figure 105 Weibull Plot of Tin-Silver-Copper CLCC-20 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for tin-silver-copper 305 CLCC-20 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 106. Overall, the probability that immersion silver board finish performs better than the ENIG board finish is 75-percent.

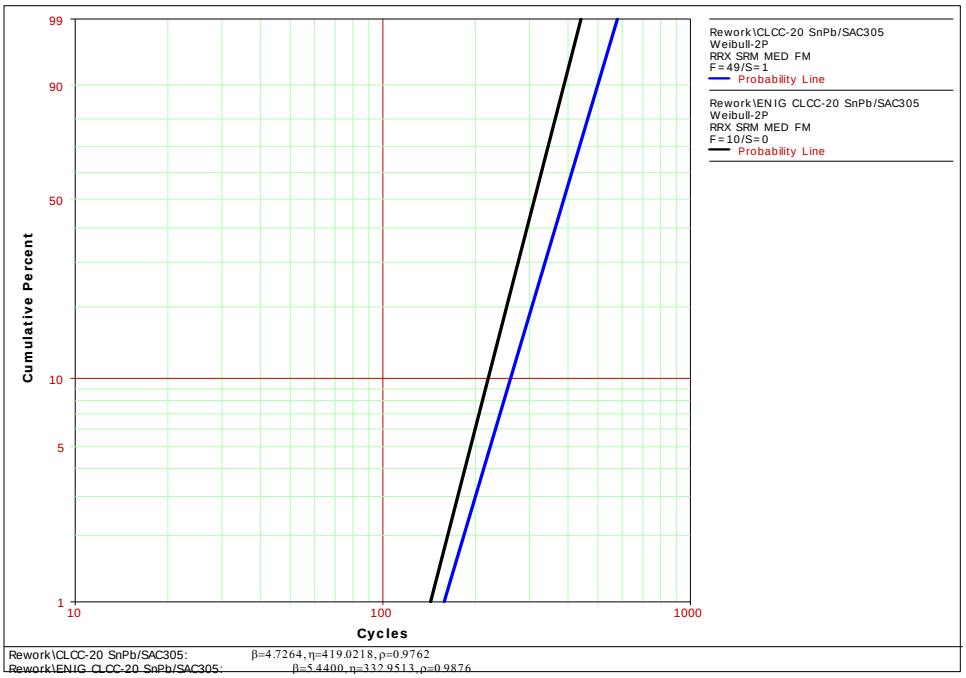


Figure 106 Comparison of ENIG and Immersion Silver Board Finish for Tin-Silver-Copper 305 CLCC-20 with Tin-Lead Solder Paste on Rework Test Vehicles. Rework/CLCC-20 SnPb/SAC305 will last longer with probability of 75%. Convergence Delta at Solution is 0.00000025%

The Weibull plot for tin-lead solder dipped TQFP-144 components soldered with tin-lead solder paste on ENIG board finish reworked test vehicle is shown in Figure 107. The 2-parameter Weibull plot is a fair fit of the data, where the fitted line has a ρ (rho) value of 92-percent.

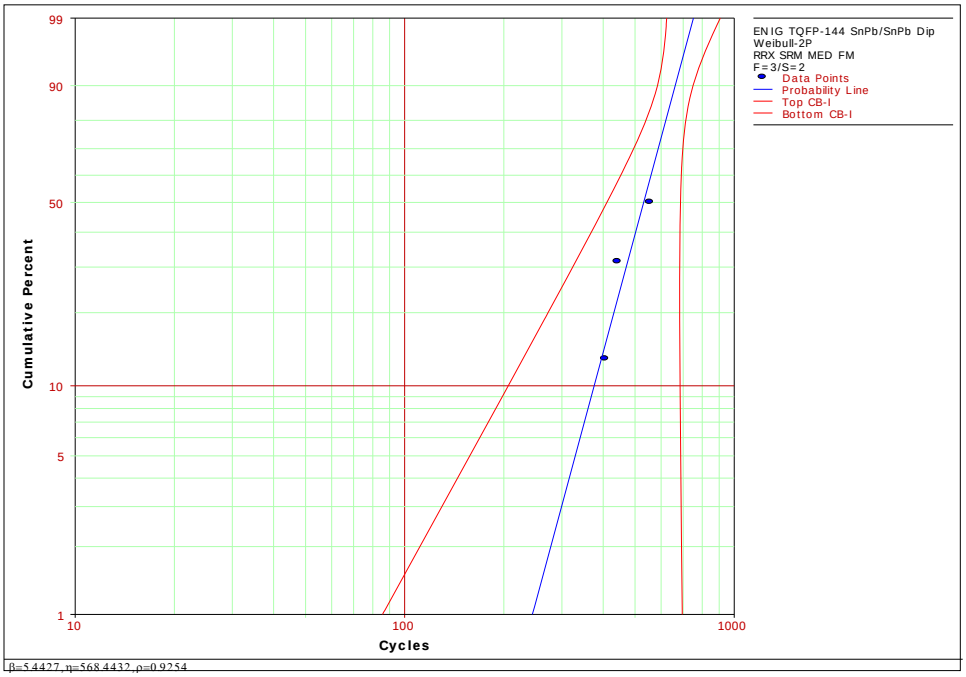


Figure 107 Weibull Plot of Tin-Lead Solder Dipped TQFP-144 with Tin-Lead Solder Paste on Electroless Nickel Immersion Gold Rework Test Vehicle

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for tin-lead solder dipped TQFP-144 components soldered with tin-lead solder paste on rework test vehicles is shown in Figure 108. Overall, the probability that immersion silver board finish performs better than the ENIG board finish is 93-percent.

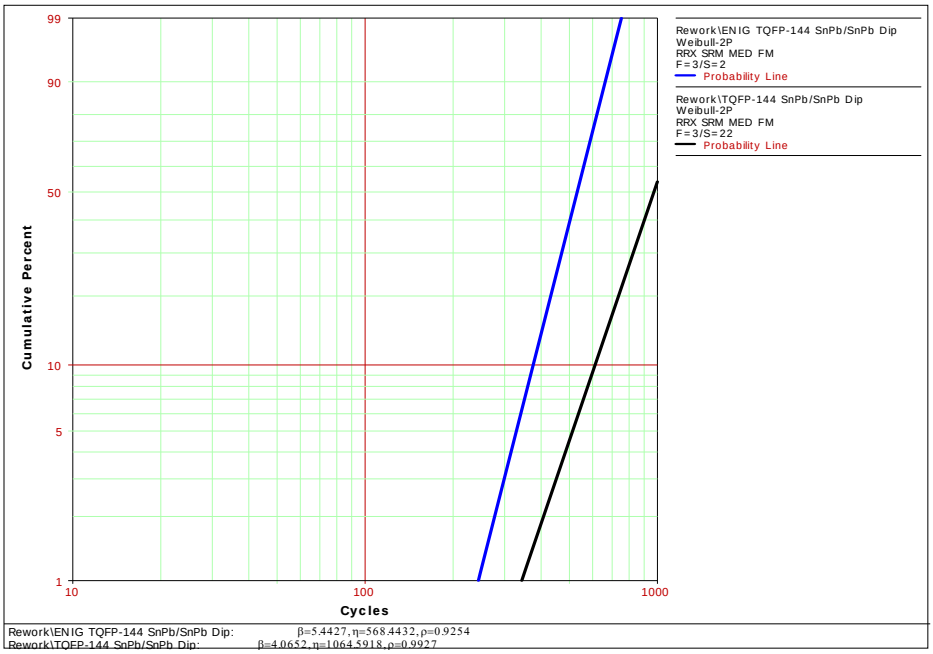


Figure 108 Comparison of ENIG and Immersion Silver Board Finish for Tin-Lead Solder Dipped TQFP-144 with Tin-Lead Solder Paste on Rework Test Vehicles. Rework/TQFP-144 SnPb/SnPb Dip will last longer with probability of 93%. Convergence Delta at Solution is 0.00000201%

The Weibull plot for reworked tin TSOP-50 components soldered with tin-lead solder wire on ENIG board finish reworked test vehicle is shown in Figure 109. The 2-parameter Weibull plot is an excellent fit of the data since there are only two data points, therefore the fitted line has a ρ (rho) value of 100-percent.

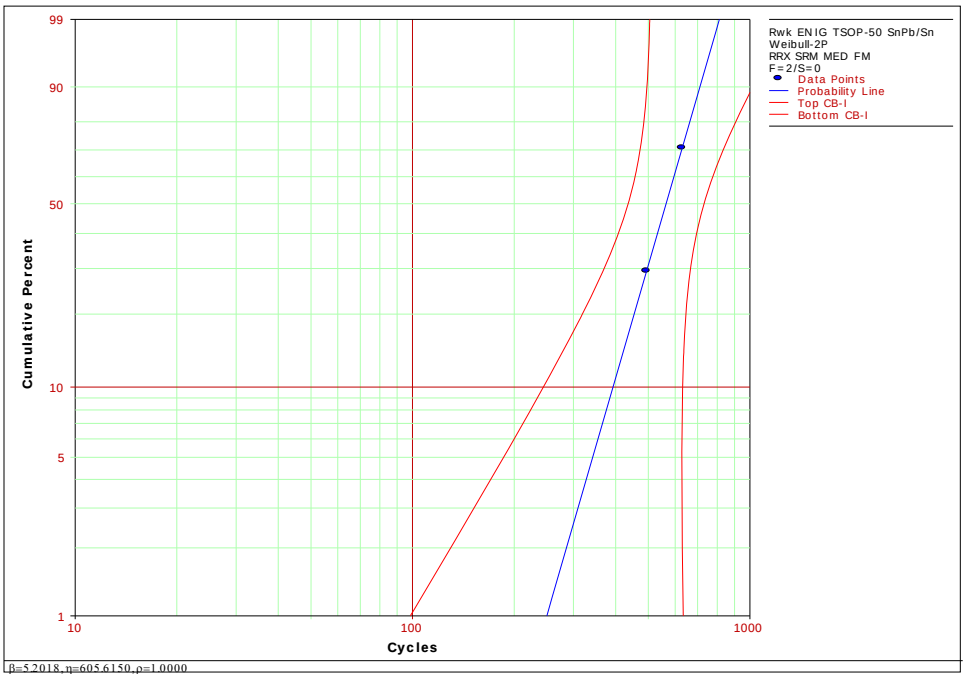


Figure 109 Weibull Plot of Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Electroless Nickel Immersion Gold Rework Test Vehicle

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for reworked tin TSOP-50 components soldered with tin-lead solder wire on rework test vehicles is shown in Figure 110. Based on the probability results, both sets of data came from the same population.

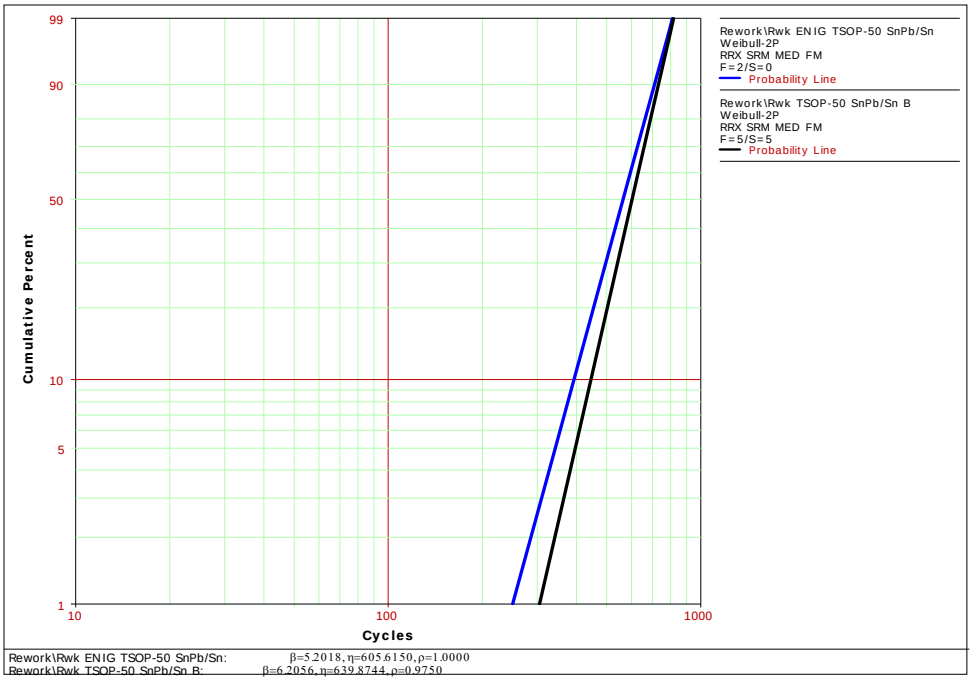


Figure 110 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles. Based on the above probability both data sets are probably from the same population. Convergence Delta at Solution is 0.00000145%

The Weibull plot for reworked tin-lead TSOP-50 components soldered with tin-lead solder wire on ENIG board finish reworked test vehicles is shown in Figure 111. The 2-parameter Weibull plot is an excellent fit of the data since there are only two data points, therefore the fitted line has a ρ (rho) value of 100-percent.

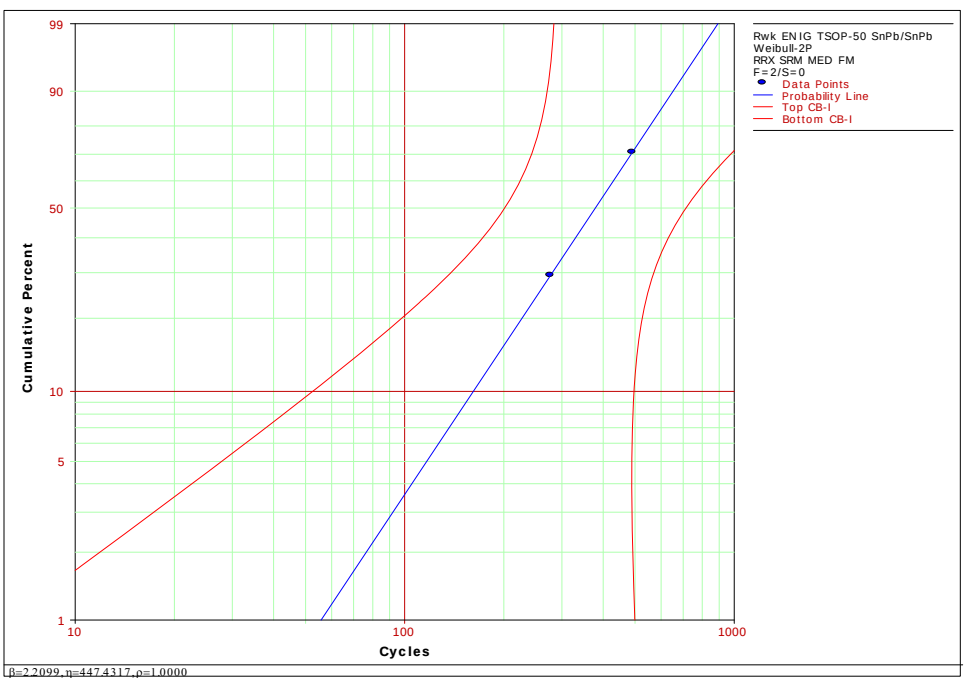


Figure 111 Weibull Plot of Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Electroless Nickel Immersion Gold Rework Test Vehicle

The Weibull plots comparing ENIG and immersion silver test vehicle board finishes for reworked tin-lead TSOP-50 components soldered with tin-lead solder wire on rework test vehicles is shown in Figure 112. Overall, the probability that immersion silver board finish performs better than the ENIG board finish is 70%.

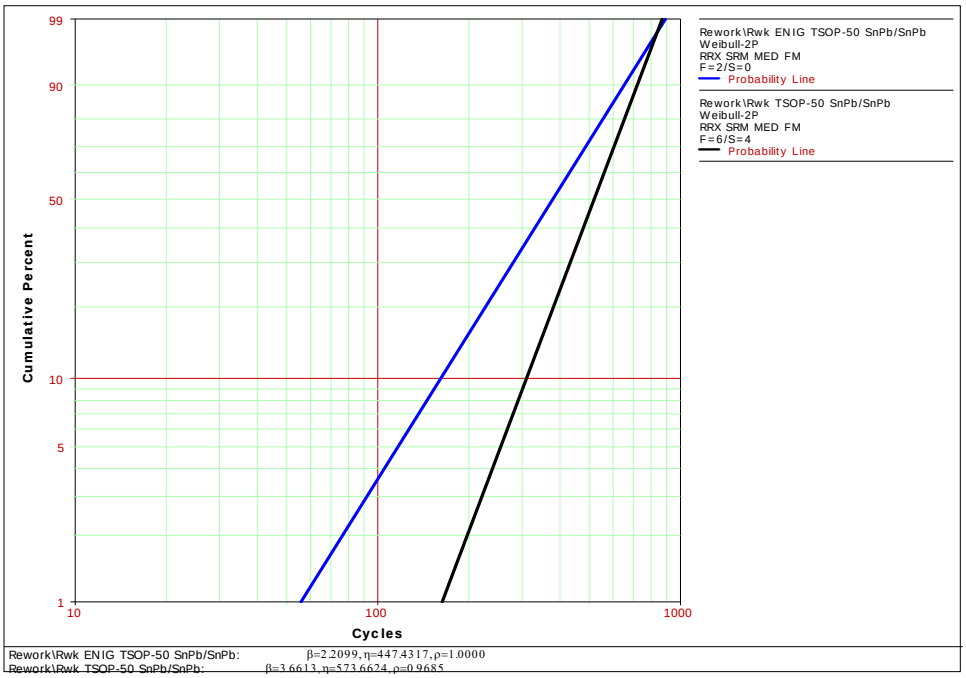


Figure 112 Comparison of ENIG and Immersion Silver Board Finish for Reworked Tin-Lead TSOP-50 with Tin-Lead Solder Wire on Rework Test Vehicles. Rework/Rwk TSOP-50 SnPb/SnPb will last longer with probability of 70%. Convergence Delta at Solution is 0.00002791%

A summary of the rework test vehicle test results is shown in Table 19.

Table 19 Summary of Rework Test Vehicle Test Results

Board Finish	Component	Alloy	Finish	New Finish	Rework Solder	β	η	ρ	Nf (1%)	Nf (10%)	Nf (63.2%)	Comments
ENIG	BGA-225	SnPb	SAC405	N/A	N/A	3.7181	514.1970	0.8104	149	281	514	
ENIG	BGA-225	SnPb	SnPb	SAC405	SnPb	7.1074	446.9001	1.0000	234	326	447	Outlier
ENIG	BGA-225	SnPb	SnPb	SnPb	Flux Only							
ENIG	CLCC-20	SnPb	SAC305	N/A	N/A	5.4400	332.9513	0.9876	143	220	333	
ENIG	CSP-100	SnPb	SAC105	N/A	N/A							
ENIG	CSP-100	SnPb	SnPb	SAC105	SnPb							
ENIG	CSP-100	SnPb	SnPb	SnPb	Flux Only							
ENIG	PDIP-20	SnPb	NiPdAu	N/A	N/A							
ENIG	PDIP-20	SnPb	Sn	N/A	N/A							
ENIG	PDIP-20	SnPb	SnPb	Sn	SnPb							
ENIG	PTH	SnPb	ENIG	N/A	N/A							
ENIG	QFN-20	SnPb	Matte Sn	N/A	N/A							
ENIG	TQFP-144	SnPb	NiPdAu	N/A	N/A							
ENIG	TQFP-144	SnPb	SnPb Dip	N/A	N/A	5.4427	568.4432	0.9254	244	376	568	
ENIG	TSOP-50	SnPb	Sn	N/A	N/A							
ENIG	TSOP-50	SnPb	SnBi	N/A	N/A							
ENIG	TSOP-50	SnPb	SnPb	Sn	SnPb	5.2018	605.6150	1.0000	250	393	606	
ENIG	TSOP-50	SnPb	SnPb	SnPb	SnPb	2.2019	447.4317	1.0000	55	161	447	
ImAg	BGA-225	SAC305	SAC405	SAC405	Flux Only	5.9370	603.2388	0.9732	278	413	603	Outliers
ImAg	BGA-225	SAC305	SAC405	SAC405	SnPb	4.3366	690.0655	0.9897	239	411	690	Outlier
ImAg	BGA-225	SnPb	SAC405	N/A	N/A	3.9489	650.6179	0.9380	203	368	651	
ImAg	BGA-225	SAC305	SnPb	N/A	N/A	2.4329	570.5046	0.8782	86	226	570	
ImAg	BGA-225	SnPb	SnPb	SAC405	SnPb	2.1429	337.2038	0.9879	39	118	337	
ImAg	BGA-225	SnPb	SnPb	SnPb	Flux Only	10.4260	535.6196	0.9075	345	432	536	
ImAg	CLCC-20	SnPb	SAC305	N/A	N/A	4.7264	419.0218	0.9762	158	260	419	
ImAg	CLCC-20	SAC305	SnPb	N/A	N/A	5.3256	338.4779	0.9797	143	222	338	
ImAg	CSP-100	SAC305	SAC105	SAC105	Flux Only	4.8067	819.6114	0.9919	315	513	820	
ImAg	CSP-100	SAC305	SAC105	SAC105	SnPb	1.2627	330.9490	0.9802	9	56	331	
ImAg	CSP-100	SAC305	SAC105	N/A	N/A	5.5733	647.5632	0.9380	284	432	648	
ImAg	CSP-100	SnPb	SAC105	N/A	N/A	4.5184	554.0556	0.9738	200	337	554	
ImAg	CSP-100	SAC305	SnPb	N/A	N/A							
ImAg	CSP-100	SnPb	SnPb	SAC105	SnPb							
ImAg	CSP-100	SnPb	SnPb	SnPb	Flux Only							
ImAg	PDIP-20	SnPb	NiPdAu	N/A	N/A							
ImAg	PDIP-20	SN100C	Sn	Sn	SN100C							
ImAg	PDIP-20	SN100C	Sn	N/A	N/A							
ImAg	PDIP-20	SnPb	Sn	N/A	N/A							
ImAg	PDIP-20	SnPb	SnPb	Sn	SnPb	4.1289	710.6465	0.8880	233	412	711	
ImAg	PTH	SN100C	ImAg	N/A	N/A							
ImAg	PTH	SnPb	ImAg	N/A	N/A							
ImAg	QFN-20	SnPb	Matte Sn	N/A	N/A							
ImAg	QFN-20	SAC305	SnPb	N/A	N/A							
ImAg	TQFP-144	SAC305	NiPdAu	N/A	N/A							
ImAg	TQFP-144	SnPb	NiPdAu	N/A	N/A							
ImAg	TQFP-144	SAC305	SAC305	N/A	N/A	0.8170	2243.3698	0.9453	8	143	2242	Outlier
ImAg	TQFP-144	SnPb	SnPb Dip	N/A	N/A	4.0652	1064.5918	0.9927	343	612	1065	
ImAg	TSOP-50	SAC305	Sn	Sn	SnPb	3.7075	621.8806	0.9560	180	339	622	Outlier
ImAg	TSOP-50	SnPb	Sn	N/A	N/A	10.7888	669.6056	0.9043	437	544	670	
ImAg	TSOP-50	SAC305	SnBi	SnBi	SAC305	6.3318	490.4146	0.9704	237	344	490	
ImAg	TSOP-50	SAC305	SnBi	N/A	N/A	5.9566	623.1129	0.9543	288	427	623	
ImAg	TSOP-50	SnPb	SnBi	N/A	N/A	4.5837	715.7281	0.9847	262	438	716	
ImAg	TSOP-50	SAC305	SnPb	N/A	N/A	2.4607	1064.3225	0.9222	164	426	1064	
ImAg	TSOP-50	SnPb	SnPb	Sn	SnPb	6.2056	639.8740	0.9750	305	445	640	
ImAg	TSOP-50	SnPb	SnPb	SnPb	SnPb	3.6613	573.6624	0.9685	163	310	574	

Statistical Analysis

Additional statistical analysis was conducted using Statgraphics version 5 software. Variance component analysis was conducted on all the N10 data (includes rework and ENIG data) and the software results are shown in Table 20 and graphically presented in Figure 113. The analysis of variance table divides the variance of the cycles to failure (N10) into three components, one for each factor. The goal of such an analysis is to estimate the amount of variability contributed by each of the factors, called the variance components analysis. The factors included: component type, lead finish and solder alloy or paste, as well as unexplained variance or noise.

The analysis shows that solder joint reliability was influenced by the choice of lead finish, but it was not more significant than the choice of component type or random noise. The analysis was only an approximate estimate since censored values (samples that did not fail) were left at their last measured cycle. The random noise would include other factors not included in the experiment of analysis. The analysis further shows that the influence due to solder alloy or paste is very low.

Table 20 Variance Component Analysis of All Data

Source	Sum of Squares	Df	Mean Square	Var. Comp.	Percent
TOTAL (Corrected)	1.23E+06	61			
Package	441109	6	73518.1	5646.32	24.51
Finish	211609	8	26451.1	3032.4	13.16
Alloy	185771	20	9288.53	0	0
Noise	387635	27	14356.8	14356.8	62.32

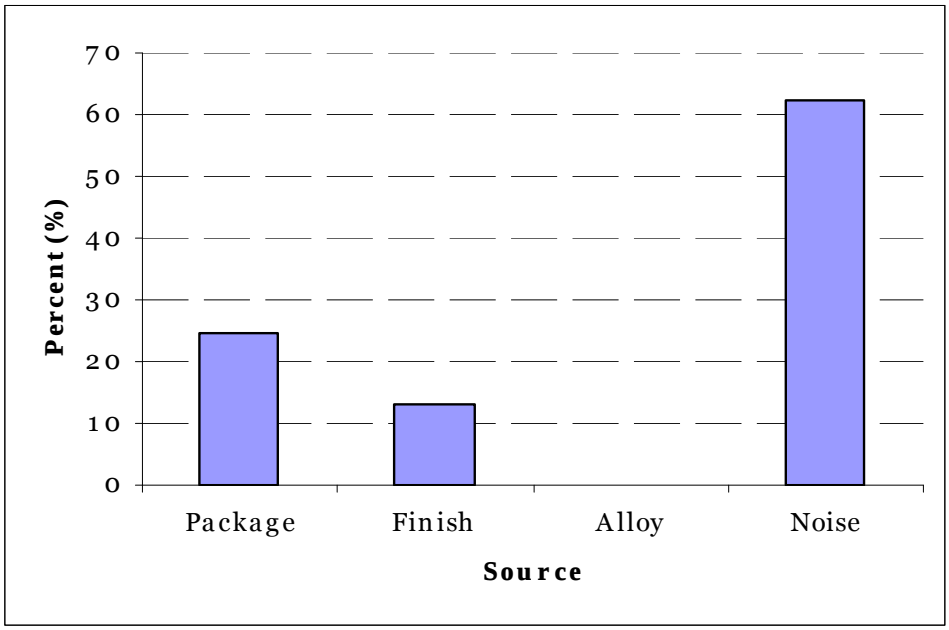


Figure 113 Chart of Variance Component Analysis of All Data

The data was also separated to analyze solder joint reliability of the manufactured test vehicles only, excluding the rework and ENIG data. The ENIG sample size was too small to develop statistically based recommendations and the rework data included several different combinations of reworked and non-reworked components, making it difficult to compare specific combinations of solder and lead finish. It is also suspected, that the high result of unexplained variation came from the rework data results.

Thus variance component analysis was conducted on the manufactured data less ENIG and the software results are shown in Table 21 and graphically presented in Figure 114. The analysis shows that solder joint reliability was influenced by the choice of solder alloy and random noise, but it was not as significant as the choice of component

type. Again, the analysis was an approximate estimate since censored values were left at their last measured cycle. The random noise would include factors not included in the experiment of analysis. The analysis further shows that the influence due to component finish is not a factor.

Table 21 Variance Component Analysis of Manufactured Data

Source	Sum of Squares	Df	Mean Square	Var. Comp.	Percent
TOTAL (Corrected)	7.51E+05	32			
Package	621231	6	103538	21827.9	79.73
Finish	18251.4	5	3650.28	0	0
Alloy	104581	18	5810.05	3116.59	11.38
Noise	7301.24	3	2433.75	2433.75	8.89

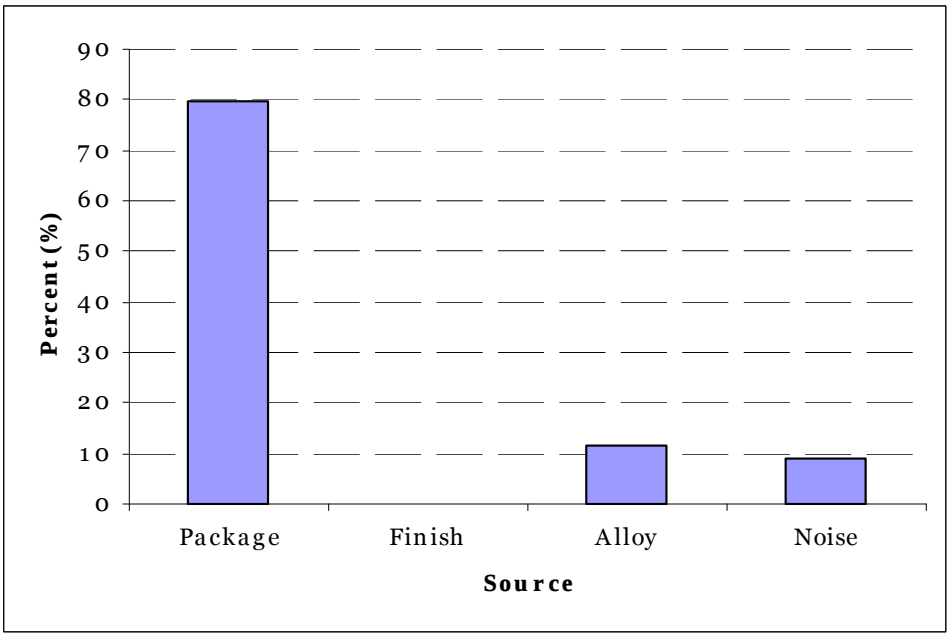


Figure 114 Chart of Variance Component Analysis of Manufactured Data

Overall, from the two variance component analysis the component type resulted as the greatest effect on solder joint reliability performance. The plated-through-hole components proved to be more reliable than the surface mount technology components. The relative ranking of the different component types used with tin-lead solder on manufactured test vehicles less ENIG is shown in Figure 115. The immersion silver finished plated-through-hole (PTH), tin PDIP-20, nickel-palladium-gold PDIP-20, matte tin QFN-20 and tin-lead dipped TQFP-144 components performed the best, none recorded a failure. The tin-lead and tin-silver-copper 405 BGA-225 components had the worst solder joint reliability performance.

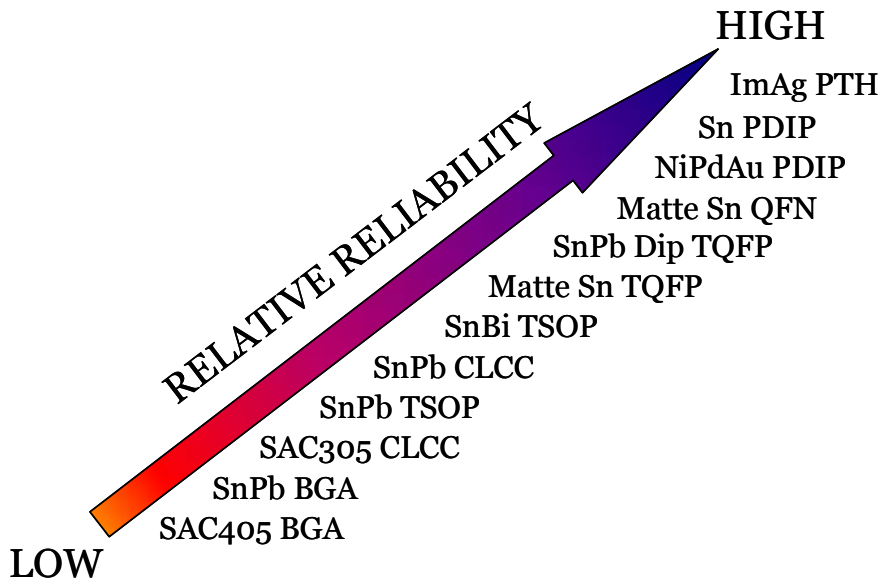


Figure 115 Relative Reliability of Components for Tin-Lead Solder on Manufactured Test Vehicles less ENIG

The relative ranking of the different component types and finishes soldered with tin-silver-copper 305 solder paste on manufactured test vehicles less ENIG is shown in Figure 116. The matte tin QFN-20 and tin-lead dipped TQFP-144 components performed the best, none recorded a failure. The tin-silver-copper 405 and tin-lead BGA-225 components had the worst solder joint reliability performance. No PTH components were soldered with tin-silver-copper 305 solder paste.

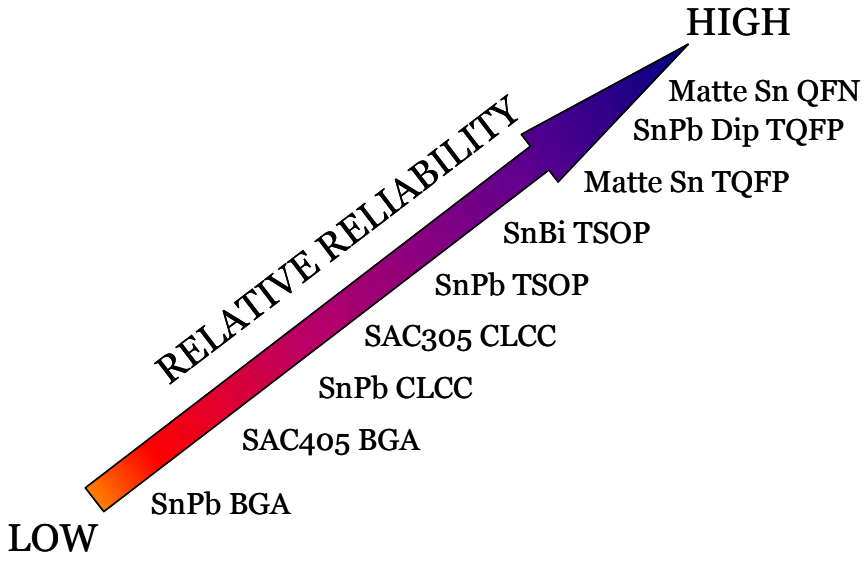


Figure 116 Relative Reliability of Components for Tin-Silver-Copper 305 Solder on Manufactured Test Vehicles less ENIG

The relative ranking of the different components types and finishes soldered with tin-copper solder paste on manufactured test vehicles less ENIG is shown in Figure 117. The immersion silver finished plated-through-hole (PTH) and nickel-palladium-gold PDIP-20 components performed the best, none recorded a failure. The tin-lead BGA-225 components had the worst solder joint reliability performance.

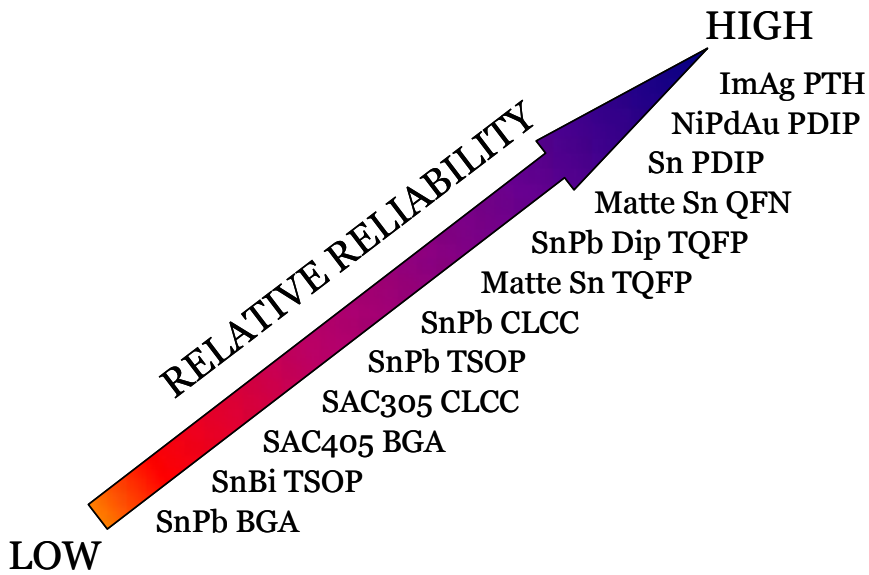


Figure 117 Relative Reliability of Components for Tin-Copper Solder on Manufactured Test Vehicles less ENIG

The interaction and 95-percent confidence intervals plot for BGA-225 components including all the data is shown in Figure 118. The plot shows that tin-lead BGA-225 components soldered with either tin-silver-copper 305 or tin-copper solder paste will result in reduced solder joint reliability when compared to the baseline, tin-lead solder paste. So, mixing of tin-lead BGA-225 components with lead-free solder pastes will result in reduced reliability. Though, mixing tin-silver-copper 405 BGA-225 components with tin-silver-copper 305 solder paste will result in better solder joint reliability than any of the combinations tested for BGA-225 components.

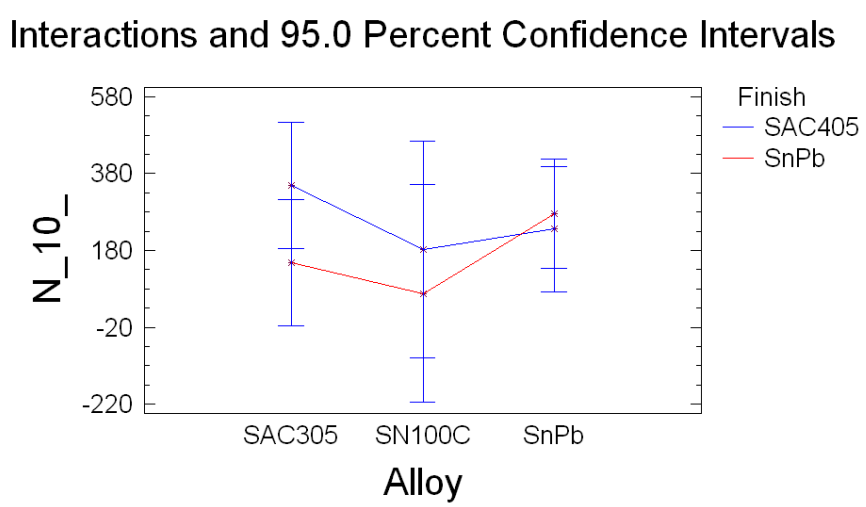


Figure 118 Interaction and 95-Percent Confidence Intervals for BGA-225 Components - All Data

The interaction and 95-percent confidence intervals plot for BGA-225 components excluding ENIG data is shown in Figure 119. The plot shows that tin-lead BGA-225 components soldered with either tin-silver-copper 305 or tin-copper solder paste will result in reduced solder joint reliability than with tin-lead solder paste. The mixing of tin-lead BGA-225 components with lead-free solder pastes will reduce solder joint reliability. Mixing tin-silver-copper 405 BGA-225 components with tin-silver-copper 305 solder results in solder joint reliability as good as tin-lead BGA-225 components soldered with tin-lead solder paste.

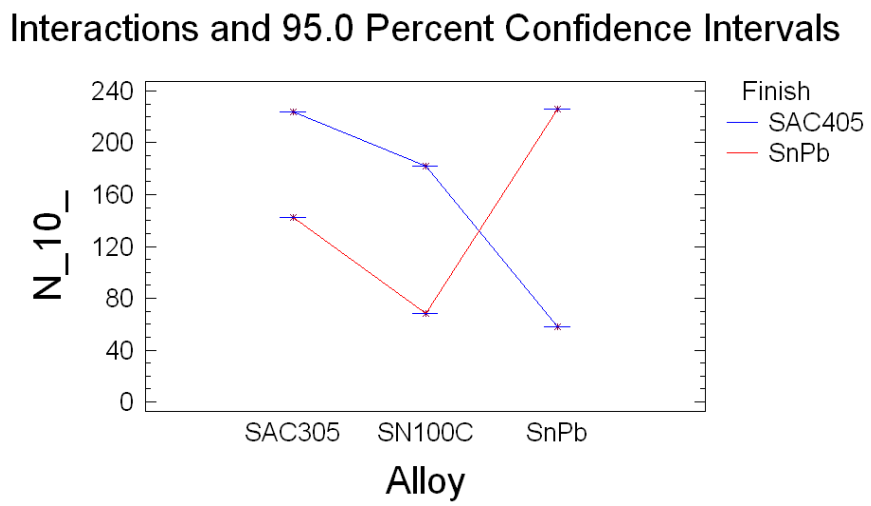


Figure 119 Interaction and 95-Percent Confidence Intervals for Mfg BGA-225 Components excluding ENIG

Comparing Statistical Analysis with 2005 JCAA/JG-PP Study

When comparing the statistical analysis of this study with the statistical analysis of the 2005 JCAA/JG-PP Lead-Free Solder Project there are similarities between the two. Considering that both studies were not exactly the same (regarding the factors involved), each study found similar results. Component or package type resulted as the main factor significantly affecting overall solder joint reliability; see the comparison chart of variance component analysis for both studies in Figure 120. Note the variance components analysis from 2009 reflects the manufactured data only. When comparing the variance components analysis from the two studies the main difference from the 2005 study is the inclusion of component location on the test vehicle in the x- and y-axis. The 2009 study did not factor in component location because the position of a component along the x-axis (along the long dimension of the board) had a minor effect on solder joint reliability and the location of a component along the y-axis had no effect on solder joint reliability, therefore excluded from the 2009 study.

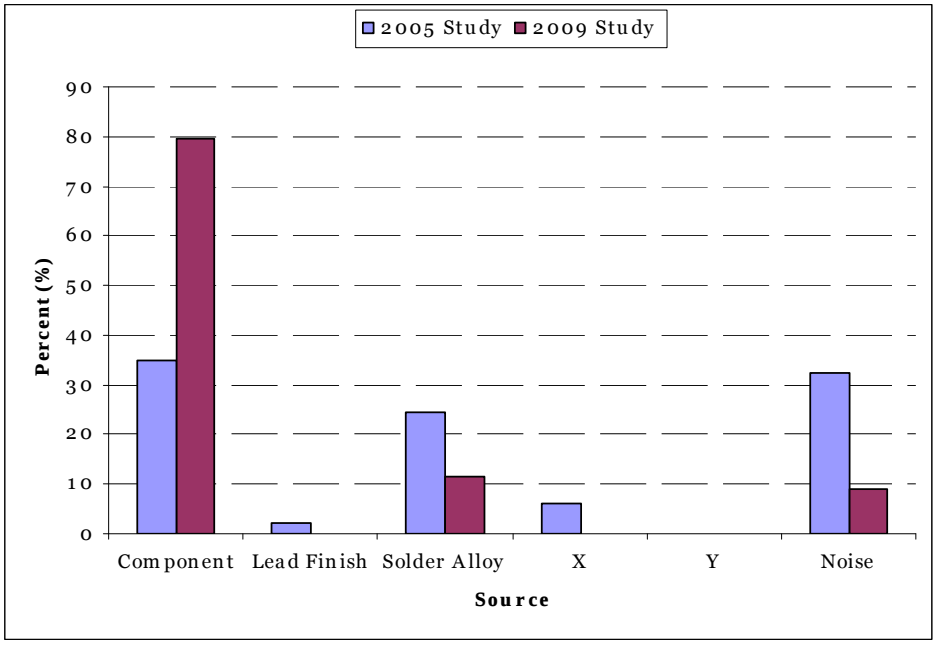


Figure 120 Comparison Chart of Variance Components Analysis of both the 2005 JCAA/JG-PP Lead-Free Solder Project and the 2009 NASA-DoD Lead-Free Solder Electronics Project Manufactured Data

Both analyses found that plated-through-hole components proved to be more reliable than the surface mount technology components. Both studies also found that the choice of solder alloy has a secondary effect on solder joint reliability. In general, tin-silver-copper soldered components were less reliable than the tin-lead soldered controls. In general, reworked components were less reliable than the manufactured (unreworked) components. Table 22 shows the number of cycles to failure with 10% confidence limits (N10) per component type, solder alloy and finish from both solder joint studies. The N10 data shows the similiarities of the data results between the two tests, but it also shows that component survivability is dependant on test and process controls.

Table 22 Comparison of Manufactured Test Vehicle Test Results to 2005 JCAA/JG-PP Lead-Free Solder Project Results

Component	Alloy	Finish	2009 Nf (10%)	2005 Nf (10%)
BGA-225	SAC305	SAC405	224	166[1]
BGA-225	SAC305	SnPb	142	66[1]
BGA-225	SnPb	SnPb	226	297
CLCC-20	SAC305	SAC305	267	186[2]
CLCC-20	SAC305	SnPb	237	268[1]
CLCC-20	SnPb	SnPb	373	296
CSP-100	SAC305	SAC105	536[3]	34[2]
CSP-100	SnPb	SnPb	539[3]	84
TQFP-144	SAC305	Matte Sn	535	360[1]
TQFP-144	SnPb	Matte Sn	488	438
TSOP-50	SAC305	SnPb	312	321
TSOP-50	SnPb	SnPb	318	387

Conclusions

[1] SAC405 solder alloy used.

[2] SAC405 solder paste and component finish.

[3] Footprint error resulted in higher than expected N10.

Overall, the component type had the greatest effect on solder joint reliability performance. The plated-through-hole components proved to be more reliable than the surface mount technology components. The plated-through-holes, PDIP-20, TQFP-144 and QFN-20 components performed the best. Of the surface mount technology, the BGA-225 components performed the worst.

The solder alloy had a secondary effect on solder joint reliability. In general, tin-lead finished components soldered with tin-lead solder paste were the most reliable. In general, tin-silver-copper soldered components were less reliable than the tin-lead soldered controls. The lower reliability of the tin-silver-copper 305 solder joints does not necessarily rule out the use of tin-silver copper solder alloy on military electronics. In several cases, tin-silver-copper 305 solder performed statistically as good as or equal to the baseline, tin-lead solder.

The effect of tin-lead contamination on BGA-225 components degrades early life performance of tin-copper solder paste, but it can also degrade early life performance of tin-silver-copper 305 solder paste. The effect of tin-lead contamination on BGA-225 components soldered with tin-silver-copper 305 solder paste was less than the effect on tin-lead contamination on tin-copper solder.

CSP-100 components are the exception, where tin-lead CSP-100 components soldered with tin-silver-copper 305 solder paste performed better than or equal to tin-lead CSP-100 components soldered with tin-lead solder paste. The chip scale package components were not drafted correctly during the design stage, therefore CSP-100 components results can only be used to compare within chip scale packages.

The probability plots of soldering tin-lead and tin-silver-copper 305 solder components onto eletroless nickel immersion gold (ENIG) finished test vehicles were compared using BGA-225 and CLCC-20 components. In general, tin-lead components soldered with tin-silver-copper 305 solder paste onto immersion gold performed better than tin-silver-copper 305 components soldered onto ENIG finished test vehicles. One exception is the performance of tin-lead CLCC-20 components soldered with tin-silver-copper 305 solder paste onto ENIG test vehicle performing better than the immersion gold test vehicle. Keep in mind, the ENIG sample size consisted of two test vehicles.

In general, reworked components were less reliable than the unreworked components. This is especially true with reworked lead-free CSP-100, reworked lead-free BGA-225 and unreworked lead-free TQFP-144 components; these components did not survive beyond 200 cycles. The exceptions were the immersion gold plated-through-hole components, nickel-palladium-gold TQFP-144, matte tin and tin-lead QFN-20, and tin PDIP-20 components where a majority of these components were soldered with tin-lead solder and did not fail. Approximately, 37% of rework test vehicle components soldered with tin-lead solder paste failed, where as, 53% of rework test vehicle components soldered with tin-silver-copper 305 solder paste failed. This suggests that reworking surface mount technology components with lead-free solder continues to pose processing challenges.

When comparing the performance of components soldered onto the two different test vehicle board finishes, immersion silver and electroless nickel immersion gold (ENIG); the immersion silver finish of the manufactured test vehicles had better reliability of solder joints than components soldered onto and ENIG surface finish. This is supported in several of the 2-parameter Weibull plots generated with the data.

Recommendations

Based on the results of this test, few recommendations are proposed. The results of the combined environments test (CET) should be compared to the results of the pure thermal cycling and vibration tests executed in the NASA-DoD Lead-Free Electronics Project. If the general results and conclusions are similar, then CET may be a useful tool to accelerate the testing of other promising lead-free solder alloys.

From this testing, it appears the selection of component type and lead-free solder combinations should be considered critical factors when considering converting to lead-free solder assembly, especially for surface mount technology design configurations. Further investigation in terms of destructive physical analysis and microsection analysis are recommended for reworked components, particularly, the lead-free solder reworked components on test vehicle serial number 180 and 181, due to the unusual number of early life failures on each test vehicle.

Since this test evaluated only solder joint reliability, additional tests must be done to validate assembly reliability with respect to the effect of higher reflow temperatures on printed circuit boards and functional integrated circuits. Additional testing on some functional military electronics is warranted.

References

"Combined Environments Test, Test Procedure," February 2009.

IPC/EIA J-STD-001. "Requirements for Soldered Electrical and Electronic Assemblies," January 2009.

IPC-SM-785. "Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments," January 2009.

IPC-6012A. "Qualification and Performance Specification for Rigid Printed Boards," October 2009.

IPC-9701. "Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments," February 2009.

J. Bradford, J. Felty and B. Russell, "JCAA/JG-PP Lead-Free Electronics Project: Combined Environments Test," August 2005.

K. R. Kessel, et al. "NASA-DoD Lead-Free Electronics Project Plan", August 2009.

MIL-STD-810F, Method 514.5. "Vibration".

MIL-STD-810F, Method 520.2. "Temperature, Humidity, Vibration, and Altitude".

Appendixes

Appendix A: Manufactured Assembly Raw Test Data

Appendix B: Rework Assembly Raw Test Data

Appendix C: Pretest Inspection Logs

Appendix D: Environmental Test Laboratory Logs

Appendix E: Post Test Inspection Logs

Appendix F: Vibration Profiles

Appendix A: Manufactured Assembly Raw Test Data

Table 23 Manufactured Assembly Raw Data

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
23	1	U1	TQFP-144	Matte Sn	SnPb	604		
23	2	U26	TSOP-50	SnPb	SnPb	650		
23	3	U41	TQFP-144	Matte Sn	SnPb	650		
23	4	U9	CLCC-20	SAC305	SnPb	650	X	Failed after 650 cycles during Trouble Shoot
23	5	U27	QFN-20	Matte Sn	SnPb	650		
23	6	U18	BGA-225	SAC405	SnPb	97		
23	7	U39	TSOP-50	SnBi	SnPb	650		
23	8	U56	BGA-225	SnPb	SnPb	650		Repaired wire from set-up; Solder balls behind component
23	9	U40	TSOP-50	SnPb	SnPb	650		
23	10	U3	TQFP-144	SnPb Dip	SnPb	650		
23	11	U13	CLCC-20	SAC305	SnPb	498	X	
23	12	U32	CSP-100	SAC105	SnPb	423		
23	13	U57	TQFP-144	SnPb Dip	SnPb	650		
23	14	U14	CLCC-20	SnPb	SnPb	650	X	Failed after 650 cycles during Trouble Shoot
23	16	U25	TSOP-50	SnBi	SnPb	650		
23	17	U50	CSP-100	SAC105	SnPb	650		
23	18	U33	CSP-100	SAC105	SnPb	650		
23	19	U58	TQFP-144	Matte Sn	SnPb	650		Exposed wire from peeling, not broken
23	20	U12	TSOP-50	SnBi	SnPb	650		Exposed wire from peeling, not broken
23	21	U36	CSP-100	SnPb	SnPb	650		Exposed wire from peeling, not broken
23	22	U55	BGA-225	SAC405	SnPb	650		Exposed wire from peeling, not broken
23	23	U17	CLCC-20	SnPb	SnPb	556	X	Exposed wire from peeling, not broken
23	24	U2	BGA-225	SnPb	SnPb	314		Exposed wire from peeling, not broken
23	25	U31	TQFP-144	SnPb Dip	SnPb	650		Exposed wire from peeling, not broken
23	26	U45	CLCC-20	SnPb	SnPb	650	X	Failed after 650 cycles during Trouble Shoot; Exposed wire from peeling, not broken
23	27	U46	CLCC-20	SAC305	SnPb	568	X	Exposed wire from peeling, not broken
23	28	U47	QFN-20	Matte Sn	SnPb	650		Exposed wire from peeling, not broken
23	29	U19	CSP-100	SnPb	SnPb	650		Exposed wire from peeling, not broken
23	30	U24	TSOP-50	SnPb	SnPb	650		Exposed wire from peeling, not broken
23	31	U42	CSP-100	SnPb	SnPb	650		Exposed wire from peeling, not broken
23	32	U4	BGA-225	SAC405	SnPb	104		Exposed wire from peeling, not broken
23	33	U43	BGA-225	SAC405	SnPb	120		
23	34	U20	TQFP-144	Matte Sn	SnPb	650		
23	35	U21	BGA-225	SnPb	SnPb	650		
23	36	U44	BGA-225	SnPb	SnPb	650		
23	37	U61	TSOP-50	SnBi	SnPb	650		
23	38	U54	QFN-20	Matte Sn	SnPb	650		
23	39	U48	TQFP-144	SnPb Dip	SnPb	650		
23	40	U7	TQFP-144	Matte Sn	SnPb	650		
23	41	U22	CLCC-20	SAC305	SnPb	650	X	Failed after 650 cycles during Trouble Shoot
23	42	U16	TSOP-50	SnPb	SnPb	113	X	Found FOD, took photo
23	43	U37	CSP-100	SnPb	SnPb	650		
23	44	U11	PDIP-20	Sn		650		
23	45	U30	PDIP-20	Sn		650		
23	46	U35	CSP-100	SAC105	SnPb	650		
23	47	U38	PDIP-20	Sn		650		
23	48	U49	PDIP-20	NiPdAu		650		
23	49	U51	PDIP-20	Sn		650		
23	50	U59	PDIP-20	NiPdAu		650		
23	51	U63	CSP-100	SAC105	SnPb	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
23	52	U5	BGA-225	SnPb	SnPb	650		
23	53	U6	BGA-225	SAC405	SnPb	40		
23	54	U34	TQFP-144	SnPb Dip	SnPb	650		
23	55	U52	CLCC-20	SnPb	SnPb	650	X	Failed after 650 cycles during Trouble Shoot
23	56	U53	CLCC-20	SAC305	SnPb	502	X	
23	57	U62	TSOP-50	SnPb	SnPb	650		
23	58	U60	CSP-100	SnPb	SnPb	650		
23	59	U10	CLCC-20	SnPb	SnPb	514	X	
23	60	U28	QFN-20	Matte Sn	SnPb	650		
23	61	U29	TSOP-50	SnBi	SnPb	650		
23	62	U8	PDIP-20	NiPdAu		650		
23	63	U23	PDIP-20	NiPdAu		650		
23	64	PTH's	PTH's	ImAg		650		
69	65	U1	TQFP-144	SnPb Dip	SAC305	650		
69	66	U26	TSOP-50	SnBi	SAC305	527		
69	67	U41	TQFP-144	SnPb Dip	SAC305	650		
69	68	U9	CLCC-20	SnPb	SAC305	282	X	
69	69	U27	QFN-20	Matte Sn	SAC305	650		
69	70	U18	BGA-225	SnPb	SAC305	591		
69	71	U39	TSOP-50	SnPb	SAC305	650		
69	72	U56	BGA-225	SAC405	SAC305	650		
69	73	U40	TSOP-50	SnBi	SAC305	650		
69	74	U3	TQFP-144	Matte Sn	SAC305	650		
69	75	U13	CLCC-20	SnPb	SAC305	256	X	
69	76	U32	CSP-100	SnPb	SAC305	650		
69	77	U57	TQFP-144	Matte Sn	SAC305	650		
69	78	U14	CLCC-20	SAC305	SAC305	497		
69	80	U25	TSOP-50	SnPb	SAC305	650		
69	81	U50	CSP-100	SnPb	SAC305	650		
69	82	U33	CSP-100	SnPb	SAC305	650		
69	83	U58	TQFP-144	SnPb Dip	SAC305	650		Pin holes in back side of component in solder, took photo
69	84	U12	TSOP-50	SnPb	SAC305	549		
69	85	U36	CSP-100	SAC105	SAC305	650		
69	86	U55	BGA-225	SnPb	SAC305	650		
69	87	U17	CLCC-20	SAC305	SAC305	365	X	
69	88	U2	BGA-225	SAC405	SAC305	620		
69	89	U31	TQFP-144	Matte Sn	SAC305	650		
69	90	U45	CLCC-20	SAC305	SAC305	340	X	
69	91	U46	CLCC-20	SnPb	SAC305	317	X	Corrosion back side of component, took photo
69	92	U47	QFN-20	Matte Sn	SAC305	650		
69	93	U19	CSP-100	SAC105	SAC305	650		
69	94	U24	TSOP-50	SnBi	SAC305	650		
69	95	U42	CSP-100	SAC105	SAC305	650		
69	96	U4	BGA-225	SnPb	SAC305	650		
69	97	U43	BGA-225	SnPb	SAC305	650		
69	98	U20	TQFP-144	SnPb Dip	SAC305	650		
69	99	U21	BGA-225	SAC405	SAC305	650		
69	100	U44	BGA-225	SAC405	SAC305	650		
69	101	U61	TSOP-50	SnPb	SAC305	650		
69	102	U54	QFN-20	Matte Sn	SAC305	650		
69	103	U48	TQFP-144	Matte Sn	SAC305	650		
69	104	U7	TQFP-144	SnPb Dip	SAC305	650		
69	105	U22	CLCC-20	SnPb	SAC305	446		
69	106	U16	TSOP-50	SnBi	SAC305	604		
69	107	U37	CSP-100	SAC105	SAC305	650		
69	108	U11	PDIP-20	Sn		650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
69	109	U30	PDIP-20	Sn		650		
69	110	U35	CSP-100	SnPb	SAC305	650		
69	111	U38	PDIP-20	Sn		650		
69	112	U49	PDIP-20	Sn		650		
69	113	U51	PDIP-20	Sn		650		
69	114	U59	PDIP-20	Sn		650		
69	115	U63	CSP-100	SnPb	SAC305	650		
69	116	U5	BGA-225	SAC405	SAC305	650		
69	117	U6	BGA-225	SnPb	SAC305	650		
69	118	U34	TQFP-144	Matte Sn	SAC305	650		
69	119	U52	CLCC-20	SAC305	SAC305	312		
69	120	U53	CLCC-20	SnPb	SAC305	438		
69	121	U62	TSOP-50	SnBi	SAC305	621		
69	122	U60	CSP-100	SAC105	SAC305	650		
69	123	U10	CLCC-20	SAC305	SAC305	414		Cap fell off
69	124	U28	QFN-20	Matte Sn	SAC305	650		
69	125	U29	TSOP-50	SnPb	SAC305	532		
69	126	U8	PDIP-20	Sn		650		
69	127	U23	PDIP-20	Sn		650		
69	128	PTH's	PTH's	ImAg		650		
71	129	U1	TQFP-144	SnPb Dip	SAC305	650		
71	130	U26	TSOP-50	SnBi	SAC305	497		
71	131	U41	TQFP-144	SnPb Dip	SAC305	650		
71	132	U9	CLCC-20	SnPb	SAC305	322	X	
71	133	U27	QFN-20	Matte Sn	SAC305	650		
71	134	U18	BGA-225	SnPb	SAC305	247		
71	135	U39	TSOP-50	SnPb	SAC305	650		
71	136	U56	BGA-225	SAC405	SAC305	242		
71	137	U40	TSOP-50	SnBi	SAC305	580		
71	138	U3	TQFP-144	Matte Sn	SAC305	650		
71	139	U13	CLCC-20	SnPb	SAC305	238	X	
71	140	U32	CSP-100	SnPb	SAC305	650		
71	141	U57	TQFP-144	Matte Sn	SAC305	650		
71	142	U14	CLCC-20	SAC305	SAC305	529	X	
71	144	U25	TSOP-50	SnPb	SAC305	650		
71	145	U50	CSP-100	SnPb	SAC305	650		
71	146	U33	CSP-100	SnPb	SAC305	650		
71	147	U58	TQFP-144	SnPb Dip	SAC305	650		
71	148	U12	TSOP-50	SnPb	SAC305	537		
71	149	U36	CSP-100	SAC105	SAC305	650		
71	150	U55	BGA-225	SnPb	SAC305	157		
71	151	U17	CLCC-20	SAC305	SAC305	514	X	
71	152	U2	BGA-225	SAC405	SAC305	330		
71	153	U31	TQFP-144	Matte Sn	SAC305	650		
71	154	U45	CLCC-20	SAC305	SAC305	497	X	
71	155	U46	CLCC-20	SnPb	SAC305	500	X	
71	156	U47	QFN-20	Matte Sn	SAC305	650		
71	157	U19	CSP-100	SAC105	SAC305	461		
71	158	U24	TSOP-50	SnBi	SAC305	624		
71	159	U42	CSP-100	SAC105	SAC305	555		
71	160	U4	BGA-225	SnPb	SAC305	563		
71	161	U43	BGA-225	SnPb	SAC305	213		Exposed wire from peeling, not broken
71	162	U20	TQFP-144	SnPb Dip	SAC305	650		Exposed wire from peeling, not broken
71	163	U21	BGA-225	SAC405	SAC305	601		
71	164	U44	BGA-225	SAC405	SAC305	196		
71	165	U61	TSOP-50	SnPb	SAC305	553		
71	166	U54	QFN-20	Matte Sn	SAC305	650		
71	167	U48	TQFP-144	Matte Sn	SAC305	650		
71	168	U7	TQFP-144	SnPb Dip	SAC305	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
71	169	U22	CLCC-20	SnPb	SAC305	218	X	
71	170	U16	TSOP-50	SnBi	SAC305	208		
71	171	U37	CSP-100	SAC105	SAC305	650		
71	172	U11	PDIP-20	NiPdAu		650		
71	173	U30	PDIP-20	NiPdAu		650		
71	174	U35	CSP-100	SnPb	SAC305	498		
71	175	U38	PDIP-20	NiPdAu		650		
71	176	U49	PDIP-20	Sn		650		
71	177	U51	PDIP-20	Sn		650		
71	178	U59	PDIP-20	Sn		650		
71	179	U63	CSP-100	SnPb	SAC305	650		
71	180	U5	BGA-225	SAC405	SAC305	54		
71	181	U6	BGA-225	SnPb	SAC305	498		
71	182	U34	TQFP-144	Matte Sn	SAC305	650		
71	183	U52	CLCC-20	SAC305	SAC305	650		
71	184	U53	CLCC-20	SnPb	SAC305	302		
71	185	U62	TSOP-50	SnBi	SAC305	517		
71	186	U60	CSP-100	SAC105	SAC305	623		
71	187	U10	CLCC-20	SAC305	SAC305	512	X	
71	188	U28	QFN-20	Matte Sn	SAC305	650		
71	189	U29	TSOP-50	SnPb	SAC305	516		
71	190	U8	PDIP-20	Sn		650		
71	191	U23	PDIP-20	Sn		650		
71	192	PTH's	PTH's	ImAg		650		
118	193	U1	TQFP-144	SnPb Dip	SN100C	548		
118	194	U26	TSOP-50	SnBi	SN100C	250		
118	195	U41	TQFP-144	SnPb Dip	SN100C	635		
118	196	U9	CLCC-20	SnPb	SN100C	332	X	
118	197	U27	QFN-20	Matte Sn	SN100C	650		
118	198	U18	BGA-225	SnPb	SN100C	345		
118	199	U39	TSOP-50	SnPb	SN100C	493		
118	200	U56	BGA-225	SAC405	SN100C	510		
118	201	U40	TSOP-50	SnBi	SN100C	428		
118	202	U3	TQFP-144	Matte Sn	SN100C	494		Exposed wire, not broken
118	203	U13	CLCC-20	SnPb	SN100C	259	X	
118	204	U32	CSP-100	SnPb	SN100C	350		
118	205	U57	TQFP-144	Matte Sn	SN100C	568		
118	206	U14	CLCC-20	SAC305	SN100C	314	X	
118	208	U25	TSOP-50	SnPb	SN100C	482		
118	209	U50	CSP-100	SnPb	SN100C	650		
118	210	U33	CSP-100	SnPb	SN100C	650		
118	211	U58	TQFP-144	SnPb Dip	SN100C	643		
118	212	U12	TSOP-50	SnPb	SN100C	204		
118	213	U36	CSP-100	SAC105	SN100C	536		Exposed wire from peeling, not broken
118	214	U55	BGA-225	SnPb	SN100C	369		Exposed wire from peeling, not broken
118	215	U17	CLCC-20	SAC305	SN100C	225	X	
118	216	U2	BGA-225	SAC405	SN100C	234		
118	217	U31	TQFP-144	Matte Sn	SN100C	540		
118	218	U45	CLCC-20	SAC305	SN100C	492	X	Exposed wire from peeling, not broken
118	219	U46	CLCC-20	SnPb	SN100C	464	X	
118	220	U47	QFN-20	Matte Sn	SN100C	650		
118	221	U19	CSP-100	SAC105	SN100C	627		
118	222	U24	TSOP-50	SnBi	SN100C	202		
118	223	U42	CSP-100	SAC105	SN100C	650		
118	224	U4	BGA-225	SnPb	SN100C	468		
118	225	U43	BGA-225	SnPb	SN100C	555		
118	226	U20	TQFP-144	SnPb Dip	SN100C	593		
118	227	U21	BGA-225	SAC405	SN100C	650		
118	228	U44	BGA-225	SAC405	SN100C	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
118	229	U61	TSOP-50	SnPb	SN100C	491		
118	230	U54	QFN-20	Matte Sn	SN100C	650		
118	231	U48	TQFP-144	Matte Sn	SN100C	650		
118	232	U7	TQFP-144	SnPb Dip	SN100C	434		
118	233	U22	CLCC-20	SnPb	SN100C	279	X	
118	234	U16	TSOP-50	SnBi	SN100C	315		
118	235	U37	CSP-100	SAC105	SN100C	650		
118	236	U11	PDIP-20	Sn		634		
118	237	U30	PDIP-20	Sn		650		
118	238	U35	CSP-100	SnPb	SN100C	650		
118	239	U38	PDIP-20	Sn		344		
118	240	U49	PDIP-20	Sn		650		
118	241	U51	PDIP-20	Sn		650		
118	242	U59	PDIP-20	Sn		460		
118	243	U63	CSP-100	SnPb	SN100C	650		
118	244	U5	BGA-225	SAC405	SN100C	542		
118	245	U6	BGA-225	SnPb	SN100C	555		
118	246	U34	TQFP-144	Matte Sn	SN100C	650		
118	247	U52	CLCC-20	SAC305	SN100C	324		
118	248	U53	CLCC-20	SnPb	SN100C	650		Cap fell off
118	249	U62	TSOP-50	SnBi	SN100C	248		
118	250	U60	CSP-100	SAC105	SN100C	650		
118	251	U10	CLCC-20	SAC305	SN100C	366	X	
118	252	U28	QFN-20	Matte Sn	SN100C	650		
118	253	U29	TSOP-50	SnPb	SN100C	497		
118	254	U8	PDIP-20	Sn		650		
118	255	U23	PDIP-20	Sn		446		
118	256	PTH's	PTH's	ImAg		650		
22	257	U1	TQFP-144	Matte Sn	SnPb	650		Cracked insulation around wire
22	258	U26	TSOP-50	SnPb	SnPb	545		
22	259	U41	TQFP-144	Matte Sn	SnPb	650		
22	260	U9	CLCC-20	SAC305	SnPb	484	X	
22	261	U27	QFN-20	Matte Sn	SnPb	650		
22	262	U18	BGA-225	SAC405	SnPb	89		
22	263	U39	TSOP-50	SnBi	SnPb	576		
22	264	U56	BGA-225	SnPb	SnPb	575		
22	265	U40	TSOP-50	SnPb	SnPb	650		
22	266	U3	TQFP-144	SnPb Dip	SnPb	650		
22	267	U13	CLCC-20	SAC305	SnPb	288	X	
22	268	U32	CSP-100	SAC105	SnPb	510		
22	269	U57	TQFP-144	SnPb Dip	SnPb	650		
22	270	U14	CLCC-20	SnPb	SnPb	574	X	
22	272	U25	TSOP-50	SnBi	SnPb	579		
22	273	U50	CSP-100	SAC105	SnPb	506		
22	274	U33	CSP-100	SAC105	SnPb	512		
22	275	U58	TQFP-144	Matte Sn	SnPb	650		
22	276	U12	TSOP-50	SnBi	SnPb	543		
22	277	U36	CSP-100	SnPb	SnPb	650		
22	278	U55	BGA-225	SAC405	SnPb	133		Solder balls back side of component
22	279	U17	CLCC-20	SnPb	SnPb	424	X	
22	280	U2	BGA-225	SnPb	SnPb	513		
22	281	U31	TQFP-144	SnPb Dip	SnPb	650		
22	282	U45	CLCC-20	SnPb	SnPb	392	X	
22	283	U46	CLCC-20	SAC305	SnPb	322	X	
22	284	U47	QFN-20	Matte Sn	SnPb	650		
22	285	U19	CSP-100	SnPb	SnPb	650		
22	286	U24	TSOP-50	SnPb	SnPb	650		
22	287	U42	CSP-100	SnPb	SnPb	650		
22	288	U4	BGA-225	SAC405	SnPb	158		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
22	289	U43	BGA-225	SAC405	SnPb	160		Cracked insulation around wire
22	290	U20	TQFP-144	Matte Sn	SnPb	650		
22	291	U21	BGA-225	SnPb	SnPb	650		
22	292	U44	BGA-225	SnPb	SnPb	650		
22	293	U61	TSOP-50	SnBi	SnPb	614		
22	294	U54	QFN-20	Matte Sn	SnPb	650		
22	295	U48	TQFP-144	SnPb Dip	SnPb	650		
22	296	U7	TQFP-144	Matte Sn	SnPb	555		
22	297	U22	CLCC-20	SAC305	SnPb	370	X	
22	298	U16	TSOP-50	SnPb	SnPb	530		
22	299	U37	CSP-100	SnPb	SnPb	650		
22	300	U11	PDIP-20	Sn		650		
22	301	U30	PDIP-20	Sn		650		
22	302	U35	CSP-100	SAC105	SnPb	498		
22	303	U38	PDIP-20	Sn		650		
22	304	U49	PDIP-20	NiPdAu		650		
22	305	U51	PDIP-20	Sn		650		
22	306	U59	PDIP-20	NiPdAu		650		
22	307	U63	CSP-100	SAC105	SnPb	557		
22	308	U5	BGA-225	SnPb	SnPb	532		
22	309	U6	BGA-225	SAC405	SnPb	142		
22	310	U34	TQFP-144	SnPb Dip	SnPb	650		
22	311	U52	CLCC-20	SnPb	SnPb	497	X	
22	312	U53	CLCC-20	SAC305	SnPb	387	X	
22	313	U62	TSOP-50	SnPb	SnPb	650		
22	314	U60	CSP-100	SnPb	SnPb	650		
22	315	U10	CLCC-20	SnPb	SnPb	506		
22	316	U28	QFN-20	Matte Sn	SnPb	650		
22	317	U29	TSOP-50	SnBi	SnPb	588		
22	318	U8	PDIP-20	NiPdAu		650		
22	319	U23	PDIP-20	NiPdAu		650		
22	320	PTH's	PTH's	ImAg		650		
120	321	U1	TQFP-144	SnPb Dip	SN100C	626		Exposed wire, not broken
120	322	U26	TSOP-50	SnBi	SN100C	272		
120	323	U41	TQFP-144	SnPb Dip	SN100C	650		Exposed wire, not broken
120	324	U9	CLCC-20	SnPb	SN100C	508	X	
120	325	U27	QFN-20	Matte Sn	SN100C	650		
120	326	U18	BGA-225	SnPb	SN100C	514		
120	327	U39	TSOP-50	SnPb	SN100C	612		
120	328	U56	BGA-225	SAC405	SN100C	512		
120	329	U40	TSOP-50	SnBi	SN100C	481		
120	330	U3	TQFP-144	Matte Sn	SN100C	608		
120	331	U13	CLCC-20	SnPb	SN100C	600	X	
120	332	U32	CSP-100	SnPb	SN100C	573		
120	333	U57	TQFP-144	Matte Sn	SN100C	528		
120	334	U14	CLCC-20	SAC305	SN100C	507	X	
120	336	U25	TSOP-50	SnPb	SN100C	581		
120	337	U50	CSP-100	SnPb	SN100C	650		
120	338	U33	CSP-100	SnPb	SN100C	650		
120	339	U58	TQFP-144	SnPb Dip	SN100C	650		
120	340	U12	TSOP-50	SnPb	SN100C	497		
120	341	U36	CSP-100	SAC105	SN100C	650		
120	342	U55	BGA-225	SnPb	SN100C	525		
120	343	U17	CLCC-20	SAC305	SN100C	458	X	
120	344	U2	BGA-225	SAC405	SN100C	307		
120	345	U31	TQFP-144	Matte Sn	SN100C	650		
120	346	U45	CLCC-20	SAC305	SN100C	323		Cap fell off
120	347	U46	CLCC-20	SnPb	SN100C	498	X	
120	348	U47	QFN-20	Matte Sn	SN100C	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
120	349	U19	CSP-100	SAC105	SN100C	650		
120	350	U24	TSOP-50	SnBi	SN100C	328		
120	351	U42	CSP-100	SAC105	SN100C	650		
120	352	U4	BGA-225	SnPb	SN100C	153		
120	353	U43	BGA-225	SnPb	SN100C	172		
120	354	U20	TQFP-144	SnPb Dip	SN100C	503		Insulation sliced, wire not broken, slightly exposed
120	355	U21	BGA-225	SAC405	SN100C	558		
120	356	U44	BGA-225	SAC405	SN100C	638		
120	357	U61	TSOP-50	SnPb	SN100C	552		
120	358	U54	QFN-20	Matte Sn	SN100C	650		
120	359	U48	TQFP-144	Matte Sn	SN100C	650		
120	360	U7	TQFP-144	SnPb Dip	SN100C	519		
120	361	U22	CLCC-20	SnPb	SN100C	256	X	
120	362	U16	TSOP-50	SnBi	SN100C	246		
120	363	U37	CSP-100	SAC105	SN100C	476		
120	364	U11	PDIP-20	NiPdAu		650		
120	365	U30	PDIP-20	NiPdAu		650		
120	366	U35	CSP-100	SnPb	SN100C	506		
120	367	U38	PDIP-20	NiPdAu		650		
120	368	U49	PDIP-20	NiPdAu		650		
120	369	U51	PDIP-20	NiPdAu		650		
120	370	U59	PDIP-20	NiPdAu		650		
120	371	U63	CSP-100	SnPb	SN100C	562		
120	372	U5	BGA-225	SAC405	SN100C	213		
120	373	U6	BGA-225	SnPb	SN100C	538		
120	374	U34	TQFP-144	Matte Sn	SN100C	551		
120	375	U52	CLCC-20	SAC305	SN100C	520		
120	376	U53	CLCC-20	SnPb	SN100C	323		
120	377	U62	TSOP-50	SnBi	SN100C	276		
120	378	U60	CSP-100	SAC105	SN100C	650		
120	379	U10	CLCC-20	SAC305	SN100C	498		
120	380	U28	QFN-20	Matte Sn	SN100C	551		
120	381	U29	TSOP-50	SnPb	SN100C	426		
120	382	U8	PDIP-20	Sn		650		
120	383	U23	PDIP-20	NiPdAu		650		
120	384	PTH's	PTH's	ImAg		650		
73	385	U1	TQFP-144	SnPb Dip	SAC305	650		Insulation of wire cracked, not broken
73	386	U26	TSOP-50	SnBi	SAC305	201		
73	387	U41	TQFP-144	SnPb Dip	SAC305	650		Insulation of wire cracked, not broken
73	388	U9	CLCC-20	SnPb	SAC305	327	X	
73	389	U27	QFN-20	Matte Sn	SAC305	650		
73	390	U18	BGA-225	SnPb	SAC305	169		
73	391	U39	TSOP-50	SnPb	SAC305	650		
73	392	U56	BGA-225	SAC405	SAC305	500		
73	393	U40	TSOP-50	SnBi	SAC305	499		
73	394	U3	TQFP-144	Matte Sn	SAC305	498		
73	395	U13	CLCC-20	SnPb	SAC305	302	X	
73	396	U32	CSP-100	SnPb	SAC305	650		
73	397	U57	TQFP-144	Matte Sn	SAC305	512		
73	398	U14	CLCC-20	SAC305	SAC305	306	X	
73	400	U25	TSOP-50	SnPb	SAC305	525		
73	401	U50	CSP-100	SnPb	SAC305	527		
73	402	U33	CSP-100	SnPb	SAC305	548		
73	403	U58	TQFP-144	SnPb Dip	SAC305	650		
73	404	U12	TSOP-50	SnPb	SAC305	384		
73	405	U36	CSP-100	SAC105	SAC305	591		
73	406	U55	BGA-225	SnPb	SAC305	68		
73	407	U17	CLCC-20	SAC305	SAC305	457	X	

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
73	408	U2	BGA-225	SAC405	SAC305	506		
73	409	U31	TQFP-144	Matte Sn	SAC305	533		
73	410	U45	CLCC-20	SAC305	SAC305	227	X	
73	411	U46	CLCC-20	SnPb	SAC305	241	X	
73	412	U47	QFN-20	Matte Sn	SAC305	650		
73	413	U19	CSP-100	SAC105	SAC305	538		
73	414	U24	TSOP-50	SnBi	SAC305	522	X	
73	415	U42	CSP-100	SAC105	SAC305	518		
73	416	U4	BGA-225	SnPb	SAC305	174		
73	417	U43	BGA-225	SnPb	SAC305	110	X	
73	418	U20	TQFP-144	SnPb Dip	SAC305	650		
73	419	U21	BGA-225	SAC405	SAC305	532		
73	420	U44	BGA-225	SAC405	SAC305	511		
73	421	U61	TSOP-50	SnPb	SAC305	178		
73	422	U54	QFN-20	Matte Sn	SAC305	650		
73	423	U48	TQFP-144	Matte Sn	SAC305	650		
73	424	U7	TQFP-144	SnPb Dip	SAC305	650		
73	425	U22	CLCC-20	SnPb	SAC305	522	X	
73	426	U16	TSOP-50	SnBi	SAC305	504		
73	427	U37	CSP-100	SAC105	SAC305	650		
73	428	U11	PDIP-20	Sn		650		
73	429	U30	PDIP-20	Sn		650		
73	430	U35	CSP-100	SnPb	SAC305	650		
73	431	U38	PDIP-20	Sn		650		
73	432	U49	PDIP-20	Sn		650		
73	433	U51	PDIP-20	Sn		650		
73	434	U59	PDIP-20	Sn		650		
73	435	U63	CSP-100	SnPb	SAC305	650		
73	436	U5	BGA-225	SAC405	SAC305	506		
73	437	U6	BGA-225	SnPb	SAC305	188		
73	438	U34	TQFP-144	Matte Sn	SAC305	650		
73	439	U52	CLCC-20	SAC305	SAC305	212	X	
73	440	U53	CLCC-20	SnPb	SAC305	424	X	
73	441	U62	TSOP-50	SnBi	SAC305	539		
73	442	U60	CSP-100	SAC105	SAC305	650		
73	443	U10	CLCC-20	SAC305	SAC305	429	X	
73	444	U28	QFN-20	Matte Sn	SAC305	650		
73	445	U29	TSOP-50	SnPb	SAC305	516		
73	446	U8	PDIP-20	Sn		650		
73	447	U23	PDIP-20	Sn		650		
73	448	PTH's	PTH's	ImAg		650		
20	449	U1	TQFP-144	Matte Sn	SnPb	560		
20	450	U26	TSOP-50	SnPb	SnPb	502		
20	451	U41	TQFP-144	Matte Sn	SnPb	650		
20	452	U9	CLCC-20	SAC305	SnPb	252	X	
20	453	U27	QFN-20	Matte Sn	SnPb	650		
20	454	U18	BGA-225	SAC405	SnPb	116		
20	455	U39	TSOP-50	SnBi	SnPb	650		
20	456	U56	BGA-225	SnPb	SnPb	537		
20	457	U40	TSOP-50	SnPb	SnPb	650		
20	458	U3	TQFP-144	SnPb Dip	SnPb	650		
20	459	U13	CLCC-20	SAC305	SnPb	383	X	
20	460	U32	CSP-100	SAC105	SnPb	434		
20	461	U57	TQFP-144	SnPb Dip	SnPb	650		
20	462	U14	CLCC-20	SnPb	SnPb	325	X	
20	464	U25	TSOP-50	SnBi	SnPb	503		
20	465	U50	CSP-100	SAC105	SnPb	394		
20	466	U33	CSP-100	SAC105	SnPb	650		
20	467	U58	TQFP-144	Matte Sn	SnPb	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
20	468	U12	TSOP-50	SnBi	SnPb	469		
20	469	U36	CSP-100	SnPb	SnPb	650		
20	470	U55	BGA-225	SAC405	SnPb	114		
20	471	U17	CLCC-20	SnPb	SnPb	479	X	
20	472	U2	BGA-225	SnPb	SnPb	188		
20	473	U31	TQFP-144	SnPb Dip	SnPb	650		
20	474	U45	CLCC-20	SnPb	SnPb	465	X	
20	475	U46	CLCC-20	SAC305	SnPb	334	X	
20	476	U47	QFN-20	Matte Sn	SnPb	650		
20	477	U19	CSP-100	SnPb	SnPb	650		
20	478	U24	TSOP-50	SnPb	SnPb	581		
20	479	U42	CSP-100	SnPb	SnPb	650		
20	480	U4	BGA-225	SAC405	SnPb	128		
20	481	U43	BGA-225	SAC405	SnPb	94		
20	482	U20	TQFP-144	Matte Sn	SnPb	650		
20	483	U21	BGA-225	SnPb	SnPb	633		
20	484	U44	BGA-225	SnPb	SnPb	631		
20	485	U61	TSOP-50	SnBi	SnPb	522		
20	486	U54	QFN-20	Matte Sn	SnPb	650		
20	487	U48	TQFP-144	SnPb Dip	SnPb	650		
20	488	U7	TQFP-144	Matte Sn	SnPb	585		
20	489	U22	CLCC-20	SAC305	SnPb	510	X	
20	490	U16	TSOP-50	SnPb	SnPb	505		
20	491	U37	CSP-100	SnPb	SnPb	562		
20	492	U11	PDIP-20	Sn		650		
20	493	U30	PDIP-20	Sn		650		
20	494	U35	CSP-100	SAC105	SnPb	650		
20	495	U38	PDIP-20	Sn		650		
20	496	U49	PDIP-20	NiPdAu		650		
20	497	U51	PDIP-20	Sn		650		
20	498	U59	PDIP-20	NiPdAu		650		
20	499	U63	CSP-100	SAC105	SnPb	613		
20	500	U5	BGA-225	SnPb	SnPb	437		
20	501	U6	BGA-225	SAC405	SnPb	130		
20	502	U34	TQFP-144	SnPb Dip	SnPb	650		
20	503	U52	CLCC-20	SnPb	SnPb	361	X	
20	504	U53	CLCC-20	SAC305	SnPb	472	X	
20	505	U62	TSOP-50	SnPb	SnPb	624		
20	506	U60	CSP-100	SnPb	SnPb	650		
20	507	U10	CLCC-20	SnPb	SnPb	502	X	
20	508	U28	QFN-20	Matte Sn	SnPb	650		
20	509	U29	TSOP-50	SnBi	SnPb	502		
20	510	U8	PDIP-20	NiPdAu		650		
20	511	U23	PDIP-20	NiPdAu		650		
20	512	PTH's	PTH's	ImAg		650		
24	513	U1	TQFP-144	Matte Sn	SnPb	516		
24	514	U26	TSOP-50	SnPb	SnPb	512		
24	515	U41	TQFP-144	Matte Sn	SnPb	650		
24	516	U9	CLCC-20	SAC305	SnPb	503	X	
24	517	U27	QFN-20	Matte Sn	SnPb	650		
24	518	U18	BGA-225	SAC405	SnPb	111		
24	519	U39	TSOP-50	SnBi	SnPb	650		
24	520	U56	BGA-225	SnPb	SnPb	271		
24	521	U40	TSOP-50	SnPb	SnPb	584		
24	522	U3	TQFP-144	SnPb Dip	SnPb	650		
24	523	U13	CLCC-20	SAC305	SnPb	285	X	
24	524	U32	CSP-100	SAC105	SnPb	650		
24	525	U57	TQFP-144	SnPb Dip	SnPb	650		
24	526	U14	CLCC-20	SnPb	SnPb	517	X	Solder balls back side of component

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
24	528	U25	TSOP-50	SnBi	SnPb	499		
24	529	U50	CSP-100	SAC105	SnPb	542		
24	530	U33	CSP-100	SAC105	SnPb	319		
24	531	U58	TQFP-144	Matte Sn	SnPb	650		
24	532	U12	TSOP-50	SnBi	SnPb	498	X	
24	533	U36	CSP-100	SnPb	SnPb	650		
24	534	U55	BGA-225	SAC405	SnPb	86		
24	535	U17	CLCC-20	SnPb	SnPb	535	X	
24	536	U2	BGA-225	SnPb	SnPb	150		
24	537	U31	TQFP-144	SnPb Dip	SnPb	650		
24	538	U45	CLCC-20	SnPb	SnPb	450	X	
24	539	U46	CLCC-20	SAC305	SnPb	498	X	
24	540	U47	QFN-20	Matte Sn	SnPb	650		
24	541	U19	CSP-100	SnPb	SnPb	650		
24	542	U24	TSOP-50	SnPb	SnPb	497		
24	543	U42	CSP-100	SnPb	SnPb	524		
24	544	U4	BGA-225	SAC405	SnPb	96		
24	545	U43	BGA-225	SAC405	SnPb	27		
24	546	U20	TQFP-144	Matte Sn	SnPb	650		
24	547	U21	BGA-225	SnPb	SnPb	511		
24	548	U44	BGA-225	SnPb	SnPb	508		
24	549	U61	TSOP-50	SnBi	SnPb	511		
24	550	U54	QFN-20	Matte Sn	SnPb	650		
24	551	U48	TQFP-144	SnPb Dip	SnPb	650		
24	552	U7	TQFP-144	Matte Sn	SnPb	343		
24	553	U22	CLCC-20	SAC305	SnPb	388	X	
24	554	U16	TSOP-50	SnPb	SnPb	362		
24	555	U37	CSP-100	SnPb	SnPb	530		
24	556	U11	PDIP-20	Sn		650		
24	557	U30	PDIP-20	Sn		650		
24	558	U35	CSP-100	SAC105	SnPb	401		
24	559	U38	PDIP-20	Sn		650		
24	560	U49	PDIP-20	NiPdAu		650		
24	561	U51	PDIP-20	Sn		650		
24	562	U59	PDIP-20	NiPdAu		650		
24	563	U63	CSP-100	SAC105	SnPb	463		
24	564	U5	BGA-225	SnPb	SnPb	122		
24	565	U6	BGA-225	SAC405	SnPb	77		
24	566	U34	TQFP-144	SnPb Dip	SnPb	650		
24	567	U52	CLCC-20	SnPb	SnPb	650		Cap fell off
24	568	U53	CLCC-20	SAC305	SnPb	378	X	
24	569	U62	TSOP-50	SnPb	SnPb	523		
24	570	U60	CSP-100	SnPb	SnPb	650		
24	571	U10	CLCC-20	SnPb	SnPb	506	X	
24	572	U28	QFN-20	Matte Sn	SnPb	650		
24	573	U29	TSOP-50	SnBi	SnPb	362		
24	574	U8	PDIP-20	NiPdAu		650		
24	575	U23	PDIP-20	NiPdAu		650		
24	576	PTH's	PTH's	ImAg		650		
116	577	U1	TQFP-144	SnPb Dip	SN100C	650		
116	578	U26	TSOP-50	SnBi	SN100C	516		
116	579	U41	TQFP-144	SnPb Dip	SN100C	650		
116	580	U9	CLCC-20	SnPb	SN100C	540	X	
116	581	U27	QFN-20	Matte Sn	SN100C	650		
116	582	U18	BGA-225	SnPb	SN100C	497		
116	583	U39	TSOP-50	SnPb	SN100C	650		
116	584	U56	BGA-225	SAC405	SN100C	650		
116	585	U40	TSOP-50	SnBi	SN100C	650		
116	586	U3	TQFP-144	Matte Sn	SN100C	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
116	587	U13	CLCC-20	SnPb	SN100C	650		
116	588	U32	CSP-100	SnPb	SN100C	650		
116	589	U57	TQFP-144	Matte Sn	SN100C	650		
116	590	U14	CLCC-20	SAC305	SN100C	293	X	
116	592	U25	TSOP-50	SnPb	SN100C	650		
116	593	U50	CSP-100	SnPb	SN100C	650		
116	594	U33	CSP-100	SnPb	SN100C	650		
116	595	U58	TQFP-144	SnPb Dip	SN100C	650		
116	596	U12	TSOP-50	SnPb	SN100C	503		Exposed wire from peeling
116	597	U36	CSP-100	SAC105	SN100C	650		Exposed wire from peeling
116	598	U55	BGA-225	SnPb	SN100C	227		Exposed wire from peeling
116	599	U17	CLCC-20	SAC305	SN100C	502	X	Exposed wire from peeling
116	600	U2	BGA-225	SAC405	SN100C	602		Exposed wire from peeling
116	601	U31	TQFP-144	Matte Sn	SN100C	650		Exposed wire from peeling
116	602	U45	CLCC-20	SAC305	SN100C	497	X	Exposed wire from peeling
116	603	U46	CLCC-20	SnPb	SN100C	497		Exposed wire from peeling
116	604	U47	QFN-20	Matte Sn	SN100C	650		Exposed wire from peeling
116	605	U19	CSP-100	SAC105	SN100C	650		Exposed wire from peeling
116	606	U24	TSOP-50	SnBi	SN100C	555		Exposed wire from peeling
116	607	U42	CSP-100	SAC105	SN100C	650		Exposed wire from peeling
116	608	U4	BGA-225	SnPb	SN100C	650		Exposed wire from peeling
116	609	U43	BGA-225	SnPb	SN100C	650		
116	610	U20	TQFP-144	SnPb Dip	SN100C	650		
116	611	U21	BGA-225	SAC405	SN100C	650		
116	612	U44	BGA-225	SAC405	SN100C	650		
116	613	U61	TSOP-50	SnPb	SN100C	650		
116	614	U54	QFN-20	Matte Sn	SN100C	650		
116	615	U48	TQFP-144	Matte Sn	SN100C	650		
116	616	U7	TQFP-144	SnPb Dip	SN100C	650		
116	617	U22	CLCC-20	SnPb	SN100C	228	X	
116	618	U16	TSOP-50	SnBi	SN100C	650		
116	619	U37	CSP-100	SAC105	SN100C	650		
116	620	U11	PDIP-20	NiPdAu		650		
116	621	U30	PDIP-20	NiPdAu		650		
116	622	U35	CSP-100	SnPb	SN100C	650		
116	623	U38	PDIP-20	NiPdAu		650		
116	624	U49	PDIP-20	NiPdAu		650		
116	625	U51	PDIP-20	NiPdAu		650		Exposed wire from peeling
116	626	U59	PDIP-20	NiPdAu		650		Exposed wire from peeling
116	627	U63	CSP-100	SnPb	SN100C	650		Exposed wire from peeling
116	628	U5	BGA-225	SAC405	SN100C	650		Exposed wire from peeling
116	629	U6	BGA-225	SnPb	SN100C	650		Exposed wire from peeling
116	630	U34	TQFP-144	Matte Sn	SN100C	650		Exposed wire from peeling
116	631	U52	CLCC-20	SAC305	SN100C	497		Exposed wire from peeling
116	632	U53	CLCC-20	SnPb	SN100C	243		Exposed wire from peeling
116	633	U62	TSOP-50	SnBi	SN100C	565		
116	634	U60	CSP-100	SAC105	SN100C	650		
116	635	U10	CLCC-20	SAC305	SN100C	650		
116	636	U28	QFN-20	Matte Sn	SN100C	650		
116	637	U29	TSOP-50	SnPb	SN100C	650		
116	638	U8	PDIP-20	NiPdAu		650		
116	639	U23	PDIP-20	NiPdAu		650		
116	640	PTH's	PTH's	ImAg		650		
72	641	U1	TQFP-144	SnPb Dip	SAC305	650		
72	642	U26	TSOP-50	SnBi	SAC305	518		
72	643	U41	TQFP-144	SnPb Dip	SAC305	650		
72	644	U9	CLCC-20	SnPb	SAC305	344	X	
72	645	U27	QFN-20	Matte Sn	SAC305	650		
72	646	U18	BGA-225	SnPb	SAC305	560		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
72	647	U39	TSOP-50	SnPb	SAC305	650		
72	648	U56	BGA-225	SAC405	SAC305	561		
72	649	U40	TSOP-50	SnBi	SAC305	560		
72	650	U3	TQFP-144	Matte Sn	SAC305	650		
72	651	U13	CLCC-20	SnPb	SAC305	282	X	
72	652	U32	CSP-100	SnPb	SAC305	650		
72	653	U57	TQFP-144	Matte Sn	SAC305	650		Exposed wire from peeling, not broken
72	654	U14	CLCC-20	SAC305	SAC305	510	X	
72	656	U25	TSOP-50	SnPb	SAC305	650		
72	657	U50	CSP-100	SnPb	SAC305	650		
72	658	U33	CSP-100	SnPb	SAC305	650		
72	659	U58	TQFP-144	SnPb Dip	SAC305	650		
72	660	U12	TSOP-50	SnPb	SAC305	516		
72	661	U36	CSP-100	SAC105	SAC305	650		
72	662	U55	BGA-225	SnPb	SAC305	506		
72	663	U17	CLCC-20	SAC305	SAC305	344	X	
72	664	U2	BGA-225	SAC405	SAC305	516		
72	665	U31	TQFP-144	Matte Sn	SAC305	650		
72	666	U45	CLCC-20	SAC305	SAC305	443		Cap fell off
72	667	U46	CLCC-20	SnPb	SAC305	374	X	
72	668	U47	QFN-20	Matte Sn	SAC305	650		
72	669	U19	CSP-100	SAC105	SAC305	650		
72	670	U24	TSOP-50	SnBi	SAC305	515		
72	671	U42	CSP-100	SAC105	SAC305	625		
72	672	U4	BGA-225	SnPb	SAC305	530		Pin holes in solder on back side of component, took photo
72	673	U43	BGA-225	SnPb	SAC305	631		
72	674	U20	TQFP-144	SnPb Dip	SAC305	650		
72	675	U21	BGA-225	SAC405	SAC305	610		
72	676	U44	BGA-225	SAC405	SAC305	509		
72	677	U61	TSOP-50	SnPb	SAC305	602		
72	678	U54	QFN-20	Matte Sn	SAC305	650		
72	679	U48	TQFP-144	Matte Sn	SAC305	650		
72	680	U7	TQFP-144	SnPb Dip	SAC305	650		
72	681	U22	CLCC-20	SnPb	SAC305	504	X	
72	682	U16	TSOP-50	SnBi	SAC305	278		
72	683	U37	CSP-100	SAC105	SAC305	650		
72	684	U11	PDIP-20	Sn		650		
72	685	U30	PDIP-20	Sn		650		
72	686	U35	CSP-100	SnPb	SAC305	576		
72	687	U38	PDIP-20	Sn		650		
72	688	U49	PDIP-20	Sn		650		
72	689	U51	PDIP-20	Sn		650		
72	690	U59	PDIP-20	Sn		650		
72	691	U63	CSP-100	SnPb	SAC305	589		
72	692	U5	BGA-225	SAC405	SAC305	523		Pin holes in solder on back side of component, took photo
72	693	U6	BGA-225	SnPb	SAC305	506		Pin holes in solder on back side of component, took photo
72	694	U34	TQFP-144	Matte Sn	SAC305	650		
72	695	U52	CLCC-20	SAC305	SAC305	281	X	
72	696	U53	CLCC-20	SnPb	SAC305	546	X	
72	697	U62	TSOP-50	SnBi	SAC305	380		
72	698	U60	CSP-100	SAC105	SAC305	650		
72	699	U10	CLCC-20	SAC305	SAC305	293	X	
72	700	U28	QFN-20	Matte Sn	SAC305	650		
72	701	U29	TSOP-50	SnPb	SAC305	161		
72	702	U8	PDIP-20	Sn		650		
72	703	U23	PDIP-20	Sn		650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
72	704	PTH's	PTH's	ImAg		650		
21	705	U1	TQFP-144	Matte Sn	SnPb	498		Exposed wire from peeling after 498 cycles; Kapton tape to protect, some broken strands visible; Exposed wire in two places
21	706	U26	TSOP-50	SnPb	SnPb	590		Exposed wire from peeling, not broken; Cracked insulation further up the wire
21	707	U41	TQFP-144	Matte Sn	SnPb	650		Exposed wire from peeling, not broken; Solder balls back side of component, took photo
21	708	U9	CLCC-20	SAC305	SnPb	294	X	
21	709	U27	QFN-20	Matte Sn	SnPb	650		
21	710	U18	BGA-225	SAC405	SnPb	164		Solder balls back side of component, took photo
21	711	U39	TSOP-50	SnBi	SnPb	650		
21	712	U56	BGA-225	SnPb	SnPb	650		Solder balls back side of component, took photo
21	713	U40	TSOP-50	SnPb	SnPb	650		Exposed wire from peeling, not broken
21	714	U3	TQFP-144	SnPb Dip	SnPb	650		
21	715	U13	CLCC-20	SAC305	SnPb	536	X	
21	716	U32	CSP-100	SAC105	SnPb	545		Exposed wire from peeling, not broken
21	717	U57	TQFP-144	SnPb Dip	SnPb	1		Solder balls back side of component, took photo
21	718	U14	CLCC-20	SnPb	SnPb	498	X	
21	720	U25	TSOP-50	SnBi	SnPb	597		Exposed wire from peeling, not broken
21	721	U50	CSP-100	SAC105	SnPb	495		Exposed wire from peeling, not broken
21	722	U33	CSP-100	SAC105	SnPb	504		Exposed wire from peeling, not broken
21	723	U58	TQFP-144	Matte Sn	SnPb	650		Exposed wire from peeling, not broken
21	724	U12	TSOP-50	SnBi	SnPb	511		
21	725	U36	CSP-100	SnPb	SnPb	650		
21	726	U55	BGA-225	SAC405	SnPb	106		Solder balls back side of component, took photo
21	727	U17	CLCC-20	SnPb	SnPb	540	X	
21	728	U2	BGA-225	SnPb	SnPb	517		
21	729	U31	TQFP-144	SnPb Dip	SnPb	650		
21	730	U45	CLCC-20	SnPb	SnPb	542	X	
21	731	U46	CLCC-20	SAC305	SnPb	601	X	
21	732	U47	QFN-20	Matte Sn	SnPb	650		
21	733	U19	CSP-100	SnPb	SnPb	650		
21	734	U24	TSOP-50	SnPb	SnPb	526		Exposed wire from peeling, not broken
21	735	U42	CSP-100	SnPb	SnPb	650		
21	736	U4	BGA-225	SAC405	SnPb	255		
70	769	U1	TQFP-144	SnPb Dip	SAC305	650		Cracked insulation, wire not exposed
70	770	U26	TSOP-50	SnBi	SAC305	513		
70	771	U41	TQFP-144	SnPb Dip	SAC305	650		
70	772	U9	CLCC-20	SnPb	SAC305	243	X	
70	773	U27	QFN-20	Matte Sn	SAC305	650		
70	774	U18	BGA-225	SnPb	SAC305	500		
70	775	U39	TSOP-50	SnPb	SAC305	650		
70	776	U56	BGA-225	SAC405	SAC305	650		
70	777	U40	TSOP-50	SnBi	SAC305	546		
70	778	U3	TQFP-144	Matte Sn	SAC305	520		
70	779	U13	CLCC-20	SnPb	SAC305	290	X	
70	780	U32	CSP-100	SnPb	SAC305	650		
70	781	U57	TQFP-144	Matte Sn	SAC305	650		
70	782	U14	CLCC-20	SAC305	SAC305	503	X	
70	784	U25	TSOP-50	SnPb	SAC305	553		
70	785	U50	CSP-100	SnPb	SAC305	650		
70	786	U33	CSP-100	SnPb	SAC305	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
70	787	U58	TQFP-144	SnPb Dip	SAC305	650		
70	788	U12	TSOP-50	SnPb	SAC305	513		
70	789	U36	CSP-100	SAC105	SAC305	552		
70	790	U55	BGA-225	SnPb	SAC305	363		
70	791	U17	CLCC-20	SAC305	SAC305	292	X	
70	792	U2	BGA-225	SAC405	SAC305	503		
70	793	U31	TQFP-144	Matte Sn	SAC305	650		
70	794	U45	CLCC-20	SAC305	SAC305	502	X	
70	795	U46	CLCC-20	SnPb	SAC305	486	X	
70	796	U47	QFN-20	Matte Sn	SAC305	650		
70	797	U19	CSP-100	SAC105	SAC305	650		
70	798	U24	TSOP-50	SnBi	SAC305	570		
70	799	U42	CSP-100	SAC105	SAC305	650		
70	800	U4	BGA-225	SnPb	SAC305	492		
70	801	U43	BGA-225	SnPb	SAC305	503		
70	802	U20	TQFP-144	SnPb Dip	SAC305	650		
70	803	U21	BGA-225	SAC405	SAC305	650		
70	804	U44	BGA-225	SAC405	SAC305	554		
70	805	U61	TSOP-50	SnPb	SAC305	650		
70	806	U54	QFN-20	Matte Sn	SAC305	650		
70	807	U48	TQFP-144	Matte Sn	SAC305	575		
70	808	U7	TQFP-144	SnPb Dip	SAC305	650		
70	809	U22	CLCC-20	SnPb	SAC305	371	X	
70	810	U16	TSOP-50	SnBi	SAC305	511		
70	811	U37	CSP-100	SAC105	SAC305	650		
70	812	U11	PDIP-20	Sn		650		
70	813	U30	PDIP-20	Sn		650		
70	814	U35	CSP-100	SnPb	SAC305	650		
70	815	U38	PDIP-20	Sn		650		
70	816	U49	PDIP-20	Sn		650		
70	817	U51	PDIP-20	Sn		650		
70	818	U59	PDIP-20	Sn		650		
70	819	U63	CSP-100	SnPb	SAC305	650		
70	820	U5	BGA-225	SAC405	SAC305	531		
70	821	U6	BGA-225	SnPb	SAC305	597		
70	822	U34	TQFP-144	Matte Sn	SAC305	586		
70	823	U52	CLCC-20	SAC305	SAC305	502	X	
70	824	U53	CLCC-20	SnPb	SAC305	372	X	
70	825	U62	TSOP-50	SnBi	SAC305	387		
70	826	U60	CSP-100	SAC105	SAC305	650		
70	827	U10	CLCC-20	SAC305	SAC305	498	X	
70	828	U28	QFN-20	Matte Sn	SAC305	650		
70	829	U29	TSOP-50	SnPb	SAC305	511		
70	830	U8	PDIP-20	Sn		650		
70	831	U23	PDIP-20	Sn		650		
70	832	PTH's	PTH's	ImAg		650		
119	833	U1	TQFP-144	SnPb Dip	SN100C	384	X	Exposed wire, not broken
119	834	U26	TSOP-50	SnBi	SN100C	150	X	
119	835	U41	TQFP-144	SnPb Dip	SN100C	316	X	
119	836	U9	CLCC-20	SnPb	SN100C	306	X	
119	837	U27	QFN-20	Matte Sn	SN100C	509		
119	838	U18	BGA-225	SnPb	SN100C	94	X	
119	839	U39	TSOP-50	SnPb	SN100C	318		
119	840	U56	BGA-225	SAC405	SN100C	146		
119	841	U40	TSOP-50	SnBi	SN100C	228		
119	842	U3	TQFP-144	Matte Sn	SN100C	428		
119	843	U13	CLCC-20	SnPb	SN100C	554	X	
119	844	U32	CSP-100	SnPb	SN100C	557		
119	845	U57	TQFP-144	Matte Sn	SN100C	444		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
119	846	U14	CLCC-20	SAC305	SN100C	332	X	
119	848	U25	TSOP-50	SnPb	SN100C	311		
119	849	U50	CSP-100	SnPb	SN100C	603		
119	850	U33	CSP-100	SnPb	SN100C	585		
119	851	U58	TQFP-144	SnPb Dip	SN100C	566		
119	852	U12	TSOP-50	SnPb	SN100C	136	X	
119	853	U36	CSP-100	SAC105	SN100C	233		
119	854	U55	BGA-225	SnPb	SN100C	2	X	
119	855	U17	CLCC-20	SAC305	SN100C	200	X	
119	856	U2	BGA-225	SAC405	SN100C	122		
119	857	U31	TQFP-144	Matte Sn	SN100C	255	X	
119	858	U45	CLCC-20	SAC305	SN100C	72	X	
119	859	U46	CLCC-20	SnPb	SN100C	211	X	
119	860	U47	QFN-20	Matte Sn	SN100C	524		
119	861	U19	CSP-100	SAC105	SN100C	515		
119	862	U24	TSOP-50	SnBi	SN100C	194	X	
119	863	U42	CSP-100	SAC105	SN100C	500		
119	864	U4	BGA-225	SnPb	SN100C	100		
119	865	U43	BGA-225	SnPb	SN100C	150		
119	866	U20	TQFP-144	SnPb Dip	SN100C	607		
119	867	U21	BGA-225	SAC405	SN100C	510		
119	868	U44	BGA-225	SAC405	SN100C	234		
119	869	U61	TSOP-50	SnPb	SN100C	498		
119	870	U54	QFN-20	Matte Sn	SN100C	650		
119	871	U48	TQFP-144	Matte Sn	SN100C	638		
119	872	U7	TQFP-144	SnPb Dip	SN100C	516		
119	873	U22	CLCC-20	SnPb	SN100C	244	X	
119	874	U16	TSOP-50	SnBi	SN100C	192		
119	875	U37	CSP-100	SAC105	SN100C	650		
119	876	U11	PDIP-20	NiPdAu		650		
119	877	U30	PDIP-20	Sn		558		
119	878	U35	CSP-100	SnPb	SN100C	517		
119	879	U38	PDIP-20	Sn		650		
119	880	U49	PDIP-20	Sn		650		
119	881	U51	PDIP-20	Sn		650		
119	882	U59	PDIP-20	Sn		650		
119	883	U63	CSP-100	SnPb	SN100C	492		
119	884	U5	BGA-225	SAC405	SN100C	515		
119	885	U6	BGA-225	SnPb	SN100C	114		
119	886	U34	TQFP-144	Matte Sn	SN100C	650		
119	887	U52	CLCC-20	SAC305	SN100C	507	X	
119	888	U53	CLCC-20	SnPb	SN100C	413	X	
119	889	U62	TSOP-50	SnBi	SN100C	213		
119	890	U60	CSP-100	SAC105	SN100C	504		
119	891	U10	CLCC-20	SAC305	SN100C	497	X	
119	892	U28	QFN-20	Matte Sn	SN100C	506		
119	893	U29	TSOP-50	SnPb	SN100C	182		
119	894	U8	PDIP-20	NiPdAu		650		
119	895	U23	PDIP-20	NiPdAu		650		
119	896	PTH's	PTH's	ImAg		650		
117	897	U1	TQFP-144	SnPb Dip	SN100C	650		Wire exposed insulation cracked, not broken
117	898	U26	TSOP-50	SnBi	SN100C	209	X	
117	899	U41	TQFP-144	SnPb Dip	SN100C	650		
117	900	U9	CLCC-20	SnPb	SN100C	360	X	
117	901	U27	QFN-20	Matte Sn	SN100C	522		
117	902	U18	BGA-225	SnPb	SN100C	49		
117	903	U39	TSOP-50	SnPb	SN100C	498	X	
117	904	U56	BGA-225	SAC405	SN100C	166		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
117	905	U40	TSOP-50	SnBi	SN100C	498		
117	906	U3	TQFP-144	Matte Sn	SN100C	616		
117	907	U13	CLCC-20	SnPb	SN100C	433	X	
117	908	U32	CSP-100	SnPb	SN100C	641		
117	909	U57	TQFP-144	Matte Sn	SN100C	650		
117	910	U14	CLCC-20	SAC305	SN100C	400	X	
117	912	U25	TSOP-50	SnPb	SN100C	569		
117	913	U50	CSP-100	SnPb	SN100C	650		
117	914	U33	CSP-100	SnPb	SN100C	569		
117	915	U58	TQFP-144	SnPb Dip	SN100C	650		
117	916	U12	TSOP-50	SnPb	SN100C	176		
117	917	U36	CSP-100	SAC105	SN100C	509		
117	918	U55	BGA-225	SnPb	SN100C	202		
117	919	U17	CLCC-20	SAC305	SN100C	484	X	
117	920	U2	BGA-225	SAC405	SN100C	181		
117	921	U31	TQFP-144	Matte Sn	SN100C	510		
117	922	U45	CLCC-20	SAC305	SN100C	264	X	
117	923	U46	CLCC-20	SnPb	SN100C	497	X	
117	924	U47	QFN-20	Matte Sn	SN100C	650		
117	925	U19	CSP-100	SAC105	SN100C	635		
117	926	U24	TSOP-50	SnBi	SN100C	498		
117	927	U42	CSP-100	SAC105	SN100C	511		
117	928	U4	BGA-225	SnPb	SN100C	20		
117	929	U43	BGA-225	SnPb	SN100C	380		Wire exposed from peeling, not broken
117	930	U20	TQFP-144	SnPb Dip	SN100C	639		
117	931	U21	BGA-225	SAC405	SN100C	537		
117	932	U44	BGA-225	SAC405	SN100C	645		
117	933	U61	TSOP-50	SnPb	SN100C	597		
117	934	U54	QFN-20	Matte Sn	SN100C	650		
117	935	U48	TQFP-144	Matte Sn	SN100C	596		
117	936	U7	TQFP-144	SnPb Dip	SN100C	573		
117	937	U22	CLCC-20	SnPb	SN100C	499	X	
117	938	U16	TSOP-50	SnBi	SN100C	276		
117	939	U37	CSP-100	SAC105	SN100C	587		
117	940	U11	PDIP-20	NiPdAu		650		
117	941	U30	PDIP-20	NiPdAu		650		
117	942	U35	CSP-100	SnPb	SN100C	650		
117	943	U38	PDIP-20	NiPdAu		650		
117	944	U49	PDIP-20	NiPdAu		650		
117	945	U51	PDIP-20	NiPdAu		650		
117	946	U59	PDIP-20	NiPdAu		650		
117	947	U63	CSP-100	SnPb	SN100C	580		
117	948	U5	BGA-225	SAC405	SN100C	515		
117	949	U6	BGA-225	SnPb	SN100C	330		
117	950	U34	TQFP-144	Matte Sn	SN100C	650		
117	951	U52	CLCC-20	SAC305	SN100C	500	X	
117	952	U53	CLCC-20	SnPb	SN100C	650		
117	953	U62	TSOP-50	SnBi	SN100C	512		
117	954	U60	CSP-100	SAC105	SN100C	650		
117	955	U10	CLCC-20	SAC305	SN100C	560	X	
117	956	U28	QFN-20	Matte Sn	SN100C	650		
117	957	U29	TSOP-50	SnPb	SN100C	502		
117	958	U8	PDIP-20	Sn		650		
117	959	U23	PDIP-20	NiPdAu		650		
117	960	PTH's	PTH's	ImAg		650		
21	993	U43	BGA-225	SAC405	SnPb	650		
21	994	U20	TQFP-144	Matte Sn	SnPb	650		
21	995	U21	BGA-225	SnPb	SnPb	650		
21	996	U44	BGA-225	SnPb	SnPb	650		

Board ID	Anatech Channel	Ref Des	Component	Finish	Paste	Cycles at First Failure	Missing	Comment
21	997	U61	TSOP-50	SnBi	SnPb	650		
21	998	U54	QFN-20	Matte Sn	SnPb	650		
21	999	U48	TQFP-144	SnPb Dip	SnPb	650		
21	1000	U7	TQFP-144	Matte Sn	SnPb	543		
21	1001	U22	CLCC-20	SAC305	SnPb	232	X	
21	1002	U16	TSOP-50	SnPb	SnPb	344		
21	1003	U37	CSP-100	SnPb	SnPb	493		
21	1004	U11	PDIP-20	Sn		650		
21	1005	U30	PDIP-20	Sn		650		
21	1006	U35	CSP-100	SAC105	SnPb	194		
21	1007	U38	PDIP-20	Sn		650		
21	1008	U49	PDIP-20	NiPdAu		650		
21	1009	U51	PDIP-20	Sn		650		
21	1010	U59	PDIP-20	NiPdAu		650		
21	1011	U63	CSP-100	SAC105	SnPb	650		
21	1012	U5	BGA-225	SnPb	SnPb	650		
21	1013	U6	BGA-225	SAC405	SnPb	234		
21	1014	U34	TQFP-144	SnPb Dip	SnPb	0		
21	1015	U52	CLCC-20	SnPb	SnPb	394	X	
21	1016	U53	CLCC-20	SAC305	SnPb	498	X	
21	1017	U62	TSOP-50	SnPb	SnPb	575		
21	1018	U60	CSP-100	SnPb	SnPb	650		
21	1019	U10	CLCC-20	SnPb	SnPb	322	X	
21	1020	U28	QFN-20	Matte Sn	SnPb	650		
21	1021	U29	TSOP-50	SnBi	SnPb	291		
21	1022	U8	PDIP-20	NiPdAu		650		
21	1023	U23	PDIP-20	NiPdAu		650		
21	1024	PTH's	PTH's	ImAg		650		

Appendix B: Rework Assembly Raw Test Data

Table 24 Rework Assembly Raw Data

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
163	1	U1	TQFP-144	SAC305 Dip			650		Exposed wire, not broken
163	2	U26	TSOP-50	SnBi	SnBi	SAC305	416		
163	3	U41	TQFP-144	SAC305 Dip			650		
163	4	U9	CLCC-20	SnPb			258	X	
163	5	U27	QFN-20	SnPb			650		
163	6	U18	BGA-225	SAC405	SAC405	SnPb	514		
163	7	U39	TSOP-50	SnBi			648		
163	8	U56	BGA-225	SAC405	SAC405	Flux Only	438		
163	9	U40	TSOP-50	SnPb			650		
163	10	U3	TQFP-144	NiPdAu			650		
163	11	U13	CLCC-20	SnPb			420	X	
163	12	U32	CSP-100	SnPb			650		
163	13	U57	TQFP-144	NiPdAu			650		
163	14	U14	CLCC-20	SnPb			308	X	
163	16	U25	TSOP-50	Sn	Sn	SnPb	650		
163	17	U50	CSP-100	SAC105	SAC105	Flux Only	650		
163	18	U33	CSP-100	SAC105	SAC105	SnPb	650		
163	19	U58	TQFP-144	SAC305 Dip			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
163	20	U12	TSOP-50	Sn	Sn	SnPb	612		
163	21	U36	CSP-100	SAC105			630		
163	22	U55	BGA-225	SnPb			413		
163	23	U17	CLCC-20	SnPb			179	X	
163	24	U2	BGA-225	SAC405	SAC405	Flux Only	560		
163	25	U31	TQFP-144	NiPdAu			650		
163	26	U45	CLCC-20	SnPb			361	X	
163	27	U46	CLCC-20	SnPb			374	X	
163	28	U47	QFN-20	SnPb			650		
163	29	U19	CSP-100	SAC105	SAC105	Flux Only	650		
163	30	U24	TSOP-50	SnBi	SnBi	SAC305	416		
163	31	U42	CSP-100	SAC105	SAC105	SnPb	597		
163	32	U4	BGA-225	SnPb			433		
163	33	U43	BGA-225	SAC405	SAC405	SnPb	650		
163	34	U20	TQFP-144	SAC305 Dip			650		
163	35	U21	BGA-225	SAC405	SAC405	Flux Only	650		
163	36	U44	BGA-225	SnPb			650		
163	37	U61	TSOP-50	SnBi			508		
163	38	U54	QFN-20	SnPb			650		
163	39	U48	TQFP-144	NiPdAu			650		
163	40	U7	TQFP-144	SAC305 Dip			650		
163	41	U22	CLCC-20	SnPb			404	X	
163	42	U16	TSOP-50	SnPb			601		
163	43	U37	CSP-100	SAC105	SAC105	Flux Only	650		
163	44	U11	PDIP-20	Sn	Sn	SN100C	650		
163	45	U30	PDIP-20	Sn			650		
163	46	U35	CSP-100	SnPb			650		
163	47	U38	PDIP-20	Sn			650		
163	48	U49	PDIP-20	Sn			466		
163	49	U51	PDIP-20	Sn	Sn	SN100C	391		
163	50	U59	PDIP-20	Sn			650		
163	51	U63	CSP-100	SnPb			650		
163	52	U5	BGA-225	SnPb			420		
163	53	U6	BGA-225	SAC405	SAC405	SnPb	650		
163	54	U34	TQFP-144	NiPdAu			650		
163	55	U52	CLCC-20	SnPb			423	X	
163	56	U53	CLCC-20	SnPb			309	X	
163	57	U62	TSOP-50	SnPb			650		
163	58	U60	CSP-100	SAC105	SAC105	SnPb	459		
163	59	U10	CLCC-20	SnPb			410	X	
163	60	U28	QFN-20	SnPb			650		
163	61	U29	TSOP-50	SnBi			650		
163	62	U8	PDIP-20	Sn			650		
163	63	U23	PDIP-20	Sn			650		
163	64	PTH's	PTH's	ImAg			650		
158	65	U1	TQFP-144	SnPb Dip			406		Broken wire
158	66	U26	TSOP-50	SnPb	Sn	SnPb	494		
158	67	U41	TQFP-144	SnPb Dip			650		
158	68	U9	CLCC-20	SAC305			309	X	
158	69	U27	QFN-20	Matte Sn			650		
158	70	U18	BGA-225	SnPb	SAC405	SnPb	385		
158	71	U39	TSOP-50	Sn			650		
158	72	U56	BGA-225	SnPb	SnPb	Flux Only	650		
158	73	U40	TSOP-50	SnBi			650		
158	74	U3	TQFP-144	NiPdAu			340		
158	75	U13	CLCC-20	SAC305			340	X	
158	76	U32	CSP-100	SAC105			631		
158	77	U57	TQFP-144	NiPdAu			650		Exposed wire, not broken
158	78	U14	CLCC-20	SAC305			365	X	
158	80	U25	TSOP-50	SnPb	SnPb	SnPb	491		
158	81	U50	CSP-100	SnPb	SnPb	Flux Only	650		
158	82	U33	CSP-100	SnPb	SAC105	SnPb	533		
158	83	U58	TQFP-144	SnPb Dip			650		
158	84	U12	TSOP-50	SnPb	SnPb	SnPb	277		
158	85	U36	CSP-100	SAC105			650		
158	86	U55	BGA-225	SAC405			650		
158	87	U17	CLCC-20	SAC305			356	X	
158	88	U2	BGA-225	SnPb	SnPb	Flux Only	354		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
158	89	U31	TQFP-144	NiPdAu			650		
158	90	U45	CLCC-20	SAC305			306	X	
158	91	U46	CLCC-20	SAC305			412	X	
158	92	U47	QFN-20	Matte Sn			650		
158	93	U19	CSP-100	SnPb	SnPb	Flux Only	650		
158	94	U24	TSOP-50	SnPb	Sn	SnPb	630		
158	95	U42	CSP-100	SnPb	SAC105	SnPb	650		
158	96	U4	BGA-225	SAC405			346		
158	97	U43	BGA-225	SnPb	SAC405	SnPb	460		Crushed wire
158	98	U20	TQFP-144	SnPb Dip			555		
158	99	U21	BGA-225	SnPb	SnPb	Flux Only	650		
158	100	U44	BGA-225	SAC405			570		
158	101	U61	TSOP-50	Sn			650		
158	102	U54	QFN-20	Matte Sn			650		
158	103	U48	TQFP-144	NiPdAu			650		
158	104	U7	TQFP-144	SnPb Dip			443		
158	105	U22	CLCC-20	SAC305			253	X	
158	106	U16	TSOP-50	SnBi			472		
158	107	U37	CSP-100	SnPb	SnPb	Flux Only	650		
158	108	U11	PDIP-20	SnPb	Sn	SnPb	650		
158	109	U30	PDIP-20	Sn			650		
158	110	U35	CSP-100	SAC105			650		
158	111	U38	PDIP-20	Sn			522		
158	112	U49	PDIP-20	NiPdAu			650		
158	113	U51	PDIP-20	SnPb	Sn	SnPb	650		
158	114	U59	PDIP-20	Sn			650		
158	115	U63	CSP-100	SAC105			650		
158	116	U5	BGA-225	SAC405			350		
158	117	U6	BGA-225	SnPb	SAC405	SnPb	1		
158	118	U34	TQFP-144	NiPdAu			650		
158	119	U52	CLCC-20	SAC305			293	X	
158	120	U53	CLCC-20	SAC305			214	X	
158	121	U62	TSOP-50	SnBi			650		
158	122	U60	CSP-100	SnPb	SAC105	SnPb	650		
158	123	U10	CLCC-20	SAC305			234	X	
158	124	U28	QFN-20	Matte Sn			650		
158	125	U29	TSOP-50	Sn			481		
158	126	U8	PDIP-20	NiPdAu			650		
158	127	U23	PDIP-20	NiPdAu			650		
158	128	PTH's	PTH's	ENIG			650		
181	129	U1	TQFP-144	SAC305 Dip			482		
181	130	U26	TSOP-50	SnBi	SnBi	SAC305	376		
181	131	U41	TQFP-144	SAC305 Dip			1		
181	132	U9	CLCC-20	SnPb			240	X	
181	133	U27	QFN-20	SnPb			618		
181	134	U18	BGA-225	SAC405	SAC405	SnPb	347		
181	135	U39	TSOP-50	SnBi			522		
181	136	U56	BGA-225	SAC405	SAC405	Flux Only	1		
181	137	U40	TSOP-50	SnPb			650		
181	138	U3	TQFP-144	NiPdAu			650		
181	139	U13	CLCC-20	SnPb			394	X	
181	140	U32	CSP-100	SnPb			650		
181	141	U57	TQFP-144	NiPdAu			650		
181	142	U14	CLCC-20	SnPb			202	X	
181	144	U25	TSOP-50	Sn	Sn	SnPb	1		
181	145	U50	CSP-100	SAC105	SAC105	Flux Only	650		
181	146	U33	CSP-100	SAC105	SAC105	SnPb	58		
181	147	U58	TQFP-144	SAC305 Dip			650		
181	148	U12	TSOP-50	Sn	Sn	SnPb	500		
181	149	U36	CSP-100	SAC105			465		
181	150	U55	BGA-225	SnPb			650		
181	151	U17	CLCC-20	SnPb			250	X	
181	152	U2	BGA-225	SAC405	SAC405	Flux Only	1		
181	153	U31	TQFP-144	NiPdAu			650		
181	154	U45	CLCC-20	SnPb			292	X	
181	155	U46	CLCC-20	SnPb			382	X	
181	156	U47	QFN-20	SnPb			650		
181	157	U19	CSP-100	SAC105	SAC105	Flux Only	650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
181	158	U24	TSOP-50	SnBi	SnBi	SAC305	521		
181	159	U42	CSP-100	SAC105	SAC105	SnPb	254		
181	160	U4	BGA-225	SnPb			107		
181	161	U43	BGA-225	SAC405	SAC405	SnPb	650		
181	162	U20	TQFP-144	SAC305 Dip			650		
181	163	U21	BGA-225	SAC405	SAC405	Flux Only	2		
181	164	U44	BGA-225	SnPb			159		
181	165	U61	TSOP-50	SnBi			622		
181	166	U54	QFN-20	SnPb			650		
181	167	U48	TQFP-144	NiPdAu			650		
181	168	U7	TQFP-144	SAC305 Dip			28		
181	169	U22	CLCC-20	SnPb			318	X	
181	170	U16	TSOP-50	SnPb			650		
181	171	U37	CSP-100	SAC105	SAC105	Flux Only	650		
181	172	U11	PDIP-20	Sn	Sn	SN100C	556		
181	173	U30	PDIP-20	Sn			650		
181	174	U35	CSP-100	SnPb			650		
181	175	U38	PDIP-20	Sn			650		
181	176	U49	PDIP-20	Sn			650		
181	177	U51	PDIP-20	Sn	Sn	SN100C	650		
181	178	U59	PDIP-20	Sn			650		
181	179	U63	CSP-100	SnPb			650		
181	180	U5	BGA-225	SnPb			396		
181	181	U6	BGA-225	SAC405	SAC405	SnPb	650		
181	182	U34	TQFP-144	NiPdAu			650		
181	183	U52	CLCC-20	SnPb			416	X	
181	184	U53	CLCC-20	SnPb			394	X	
181	185	U62	TSOP-50	SnPb			650		
181	186	U60	CSP-100	SAC105	SAC105	SnPb	275		
181	187	U10	CLCC-20	SnPb			225	X	
181	188	U28	QFN-20	SnPb			650		
181	189	U29	TSOP-50	SnBi			504		
181	190	U8	PDIP-20	Sn			650		
181	191	U23	PDIP-20	Sn			650		
181	192	PTH's	PTH's	ImAg			650		
143	193	U1	TQFP-144	SnPb Dip			650		Exposed wire, not broken
143	194	U26	TSOP-50	SnPb	Sn	SnPb	418		
143	195	U41	TQFP-144	SnPb Dip			650		
143	196	U9	CLCC-20	SAC305			400	X	
143	197	U27	QFN-20	Matte Sn			650		
143	198	U18	BGA-225	SnPb	SAC405	SnPb	165		
143	199	U39	TSOP-50	Sn			650		
143	200	U56	BGA-225	SnPb	SnPb	Flux Only	650		
143	201	U40	TSOP-50	SnBi			650		
143	202	U3	TQFP-144	NiPdAu			650		
143	203	U13	CLCC-20	SAC305			314	X	
143	204	U32	CSP-100	SAC105			462		Exposed wire, not broken
143	205	U57	TQFP-144	NiPdAu			650		
143	206	U14	CLCC-20	SAC305			451	X	
143	208	U25	TSOP-50	SnPb	SnPb	SnPb	650		
143	209	U50	CSP-100	SnPb	SnPb	Flux Only	650		
143	210	U33	CSP-100	SnPb	SAC105	SnPb	650		
143	211	U58	TQFP-144	SnPb Dip			650		
143	212	U12	TSOP-50	SnPb	SnPb	SnPb	327		
143	213	U36	CSP-100	SAC105			280		
143	214	U55	BGA-225	SAC405			650		
143	215	U17	CLCC-20	SAC305			312	X	
143	216	U2	BGA-225	SnPb	SnPb	Flux Only	420		
143	217	U31	TQFP-144	NiPdAu			650		
143	218	U45	CLCC-20	SAC305			306	X	
143	219	U46	CLCC-20	SAC305			368	X	
143	220	U47	QFN-20	Matte Sn			650		
143	221	U19	CSP-100	SnPb	SnPb	Flux Only	650		
143	222	U24	TSOP-50	SnPb	Sn	SnPb	490		
143	223	U42	CSP-100	SnPb	SAC105	SnPb	650		
143	224	U4	BGA-225	SAC405			632		
143	225	U43	BGA-225	SnPb	SAC405	SnPb	249		
143	226	U20	TQFP-144	SnPb Dip			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
143	227	U21	BGA-225	SnPb	SnPb	Flux Only	650		
143	228	U44	BGA-225	SAC405			432		
143	229	U61	TSOP-50	Sn			650		
143	230	U54	QFN-20	Matte Sn			650		
143	231	U48	TQFP-144	NiPdAu			650		
143	232	U7	TQFP-144	SnPb Dip			650		
143	233	U22	CLCC-20	SAC305			250	X	
143	234	U16	TSOP-50	SnBi			436		
143	235	U37	CSP-100	SnPb	SnPb	Flux Only	650		
143	236	U11	PDIP-20	SnPb	Sn	SnPb	644		
143	237	U30	PDIP-20	Sn			650		
143	238	U35	CSP-100	SAC105			456		
143	239	U38	PDIP-20	Sn			650		
143	240	U49	PDIP-20	NiPdAu			650		
143	241	U51	PDIP-20	SnPb	Sn	SnPb	650		
143	242	U59	PDIP-20	Sn			650		
143	243	U63	CSP-100	SAC105			650		
143	244	U5	BGA-225	SAC405			455		
143	245	U6	BGA-225	SnPb	SAC405	SnPb	278		
143	246	U34	TQFP-144	NiPdAu			650		
143	247	U52	CLCC-20	SAC305			398	X	
143	248	U53	CLCC-20	SAC305			483	X	
143	249	U62	TSOP-50	SnBi			650		
143	250	U60	CSP-100	SnPb	SAC105	SnPb	650		
143	251	U10	CLCC-20	SAC305			264	X	
143	252	U28	QFN-20	Matte Sn			650		
143	253	U29	TSOP-50	Sn			510		
143	254	U8	PDIP-20	NiPdAu			650		
143	255	U23	PDIP-20	NiPdAu			650		
143	256	PTH's	PTH's	ImAg			650		
139	257	U1	TQFP-144	SnPb Dip			650		
139	258	U26	TSOP-50	SnPb	Sn	SnPb	580		
139	259	U41	TQFP-144	SnPb Dip			650		
139	260	U9	CLCC-20	SAC305			412	X	
139	261	U27	QFN-20	Matte Sn			650		
139	262	U18	BGA-225	SnPb	SAC405	SnPb	89		
139	263	U39	TSOP-50	Sn			650		
139	264	U56	BGA-225	SnPb	SnPb	Flux Only	650		
139	265	U40	TSOP-50	SnBi			650		
139	266	U3	TQFP-144	NiPdAu			650		
139	267	U13	CLCC-20	SAC305			516	X	
139	268	U32	CSP-100	SAC105			284		
139	269	U57	TQFP-144	NiPdAu			650		
139	270	U14	CLCC-20	SAC305			428	X	
139	272	U25	TSOP-50	SnPb	SnPb	SnPb	650		
139	273	U50	CSP-100	SnPb	SnPb	Flux Only	650		
139	274	U33	CSP-100	SnPb	SAC105	SnPb	650		
139	275	U58	TQFP-144	SnPb Dip			650		
139	276	U12	TSOP-50	SnPb	SnPb	SnPb	293		
139	277	U36	CSP-100	SAC105			498		
139	278	U55	BGA-225	SAC405			497		
139	279	U17	CLCC-20	SAC305			401	X	
139	280	U2	BGA-225	SnPb	SnPb	Flux Only	404		
139	281	U31	TQFP-144	NiPdAu			650		
139	282	U45	CLCC-20	SAC305			375	X	
139	283	U46	CLCC-20	SAC305			330	X	
139	284	U47	QFN-20	Matte Sn			650		
139	285	U19	CSP-100	SnPb	SnPb	Flux Only	650		
139	286	U24	TSOP-50	SnPb	Sn	SnPb	650		
139	287	U42	CSP-100	SnPb	SAC105	SnPb	421		
139	288	U4	BGA-225	SAC405			433		
139	289	U43	BGA-225	SnPb	SAC405	SnPb	170		
139	290	U20	TQFP-144	SnPb Dip			650		
139	291	U21	BGA-225	SnPb	SnPb	Flux Only	650		
139	292	U44	BGA-225	SAC405			411		
139	293	U61	TSOP-50	Sn			650		
139	294	U54	QFN-20	Matte Sn			650		
139	295	U48	TQFP-144	NiPdAu			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
139	296	U7	TQFP-144	SnPb Dip			564		
139	297	U22	CLCC-20	SAC305			322	X	
139	298	U16	TSOP-50	SnBi			519		
139	299	U37	CSP-100	SnPb	SnPb	Flux Only	650		
139	300	U11	PDIP-20	SnPb	Sn	SnPb	418		
139	301	U30	PDIP-20	Sn			368		
139	302	U35	CSP-100	SAC105			485		
139	303	U38	PDIP-20	Sn			414		
139	304	U49	PDIP-20	NiPdAu			650		
139	305	U51	PDIP-20	SnPb	Sn	SnPb	502		
139	306	U59	PDIP-20	Sn			650		
139	307	U63	CSP-100	SAC105			473		
139	308	U5	BGA-225	SAC405			244		
139	309	U6	BGA-225	SnPb	SAC405	SnPb	420		
139	310	U34	TQFP-144	NiPdAu			650		
139	311	U52	CLCC-20	SAC305			312	X	
139	312	U53	CLCC-20	SAC305			451	X	
139	313	U62	TSOP-50	SnBi			650		
139	314	U60	CSP-100	SnPb	SAC105	SnPb	650		
139	315	U10	CLCC-20	SAC305			316	X	
139	316	U28	QFN-20	Matte Sn			650		
139	317	U29	TSOP-50	Sn			588		
139	318	U8	PDIP-20	NiPdAu			650		
139	319	U23	PDIP-20	NiPdAu			422		
139	320	PTH's	PTH's	ImAg			650		
140	321	U1	TQFP-144	SnPb Dip			650		
140	322	U26	TSOP-50	SnPb	Sn	SnPb	589		
140	323	U41	TQFP-144	SnPb Dip			650		
140	324	U9	CLCC-20	SAC305			322	X	
140	325	U27	QFN-20	Matte Sn			650		
140	326	U18	BGA-225	SnPb	SAC405	SnPb	114		
140	327	U39	TSOP-50	Sn			650		
140	328	U56	BGA-225	SnPb	SnPb	Flux Only	650		
140	329	U40	TSOP-50	SnBi			650		
140	330	U3	TQFP-144	NiPdAu			650		
140	331	U13	CLCC-20	SAC305			216	X	
140	332	U32	CSP-100	SAC105			650		
140	333	U57	TQFP-144	NiPdAu			650		
140	334	U14	CLCC-20	SAC305			248	X	
140	336	U25	TSOP-50	SnPb	SnPb	SnPb	650		
140	337	U50	CSP-100	SnPb	SnPb	Flux Only	650		
140	338	U33	CSP-100	SnPb	SAC105	SnPb	650		
140	339	U58	TQFP-144	SnPb Dip			650		
140	340	U12	TSOP-50	SnPb	SnPb	SnPb	417		
140	341	U36	CSP-100	SAC105			391		
140	342	U55	BGA-225	SAC405			650		
140	343	U17	CLCC-20	SAC305			524	X	
140	344	U2	BGA-225	SnPb	SnPb	Flux Only	650		
140	345	U31	TQFP-144	NiPdAu			650		
140	346	U45	CLCC-20	SAC305			452	X	
140	347	U46	CLCC-20	SAC305			320	X	
140	348	U47	QFN-20	Matte Sn			650		
140	349	U19	CSP-100	SnPb	SnPb	Flux Only	650		
140	350	U24	TSOP-50	SnPb	Sn	SnPb	650		
140	351	U42	CSP-100	SnPb	SAC105	SnPb	650		
140	352	U4	BGA-225	SAC405			650		
140	353	U43	BGA-225	SnPb	SAC405	SnPb	416		
140	354	U20	TQFP-144	SnPb Dip			650		
140	355	U21	BGA-225	SnPb	SnPb	Flux Only	650		
140	356	U44	BGA-225	SAC405			650		
140	357	U61	TSOP-50	Sn			650		
140	358	U54	QFN-20	Matte Sn			650		
140	359	U48	TQFP-144	NiPdAu			650		
140	360	U7	TQFP-144	SnPb Dip			437		
140	361	U22	CLCC-20	SAC305			293	X	
140	362	U16	TSOP-50	SnBi			372		
140	363	U37	CSP-100	SnPb	SnPb	Flux Only	650		
140	364	U11	PDIP-20	SnPb	Sn	SnPb	398		Damaged pad from rwk

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
140	365	U30	PDIP-20	Sn			650		
140	366	U35	CSP-100	SAC105			650		
140	367	U38	PDIP-20	Sn			650		
140	368	U49	PDIP-20	NiPdAu			650		
140	369	U51	PDIP-20	SnPb	Sn	SnPb	650		
140	370	U59	PDIP-20	Sn			650		
140	371	U63	CSP-100	SAC105			650		
140	372	U5	BGA-225	SAC405			475		
140	373	U6	BGA-225	SnPb	SAC405	SnPb	650		
140	374	U34	TQFP-144	NiPdAu			650		
140	375	U52	CLCC-20	SAC305			488	X	
140	376	U53	CLCC-20	SAC305			521	X	
140	377	U62	TSOP-50	SnBi			650		
140	378	U60	CSP-100	SnPb	SAC105	SnPb	650		
140	379	U10	CLCC-20	SAC305			230	X	
140	380	U28	QFN-20	Matte Sn			650		
140	381	U29	TSOP-50	Sn			529		
140	382	U8	PDIP-20	NiPdAu			650		
140	383	U23	PDIP-20	NiPdAu			650		
140	384	PTH's	PTH's	ImAg			650		
97	385	U1	TQFP-144	SnPb Dip			650		
97	386	U26	TSOP-50	SnBi			430		
97	387	U41	TQFP-144	SnPb Dip			650		
97	388	U9	CLCC-20	SnPb			344	X	
97	389	U27	QFN-20	Matte Sn			650		
97	390	U18	BGA-225	SnPb			324		
97	391	U39	TSOP-50	SnPb			650		
97	392	U56	BGA-225	SAC405			650		
97	393	U40	TSOP-50	SnBi			650		
97	394	U3	TQFP-144	Matte Sn			650		
97	395	U13	CLCC-20	SnPb			650		
97	396	U32	CSP-100	SnPb			650		
97	397	U57	TQFP-144	Matte Sn			650		
97	398	U14	CLCC-20	SAC305			563		Lid on component fell off
97	400	U25	TSOP-50	SnPb			650		
97	401	U50	CSP-100	SnPb			650		
97	402	U33	CSP-100	SnPb			650		
97	403	U58	TQFP-144	SnPb Dip			650		
97	404	U12	TSOP-50	SnPb			586		
97	405	U36	CSP-100	SAC105			650		
97	406	U55	BGA-225	SnPb			251		
97	407	U17	CLCC-20	SAC305			359	X	
97	408	U2	BGA-225	SAC405			650		
97	409	U31	TQFP-144	Matte Sn			650		
97	410	U45	CLCC-20	SAC305			345	X	
97	411	U46	CLCC-20	SnPb			444	X	
97	412	U47	QFN-20	Matte Sn			650		
97	413	U19	CSP-100	SAC105			650		
97	414	U24	TSOP-50	SnBi			650		
97	415	U42	CSP-100	SAC105			650		
97	416	U4	BGA-225	SnPb			301		
97	417	U43	BGA-225	SnPb			432		
97	418	U20	TQFP-144	SnPb Dip			650		
97	419	U21	BGA-225	SAC405			650		
97	420	U44	BGA-225	SAC405			650		
97	421	U61	TSOP-50	SnPb			650		
97	422	U54	QFN-20	Matte Sn			650		
97	423	U48	TQFP-144	Matte Sn			650		
97	424	U7	TQFP-144	SnPb Dip			650		
97	425	U22	CLCC-20	SnPb			460		
97	426	U16	TSOP-50	SnBi			650		
97	427	U37	CSP-100	SAC105			650		
97	428	U11	PDIP-20	Sn			650		
97	429	U30	PDIP-20	Sn			650		
97	430	U35	CSP-100	SnPb			650		
97	431	U38	PDIP-20	Sn			650		
97	432	U49	PDIP-20	Sn			650		
97	433	U51	PDIP-20	Sn			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
97	434	U59	PDIP-20	Sn			650		
97	435	U63	CSP-100	SnPb			650		
97	436	U5	BGA-225	SAC405			650		
97	437	U6	BGA-225	SnPb			68		
97	438	U34	TQFP-144	Matte Sn			650		
97	439	U52	CLCC-20	SAC305			650		
97	440	U53	CLCC-20	SnPb			650		
97	441	U62	TSOP-50	SnBi			650		
97	442	U60	CSP-100	SAC105			650		
97	443	U10	CLCC-20	SAC305			650		
97	444	U28	QFN-20	Matte Sn			650		
97	445	U29	TSOP-50	SnPb			650		
97	446	U8	PDIP-20	Sn			650		
97	447	U23	PDIP-20	Sn			650		
97	448	PTH's	PTH's	ENIG			650		
183	449	U1	TQFP-144	SAC305 Dip			131		
183	450	U26	TSOP-50	SnBi	SnBi	SAC305	568		
183	451	U41	TQFP-144	SAC305 Dip			1		
183	452	U9	CLCC-20	SnPb			296	X	
183	453	U27	QFN-20	SnPb			650		
183	454	U18	BGA-225	SAC405	SAC405	SnPb	650		
183	455	U39	TSOP-50	SnBi			650		
183	456	U56	BGA-225	SAC405	SAC405	Flux Only	650		
183	457	U40	TSOP-50	SnPb			650		
183	458	U3	TQFP-144	NiPdAu			650		Wire broken upon removal from chamber
183	459	U13	CLCC-20	SnPb			345	X	
183	460	U32	CSP-100	SnPb			650		
183	461	U57	TQFP-144	NiPdAu			650		
183	462	U14	CLCC-20	SnPb			416	X	
183	464	U25	TSOP-50	Sn	Sn	SnPb	650		
183	465	U50	CSP-100	SAC105	SAC105	Flux Only	650		
183	466	U33	CSP-100	SAC105	SAC105	SnPb	381		
183	467	U58	TQFP-144	SAC305 Dip			1		
183	468	U12	TSOP-50	Sn	Sn	SnPb	650		
183	469	U36	CSP-100	SAC105			650		
183	470	U55	BGA-225	SnPb			402		
183	471	U17	CLCC-20	SnPb			420	X	
183	472	U2	BGA-225	SAC405	SAC405	Flux Only	650		
183	473	U31	TQFP-144	NiPdAu			650		
183	474	U45	CLCC-20	SnPb			426	X	
183	475	U46	CLCC-20	SnPb			332	X	
183	476	U47	QFN-20	SnPb			650		
183	477	U19	CSP-100	SAC105	SAC105	Flux Only	650		
183	478	U24	TSOP-50	SnBi	SnBi	SAC305	650		
183	479	U42	CSP-100	SAC105	SAC105	SnPb	464		
183	480	U4	BGA-225	SnPb			650		
183	481	U43	BGA-225	SAC405	SAC405	SnPb	650		
183	482	U20	TQFP-144	SAC305 Dip			650		
183	483	U21	BGA-225	SAC405	SAC405	Flux Only	650		
183	484	U44	BGA-225	SnPb			650		
183	485	U61	TSOP-50	SnBi			650		
183	486	U54	QFN-20	SnPb			650		
183	487	U48	TQFP-144	NiPdAu			650		
183	488	U7	TQFP-144	SAC305 Dip			572		
183	489	U22	CLCC-20	SnPb			324	X	
183	490	U16	TSOP-50	SnPb			650		
183	491	U37	CSP-100	SAC105	SAC105	Flux Only	650		
183	492	U11	PDIP-20	Sn	Sn	SN100C	650		
183	493	U30	PDIP-20	Sn			650		
183	494	U35	CSP-100	SnPb			650		
183	495	U38	PDIP-20	Sn			650		
183	496	U49	PDIP-20	Sn			650		
183	497	U51	PDIP-20	Sn	Sn	SN100C	650		
183	498	U59	PDIP-20	Sn			650		
183	499	U63	CSP-100	SnPb			650		
183	500	U5	BGA-225	SnPb			650		
183	501	U6	BGA-225	SAC405	SAC405	SnPb	650		
183	502	U34	TQFP-144	NiPdAu			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
183	503	U52	CLCC-20	SnPb			309		
183	504	U53	CLCC-20	SnPb			273	X	
183	505	U62	TSOP-50	SnPb			650		
183	506	U60	CSP-100	SAC105	SAC105	SnPb	122		
183	507	U10	CLCC-20	SnPb			320	X	
183	508	U28	QFN-20	SnPb			650		
183	509	U29	TSOP-50	SnBi			650		
183	510	U8	PDIP-20	Sn			650		
183	511	U23	PDIP-20	Sn			650		
183	512	PTH's	PTH's	ImAg			650		
142	513	U1	TQFP-144	SnPb Dip			650		
142	514	U26	TSOP-50	SnPb	Sn	SnPb	650		
142	515	U41	TQFP-144	SnPb Dip			650		
142	516	U9	CLCC-20	SAC305			488	X	
142	517	U27	QFN-20	Matte Sn			650		
142	518	U18	BGA-225	SnPb	SAC405	SnPb	650		
142	519	U39	TSOP-50	Sn			650		
142	520	U56	BGA-225	SnPb	SnPb	Flux Only	650		
142	521	U40	TSOP-50	SnBi			650		
142	522	U3	TQFP-144	NiPdAu			650		
142	523	U13	CLCC-20	SAC305			650		
142	524	U32	CSP-100	SAC105			650		
142	525	U57	TQFP-144	NiPdAu			650		
142	526	U14	CLCC-20	SAC305			581		
142	528	U25	TSOP-50	SnPb	SnPb	SnPb	457		
142	529	U50	CSP-100	SnPb	SnPb	Flux Only	650		
142	530	U33	CSP-100	SnPb	SAC105	SnPb	650		
142	531	U58	TQFP-144	SnPb Dip			650		
142	532	U12	TSOP-50	SnPb	SnPb	SnPb	581		
142	533	U36	CSP-100	SAC105			650		
142	534	U55	BGA-225	SAC405			650		
142	535	U17	CLCC-20	SAC305			560	X	
142	536	U2	BGA-225	SnPb	SnPb	Flux Only	650		
142	537	U31	TQFP-144	NiPdAu			650		
142	538	U45	CLCC-20	SAC305			304	X	
142	539	U46	CLCC-20	SAC305			352	X	
142	540	U47	QFN-20	Matte Sn			650		
142	541	U19	CSP-100	SnPb	SnPb	Flux Only	650		
142	542	U24	TSOP-50	SnPb	Sn	SnPb	650		
142	543	U42	CSP-100	SnPb	SAC105	SnPb	650		
142	544	U4	BGA-225	SAC405			650		
142	545	U43	BGA-225	SnPb	SAC405	SnPb	245		
142	546	U20	TQFP-144	SnPb Dip			650		
142	547	U21	BGA-225	SnPb	SnPb	Flux Only	650		
142	548	U44	BGA-225	SAC405			650		
142	549	U61	TSOP-50	Sn			650		
142	550	U54	QFN-20	Matte Sn			650		
142	551	U48	TQFP-144	NiPdAu			650		
142	552	U7	TQFP-144	SnPb Dip			650		
142	553	U22	CLCC-20	SAC305			452	X	
142	554	U16	TSOP-50	SnBi			650		
142	555	U37	CSP-100	SnPb	SnPb	Flux Only	650		
142	556	U11	PDIP-20	SnPb	Sn	SnPb	650		
142	557	U30	PDIP-20	Sn			650		
142	558	U35	CSP-100	SAC105			650		
142	559	U38	PDIP-20	Sn			650		
142	560	U49	PDIP-20	NiPdAu			650		
142	561	U51	PDIP-20	SnPb	Sn	SnPb	650		
142	562	U59	PDIP-20	Sn			650		
142	563	U63	CSP-100	SAC105			650		
142	564	U5	BGA-225	SAC405			650		
142	565	U6	BGA-225	SnPb	SAC405	SnPb	194		
142	566	U34	TQFP-144	NiPdAu			650		
142	567	U52	CLCC-20	SAC305			462	X	
142	568	U53	CLCC-20	SAC305			358	X	
142	569	U62	TSOP-50	SnBi			596		
142	570	U60	CSP-100	SnPb	SAC105	SnPb	650		
142	571	U10	CLCC-20	SAC305			515		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
142	572	U28	QFN-20	Matte Sn			650		
142	573	U29	TSOP-50	Sn			650		
142	574	U8	PDIP-20	NiPdAu			650		
142	575	U23	PDIP-20	NiPdAu			650		
142	576	PTH's	PTH's	ImAg			650		
180	577	U1	TQFP-144	SAC305 Dip			650		
180	578	U26	TSOP-50	SnBi	SnBi	SAC305	334		
180	579	U41	TQFP-144	SAC305 Dip			516		
180	580	U9	CLCC-20	SnPb			207	X	
180	581	U27	QFN-20	SnPb			650		
180	582	U18	BGA-225	SAC405	SAC405	SnPb	416		
180	583	U39	TSOP-50	SnBi			430		
180	584	U56	BGA-225	SAC405	SAC405	Flux Only	459		
180	585	U40	TSOP-50	SnPb			540		
180	586	U3	TQFP-144	NiPdAu			650		
180	587	U13	CLCC-20	SnPb			252	X	
180	588	U32	CSP-100	SnPb			650		
180	589	U57	TQFP-144	NiPdAu			650		
180	590	U14	CLCC-20	SnPb			231	X	
180	592	U25	TSOP-50	Sn	Sn	SnPb	332		
180	593	U50	CSP-100	SAC105	SAC105	Flux Only	535		
180	594	U33	CSP-100	SAC105	SAC105	SnPb	249		
180	595	U58	TQFP-144	SAC305 Dip			506		
180	596	U12	TSOP-50	Sn	Sn	SnPb	451	X	
180	597	U36	CSP-100	SAC105			511		
180	598	U55	BGA-225	SnPb			403		
180	599	U17	CLCC-20	SnPb			268	X	
180	600	U2	BGA-225	SAC405	SAC405	Flux Only	387		
180	601	U31	TQFP-144	NiPdAu			650		
180	602	U45	CLCC-20	SnPb			282	X	
180	603	U46	CLCC-20	SnPb			295	X	
180	604	U47	QFN-20	SnPb			650		
180	605	U19	CSP-100	SAC105	SAC105	Flux Only	429		
180	606	U24	TSOP-50	SnBi	SnBi	SAC305	401		
180	607	U42	CSP-100	SAC105	SAC105	SnPb	41	X	
180	608	U4	BGA-225	SnPb			416		
180	609	U43	BGA-225	SAC405	SAC405	SnPb	8		
180	610	U20	TQFP-144	SAC305 Dip			650		
180	611	U21	BGA-225	SAC405	SAC405	Flux Only	1		
180	612	U44	BGA-225	SnPb			459		
180	613	U61	TSOP-50	SnBi			508		
180	614	U54	QFN-20	SnPb			650		
180	615	U48	TQFP-144	NiPdAu			650		
180	616	U7	TQFP-144	SAC305 Dip			650		
180	617	U22	CLCC-20	SnPb			306	X	
180	618	U16	TSOP-50	SnPb			268		
180	619	U37	CSP-100	SAC105	SAC105	Flux Only	650		
180	620	U11	PDIP-20	Sn	Sn	SN100C	650		
180	621	U30	PDIP-20	Sn			650		
180	622	U35	CSP-100	SnPb			650		
180	623	U38	PDIP-20	Sn			650		
180	624	U49	PDIP-20	Sn			650		
180	625	U51	PDIP-20	Sn	Sn	SN100C	650		
180	626	U59	PDIP-20	Sn			650		
180	627	U63	CSP-100	SnPb			650		
180	628	U5	BGA-225	SnPb			417		
180	629	U6	BGA-225	SAC405	SAC405	SnPb	496		
180	630	U34	TQFP-144	NiPdAu			650		
180	631	U52	CLCC-20	SnPb			234	X	
180	632	U53	CLCC-20	SnPb			196	X	
180	633	U62	TSOP-50	SnPb			633		
180	634	U60	CSP-100	SAC105	SAC105	SnPb	527		
180	635	U10	CLCC-20	SnPb			302	X	
180	636	U28	QFN-20	SnPb			650		
180	637	U29	TSOP-50	SnBi			373		
180	638	U8	PDIP-20	Sn			650		
180	639	U23	PDIP-20	Sn			650		
180	640	PTH's	PTH's	ImAg			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
182	641	U1	TQFP-144	SAC305 Dip			508		
182	642	U26	TSOP-50	SnBi	SnBi	SAC305	490		
182	643	U41	TQFP-144	SAC305 Dip			650		
182	644	U9	CLCC-20	SnPb			312	X	
182	645	U27	QFN-20	SnPb			650		
182	646	U18	BGA-225	SAC405	SAC405	SnPb	650		
182	647	U39	TSOP-50	SnBi			616		
182	648	U56	BGA-225	SAC405	SAC405	Flux Only	650		
182	649	U40	TSOP-50	SnPb			650		
182	650	U3	TQFP-144	NiPdAu			650		
182	651	U13	CLCC-20	SnPb			313	X	
182	652	U32	CSP-100	SnPb			650		
182	653	U57	TQFP-144	NiPdAu			650		
182	654	U14	CLCC-20	SnPb			317	X	
182	656	U25	TSOP-50	Sn	Sn	SnPb	650		
182	657	U50	CSP-100	SAC105	SAC105	Flux Only	650		
182	658	U33	CSP-100	SAC105	SAC105	SnPb	65		
182	659	U58	TQFP-144	SAC305 Dip			650		
182	660	U12	TSOP-50	Sn	Sn	SnPb	368	X	
182	661	U36	CSP-100	SAC105			650		
182	662	U55	BGA-225	SnPb			402		
182	663	U17	CLCC-20	SnPb			201	X	
182	664	U2	BGA-225	SAC405	SAC405	Flux Only	520		
182	665	U31	TQFP-144	NiPdAu			650		
182	666	U45	CLCC-20	SnPb			224	X	
182	667	U46	CLCC-20	SnPb			320	X	
182	668	U47	QFN-20	SnPb			650		
182	669	U19	CSP-100	SAC105	SAC105	Flux Only	573		
182	670	U24	TSOP-50	SnBi	SnBi	SAC305	485		
182	671	U42	CSP-100	SAC105	SAC105	SnPb	152		
182	672	U4	BGA-225	SnPb			650		
182	673	U43	BGA-225	SAC405	SAC405	SnPb	650		
182	674	U20	TQFP-144	SAC305 Dip			333		
182	675	U21	BGA-225	SAC405	SAC405	Flux Only	650		
182	676	U44	BGA-225	SnPb			650		
182	677	U61	TSOP-50	SnBi			650		
182	678	U54	QFN-20	SnPb			650		
182	679	U48	TQFP-144	NiPdAu			650		
182	680	U7	TQFP-144	SAC305 Dip			650		
182	681	U22	CLCC-20	SnPb			282	X	
182	682	U16	TSOP-50	SnPb			592		
182	683	U37	CSP-100	SAC105	SAC105	Flux Only	650		
182	684	U11	PDIP-20	Sn	Sn	SN100C	650		
182	685	U30	PDIP-20	Sn			650		
182	686	U35	CSP-100	SnPb			650		
182	687	U38	PDIP-20	Sn			650		
182	688	U49	PDIP-20	Sn			650		
182	689	U51	PDIP-20	Sn	Sn	SN100C	650		
182	690	U59	PDIP-20	Sn			650		
182	691	U63	CSP-100	SnPb			650		
182	692	U5	BGA-225	SnPb			537		
182	693	U6	BGA-225	SAC405	SAC405	SnPb	650		
182	694	U34	TQFP-144	NiPdAu			650		
182	695	U52	CLCC-20	SnPb			310	X	
182	696	U53	CLCC-20	SnPb			416	X	
182	697	U62	TSOP-50	SnPb			650		
182	698	U60	CSP-100	SAC105	SAC105	SnPb	102	X	
182	699	U10	CLCC-20	SnPb			345		
182	700	U28	QFN-20	SnPb			650		
182	701	U29	TSOP-50	SnBi			508		
182	702	U8	PDIP-20	Sn			564		
182	703	U23	PDIP-20	Sn			650		
182	704	PTH's	PTH's	ImAg			650		
141	705	U1	TQFP-144	SnPb Dip			650		
141	706	U26	TSOP-50	SnPb	Sn	SnPb	501		
141	707	U41	TQFP-144	SnPb Dip			650		
141	708	U9	CLCC-20	SAC305			454	X	
141	709	U27	QFN-20	Matte Sn			650		

Board ID	Anatech Channel	Ref Des	Component	Finish Before Rework	New Com-ponent Finish	Rework Solder	Cycles at First Failure	Missing	Comment
141	710	U18	BGA-225	SnPb	SAC405	SnPb	287		
141	711	U39	TSOP-50	Sn			650		
141	712	U56	BGA-225	SnPb	SnPb	Flux Only	650		
141	713	U40	TSOP-50	SnBi			650		
141	714	U3	TQFP-144	NiPdAu			650		
141	715	U13	CLCC-20	SAC305			224	X	
141	716	U32	CSP-100	SAC105			362		
141	717	U57	TQFP-144	NiPdAu			650		
141	718	U14	CLCC-20	SAC305			342	X	
141	720	U25	TSOP-50	SnPb	SnPb	SnPb	650		
141	721	U50	CSP-100	SnPb	SnPb	Flux Only	650		
141	722	U33	CSP-100	SnPb	SAC105	SnPb	650		
141	723	U58	TQFP-144	SnPb Dip			650		
141	724	U12	TSOP-50	SnPb	SnPb	SnPb	474		
141	725	U36	CSP-100	SAC105			411		
141	726	U55	BGA-225	SAC405			527		
141	727	U17	CLCC-20	SAC305			376	X	
141	728	U2	BGA-225	SnPb	SnPb	Flux Only	468		
141	729	U31	TQFP-144	NiPdAu			650		
141	730	U45	CLCC-20	SAC305			353	X	
141	731	U46	CLCC-20	SAC305			470	X	
141	732	U47	QFN-20	Matte Sn			650		
141	733	U19	CSP-100	SnPb	SnPb	Flux Only	650		
141	734	U24	TSOP-50	SnPb	Sn	SnPb	650		
141	735	U42	CSP-100	SnPb	SAC105	SnPb	650		
141	736	U4	BGA-225	SAC405			650		
141	993	U43	BGA-225	SnPb	SAC405	SnPb	335		
141	994	U20	TQFP-144	SnPb Dip			650		
141	995	U21	BGA-225	SnPb	SnPb	Flux Only	650		
141	996	U44	BGA-225	SAC405			650		
141	997	U61	TSOP-50	Sn			650		
141	998	U54	QFN-20	Matte Sn			650		
141	999	U48	TQFP-144	NiPdAu			650		
141	1000	U7	TQFP-144	SnPb Dip			611		
141	1001	U22	CLCC-20	SAC305			250	X	
141	1002	U16	TSOP-50	SnBi			504		
141	1003	U37	CSP-100	SnPb	SnPb	Flux Only	650		
141	1004	U11	PDIP-20	SnPb	Sn	SnPb	650		
141	1005	U30	PDIP-20	Sn			650		
141	1006	U35	CSP-100	SAC105			508		
141	1007	U38	PDIP-20	Sn			650		
141	1008	U49	PDIP-20	NiPdAu			650		
141	1009	U51	PDIP-20	SnPb	Sn	SnPb	650		
141	1010	U59	PDIP-20	Sn			650		
141	1011	U63	CSP-100	SAC105			650		
141	1012	U5	BGA-225	SAC405			509		
141	1013	U6	BGA-225	SnPb	SAC405	SnPb	650		
141	1014	U34	TQFP-144	NiPdAu			650		
141	1015	U52	CLCC-20	SAC305			400	X	
141	1016	U53	CLCC-20	SAC305			443	X	
141	1017	U62	TSOP-50	SnBi			650		
141	1018	U60	CSP-100	SnPb	SAC105	SnPb	650		
141	1019	U10	CLCC-20	SAC305			259	X	
141	1020	U28	QFN-20	Matte Sn			650		
141	1021	U29	TSOP-50	Sn			650		
141	1022	U8	PDIP-20	NiPdAu			650		
141	1023	U23	PDIP-20	NiPdAu			650		
141	1024	PTH's	PTH's	ImAg			650		

Appendix C: Pretest Inspection Logs

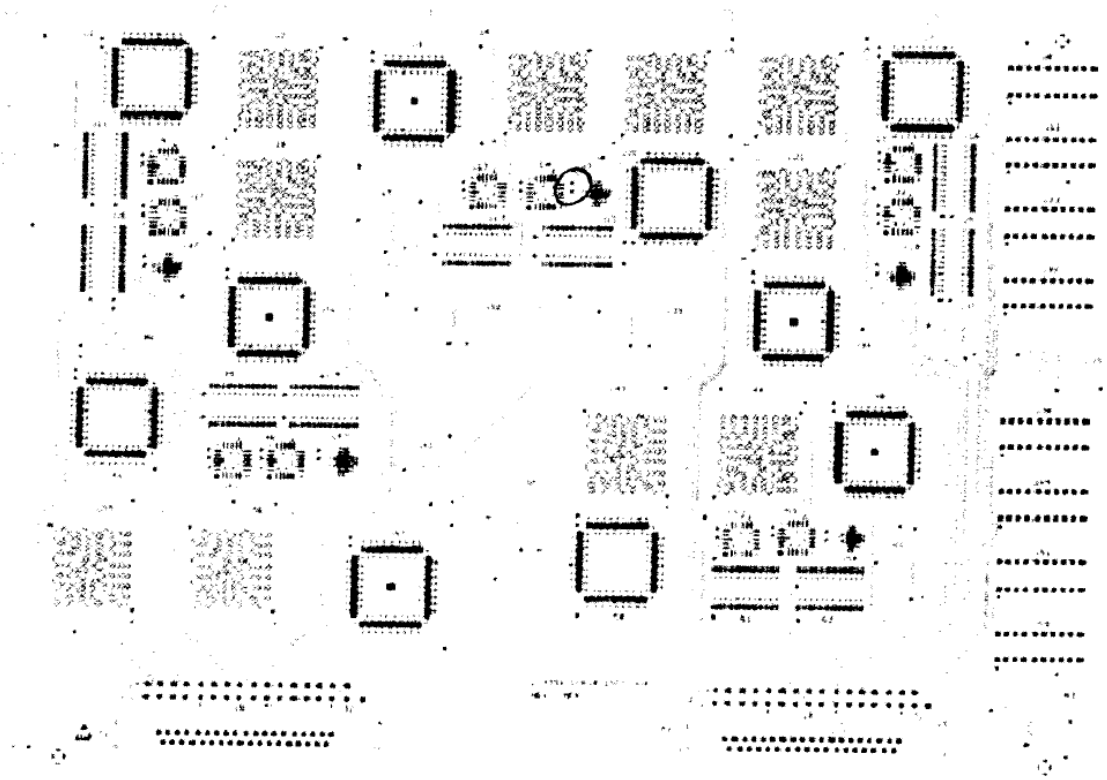
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	20
DATE	01/26/09
TIME	1:22 PM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

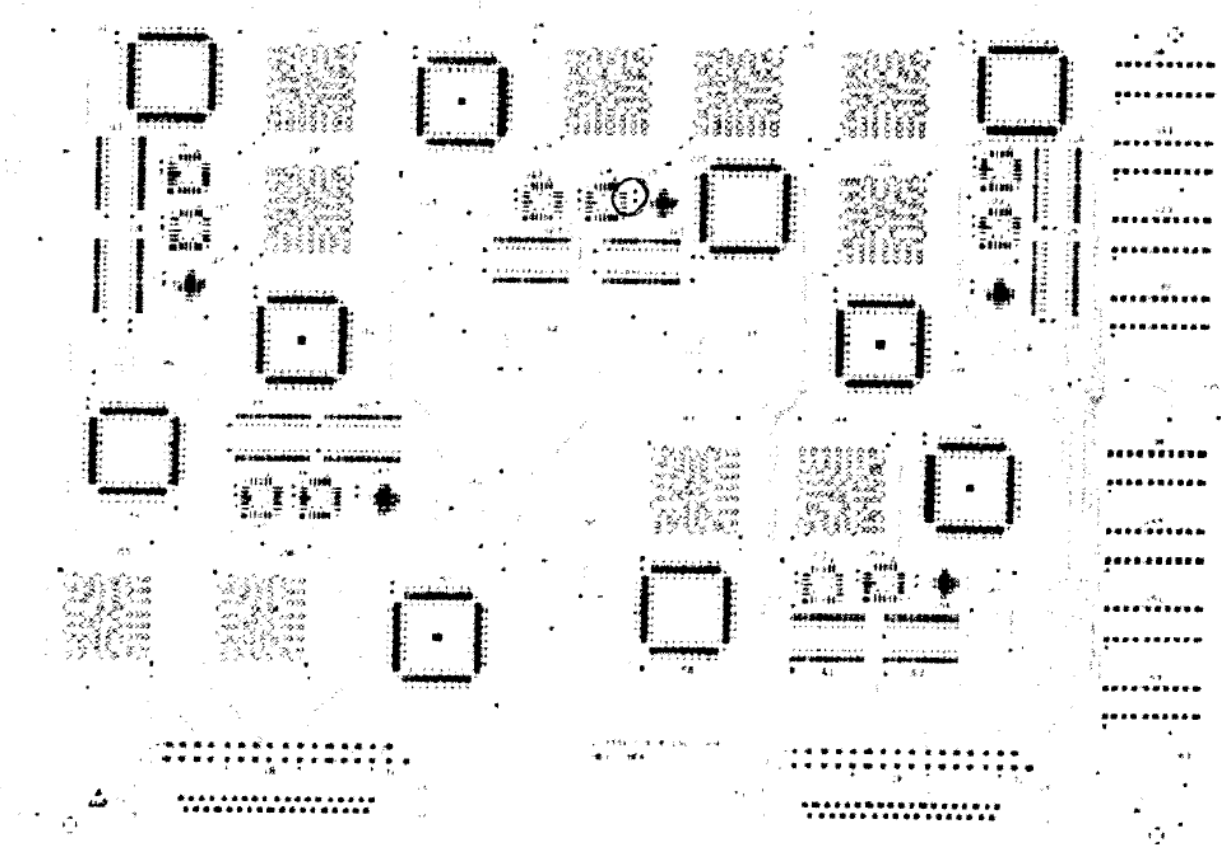
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	21
DATE	01/26/09
TIME	1:08pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

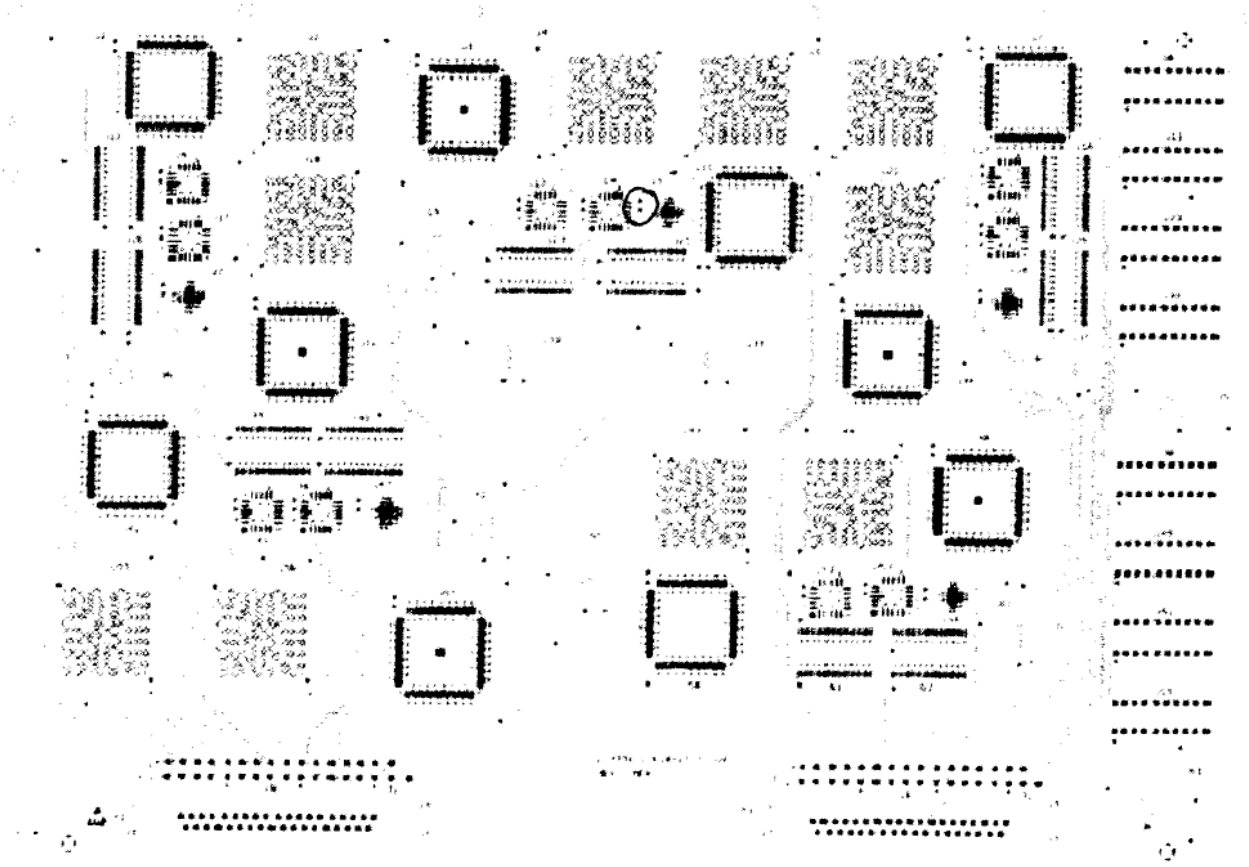
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	22
DATE	01/26/09
TIME	01:18pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

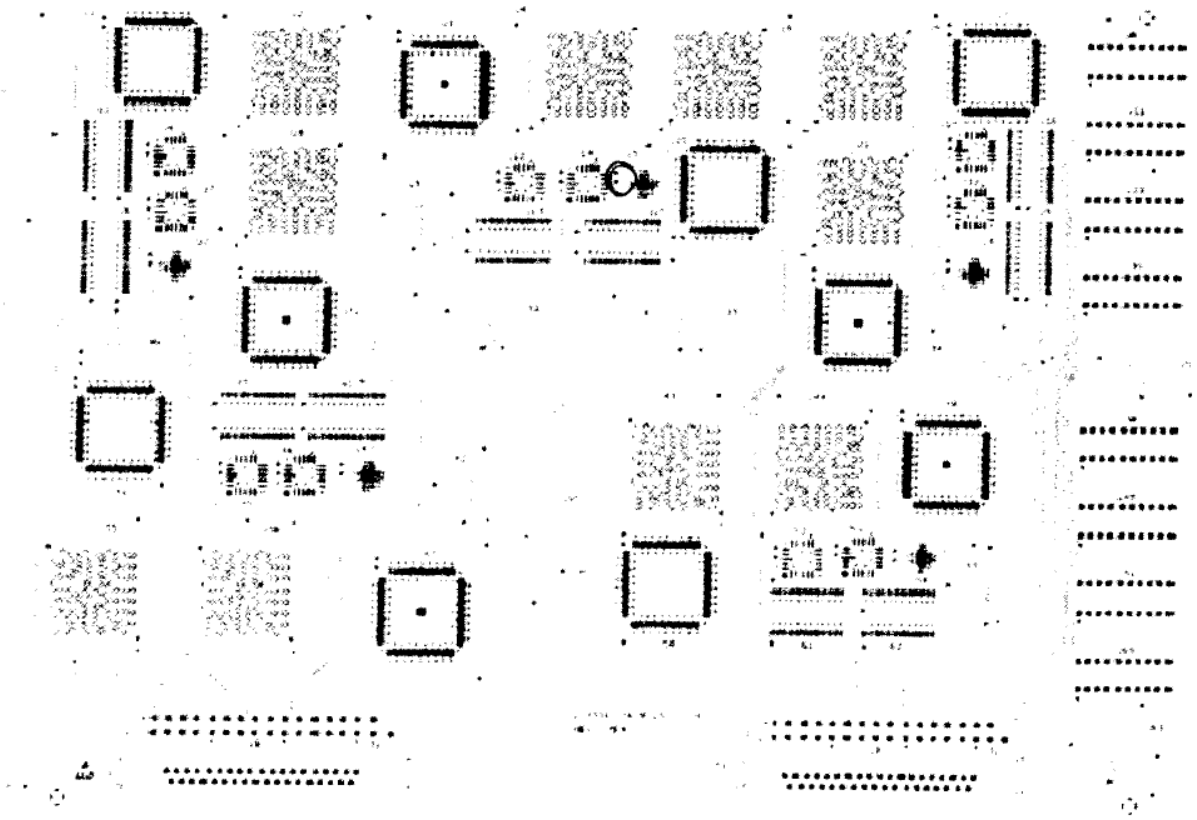
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	23
DATE	01/26/09
TIME	01:55 pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

*WARPED by 0.277 inch from bottom right corner

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

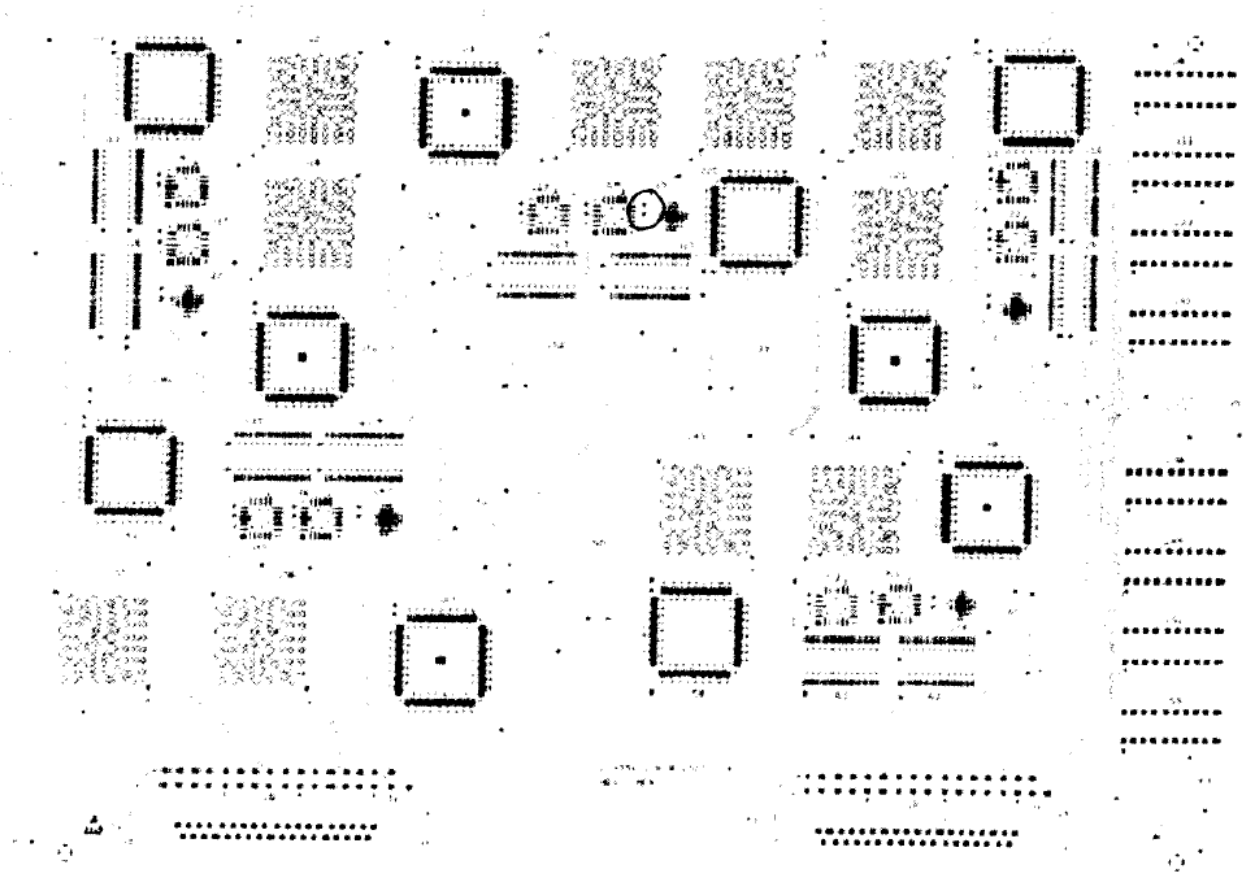
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	24
DATE	01/26/09
TIME	1:46pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

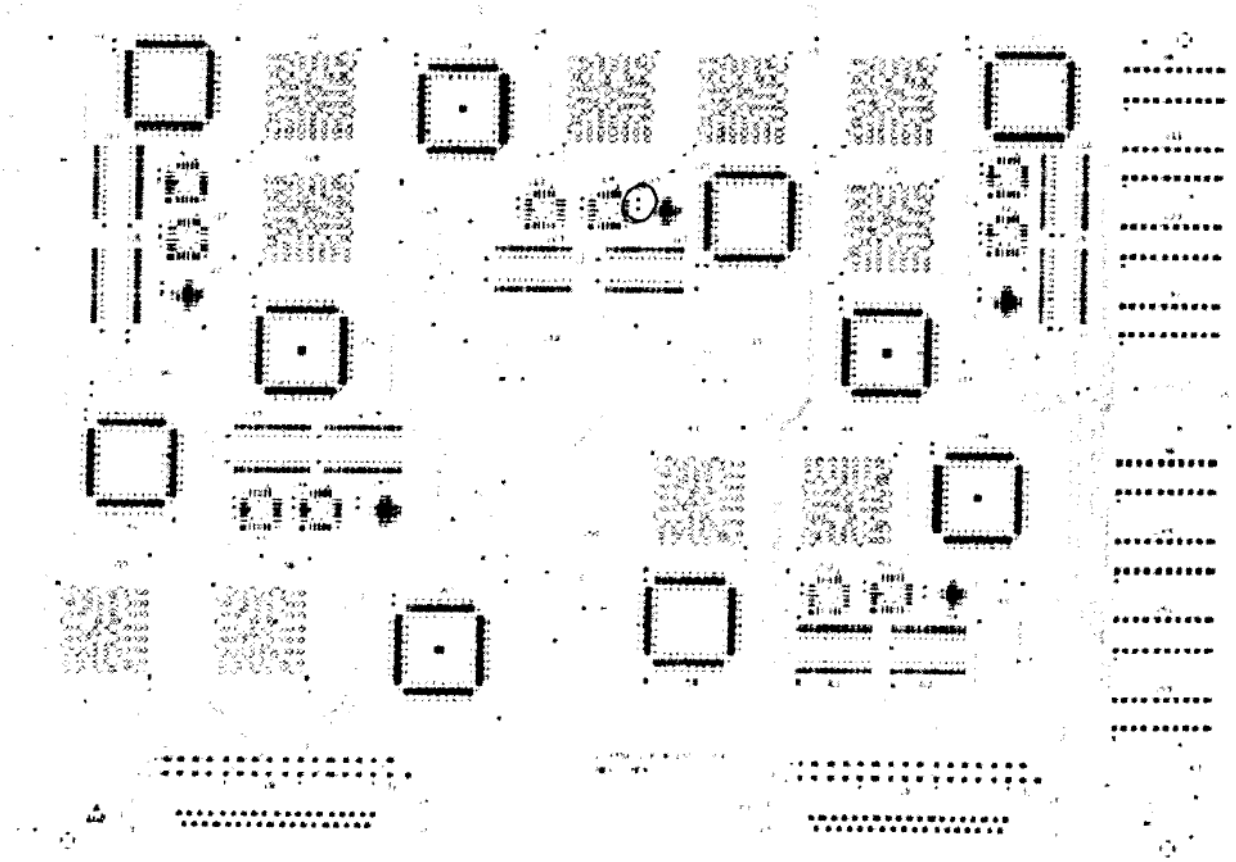
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	69
DATE	01/26/09
TIME	1:27PM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

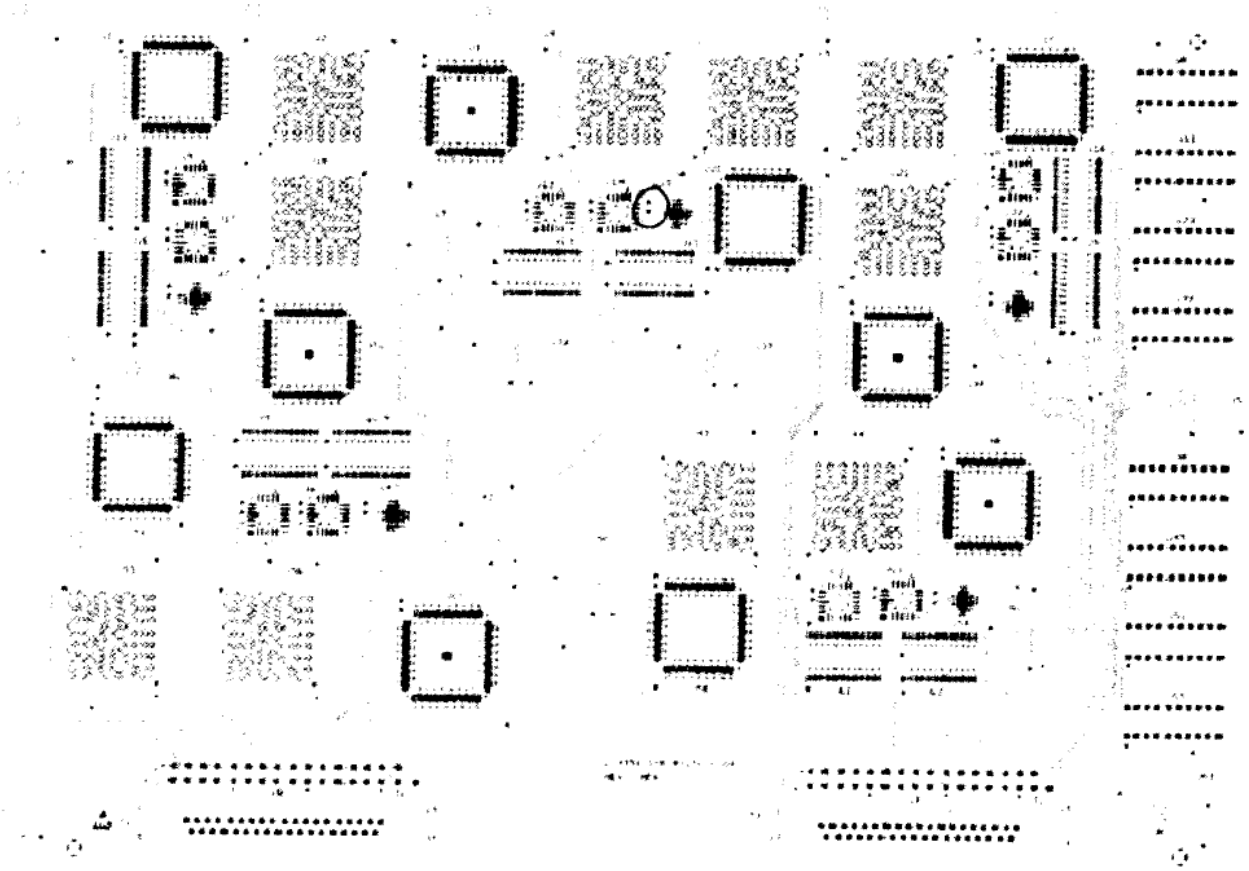
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	70
DATE	01/26/09
TIME	1:30PM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

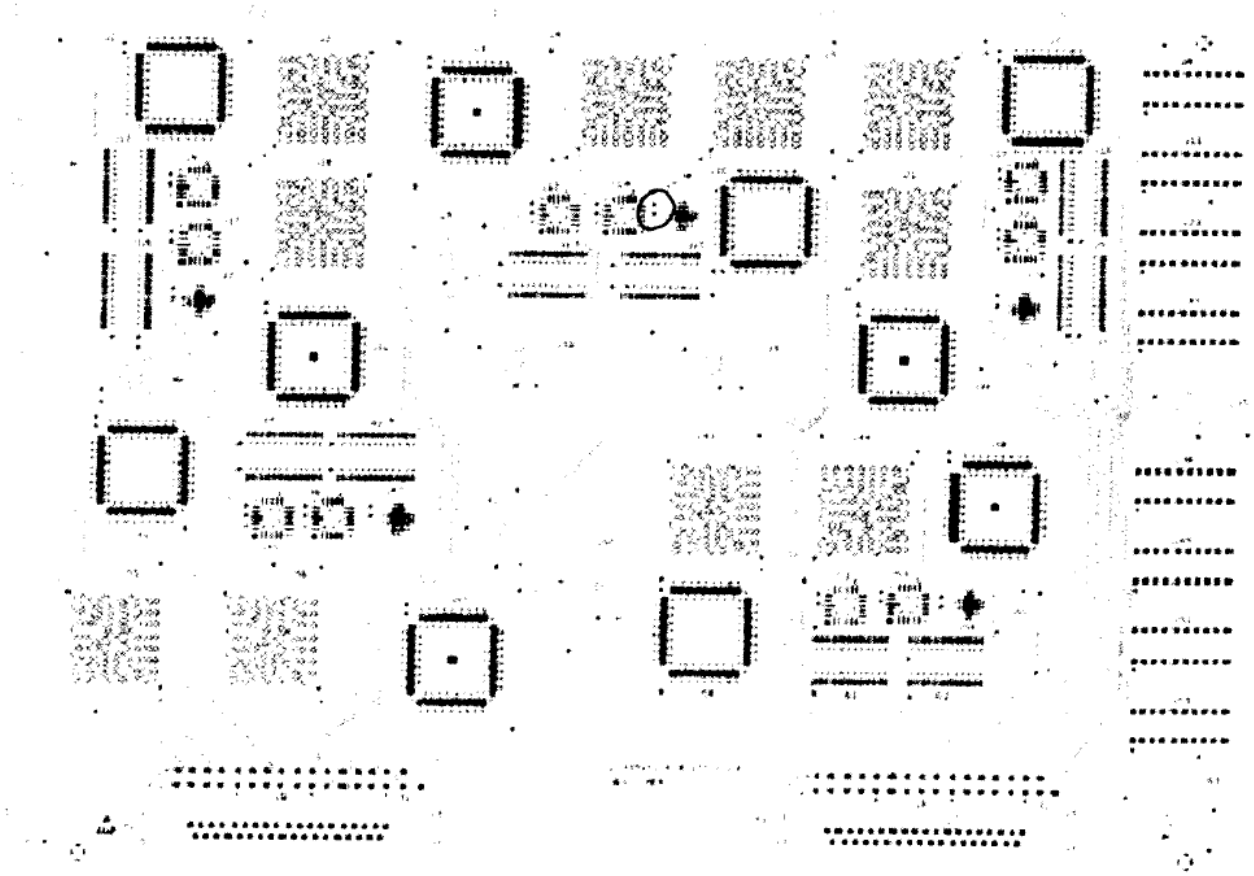
CAGE Code: 96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	71
DATE	01/26/09
TIME	01:33PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

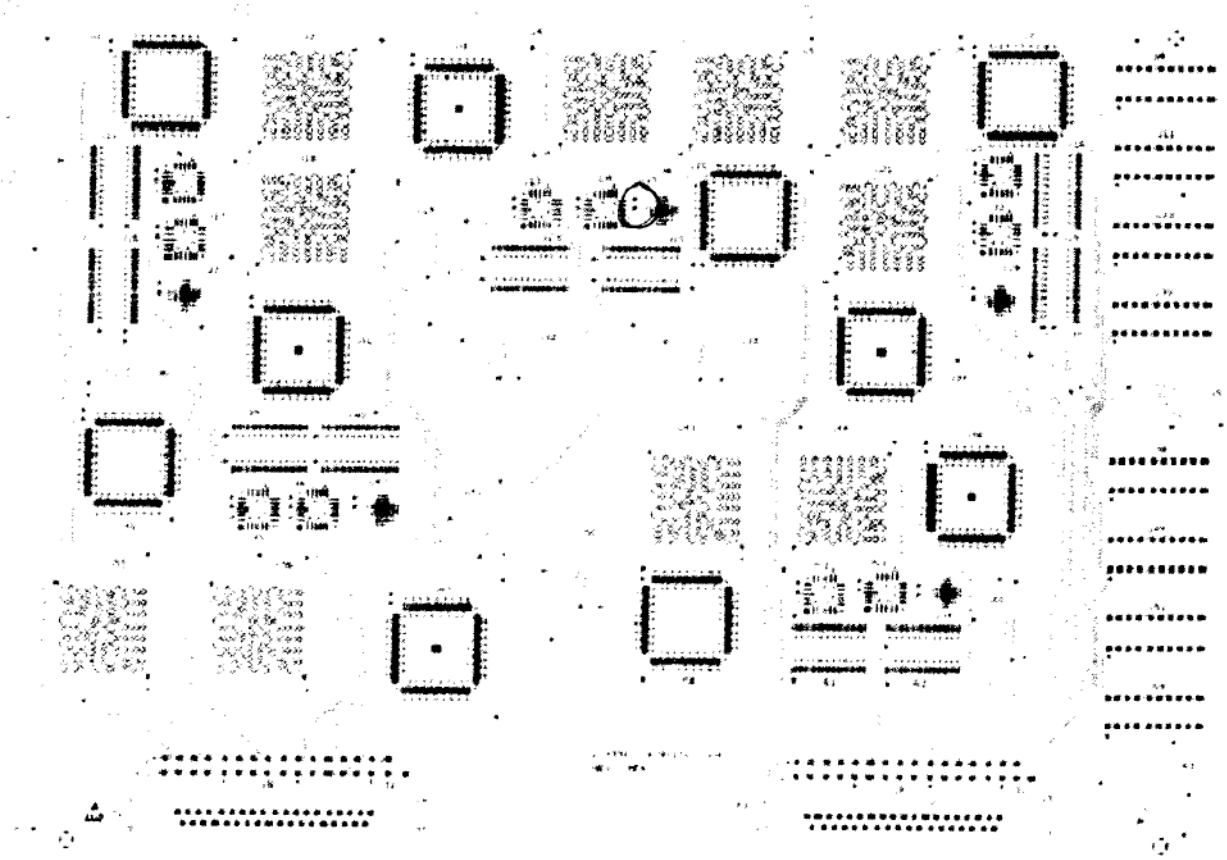
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	72
DATE	01/26/09
TIME	2:04PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

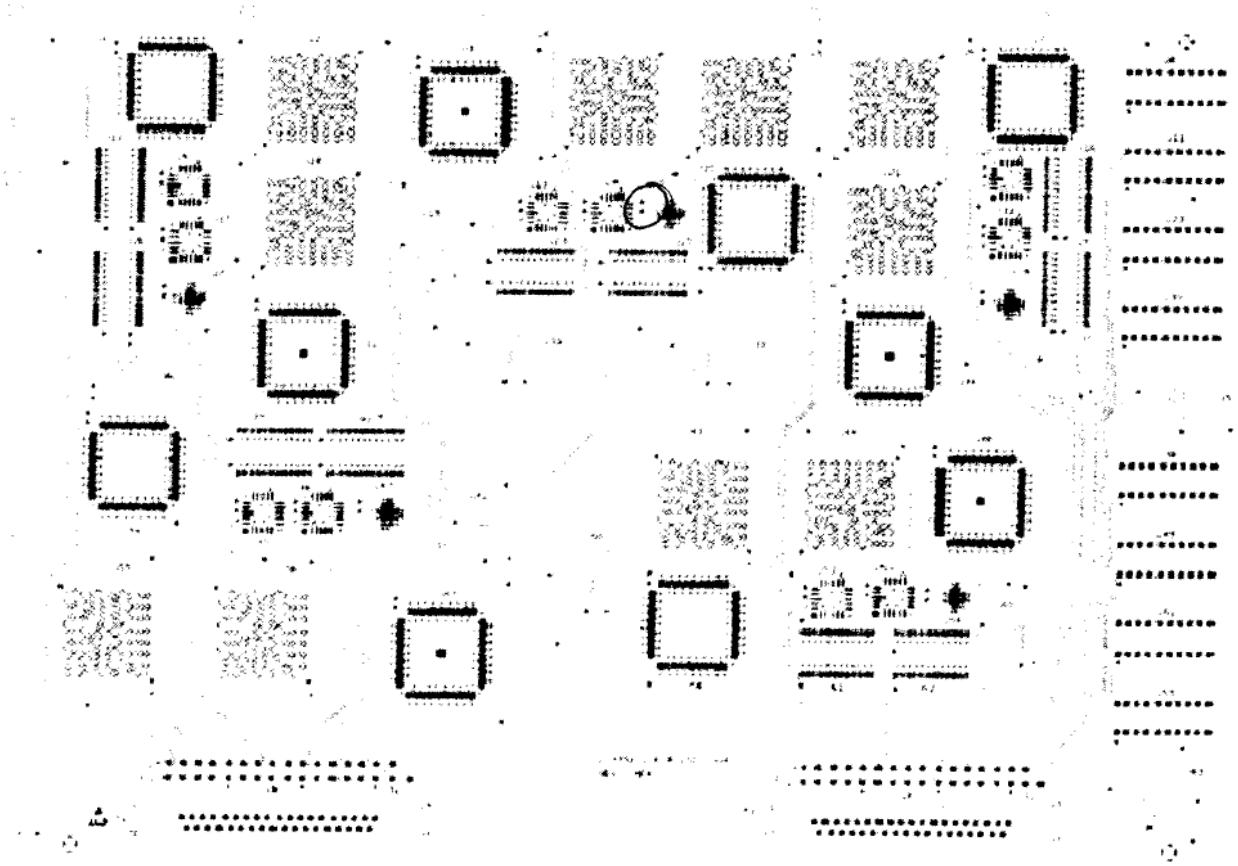
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	73
DATE	01/26/09
TIME	01:52 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

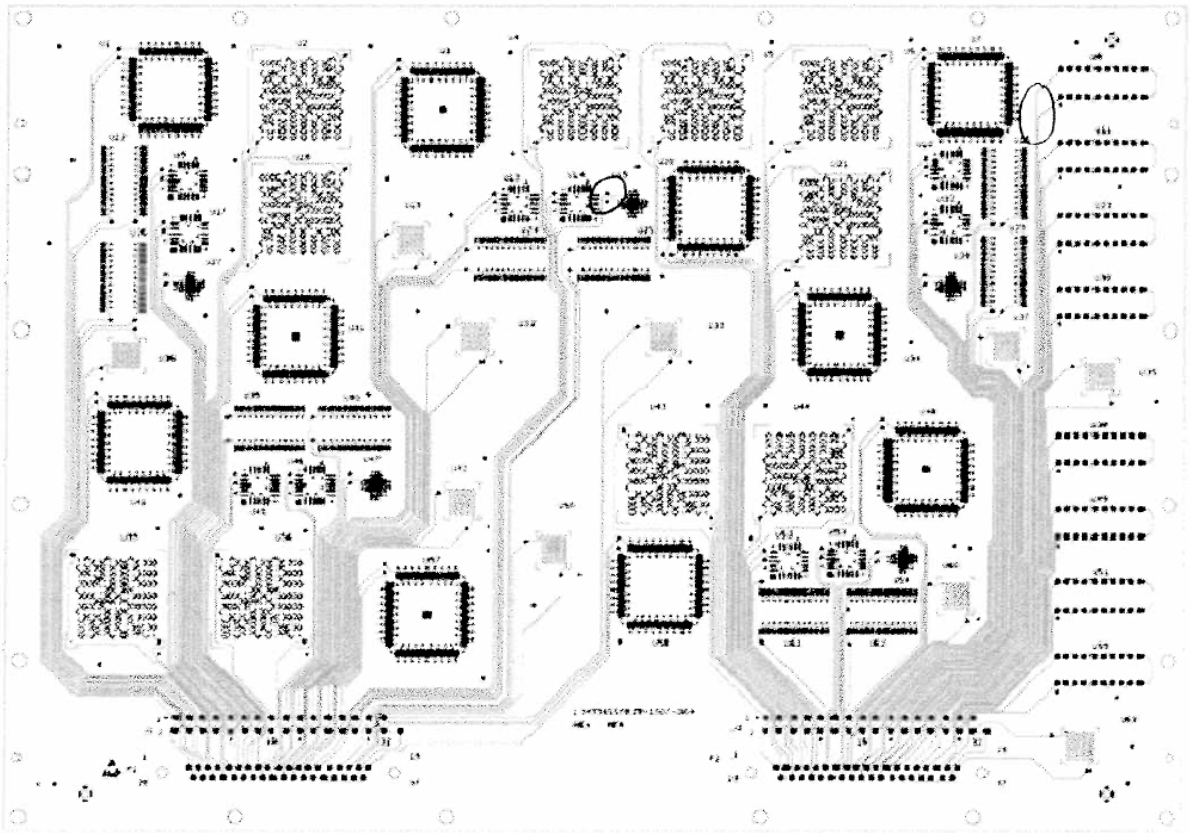
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	97
DATE	03/30/09
TIME	2:55 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
bonding mtrl contamination	Next to U8	NOTED, backside of board	649801	03/30/09
board warped	bottom left	" raised slightly	"	"

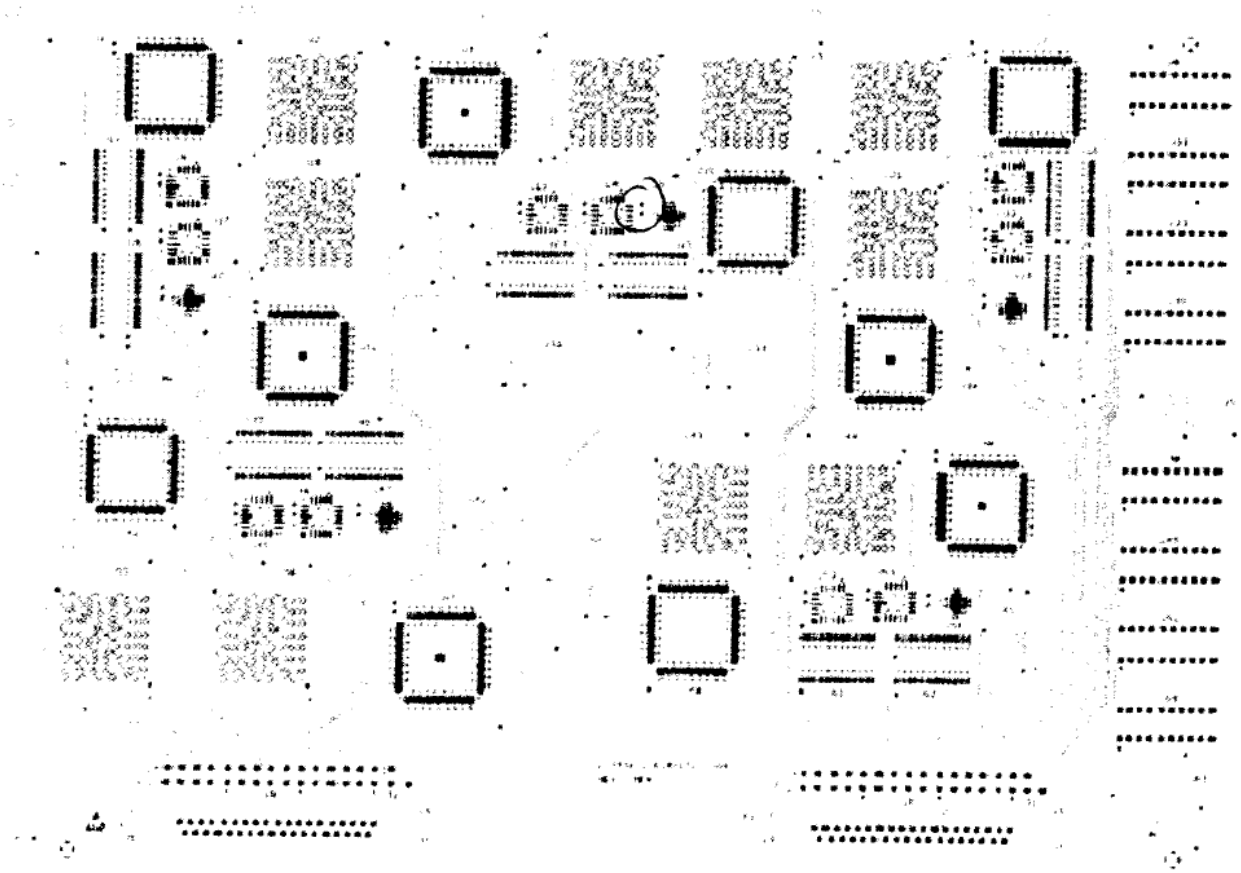
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	116
DATE	01/26/09
TIME	1:58pm
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

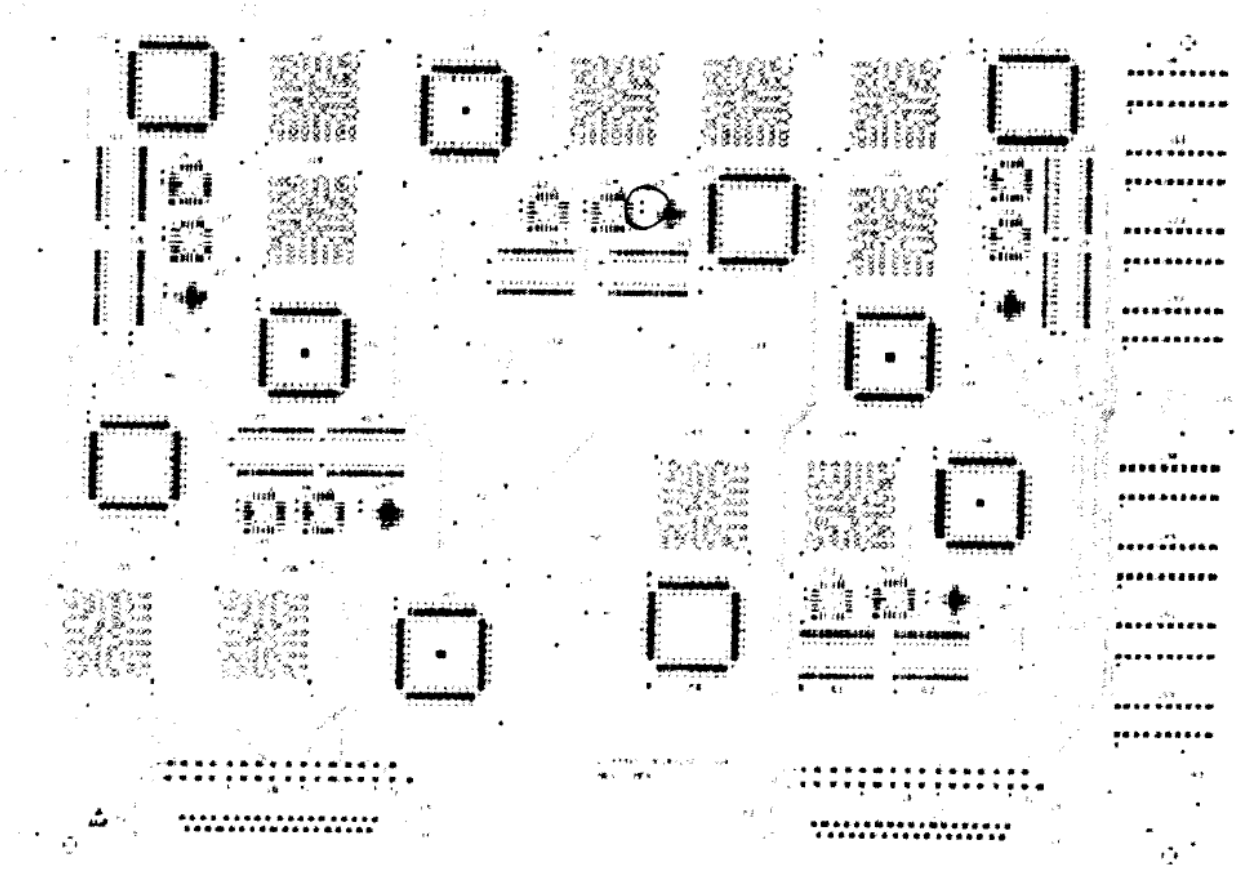
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	117
DATE	01/26/09
TIME	02:02pm
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

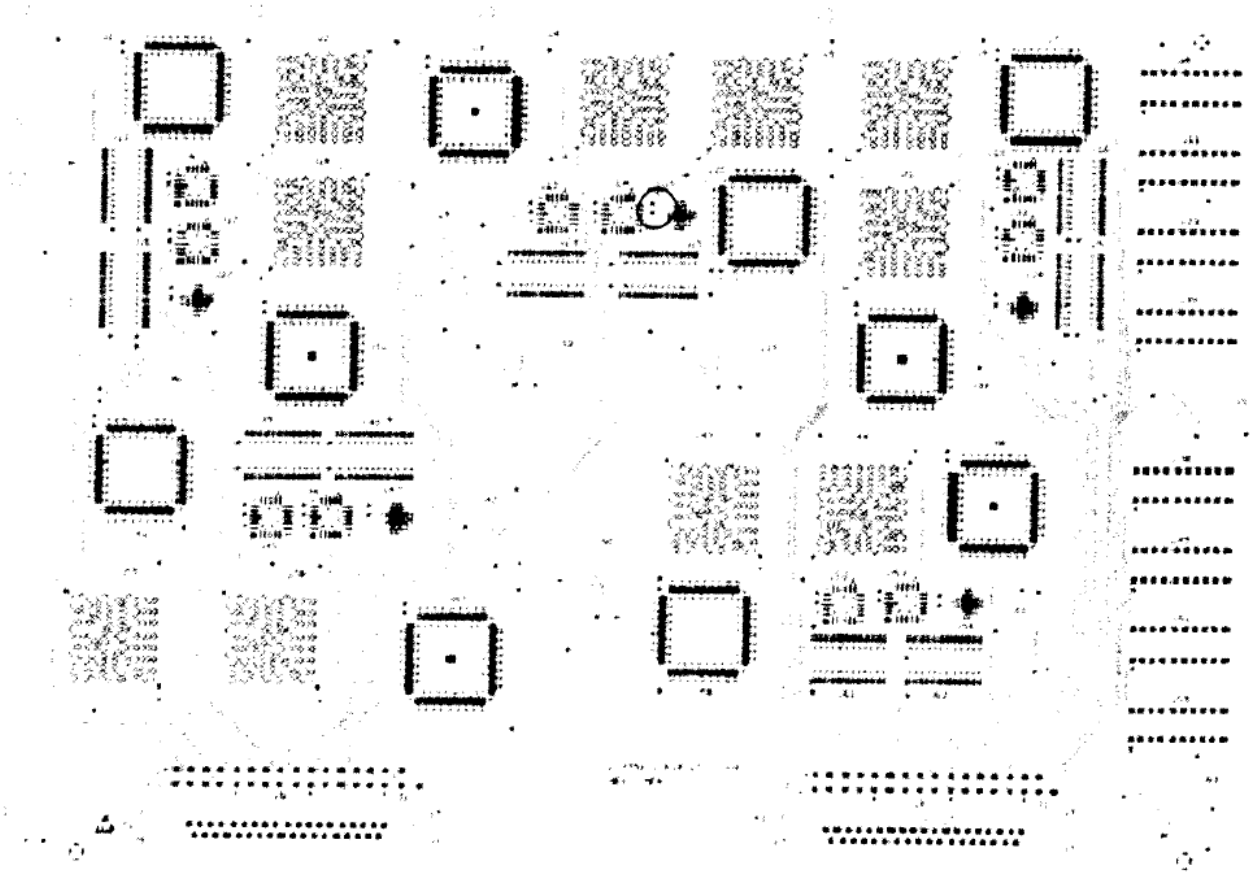
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	118
DATE	01/26/09
TIME	01:37 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

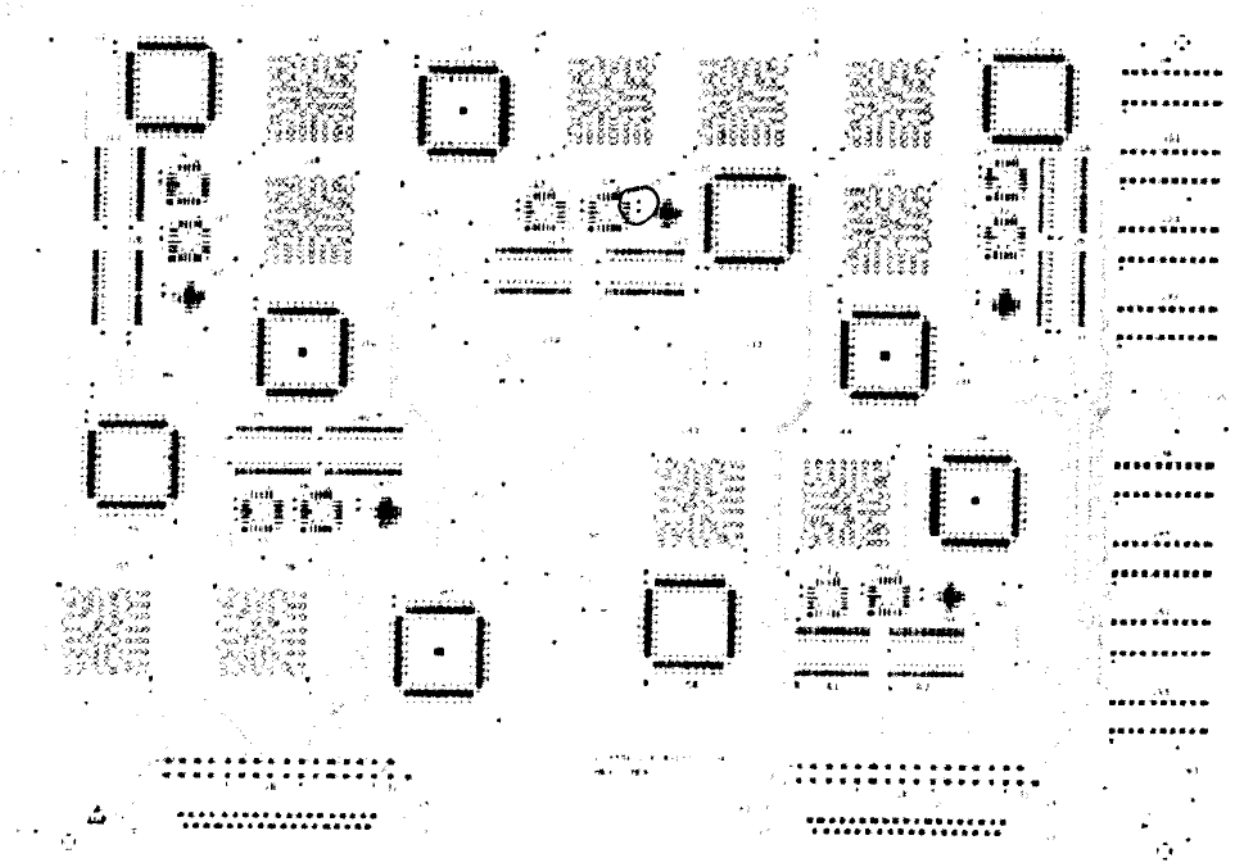
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	119
DATE	01/26/09
TIME	01:41 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

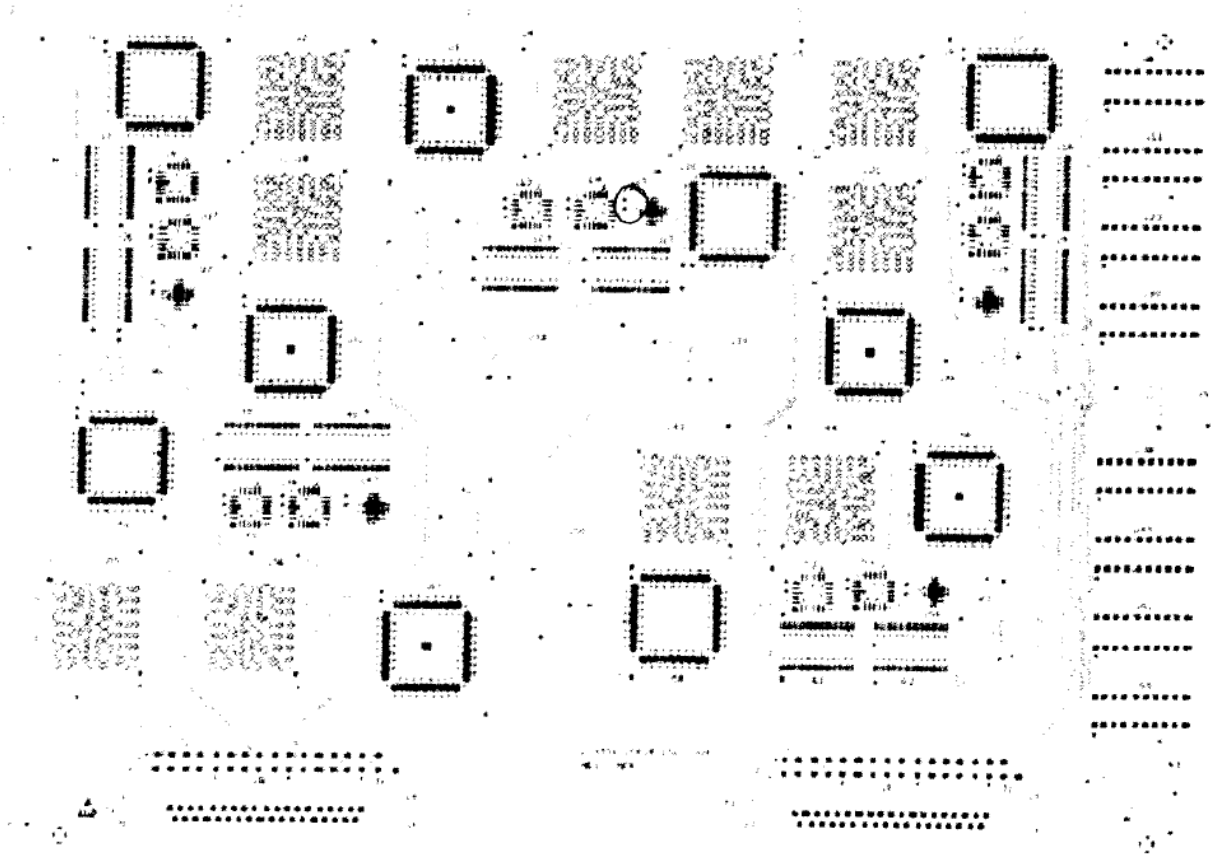
CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	120
DATE	01/26/09
TIME	1:44pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	✓
Sufficient solder?	✓
Proper part alignment?	✓
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	✓
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



CAGE Code:
96214

Combined Environments Test
26 January 2009

PRETEST INSPECTION CHECKLIST

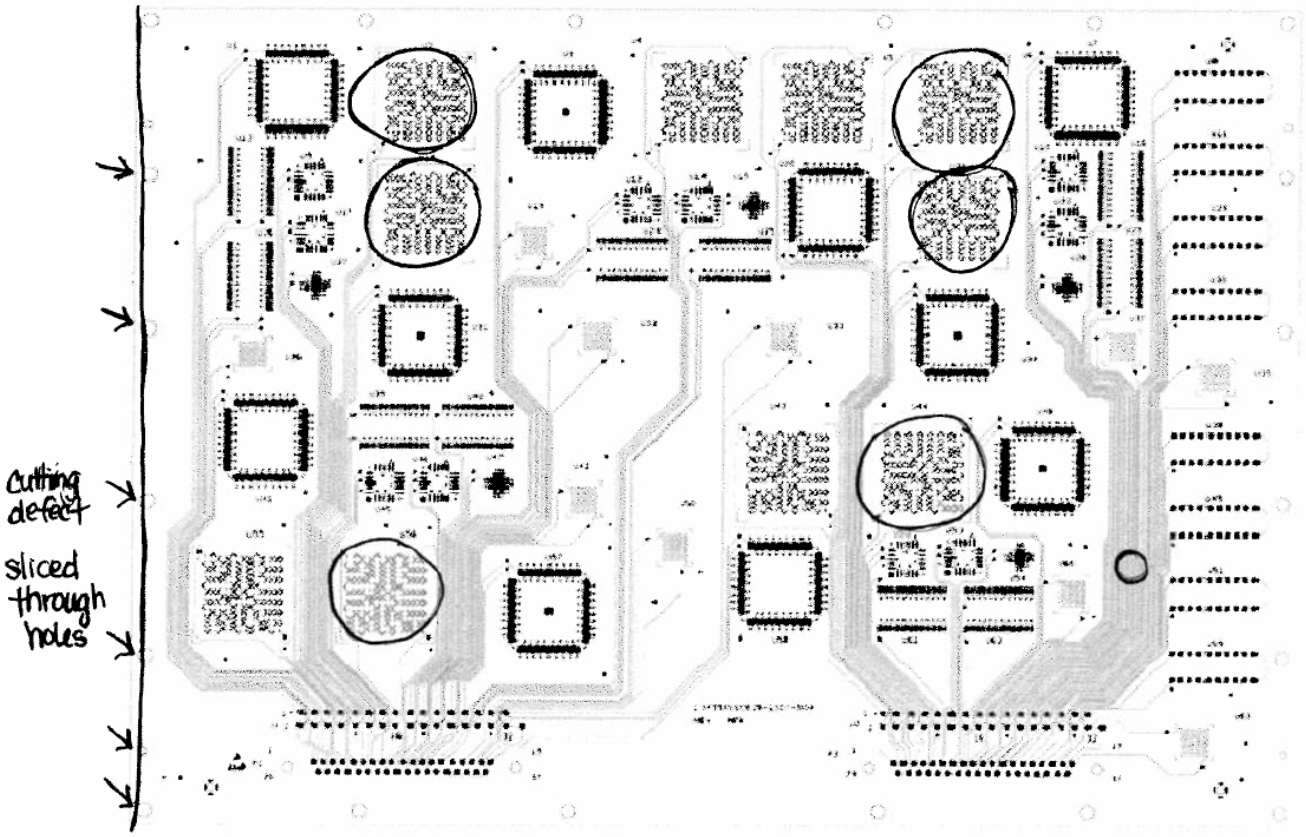
* Board warped by 0.350 inches from bottom right corner

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Missing trace	U15			

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	139
DATE	03/30/09
TIME	1:15 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	YES - some on back of board
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



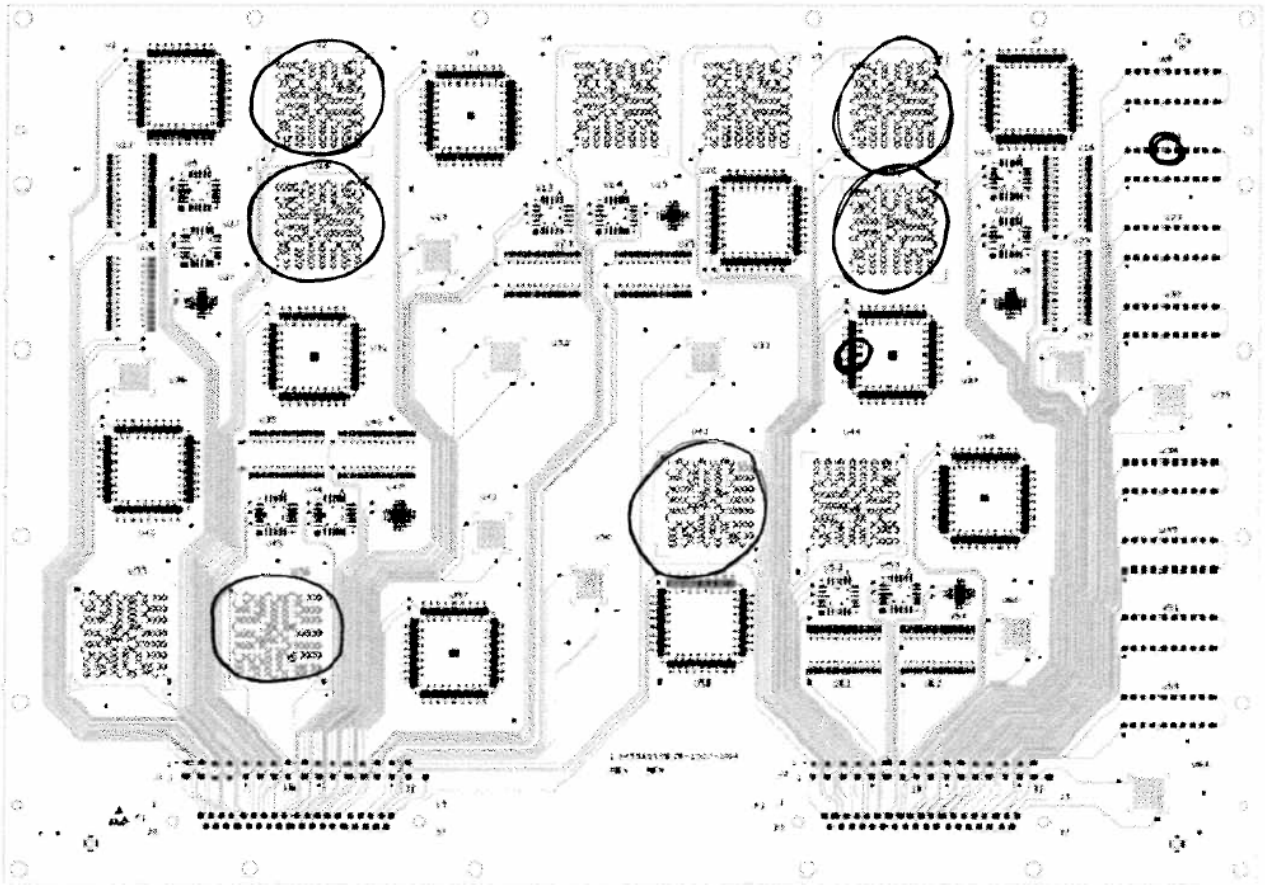
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Delamination	Near U51	small dot over traces NOTED	1049801	03/30/09
solder balls	U44	on backside of board over vias	"	"
½ filled vias	U2, U18, U56	NOTED	"	"
"	U6, U21, U44	"	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	140
DATE	03/30/09
TIME	12:00 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	YES, some on back of board
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



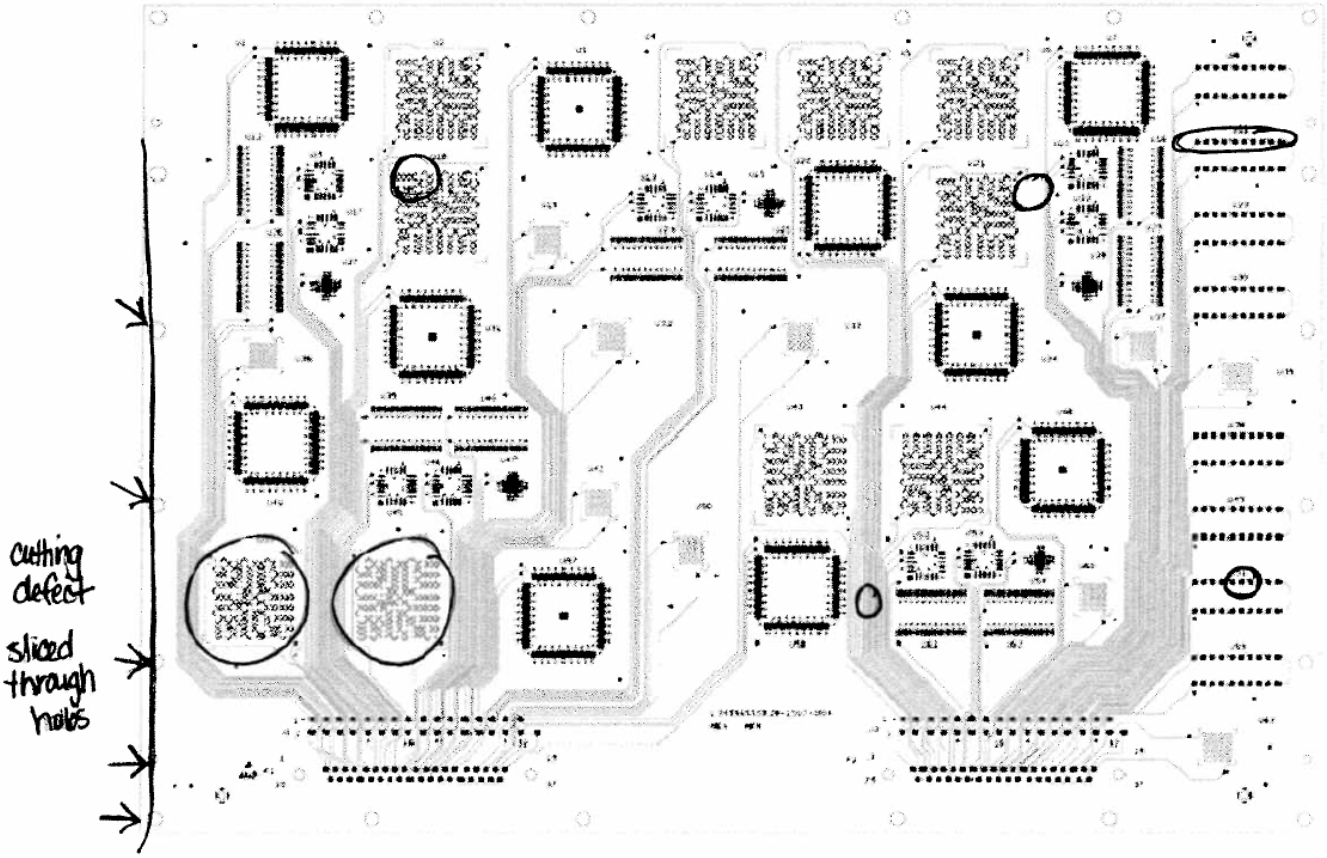
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Damaged pad	U11	NOTED	1049801	03/30/09
Solder ball	U34	NOTED to the backside	"	"
½ filled vias	U2, U18, U56	"	"	"
"	U6, U21, U43	"	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	141
DATE	03/30/09
TIME	1:30PM
INSPECTOR	CYNTHIA GARCIA, 1049801
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



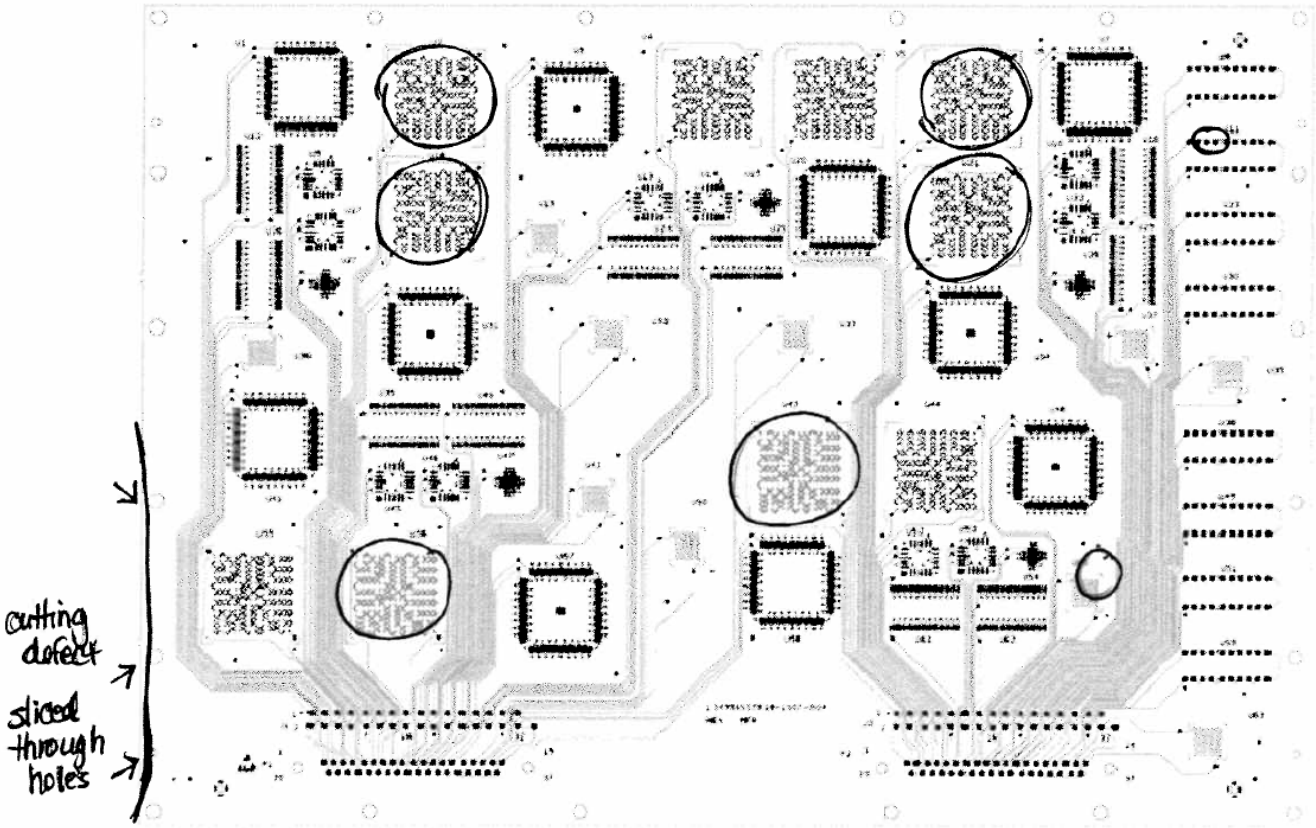
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Delamination	U11 top row	NOTED	1049801	03/30/09
"	U51 one pad	"	"	"
"	rightside U21	"	"	"
damaged area near via	U18/back	"	"	"
1/2 filled vias	U18	"	"	"
"	U55, U56	"	"	"
Delamination	between U58 & U61	NOTED on the trace on back of board	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	142
DATE	03/30/09
TIME	12:50 pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	"
Proper part alignment?	YES
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



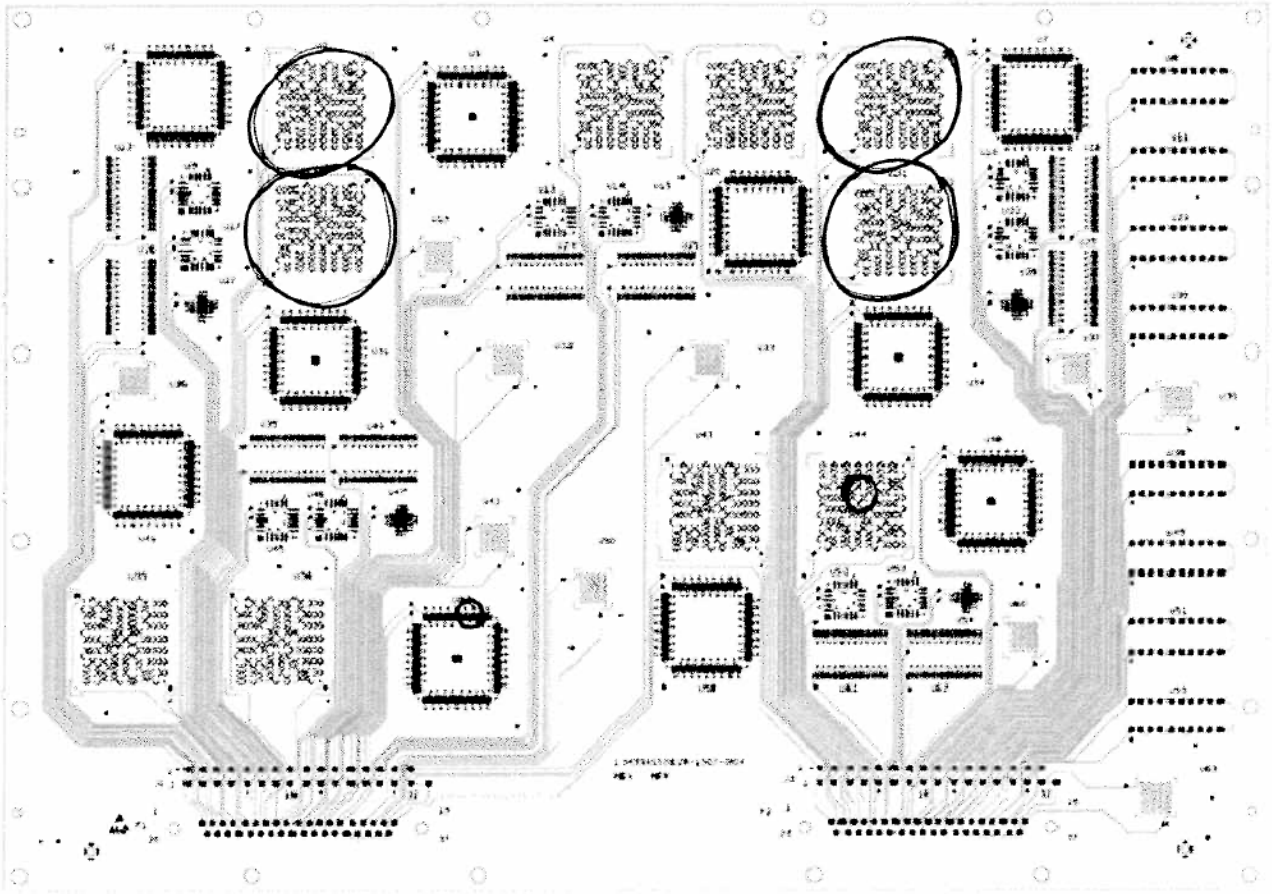
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Delamination	U60	Noted	1049801	03/30/09
Delamination	U11	small area , NOTED	"	"
1/2 filled vias	U2, U18	Noted	"	"
"	U56	"	"	"
"	U6, U21	"	"	"
"	U43	"	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	143
DATE	03/30/09
TIME	12:40 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	YES
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	NO
Bridging?	YES on U57 or could be solder ball
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



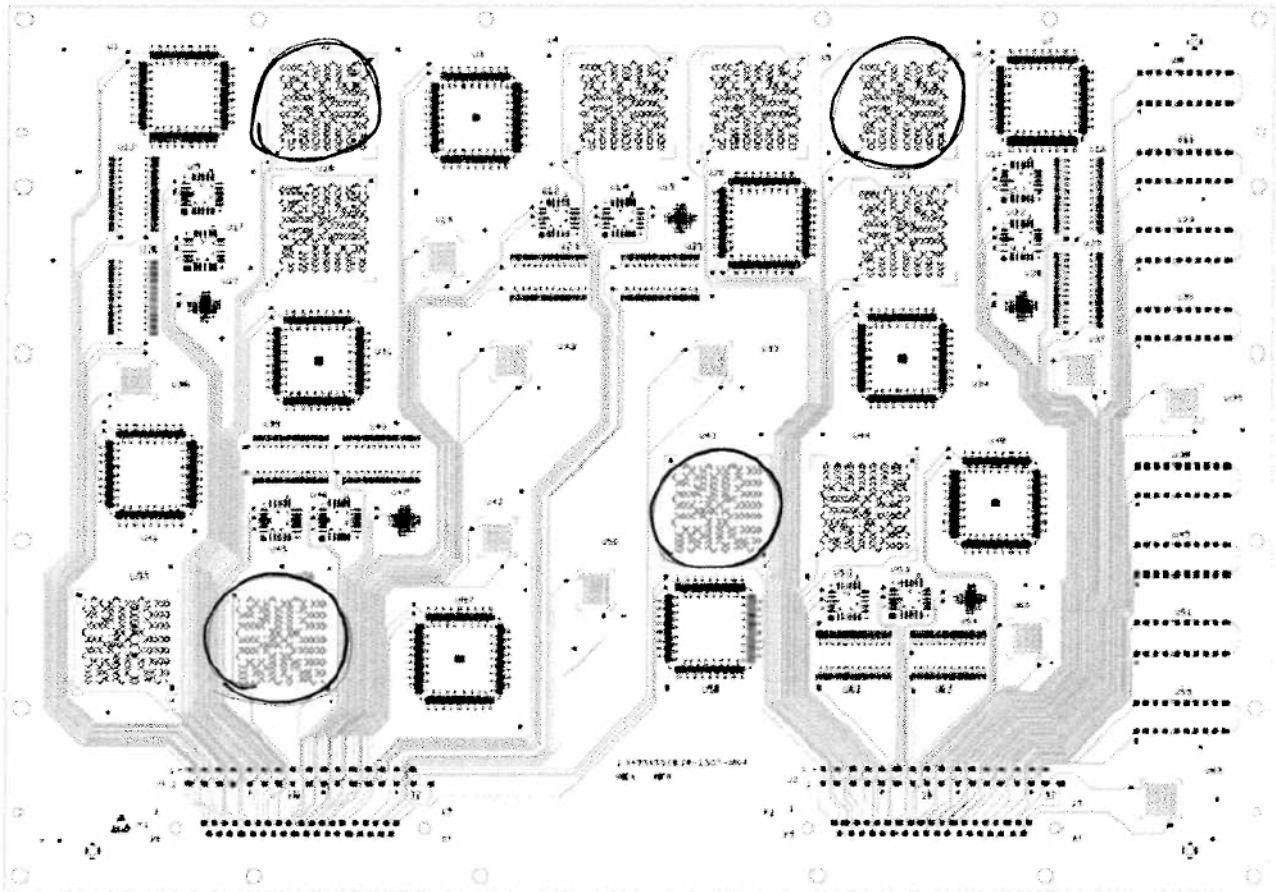
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Solder ball or Bridging	U57	Noted at 250X	1049801	03/30/09
Solder th excess backside	U44	Noted	"	"
1/2 filled vias	U2, U18	Noted	"	"
1/2 filled vias	U6, U21	"	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	158
DATE	03/30/09
TIME	11:10 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



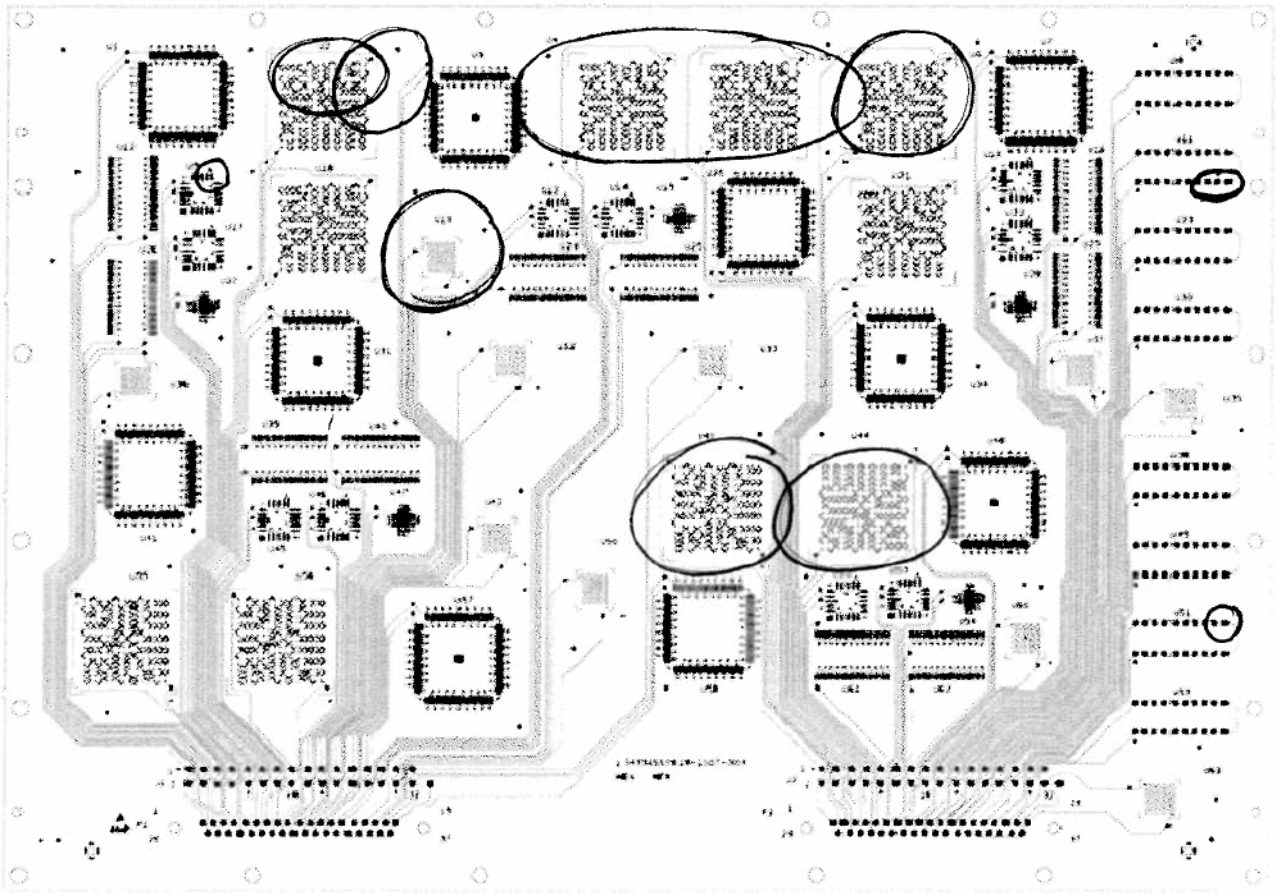
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
½ filled vias	U43	Noted	1049801	03/30/09
½ filled vias	U56	Noted	"	"
½ filled vias	U6	Noted	"	"
"	U2	"	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	163
DATE	03/30/09
TIME	2:03 pm
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



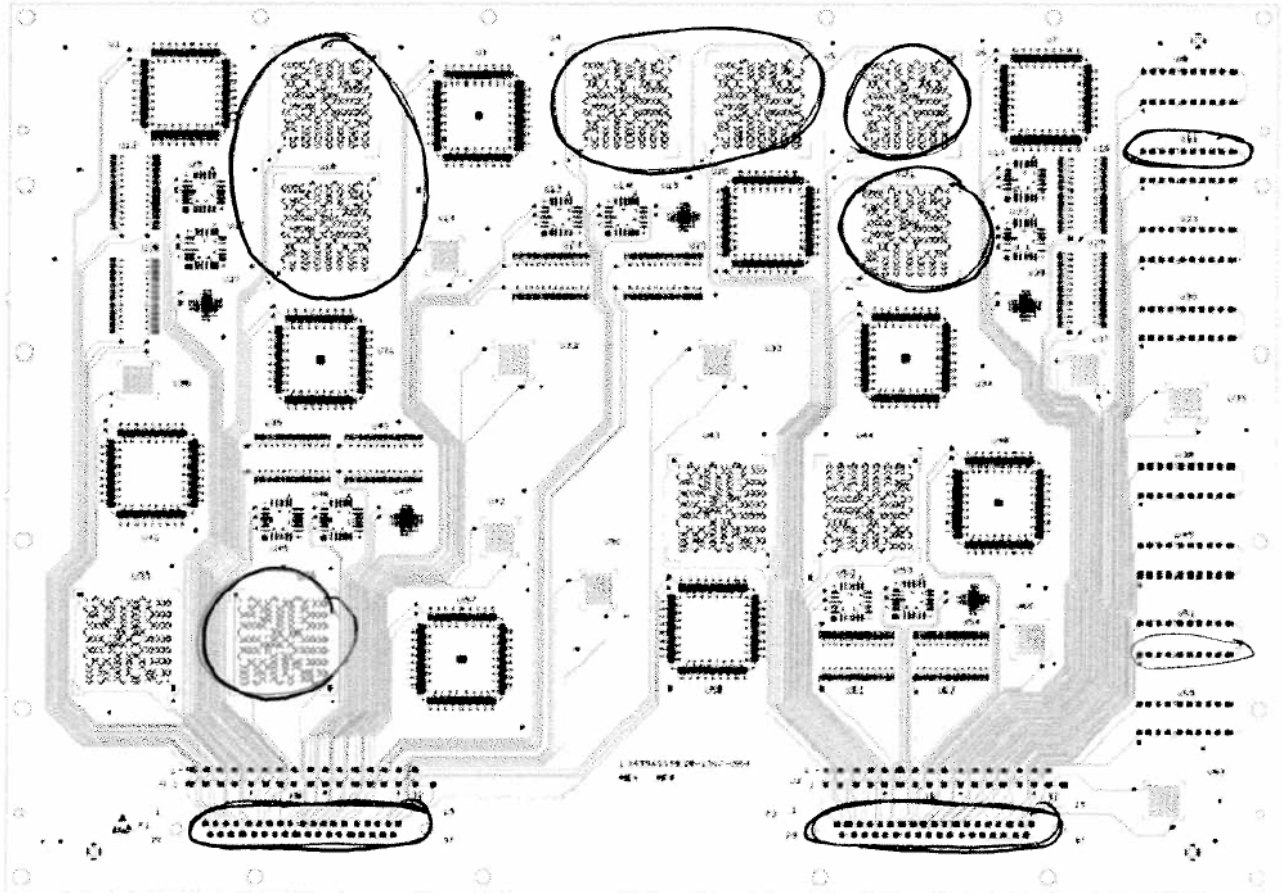
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Burned/ dark area	U19	NOTED on PWB	1049801	03/30/09
delamination	U11	NOTED, small specs bottom right	"	"
"	U51	" " spec top right	"	"
burned/ dark area	U2	NOTED	"	"
bond mtrl on lead	U17	NOTED, top right on lead – looks like insufficient wetting	"	"
burned solder	U2	NOTED on backside	"	"
"	U6, U4, U5	" "	"	"
1/2 filled vias	U43, U44	NOTED on backside	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	180
DATE	03/30/09
TIME	3:05 pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	YES - on back of board
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



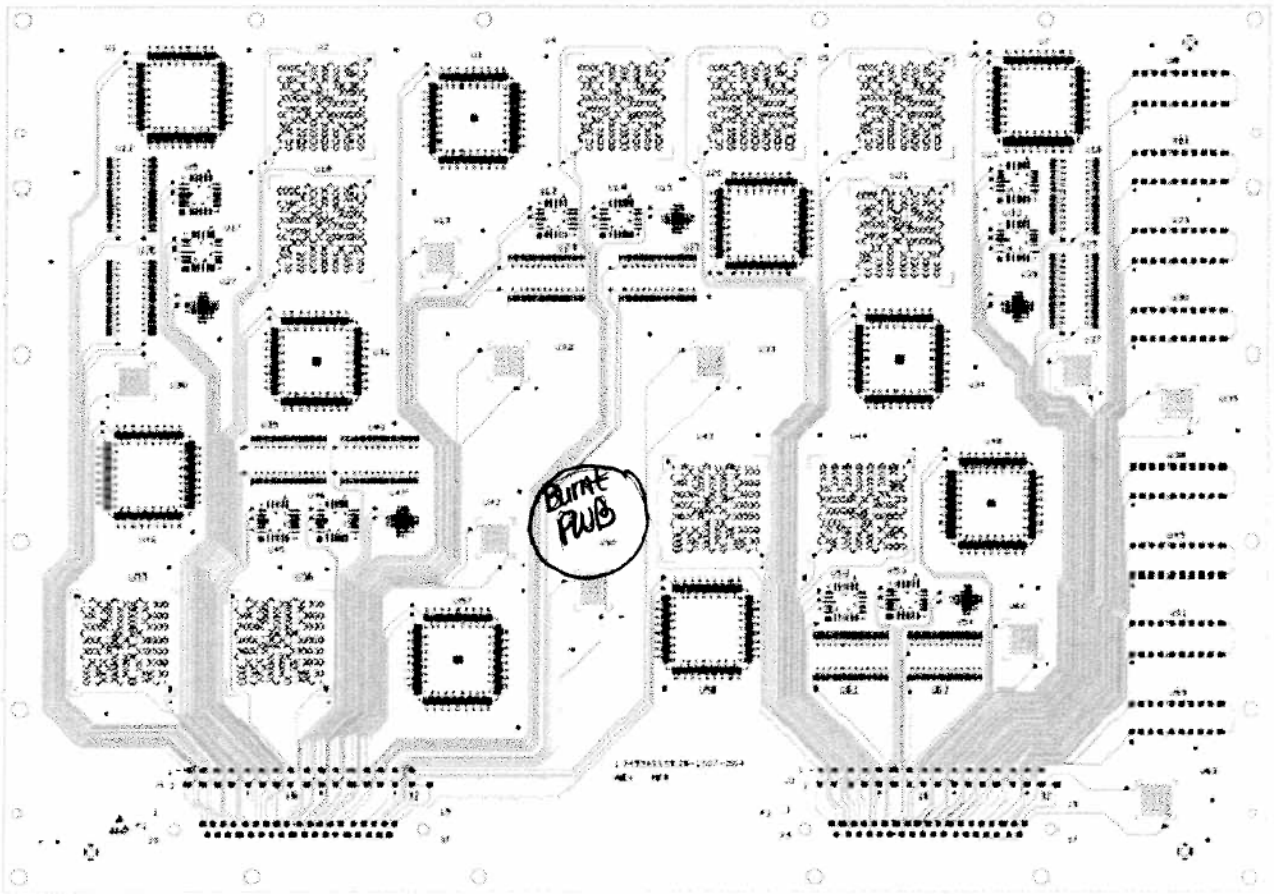
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Filled vias	Bottom Connectors	Wicked solder out & soldered wires	Jeff Bradford	03/24/09
delamination	U11	NOTED, top row, small specs	1049801	03/30/09
Solder balls	U6	NOTED, on backside over vias	"	"
½ filled vias	U6, U4, U5	"	"	"
"	U21, U56	"	"	"
"	U2, U18	"	"	"
delamination	U51	NOTED, on back side, bottom row	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	181
DATE	03/30/09
TIME	11:00 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	NO
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



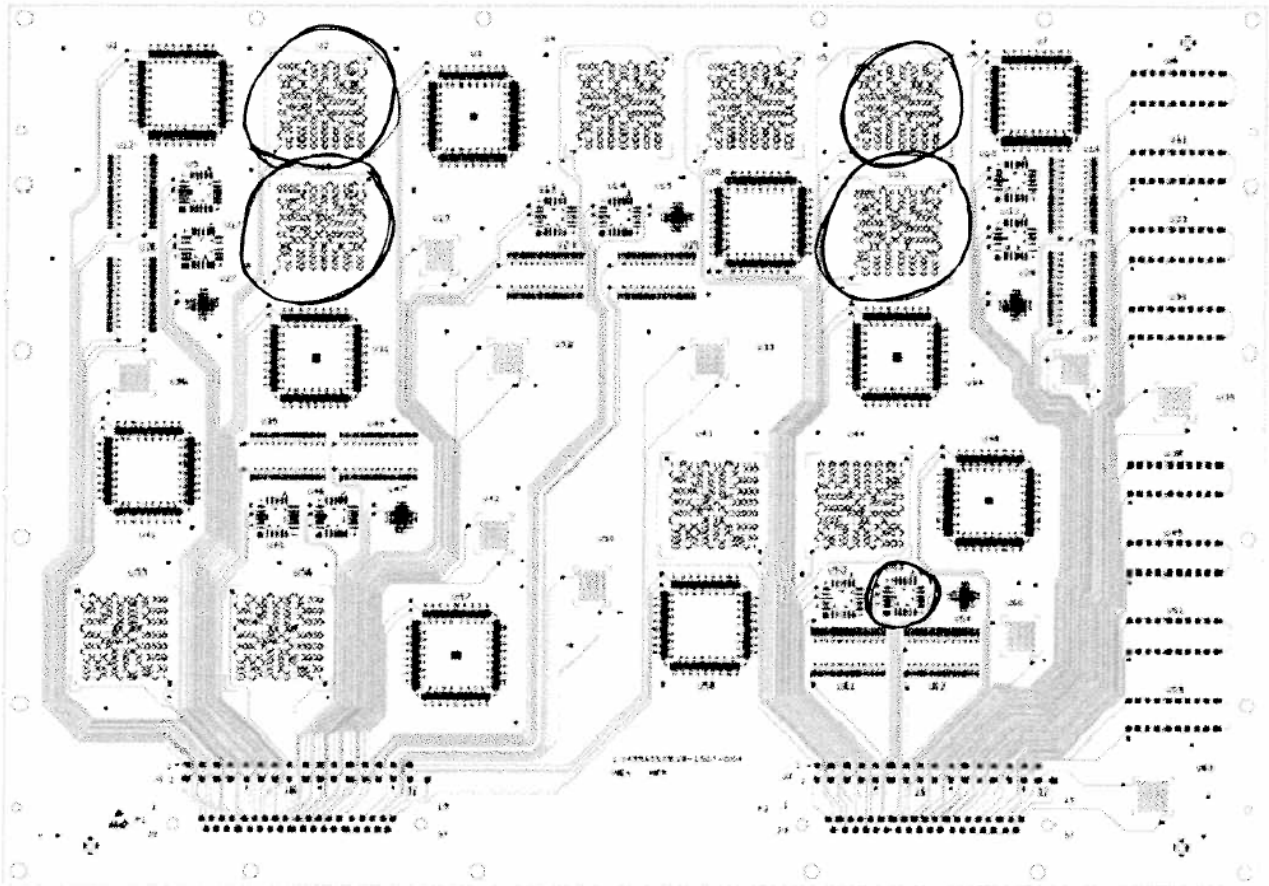
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Burnt PWB	Center, U50		1049801	03/30/09

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	182
DATE	03/30/09
TIME	1:50 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	YES - on back of board
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	"

DEFECT MAP



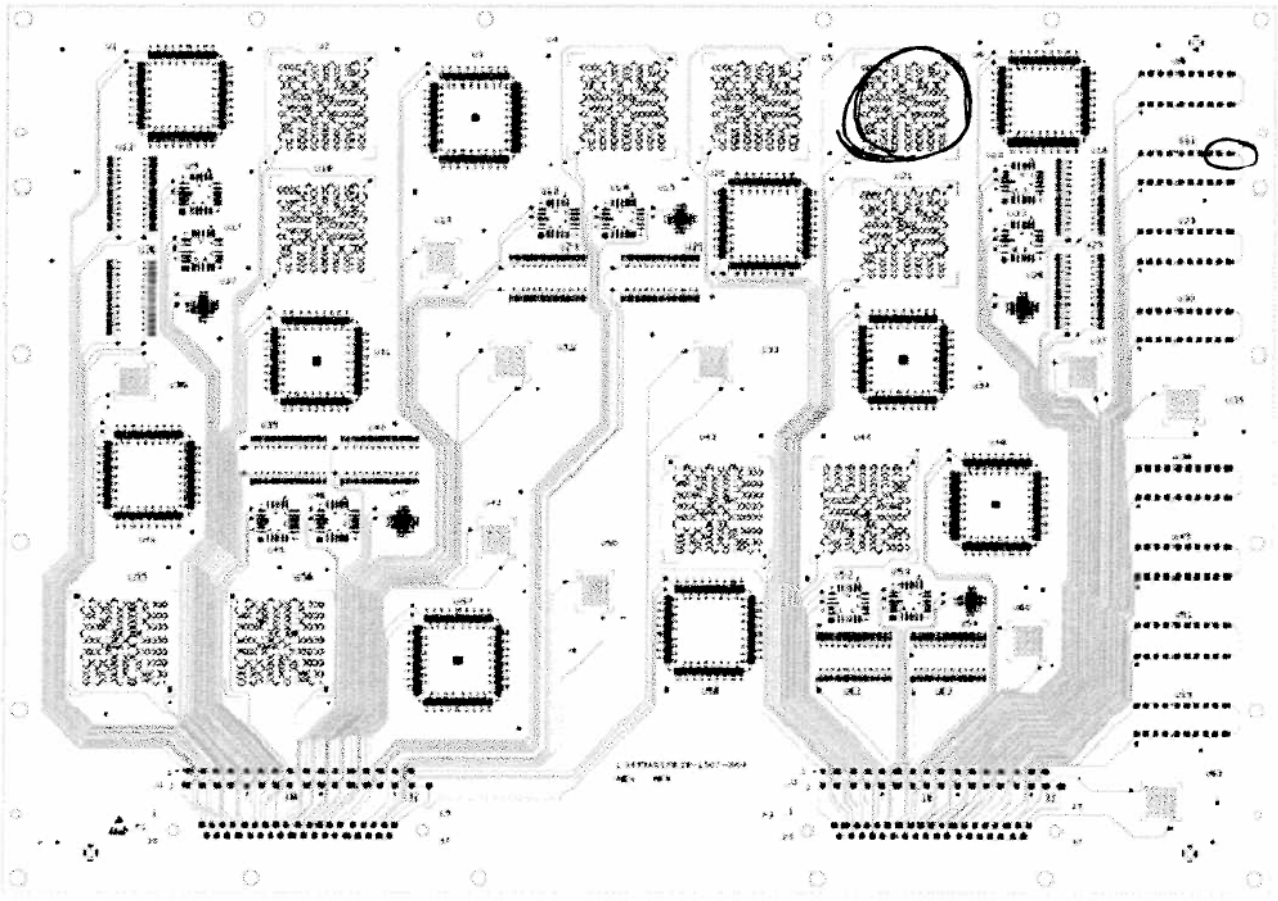
PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
Void in bonding material	U53	NOTED	1049801	03/30/09
Solder balls	U6	NOTED on backside over vias	"	"
"	U18	" " "	"	"
1/2 filled vias	U2, U18	NOTED on backside	"	"
"	U6, U21	" "	"	"
board warped	lower left	NOTED, very minor	"	"

PRETEST INSPECTION CHECKLIST

BOARD NUMBER	183
DATE	03/30/09
TIME	1:45 PM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Good solder wetting?	ACCEPTABLE
Sufficient solder?	YES
Proper part alignment?	YES
Solder balls?	YES - on back of board
Bridging?	NO
Flux removed by cleaning method?	YES
Solder appearance (roughness, striations?)	ACCEPTABLE
PTH wetting and fillet appearance?	//

DEFECT MAP



PRETEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
delamination	U11	NOTED on back of board, small spo	1049801	03/30/09
board warped	lower left corner	NOTED	"	"
missing SN	bottom front	"	"	"
Solder balls	U6	NOTED on back of board over vias	"	"

Appendix D: Environmental Test Laboratory Logs

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 1 of 7 pages

Type of Test (select one box)				
Formal	Eval	Test Proc. No.	RFTA # 142533	Unit Part No. N/A
Qual		Test Proc. Rev.	—	Unit Part No. —
Other	X	ETL Equip. Name/No.	HALT/HASS II	Mfg. Sequence No. SEE BELOW

DATE	TIME	OPERATION
2-6-09	0930	BEGIN SET UP ON PROJECT NASA-DoD LEAD-
		FREE ELECTRONICS TO PERFORM A HIGHLY ACCELER-
		ATED LIFE TEST INSTRUCTED BY COMBINED
		ENVIRONMENTS TEST PROCEDURE 19 JANUARY 2009.
		(204066)
2-9-09	0800	SET UP COMPLETED. PWB'S INSTALLED IN
		CHAMBER. MSN'S AREAS FOLLOWS: 23, 120,
		20, 72, 119, & 21 HAVE ACCELEROMETERS
		ATTACHED. MSN'S 69, 71, 118, 22, 73, 24, 116,
		70 & 117. (204066)
2-10-09	1400	START CHAMBER TO RUN A BASELINE VIBRATION
		CHECK OUT. HAD CHAMBER MALFUCTIONS. (204066)
2-11-09	1444	CHAMBER MALFUCTIONS CORRECTED. RAN
		VIBRATION BASELINE SATISFACTORY. (204066)
2-12-09	0852	START CHAMBER TO STABILIZE @ AMBIENT TEMP
		BEFORE DETERMING CYCLE TIME. (204066)
	0930	CHAMBER STABILIZED. START TEMP TO -55°C @
		20°C RAMP RATE. (204066)
	0934	CHAMBER TEMP @ -55°C. T/C'S ATTACHED TO
		7 PWB'S, WILL MONITOR TO SEE WHICH T/C HAS
		THE LONGEST LAG TO DETERMINE SOAK TIME.
		(204066)
	1020	TEMP TO 125°C, @ 20°C RAMP RATE. (204066)
	1029	CHAMBER @ 125°C. (204066)

\\pclt102\etl\forms\cli9019.0
ETL FORM CLI9019.0 960612
R.L.S.

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 2 of 7 pages

Type of Test (select one box)			
Formal / Eval	Test Proc. No. RFTA # 142533	Unit Part No. N/A	
Qual	Test Proc. Rev. —	Unit Part No. /	
Other X	ETL Equip. Name/No. HALT/HASS II	Mfg. Sequence No. N/A	

DATE	TIME	OPERATION
2-12-09	1010	TEMP TO -55°C. (204066)
	1119	CHAMBER @ -55°C START 30 MIN SOAK.
	—	(204066)
	1138	ABORT SOAK. TOO MUCH MOISTURE GETTING
	—	INSIDE CHAMBER. HOLD TEST TO RESEAL.
	—	(204066) DRY CHAMBER @ 60°C (204066)
	1354	CHAMBER DRY. TEMP TO AMBIENT, ALL
	—	PORTS ARE SEALED. (204066)
	1405	TEMP TO -55°C @ 20°C PER/MIN. (204066)
	1409	CHAMBER & TC#1 @ -55°C +/- 2°C. (204066)
	1410	TEMP TO -59°C TO SPEED UP THERMAL READING
	—	(204066)
	1424	TEMP TO 125°C. (204066)
	1433	CHAMBER @ 125°C, BUMP TEMP UP TO 129°C TO
		SPEED UP THERMAL READING. (204066)
	1448	SOAK COMPLETE. TEMP TO 23°C. WILL CHECK PROFILE.
		(204066)
	1540	PROFILE SET, START CYCLE#1. (204066)
	2026	Abort cycle, the temperature (product) and
	—	vibe control are not stable. (165402)
	2027	Stopped the Gnutek @ # 5. (165402)
2-13-09	0900	Found loose Accel + cable on control (456392)
	1030	Installed Accel using loctite, need 1 hour
	—	cure (456392)

\\pclt102\etl\forms\cli9019.0
ETL FORM CLI9019.0 960612
R.L.S.

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 3 of 7 pages

Type of Test (select one box)

	Formal	Eval
Qual		
Other	X	

Test Proc. No. RETA # 142533
Test Proc. Rev. —
ETL Equip. Name/No. HALT/HASS IC

Unit Part No. N/A
Unit Part No. —
Mfg. Sequence No. N/A

DATE	TIME	OPERATION
2-13-09	1230	STARTING CYCLE #~~1~~ 6 PER PROJECT. (204066)
	1237	HOLD TEST. CHAMBER MALFUCTION. ABORT TEST.
		(204066)
	1400	Found short in Product T/C Connector.
		Repaired T/C connection (0185127)
		Start Cycle #6 (45 cycles To GO). Anatech
	1445	Cycle ~~#6~~ #7. (0185127)
	1448	Temp Data Log started (0185127)
2-14-09	1629	The chamber product and air temperatures
		are not reading ~~correctly~~ the set point.
		SP = -59°c P+A ± -21 + -22°c. There as
		20 loops remaining. Vibe is OK. (165402)
	1632	The Honeywell = -19°c. (165402)
	1634	This irratic temperature started during
		the cold ramp, but is stabilizing. (165402)
	2334	With 13 loops remaining the above is being
		duplicated. (165402)
2-15-09	1147	50 CYCLES @ 10gs COMPLETE, ANATECH OFF. (204066)
2-16-09	1045	STARTING CYCLE #1 @ 15gs FOR 50 CYCLES (204066)
2-18-09	1250	Completed 50 cycles @ 15 gs (456392)
"	1554	STARTING cycle #1 @ 20gs (456392)
2/20/09	1810	Completed 50 cycles @ 20g's. (165402)
	1816	Begin 50 cycles @ 25g's (165402)
2/20/09	2030	Completed 50 cycles @ 25g's. (165402)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 4 of 7 pages

Type of Test (select one box)

	Formal	Eval
Qual		
Other		

Test Proc. No. RTA # 142533
Test Proc. Rev. —
ETL Equip. Name/No. HALT + HASS 2

Unit Part No. N/A
Unit Part No.
Mfg. Sequence No.

DATE	TIME	OPERATION
2/22/08	2035	Begin 50 thermal cycles @ 30g's. (165402)
	2120	The product Grms level is varying from 26.5
		to 28 g's. OK to continue per project
		rep LT. (165402)
2/23/08	0830	Test stopped @ cycle 38 remaining (456392)
	0944	Test resumed @ cycle 38 (456392)
2/24/08	2350	Completed 50 cycles @ 30g's, testing stopped. (456392)
2-26-09	1310	ANATECH & CHAMBER CYCLE out of SYNC. PROBLEM
		SOLVED. PROJECT REQUESTED TO RUN 25 CYCLES
		@ 30g's TO EQUAL TEMP CYCLES STATUS. (204066)
3-2-09	1020	COMPLETED THE 30g's STARTING 50 CYCLES
		@ 35g's. (204066)
3-4-09	0703	Found Chamber OFF (125175)
	0725	Chamber RUNNING AGAIN?? (125175)
	1229	COMPLETED THE 35g's. STARTING 50 CYCLES @ 40g's
		(204066)
	1442	COMPLETED 40g's, STARTING 50 CYCLES @ 45g's
		(204066)
	2115	The chamber temp stopped controlling and
		the vibration shut off for ~ 20 minutes
		during cycle # 7 of 50 @ 45g's. (165402)
	2116	Part of the hot temp vibe was missed. The temp
		resumed going cold and the vibe came back on. (165402)
3-8-09	1145	CHAMBER TEMP STOPPED, VIBE STOPPED, NO LN2
		(204066)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 5 of 7 pages

Type of Test (select one box)					
Formal	Eval	Test Proc. No.	RFTA # 142533	Unit Part No.	N/A
Qual		Test Proc. Rev.	N/A	Unit Serial No.	N/A
Other	X	ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
3-8-09	CONT.... 1145	FLOWING THROUGH LINES. (THAT'S THE WAY IT
		APPEARS). STOP TEST, STOP ANATECH. (204066)
3-9-09	0910	RESUME CYCLING. RESTARTED ANATECH, HOLD
		TEST, CHAMBER NOT RESPONDING. (204066)
	1045	RESUME CYCLING. CORRECTION MADE. RESTART
		ANATECH. (204066)
	1830	Completed 50 cycles @ 45 g's. (165402)
3/9/09	1900	Begin 50 cycles @ 50 g's. (165402)
3-10-09	1530	HOLD TEST, MALFUNCTION WITH VIBRATION.
		STOP ANATECH. (204066)
	1600	RESUME CYCLING. REPLACED ACCELEROMETER
		CABLE. (204066)
3-11-09	0503	Cycle #33 / 433.0. Found Vib OFF, Chamber OFF.
		(125175)
	0915	Resume Testing Cycle #33/433. (161930)
3-12-09	0045	50 cycles COMPLETED (125175)
	0816	START CYCLE #1 of 50 @ 55 g's (204066)
3/13/09	2321	The high temp air limit is Flashing red,
		set @ 200°C. The chamber temp shows that
		it did not go hot this cycle, #39, D 485.5 on
		the Anatek. The vibe and cold temp are OK. (165402)
	2334	The chamber is not going hot in cycle #40. Aborting
		test anatek = 485.5. (165402)
3-14-09	0821	RESUME CYCLING. (204066)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields

Page 6 of 7 pages

Type of Test (select one box)

	Formal	Eval
Qual		
Other	X	

Test Proc. No.	RFTA # 142533	Unit Part No.	N/A
Test Proc. Rev.	N/A	Unit Serial No.	N/A
ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
3/14/09	2000	Completed 50 cycles @ 55 gs, 496.5 on the Anatek. (165402)
3-23-09	1340	RESUME CYCLING @ 55gs FOR 53 CYCLES PER PROJECT. WILL CONTINUE TO RUN CYCLES UNTIL ENOUGH FAILURES ARE REACHED.
	1745	The vibe has stopped, NO air pressure. (165402)
	1813	Cannot get the air pressure up on the vibe controller, about cycle # 5, 501.0 on the Anatek. (165402)
3-24-09	0857	ADJUST AIR PRESSURE, RESUME CYCLING. STARTING CYCLE # 4 - ANATEK 501.0 (204066)
	1704	Vibe has shut off during the cold dwell of cycle # 11, Anatek @ 507.0. (165402)
	1721	Stop test, could not get Air ~~PSI~~ pressure up enough to run vibe. Chamber is @ hot temp in cycle # 12, Anatek @ 507.5. (165402)
3-25-09	0842	ADJUST AIR PRESSURE. RESUME CYCLING @ CYCLE # 12, ANATECH 508.0. (204066)
		NOTE: Running @ 50gs. (204066)
3-27-09	0250	53 cycles COMPLETED (125175)
	1436	Begin 50 cycles @ 55 grms (0185127)
3/27/09	2210	The air supply is intermittently shutting off + ON. (165402) During the cold ramp of cycle # 8. (165402)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 7 of 7 pages

Type of Test (select one box)					
Formal	Eval	Test Proc. No.	RFTA # 142533	Unit Part No.	N/A
Qual		Test Proc. Rev.	N/A	Unit Serial No.	N/A
Other	X	ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
3/25/09	1700	Completed 50 cycles @ 55g's. (165402)
		Anatek = 599.5. (165402)
3-30-09	1108	RESUME CYCLING. STARTING CYCLE #1 of
		50. ANATECH SHOWING 599.5. (204066) @
		55g's (204066)
	1310	Check Changed Program to 50G. level @ End of
		Cycle #2
	1410	Changed Program back to 55G @ end of cycle #3
4-01-09	1430	RAN 3 EXTRA CYCLES PER PROJECT. TEST
		COMPLETED. PROJECT WILL BRING ANOTHER
		SET of PWB's (12) TO PERFORM TESTING.
		(204066)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG 1 BS 4-22-09

Complete all Fields

Page 1 of 5 pages

Type of Test (select one box)

	Formal	Eval
Qual		
Other	X	

Test Proc. No.	RFTA # ~~142533~~ 149300 BS 4-14-09	Unit Part No.	N/A
Test Proc. Rev.	N/A	Unit Serial No.	N/A
ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
4-21	13:30	Began 50 cycles @ 10g's on new set of boards
	(1835)	per RFTA 142533
	~~1735~~	In cycle # 5 the alarm rang for temperature over
	(1837)	limit and the vibration shut down. (165402)
~~4/21/09~~	~~1737~~ (1838)	Had to reset the alarm twice. (165402)
4/21/09	~~1738~~	AnatekK = 4.5 cycles, the temperature went
		above 160°c, in both cases. (165402)
	(2037)	
	~~1937~~	Reset alarm twice for an over temp condition
		again @ hot. (165402) cycle # 8, AnatekK 7.5. (165402)
	(2237)	
	~~2137~~	alarmed twice again (had to reset 2x). (165402)
4-22-09	0037	OVERTEMP TRIPPED. RESET AND Vib CAME ON AND
		SPIKED TO ~90G's AND TRIPPED OFF. WILL ALLOW HOT
		SOAK TO COMPLETE TEST. (125175)
	0102	AMORTING TEST (125175)
	0900	AnatekK turned off
	1144	PROBLEM SOLVED. HONEYWELL T/C CAME
		LOOSE. RELONNELTED, READY TO START
		CYCLE # 11, ANATEK READING 12.0. (204066)
		NOTE: MSN's ARE AS FOLLOWS; 163, 158, 181,
		143, 139, 140, 97, 183, 142, 180, 182 & 141. (204066)
	1453	OVERTEMP TRIPPED. REATTACHED T/C TO PWB.
		(204066)
	1510	RESUME CYCLING. (204066)
4/22/09	2015	Hold cycling to add a thermocouple. (165402)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 2 of 5 pages

Type of Test (select one box)					
Formal	Eval	Test Proc. No.	149300 RFTA # ~~142533~~ BS 4-24-09	Unit Part No.	N/A
Qual		Test Proc. Rev.	N/A	Unit Serial No.	N/A
Other	X	ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
4/22/09	2023	Resume cycling @ # 20, Anatek = 19.5. (165402)
4-24-09	0327	50 cycles completed, Anatek = 50.5 (125175)
	0901	START CYCLE #1 of 50 @ 15gs. Anatek
		@ 50.5. (204066)
4-26-09	1115	Completed 50 cycles of 15g Vibration (161930)
	1123	Stop Chamber and Anatek. Anatek cycles = 100.5 (161930)
	1205	Checked Thermo couples. Reloaded Test for 50
		cycles with 20g Vibration per step #5 (161930)
	1206	Start Test cycle 101, Anatek cycle 100.5 (161930)
4-28-09	1430	COMPLETED 50 CYCLES @ 20g's. HOLD TEST
		TO CHANGE OUT T/C's. (204066)
	1545	READY TO RESUME CYCLING. START CYCLE
		#151 of 500, 50 CYCLES @ 25g's (204066)
4/29/09	1922	Error msg on Anatek - Event Detector - to-
		Computer communication failure Time-out
		with 0 of the required 128 bytes recieved.
		(165402) The clock stopped @ 7:21:13:0. (165402)
4/29/09	1930	The Anatek clock advanced to 7:21:20:20 after
		acknowledging error msg. Halt test @ cycle
		#178, 177.5 on the anatek.
4-30-09	0955	RESUME CYCLING. #178 & ANATEK #
		178.0. (204066)
		NOTE: NOTIFIED PROJECT ABOUT THE ERROR ON
		THE ANATEK. PROJECT CHECKED ANATEK (CONT....)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields Page 3 of 5 pages

Type of Test (select one box)					
Formal	Eval	Test Proc. No.	RFTA# 149300	Unit Part No.	N/A
Qual		Test Proc. Rev.	N/A	Unit Part No.	N/A
Other	X	ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
4-30-09	(CONT...)	AND INSTRUCTED TO CONTINUE CYCLING. (204066)
	0908	COMPLETED 50 CYCLES @ 25g's. STARTING 50 CYCLES @ 30g's. (204066)
5-3-09	1135	Cycles Complete (149913)
	1535	Anatek shows completed cycles = 267 and completed thermal cycles = 250.5. (165402)
5/5/09	1600	Begin 50 cycles @ 35g's. (165402)
5/5/09	1815	Completed 50 cycles @ 35g's, chamber to 55°C to dry and inspect thermocouples. (165402)
	1818	Stopped Anatek @ 300.5. (165402)
	1845	Chamber off. (165402)
	1905	Begin 50 cycles @ 40g's, Anatek @ 300.5. (165402)
	1305	Paused test to load Nasa config file
	1415	HOLD TEST TO CHECK T/C's. (204066)
	1442	RESUME CYCLING. 319.5 ON ANATEK & STARTING CYCLE 320. (204066)
	1650	Stop cycling @ # ~~328~~ (WH) 322, 321.5 on the Anatek, to check thermocouples. (165402)
	1750	Resume cycling @ # 322, 322.0 on the Anatek. (165402)
5/7/09	2250	Completed 50 cycles @ 40g's. (165402)
5/7/09	2300	Begin 50 cycles @ 45g's. (165402)
5-10-09	0107	50 cycles @ 45g's COMPLETED (125175)
	1910	Stopped Anatek. (165402)

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields

Page 4 of 5 pages

Type of Test (select one box)

	Formal	Eval
Qual		
Other	X	

Test Proc. No.	RFTA# 149300	Unit Part No.	N/A
Test Proc. Rev.	N/A	Unit Part No.	N/A
ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No.	N/A

DATE	TIME	OPERATION
5-11-09	0800	HOLDING TEST. FACILITIES REPAIRING LN2
		LINE TO STOP LEAKS. (204066)
5-21-09	1026	RESUME CYCLING. ANATEK @ 400.5 STARTING
		CYCLE #1 of 50 @ 50g's. (204066)
5/21/09	2100	Temp Chamber ~~[illegible]~~ went too cold. shut down chamber
		and opened doors with loops = 40 (106718)
5-22-09	1000	stopped Anitech @ 411.5 cycles (456392)
5-26-09	1050	RESUME CYCLING, START #12 ANATEK @ 411.5
		(204066)
	1323	Temp Ctrl oscillating, Test Stopped during
		cycle #12, (204066)
	1455	RESUME CYCLING #13 STARTED. ANATEK @
		414.0. (204066)
	1607	HOLD TEST. CHAMBER MALFUNCTION. ANATEK @
		415.0. CYCLE #14 COMPLETED. (204066)
5-28-09	1348	RESUME CYCLING. STARTING #15, ANATEK
		@ 415.0. Running @ 50g's. (204066)
	0100	~~Cycle~~ Cycle complete ANAtech @ cycle 449.5 (105162)
	0815	check units no excessive damage noted (161930)
	0816	Start cycle #1 of 55g's. Anatech cycl 449.5 (161930)
6-1-09	1000	55g, 50 Cycles Completed. (56593)
6/4/09	1740	Begin cycle #1 of 50 @ 55gs, 499.5 on the Anatek
		(165402)
6/6/09	1948	Completed 50 cycles @ 55 gs. (165402) Anatek = 549.5.

Raytheon Systems
Environmental Test Lab(ETL)

TEST LOG

Complete all Fields

Page 5 of 5 pages

Type of Test (select one box)					
	Formal	Eval	Test Proc. No.	RFTA# 149300	Unit Part No. N/A
Qual			Test Proc. Rev.	N/A	Unit Part No. N/A
Other	X		ETL Equip. Name/No.	HALT/HASS 2	Mfg. Sequence No. N/A

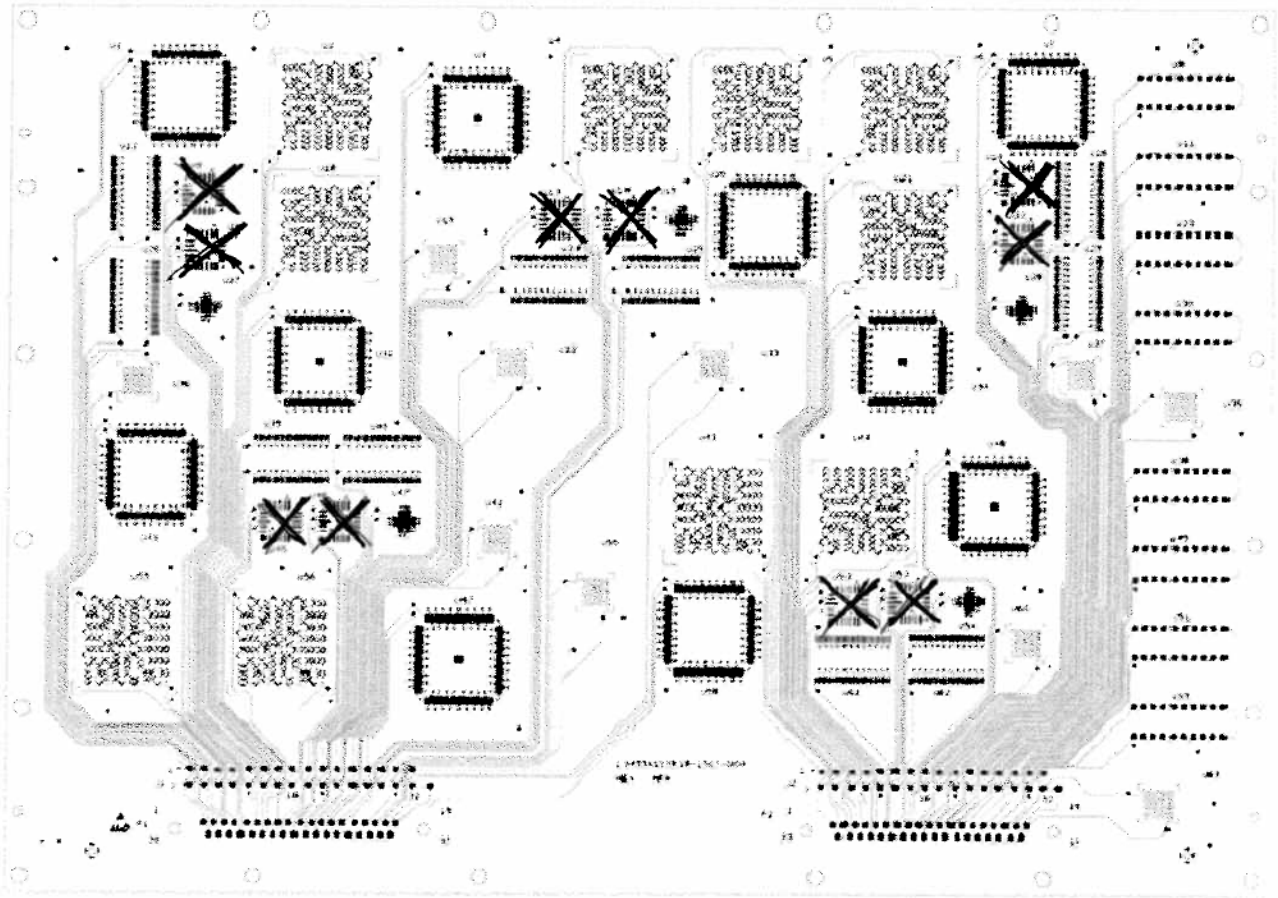
DATE	TIME	OPERATION
6-8-09	1002	RESUME CYCLING. START CYCLE # 1 of 100
		@ 55gs PER PROJECT. HOLD TEST AFTER 100
		CYCLES COMPLETE. ANATEK @ 549.5. (204066)
	1307	HOLD @ CYCLE # 4, ANATEK @ 552.5. REGLUE
		T/C's. (204066)
	1955	Chamber to room ambient. (165402)
	2001	Resume cycling @ # 4 of 100 @ 55gs, 553.0
		on the Anatek. (165402)
6-9-09	0158	Aborting cycle #9 (AT THE END OF cycle #9), ANATEK = 558.5
		BECAUSE OF TEMP CONTROL + VIB PROBLEMS (125175)
	1240	Resume testing Cycle # 10 OF 100 ANATEK = 558.5
		(56593)
	2140	Abort @ cycle # 18. Product is @ -51°C the
		set point is @ -59°C and the air is @
		-47°C. (165402) Vibe is OK and the honeywell
		is matching the air. (165402)
6-10-09	1400	RESUME CYCLING. START # 19 of 100 @ 55gs
		ANATEK @ 567.5. (204066)
6-14-09	0115	100 cycles COMPLETED. ANATEK = 650.5. (125175)
6-16-09	0900	PREPARE TO REMOVE UNITS FROM CHAMBER.
		TEST COMPLETE. (204066)

Appendix E: Post Test Inspection Logs

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 20
DATE	04/22/09
TIME	9:35AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	Some color change on(points?) - photo
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

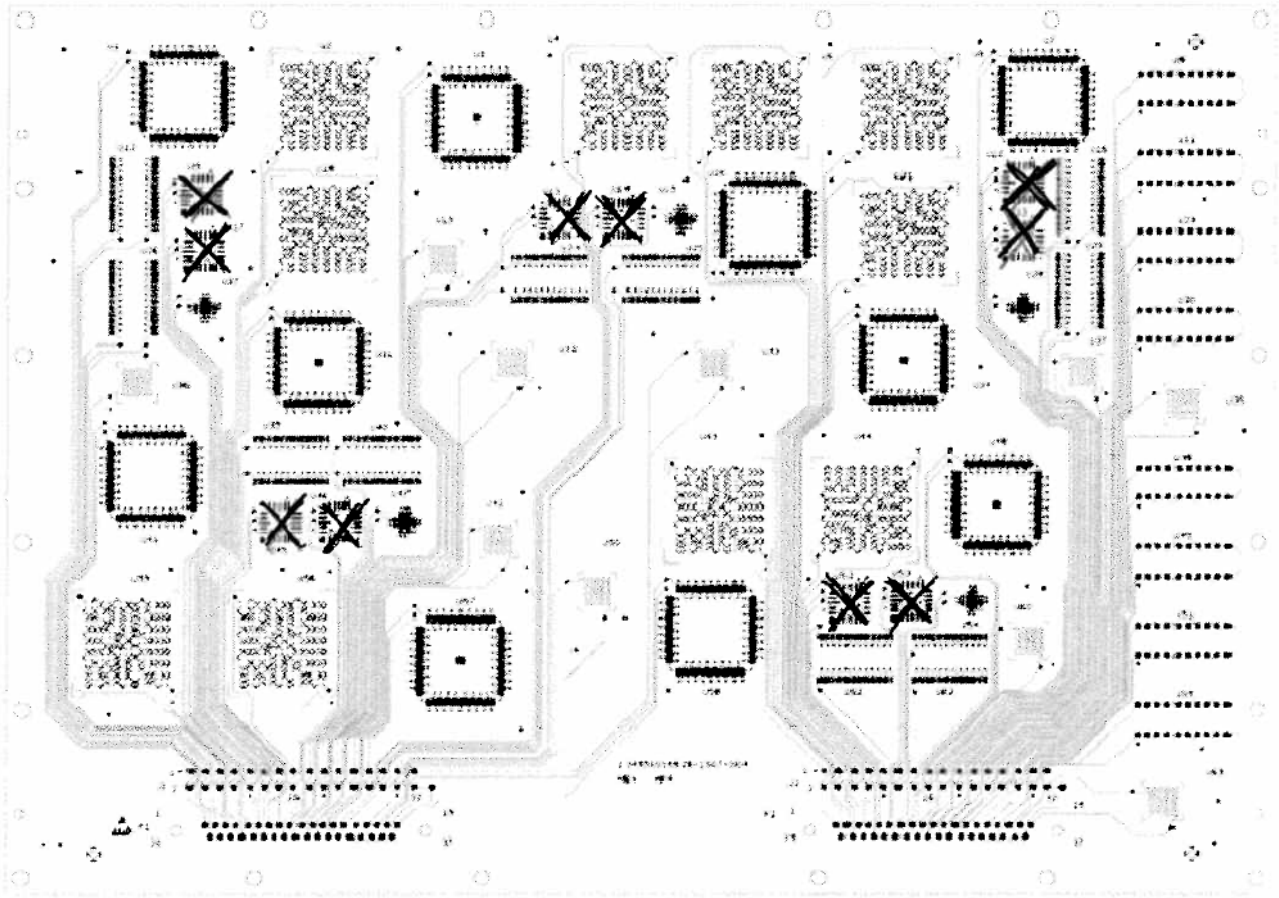
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/22/09
"	U17	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U52	"	"	"
"	U53	"	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 21
DATE	04/23/09
TIME	1:25 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

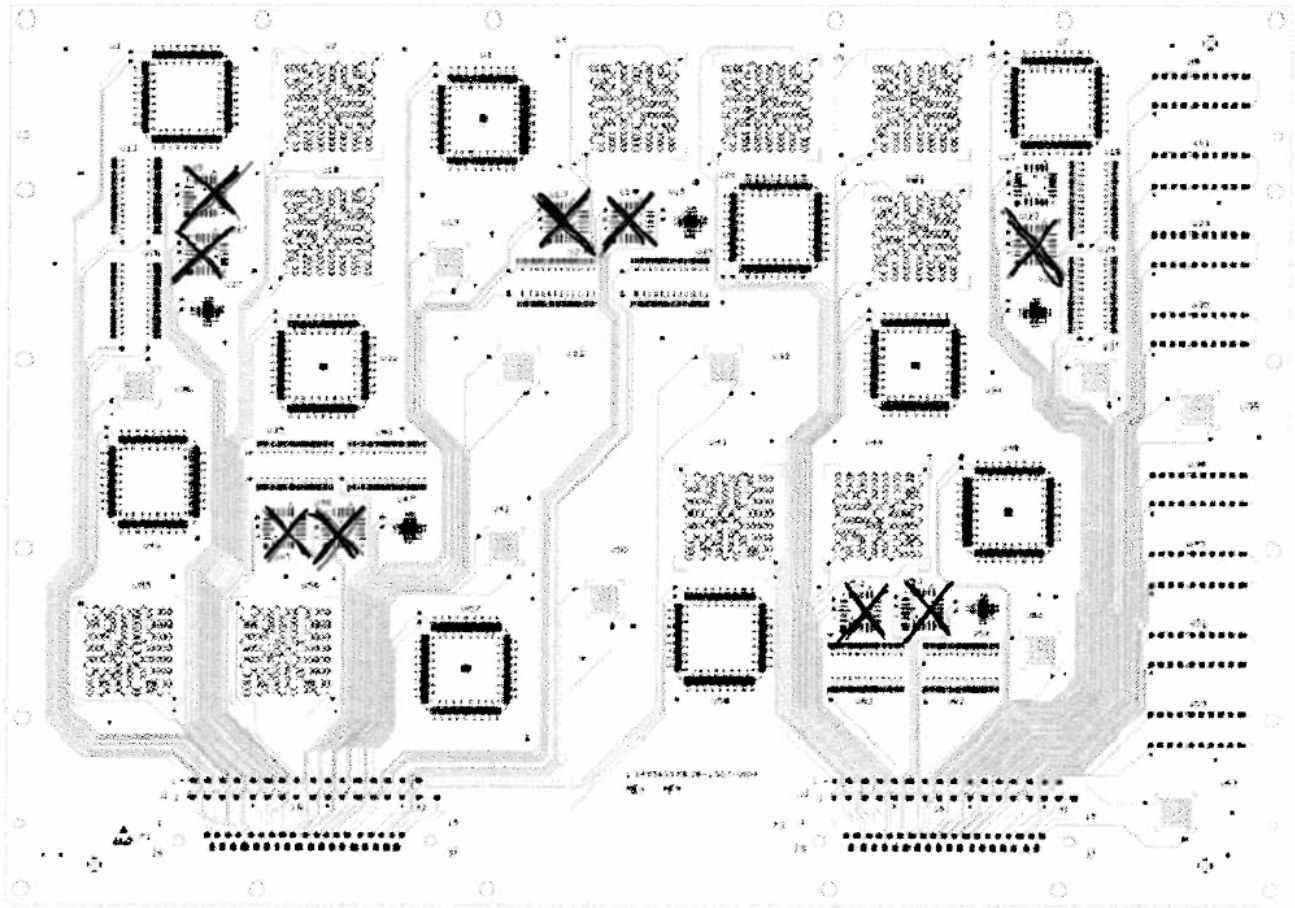
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/23/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
STIFF WIRES	PORT A	PHOTO - UP CLOSE - STUCK TOGETHER	"	"
EXPOSED WIRE	PORT A - MANY	PHOTOGRAPHED 3 AREAS	"	"
BROKEN WIRE	PORT A	PIN 1 - from peeling - PHOTOS	"	"
SOLDER BALL	BACK OF U57	PHOTOS	"	"
"	" U56	"	"	"
"	" U55	"	"	"
"	" U41	" - AND AREA ALL 4	"	"
"	" U18	"	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 22
DATE	04/23/09
TIME	12:45 pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

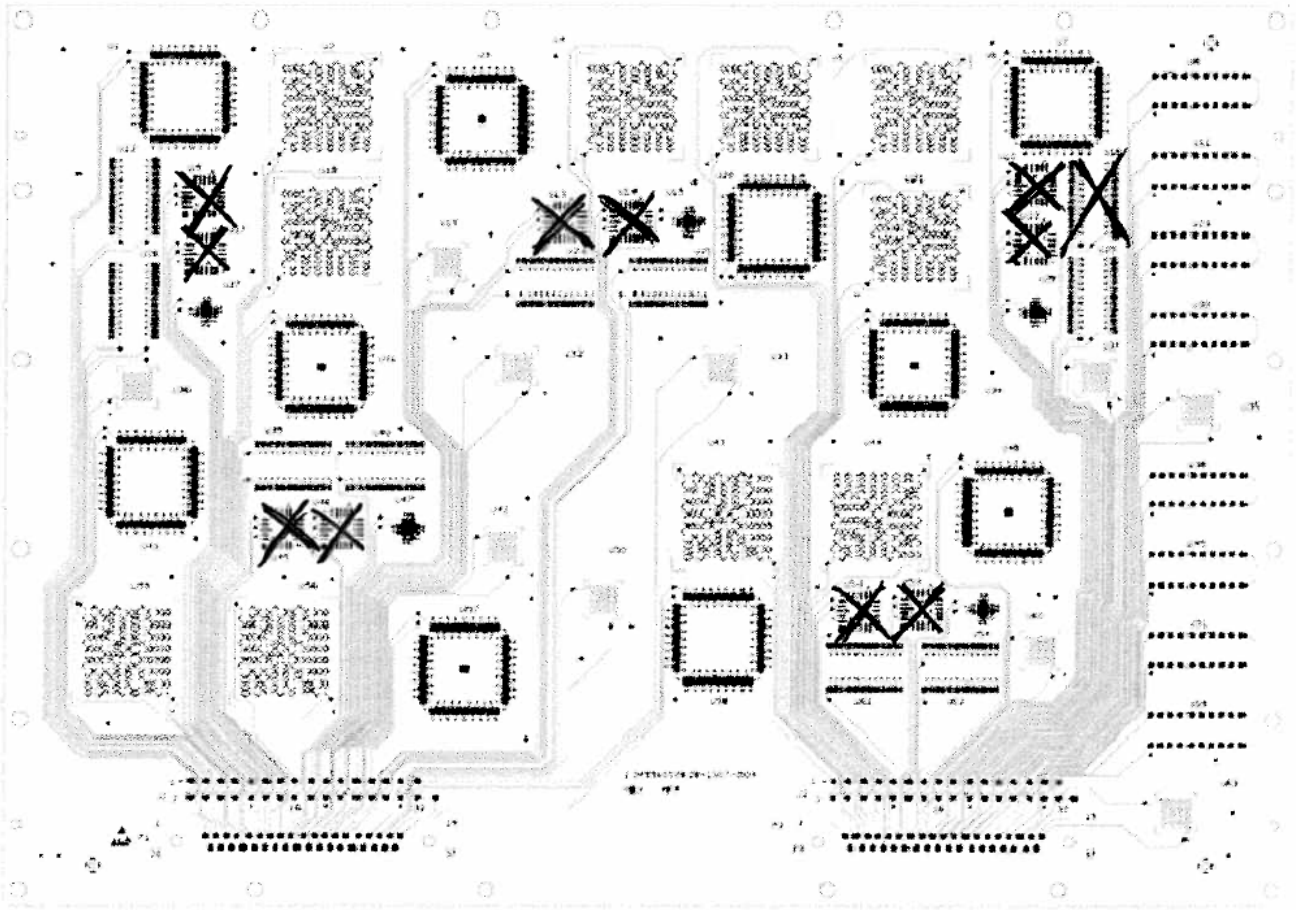
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
SOLDER BALLS	BACK OF U55	PHOTO - UP CLOSE	1049801	04/23/09
FELL OFF	U9	PHOTO	"	"
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
RESIDUE	PORT A	REACTION W/ CYBERSOLV ? PHOTO	"	"
CRACKED INSULATION	PORT A	PIN 1 BROWN WIRE NOT EXPOSED	"	"
"	PORT B	PIN 1 BROWN WIRE - PHOTO	"	"
PRESSURE POINT	PORT B	STRAIGHT LINE ACROSS - PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 23
DATE	04/23/09
TIME	2:52 PM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

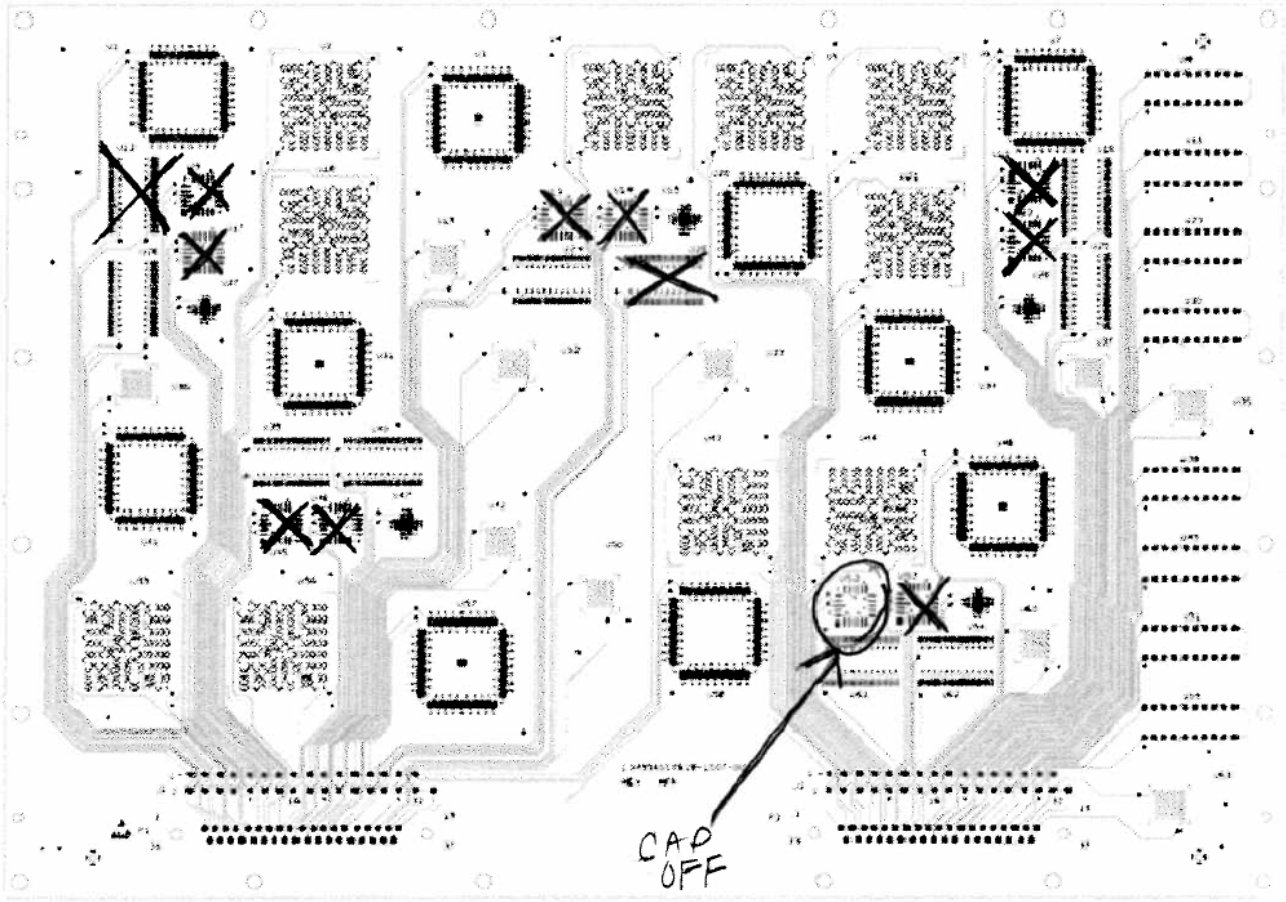
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FOD	U10, U22 & U16	PHOTO OF AREA	1049801	04/23/09
FELL OFF	U9	PHOTO	"	"
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U16	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
WIRES MELTED	PORT A	SLIGHTLY WARPED - PHOTO	"	"
WIRES FOLDED	"	STUCK TO ITSELF - PHOTO	"	"
REPAIRED WIRE	"	PIN 8 - GRAY WIRE - PHOTO	"	"
EXPOSED WIRES	"	PINS 36 & 37 - PHOTO	"	"
DAMAGE	"	FROM PEELING APART - PHOTO	"	"
WIRES STUCK	PORT B	STUCK TO ITSELF - PHOTO	"	"
SOLDER BALLS	BACK OF U56	PHOTOS	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 24
DATE	04/22/09
TIME	10 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES, SOME POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X= FELL OFF

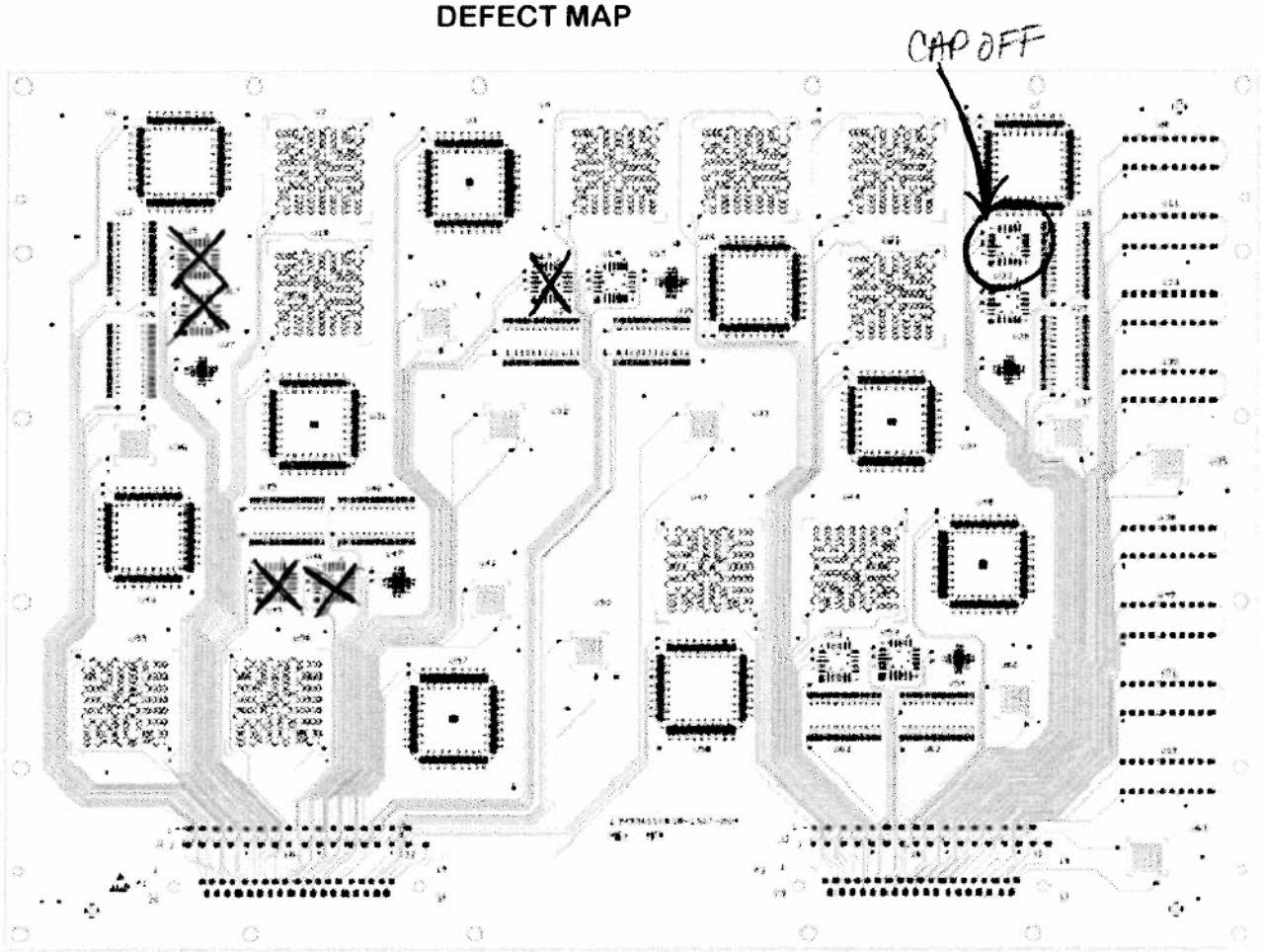
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
SOLDER BALL	BACK U14	PHOTO	1049801	04/22/09
FELL OFF	U12	//	//	//
//	U9	//	//	//
//	U17	//	//	//
//	U13	//	//	//
//	U14	//	//	//
//	U10	//	//	//
//	U22	//	//	//
//	U45	//	//	//
//	U46	//	//	//
//	U53	//	//	//
CAP OFF	U52	//	//	//

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 69
DATE	04/23/09
TIME	1:47 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

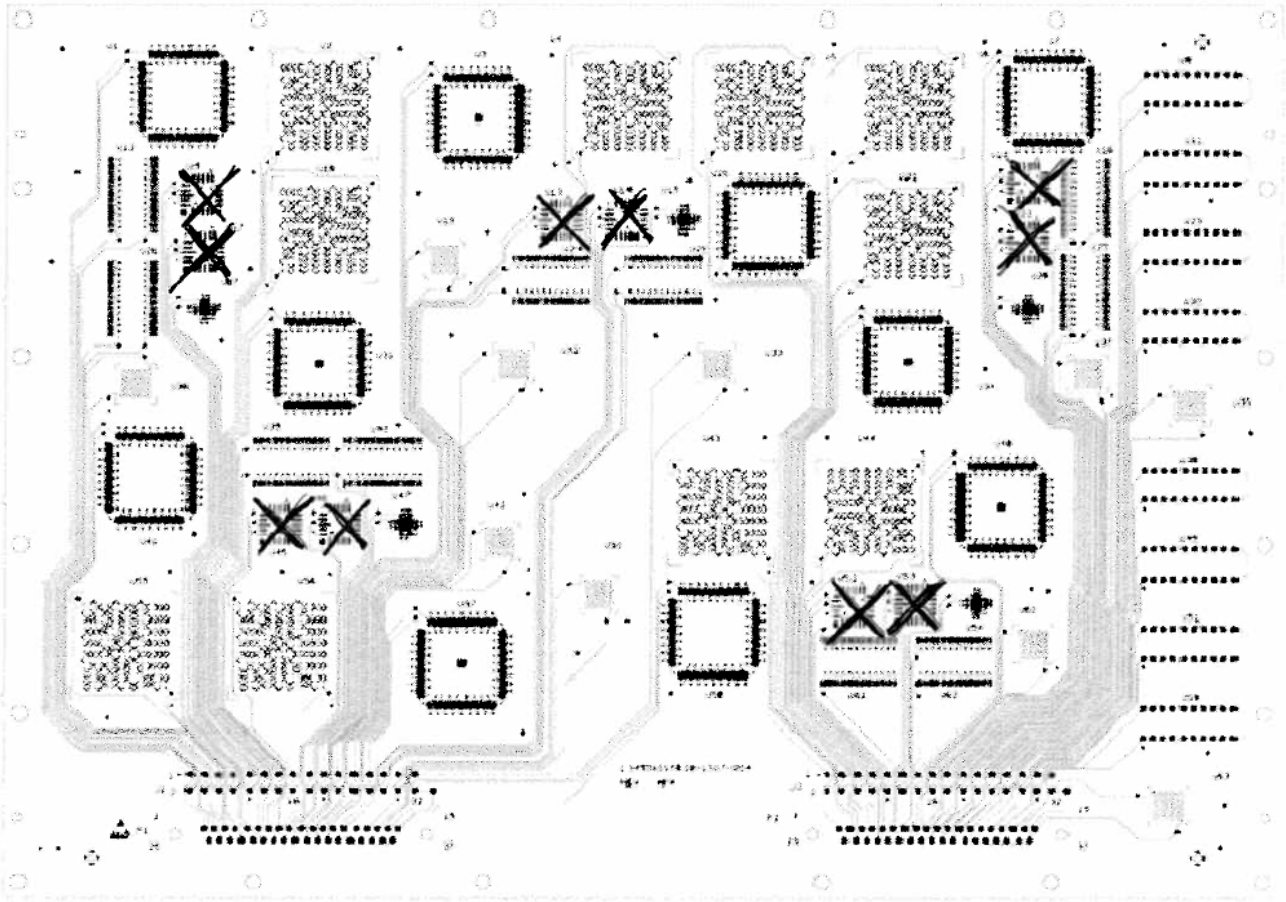
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/23/09
"	U17	"	"	"
"	U13	"	"	"
"	U45	"	"	"
"	U46	"	"	"
CAP OFF	U10	"	"	"
CORROSION	BACK OF U46	"	"	"
HOLES IN SOLDER	BACK OF U58	"	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 70
DATE	04/23/09
TIME	1:15 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES – SEE BELOW (X)
Corrosion?	YES – POINTS – PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

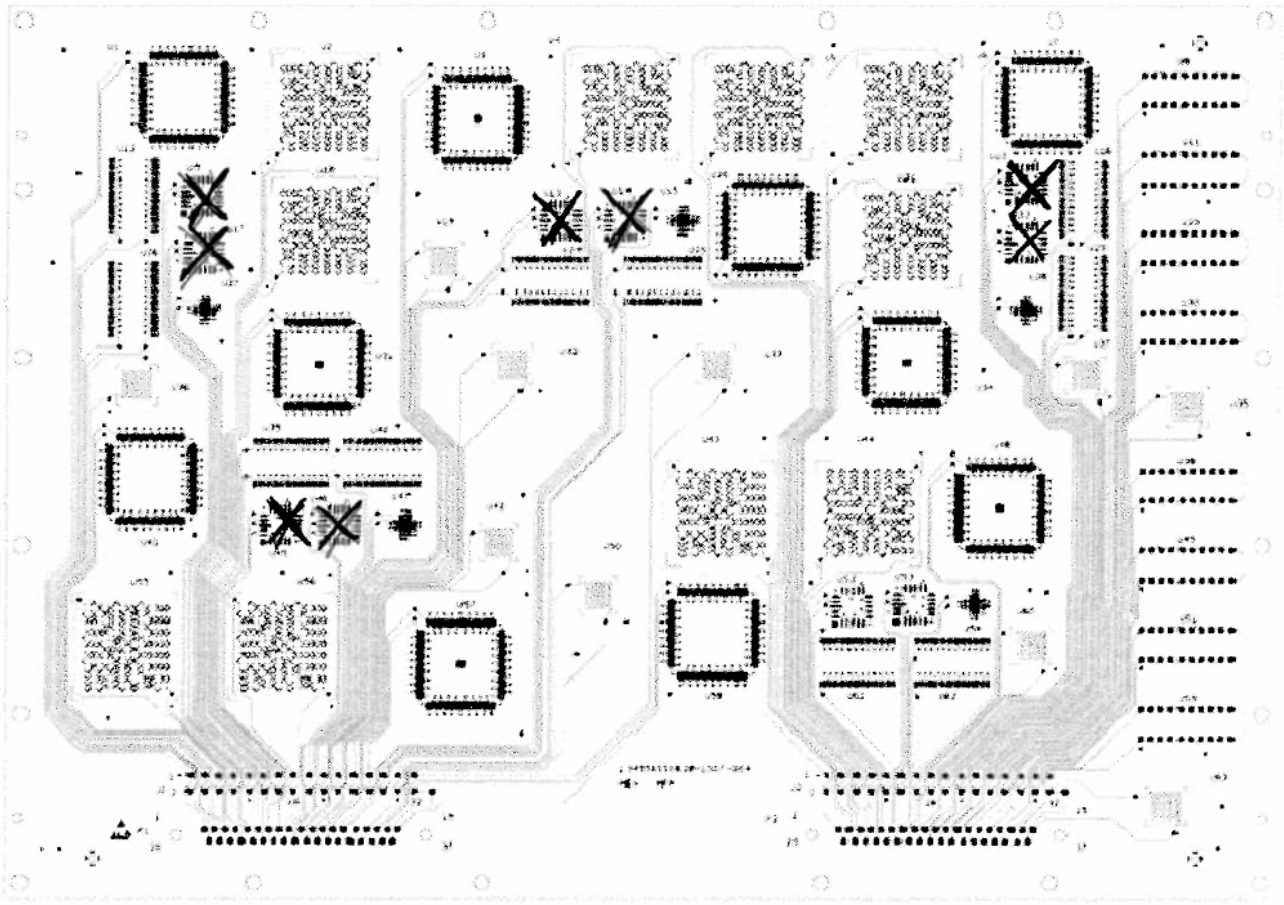
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/23/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
CRACKED INSULATION	PORT A	PIN 1 - WIRE NOT EXPOSED	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 71
DATE	04/23/09
TIME	3:13 PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

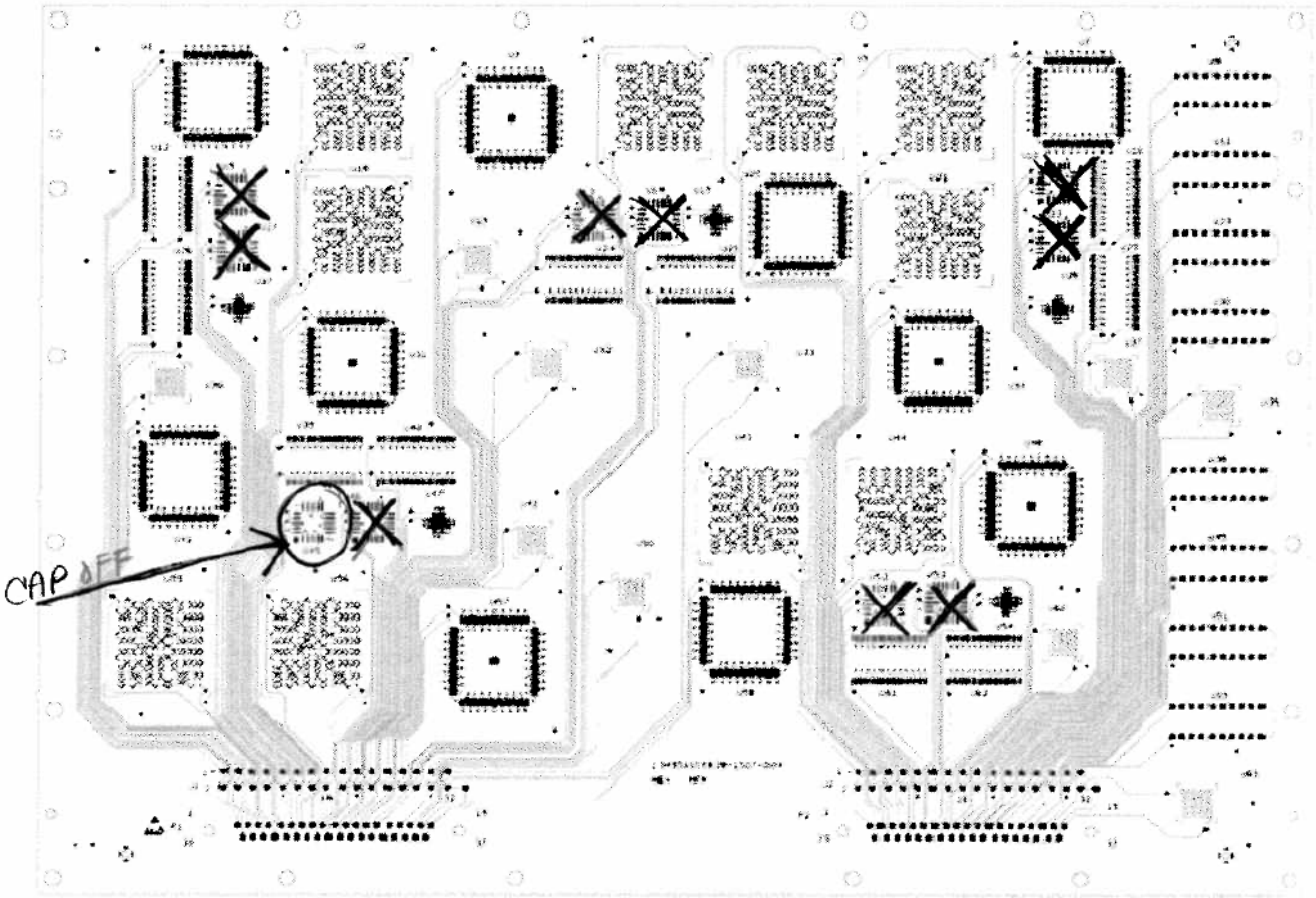
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/23/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
EXPOSED WIRES	PORT B	FROM PEELING — PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 72
DATE	04/23/09
TIME	2:35 pm
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X= FELL OFF

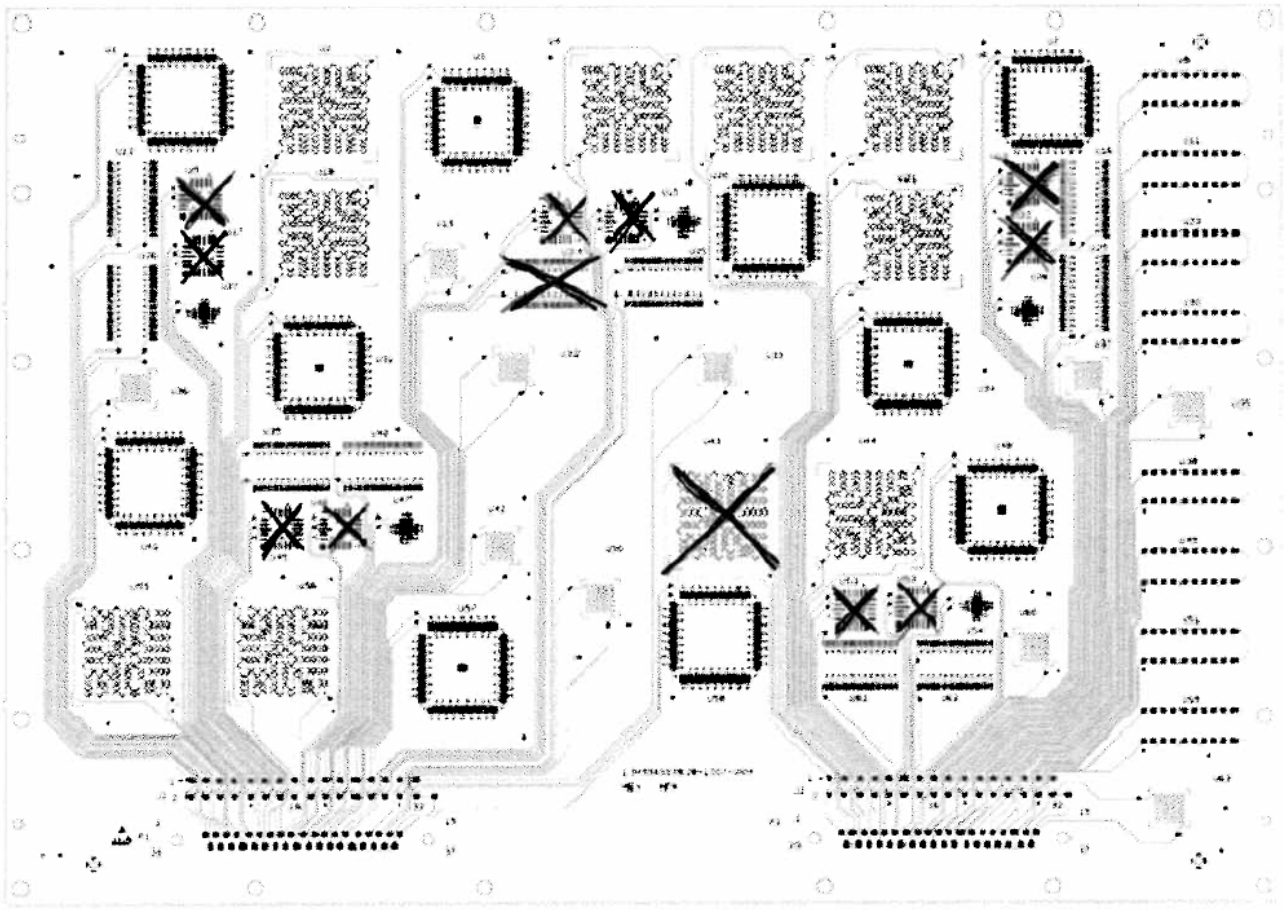
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/03/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
CAP OFF	U45	"	"	"
EXPOSED WIRE	PORT A	PIN 13 & 15 - PHOTO	"	"
HOLES IN SOLDER	U4, U5 & U6	PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 73
DATE	04/22/09
TIME	10:07 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES- SEE BELOW (X)
Corrosion?	YES- SOME POINTS- PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X= FELL OFF

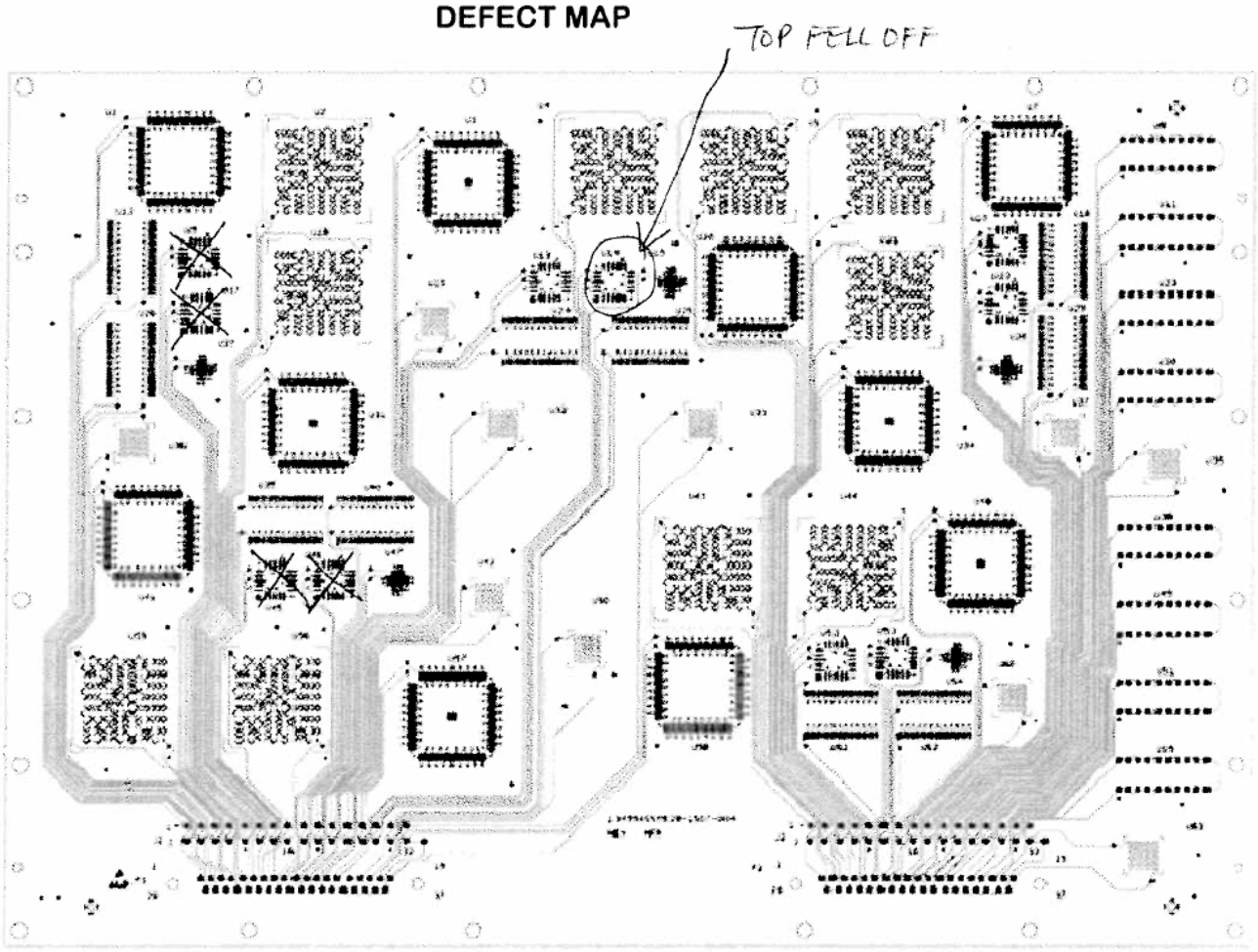
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/22/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U24	PHOTO - UP CLOSE	"	"
"	U10	PHOTO	"	"
"	U22	"	"	"
"	U43	PHOTO - UP CLOSE	"	"
"	U45	PHOTO	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
RIBBON STIFF/STUCK	PORT A	"	"	"
INSULATION CRACKED	BROWN PORT A PIN 1	WIRE IS STIFF, DOES NOT MOVE-PHOTO	"	"
"	ORANGE PORT A PIN 3	" " " " "-PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	97
DATE	07/01/09
TIME	10:45 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	
Missing parts?	YES
Corrosion?	YES - POINTS
Electrochemical migration of silver?	
Fillet lifting?	

DEFECT MAP



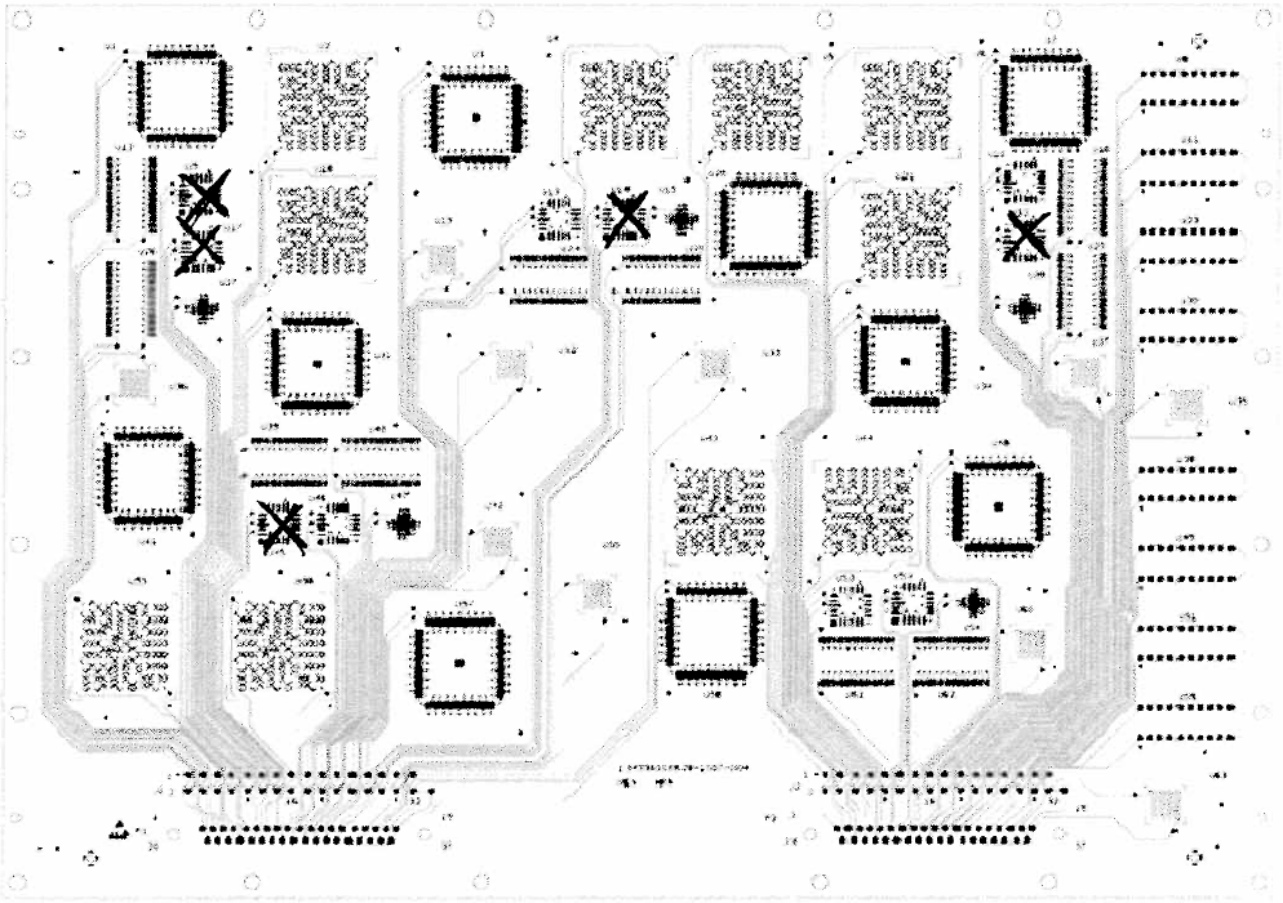
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9, U17	PHOTOS	1049801	07/01/09
" "	U45, U46	"	"	"
TOP OFF	U14	"	"	"
Delamination? BONDING WITH CONTAMINATION	Back of U8	Next to U8 - PHOTOS PREVIOUSLY NOTED	"	"
CRUSHED	" U7	SOLDER CRUSHED - PHOTOS		
"	" U1	" " "		

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 116
DATE	04/23/09
TIME	1:55PM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES- SEE BELOW (X)
Corrosion?	YES- POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

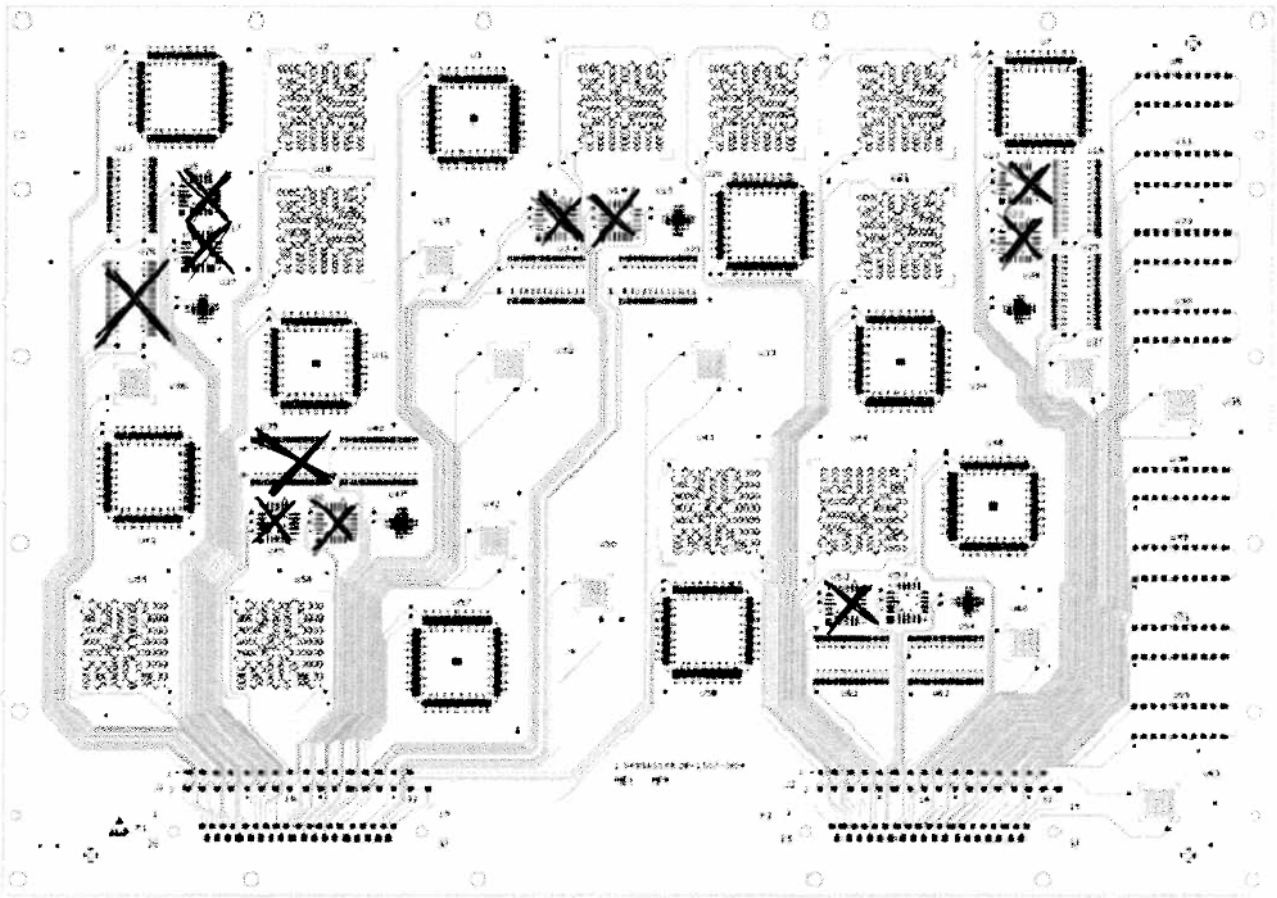
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/23/09
"	U17	"	"	"
"	U14	"	"	"
"	U22	"	"	"
"	U45	"	"	"
STIFF WIRES	PORT A	APPEAR MELTED – PHOTO	"	"
"	PORT B	" " "	"	"
EXPOSED WIRE	PORT A	PHOTO – CLOSE UP FROM PEELING	"	"
" "	PORT B	" " " " "	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 117
DATE	04/22/09
TIME	10:35 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES- SEE BELOW (X)
Corrosion?	YES- POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

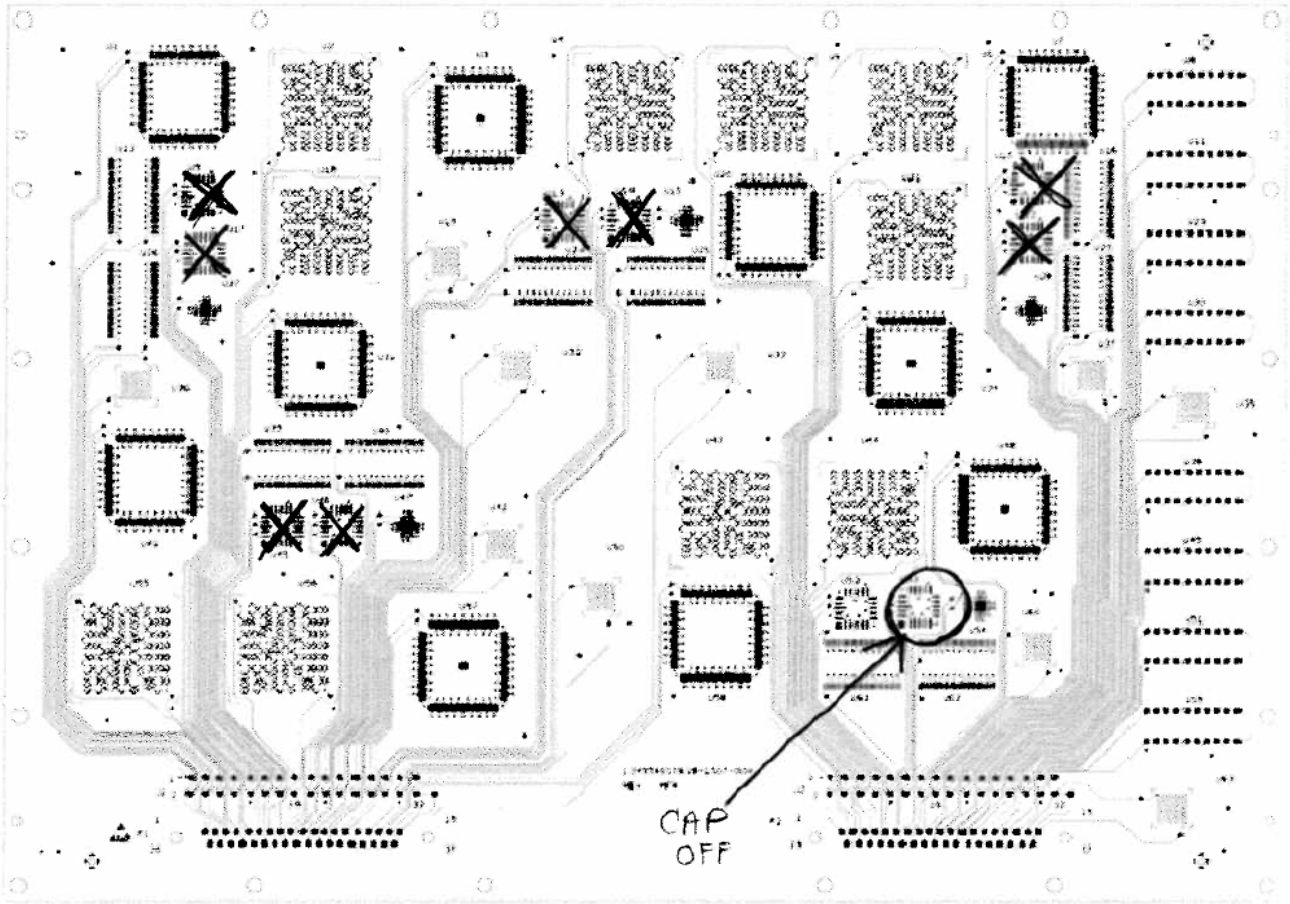
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/22/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U26	"	"	"
"	U39	"	"	"
"	U45	"	"	"
"	U46	"	"	"
"	U52	"	"	"
CRACKED INSULATION	PORTA - PIN1	BROWN WIRE SHOWING	"	"
WIRE PEELED	PORB - PIN1	BROWN WIRE EXPOSED FROM PEELING PADS	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 118
DATE	04/22/09
TIME	10:18 AM
INSPECTOR	CINTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	YES - ON POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



X = FELL OFF

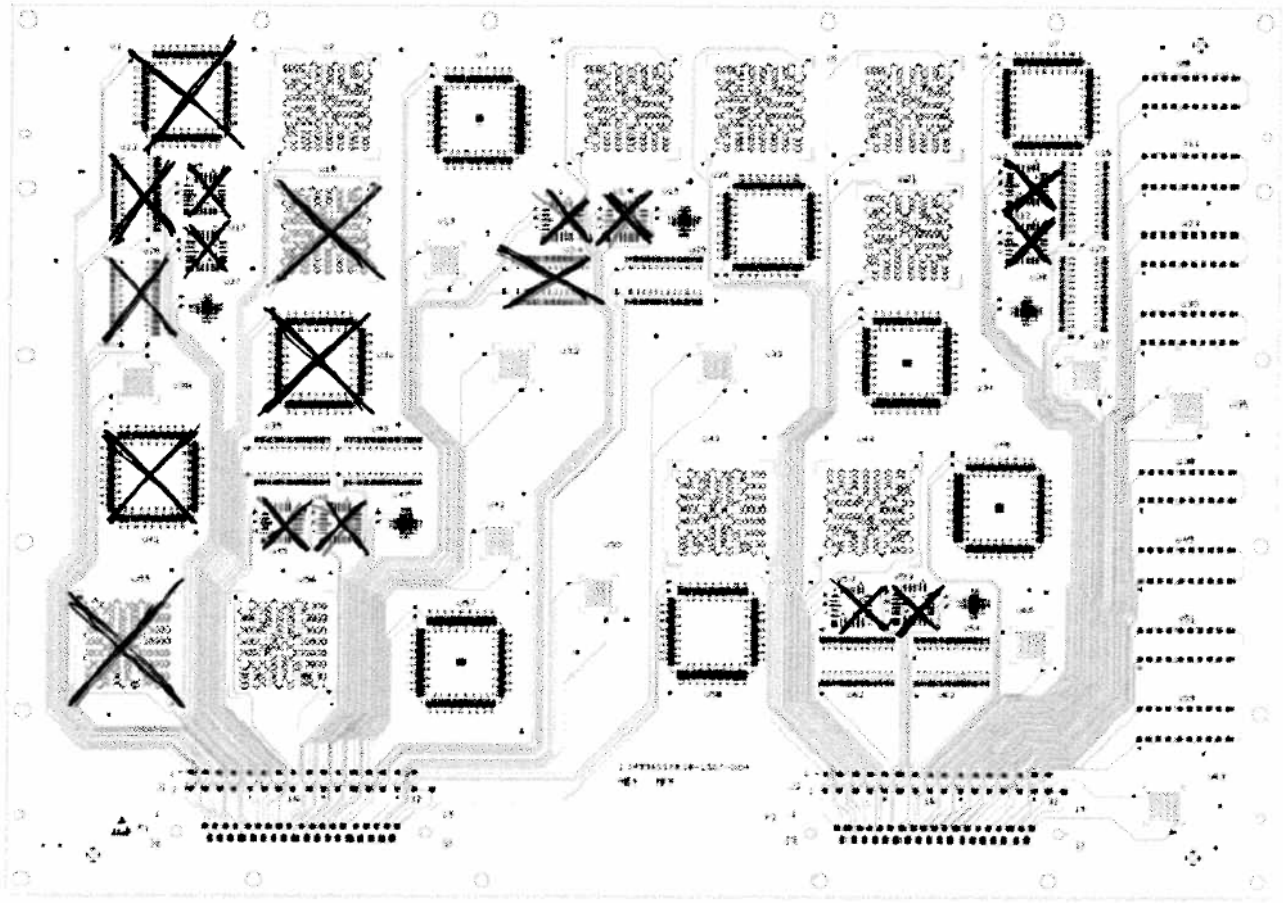
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELLOFF	U9	PHOTO	1049801	04/22/09
"	U17	"	"	"
"	U13	"	"	"
"	U14	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U45	"	"	"
"	U46	"	"	"
CAP OFF	U53	"	"	"
RIBBON STIFF	PORT A	"	"	"
EXPOSED WIRES	" "	FROM RIBBON STICKING - PHOTO	"	"
CRACKED INSULATION	" "	BLACK WIRE - PIN 10 - EXPOSED WIRE PHOTO	"	"
RIBBON STIFF	PORT B	PHOTO	"	"
WIRE EXPOSE	" "	PIN 37 - wire exposed - PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 119
DATE	04/22/09
TIME	10:47 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	
Missing parts?	
Corrosion?	YES - POINTS - PHOTO
Electrochemical migration of silver?	
Fillet lifting?	

DEFECT MAP



X= FELL OFF

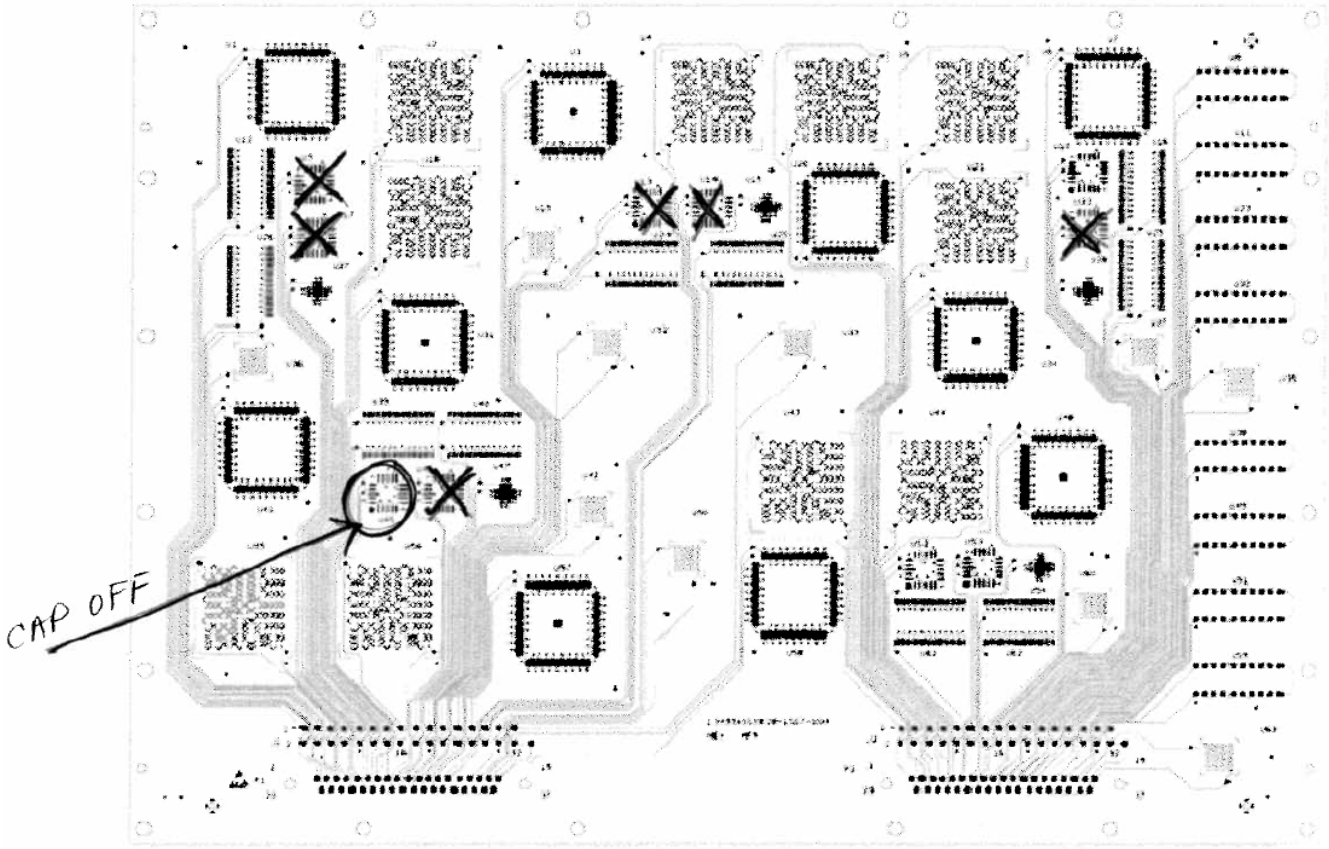
POST TEST INSPECTION CHECKLIST

DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U1	PHOTO - UP CLOSE	1049801	04/22/09
"	U12	" " "	"	"
"	U26	"	"	"
"	U9	"	"	"
"	U17	"	"	"
"	U18	"	"	"
"	U13	PHOTO	"	"
"	U14	"	"	"
"	U24	"	"	"
"	U10	"	"	"
"	U22	"	"	"
"	U31	"	"	"
"	U41	PHOTO - UP CLOSE	"	"
"	U55	" " "	"	"
"	U45	PHOTO	"	"
"	U46	"	"	"
"	U52	"	"	"
"	U53	"	"	"
EXPOSED WIRE	PORT A	PIN 1 - NOT BROKEN - PHOTO	"	"

POST TEST INSPECTION CHECKLIST

BOARD NUMBER	SN 120
DATE	04/22/09
TIME	9:45 AM
INSPECTOR	CYNTHIA GARCIA
CRITERIA	ANSI/J-STD-001, Class 3
VISUAL INSPECTION	
Changes in solder morphology?	NO
Missing parts?	YES - SEE BELOW (X)
Corrosion?	COLOR CHANGE TO POINTS - PHOTO
Electrochemical migration of silver?	NO
Fillet lifting?	NO

DEFECT MAP



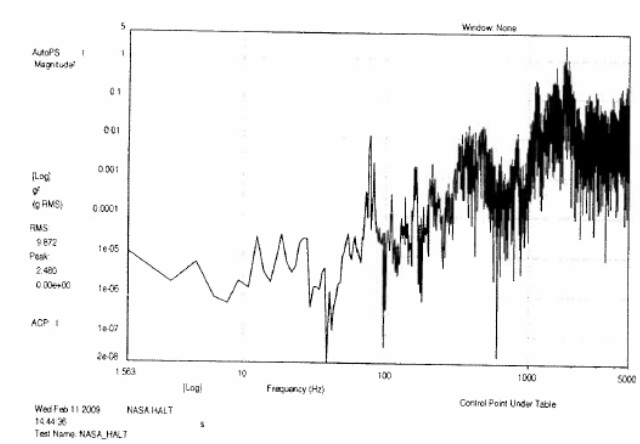
X = FELL OFF

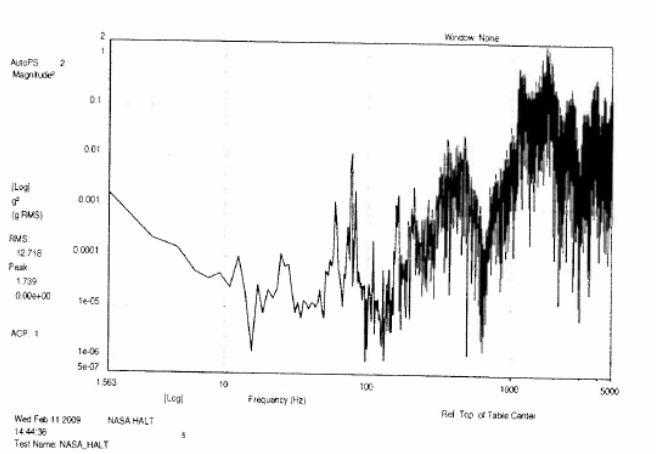
POST TEST INSPECTION CHECKLIST

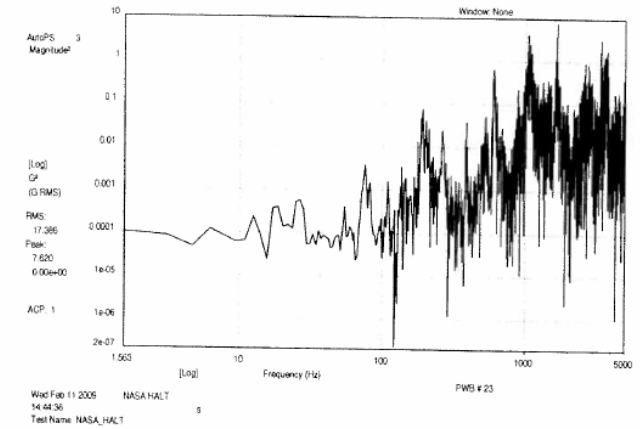
DEFECT	LOCATION	REWORK/PHOTO DOCUMENT/X-RAY/MICROSECTION	OPERATOR	DATE
FELL OFF	U9	PHOTO	1049801	04/22/09
"	U17	"	"	"
"	U13	" } UP CLOSE PHOTO	"	"
"	U14	"	"	"
"	U22	"	"	"
"	U46	"	"	"
CAP OFF	U45		"	"
EXPOSED WIRE	BROWN PORT A PIN 1	WIRE NOT BROKEN – PHOTO		
"	ORANGE PORT A PIN 3	" " " – "		
SLICE IN THE INSULATION	RED PORT A PIN 2	" " " OR EXPOSED MUCH		

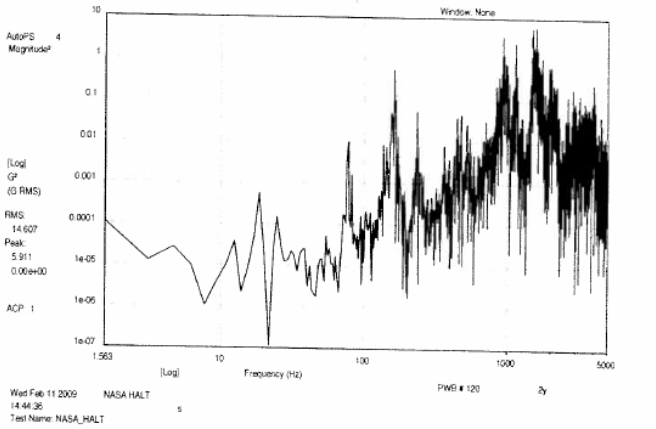
Appendix F: Vibration Profiles

10 g_{rms}

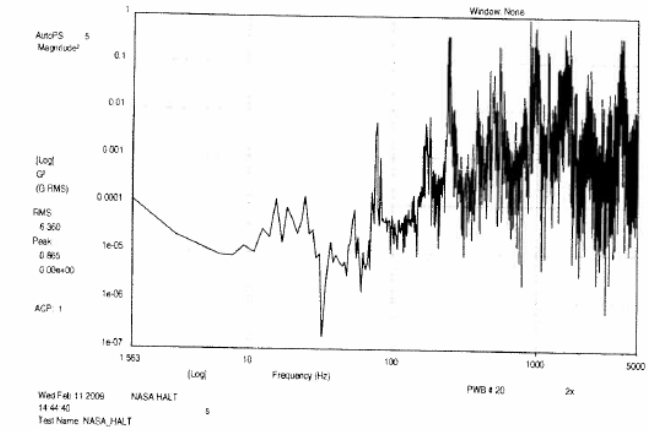


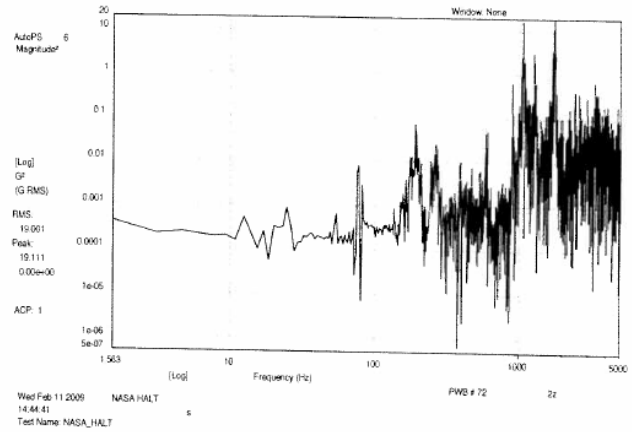


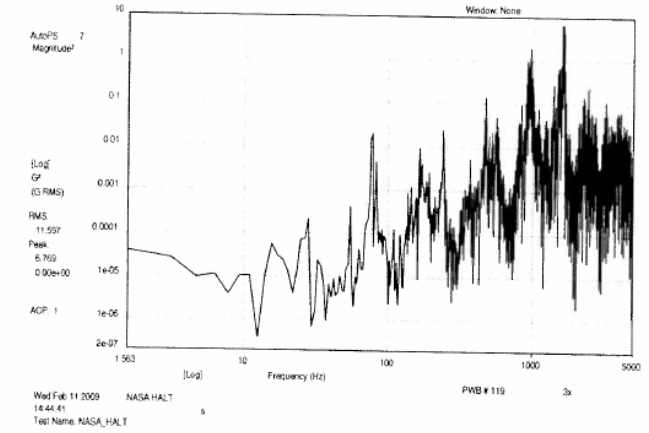


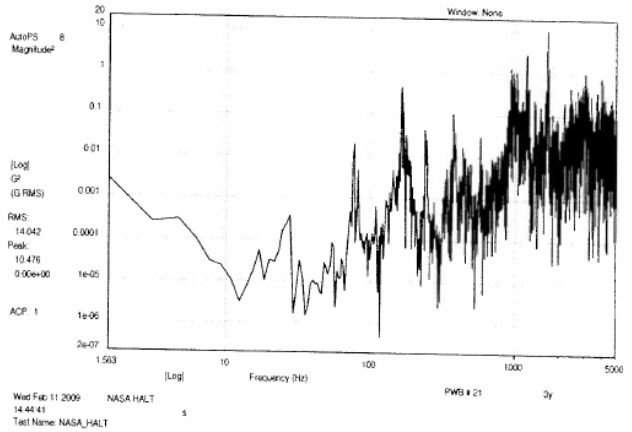


10 g_{rms}

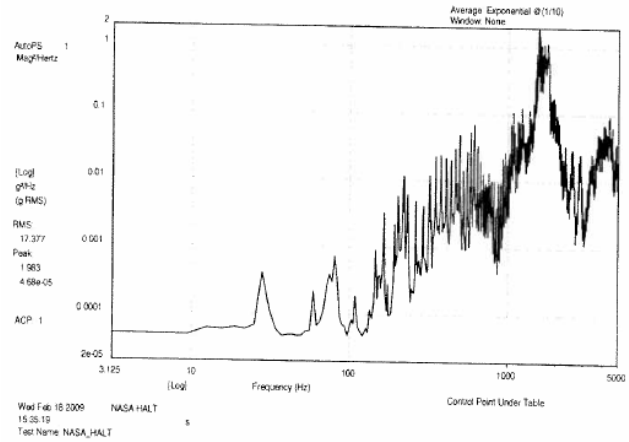

Window: None
AutoPS 5
Magnitude²
[Log]
G²
(G RMS)
RMS:
6.360
Peak
0.865
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 20
2x
Wed Feb 11 2009
14:44:40
Test Name: NASA_HALT

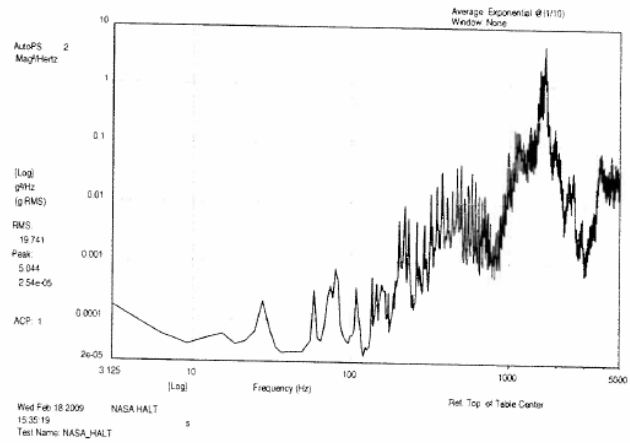

Window: None
AutoPS 6
Magnitude²
[Log]
G²
(G RMS)
RMS:
19.001
Peak:
19.111
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 72
2z
Wed Feb 11 2009
14:44:41
Test Name: NASA_HALT

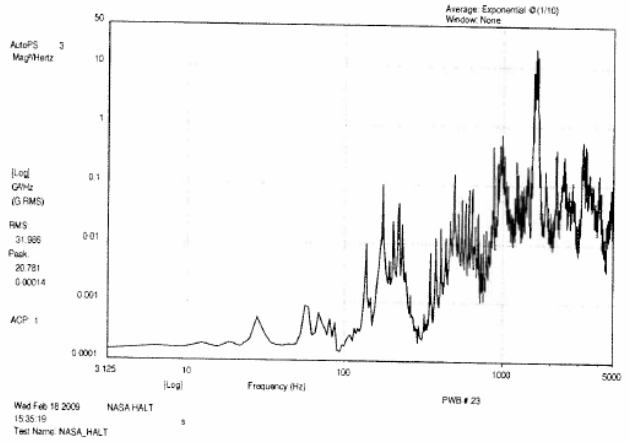

Window: None
AutoPS 7
Magnitude²
[Log]
G²
(G RMS)
RMS:
11.597
Peak
6.769
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 119
3x
Wed Feb 11 2009
14:44:41
Test Name: NASA_HALT

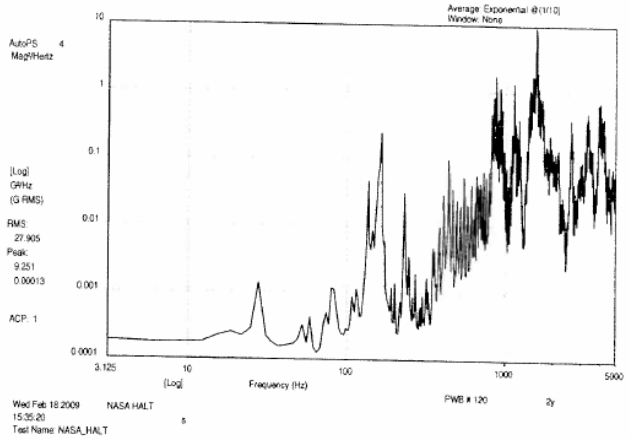

Window: None
AutoPS 8
Magnitude²
[Log]
G²
(G RMS)
RMS:
14.042
Peak:
10.476
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 21
3y
Wed Feb 11 2009
14:44:41
Test Name: NASA_HALT

15 g_{rms}

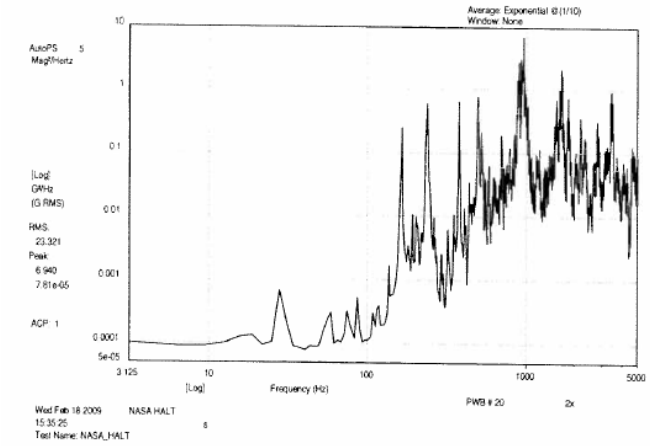

Average: Exponential Ø(1/10)
Window: None
AutoPS 1
Mag/Hertz
[Log]
gHz
(g RMS)
RMS:
17.377
Peak:
1.983
4.68e-05
ACP: 1
2
1
0.1
0.01
0.001
0.0001
2e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
Contact Point Under Table
Wed Feb 18 2009 NASA HALT
15:35:19
Test Name: NASA_HALT
s

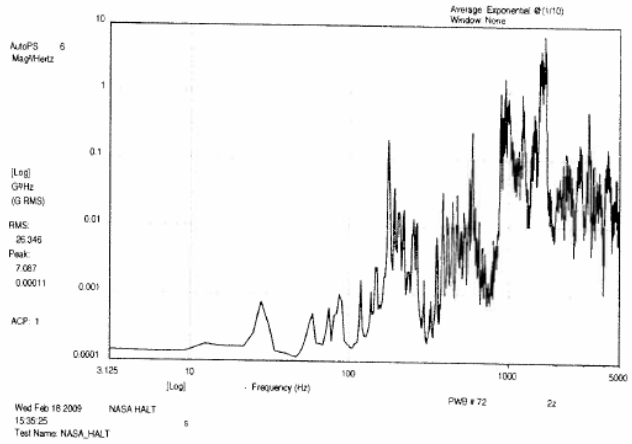

Average: Exponential Ø(1/10)
Window: None
AutoPS 2
Mag/Hertz
[Log]
gHz
(g RMS)
RMS:
19.741
Peak:
5.044
2.54e-05
ACP: 1
10
1
0.1
0.01
0.001
0.0001
2e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
Ref. Top of Table Center
Wed Feb 18 2009 NASA HALT
15:35:19
Test Name: NASA_HALT
s

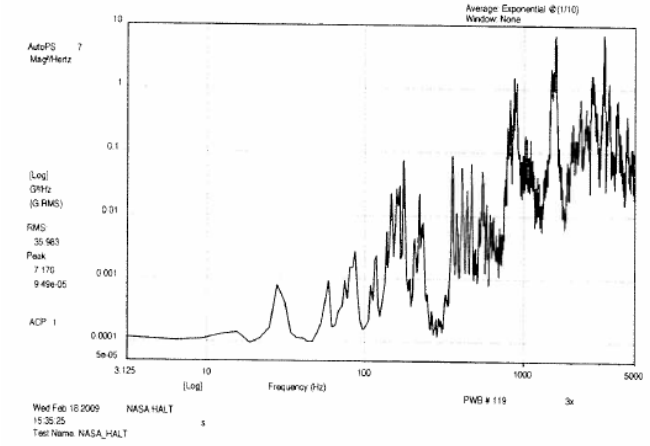

Average: Exponential Ø(1/10)
Window: None
AutoPS 3
Mag/Hertz
[Log]
GHz
(G RMS)
RMS
31.986
Peak
20.781
0.00014
ACP: 1
50
10
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 23
Wed Feb 18 2009 NASA HALT
15:35:19
Test Name: NASA_HALT
s

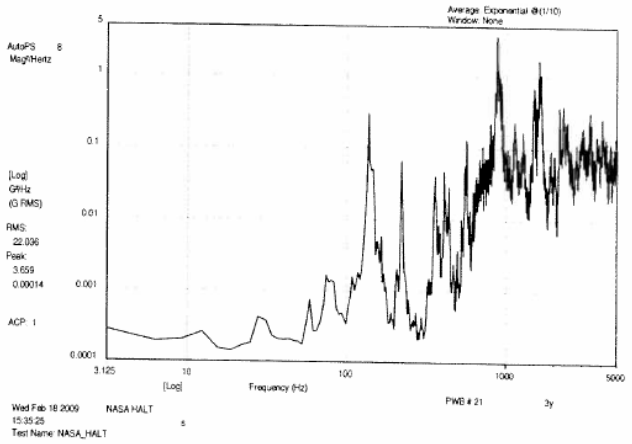

Average: Exponential Ø(1/10)
Window: None
AutoPS 4
Mag/Hertz
[Log]
GHz
(G RMS)
RMS
27.905
Peak:
9.251
0.00013
ACP: 1
10
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 120
Wed Feb 18 2009 NASA HALT
15:35:20
Test Name: NASA_HALT
s

15 g_{rms}

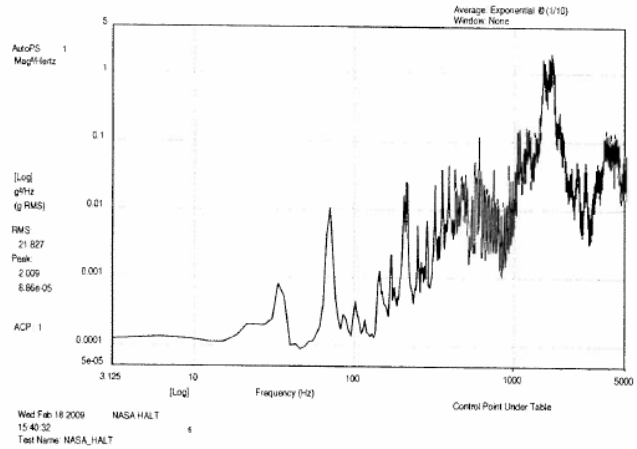

Average: Exponential @(1/10)
Window: None
AutoPS 5
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
23.321
Peak
6.940
7.81e-05
ACP: 1
10
1
0.1
0.01
0.001
0.0001
5e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 20
2x
Wed Feb 18 2009
NASA HALT
15:35:25
s
Test Name: NASA_HALT

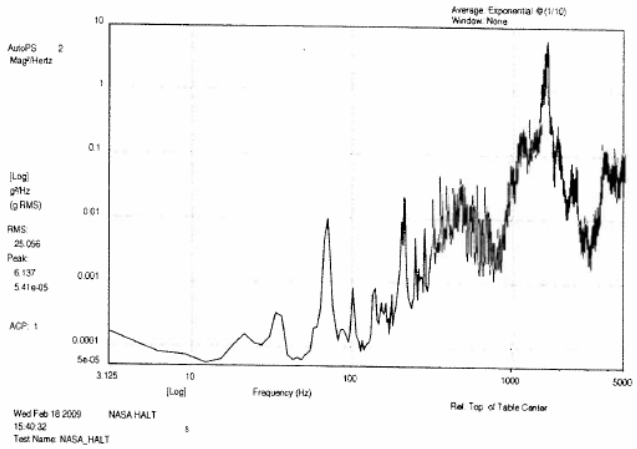

Average: Exponential @(1/10)
Window: None
AutoPS 6
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
26.346
Peak:
7.067
0.00011
ACP: 1
10
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 72
2z
Wed Feb 18 2009
NASA HALT
15:35:25
s
Test Name: NASA_HALT

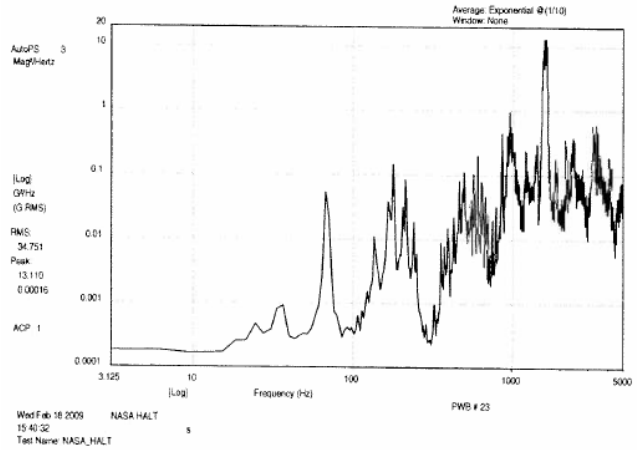

Average: Exponential @(1/10)
Window: None
AutoPS 7
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS
35.583
Peak
7.176
9.49e-05
ACP: 1
10
1
0.1
0.01
0.001
0.0001
5e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 119
3x
Wed Feb 18 2009
NASA HALT
15:35:25
s
Test Name: NASA_HALT

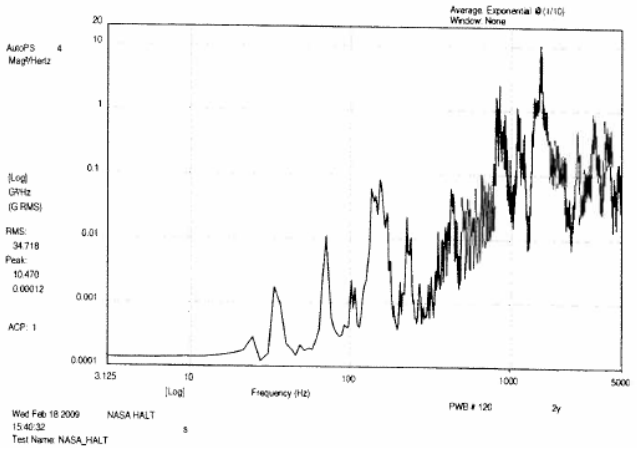

Average: Exponential @(1/10)
Window: None
AutoPS 8
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
22.036
Peak:
3.659
0.00014
ACP: 1
5
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 21
3y
Wed Feb 18 2009
NASA HALT
15:35:25
s
Test Name: NASA_HALT

20 g_{rms}

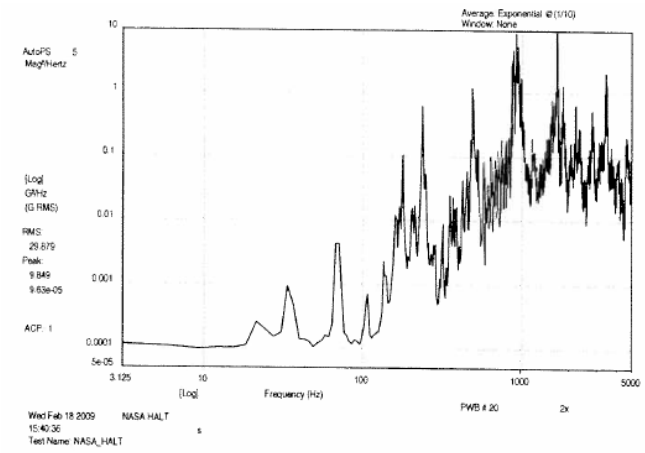

Average Exponential Φ(1/10)
Window None
AutoPS 1
Mag²/Hertz
[Log]
g²/Hz
(g RMS)
RMS
21.827
Peak
2.009
8.66e-05
ACP 1
5
1
0.1
0.01
0.001
0.0001
5e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
Control Point Under Table
Wed Feb 18 2009
NASA HALT
15:40:32
s
Test Name: NASA_HALT

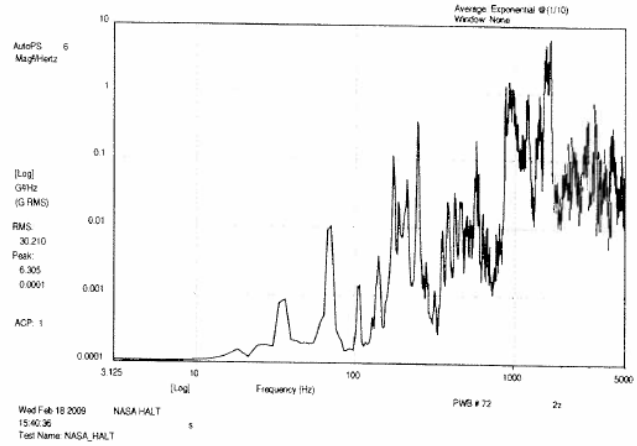

Average Exponential Φ(1/10)
Window None
AutoPS 2
Mag²/Hertz
[Log]
g²/Hz
(g RMS)
RMS:
25.056
Peak:
6.137
5.41e-05
ACP: 1
10
1
0.1
0.01
0.001
0.0001
5e-05
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
Ref. Top of Table Center
Wed Feb 18 2009
NASA HALT
15:40:32
s
Test Name: NASA_HALT

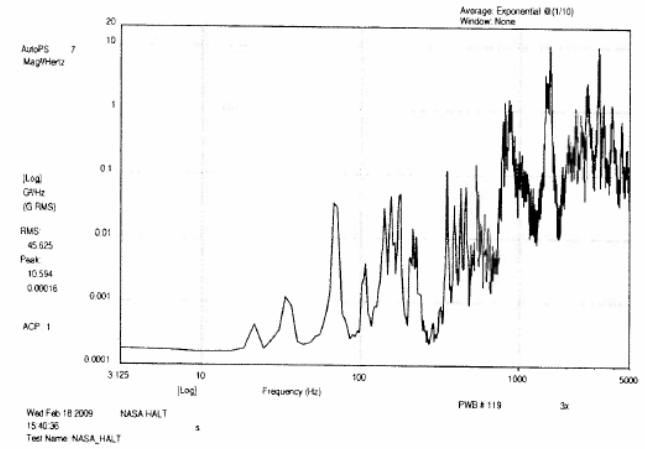

Average Exponential Φ(1/10)
Window None
AutoPS 3
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
34.751
Peak:
13.110
0.00016
ACP 1
20
10
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 23
Wed Feb 18 2009
NASA HALT
15:40:32
s
Test Name: NASA_HALT

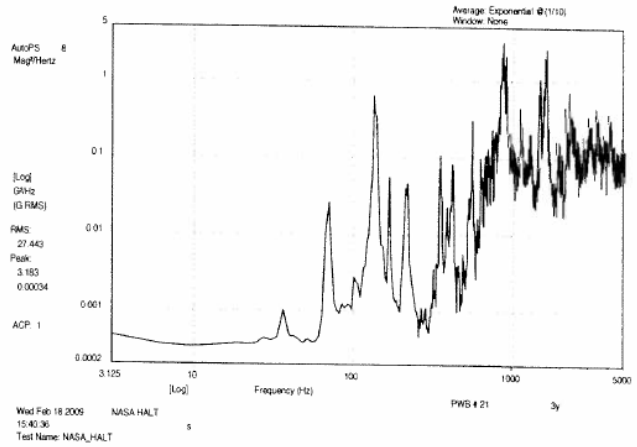

Average Exponential Φ(1/10)
Window None
AutoPS 4
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
34.718
Peak:
10.470
0.00012
ACP: 1
20
10
1
0.1
0.01
0.001
0.0001
3.125
10
100
1000
5000
[Log]
Frequency (Hz)
PWB # 126
2y
Wed Feb 18 2009
NASA HALT
15:40:32
s
Test Name: NASA_HALT

20 g_{rms}

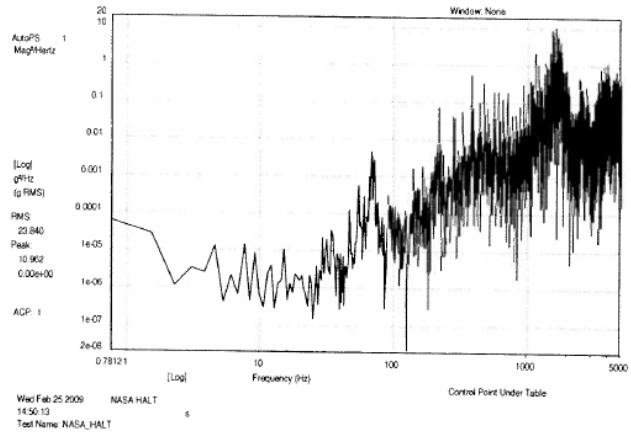

Average: Exponential @(1/10)
Window: None
AutoPS 5
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
29.879
Peak:
9.849
9.63e-05
ACP: 1
Frequency (Hz)
PWB # 20
2x
Wed Feb 18 2009
NASA HALT
15:40:36
Test Name: NASA_HALT

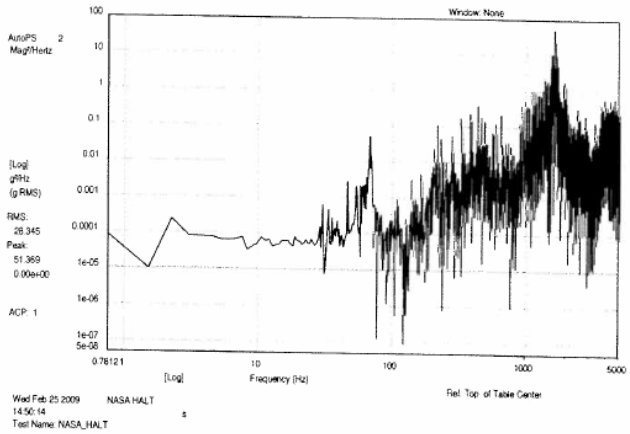

Average: Exponential @(1/10)
Window: None
AutoPS 6
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
30.210
Peak:
6.305
0.0001
ACP: 1
Frequency (Hz)
PWB # 72
2z
Wed Feb 18 2009
NASA HALT
15:40:36
Test Name: NASA_HALT

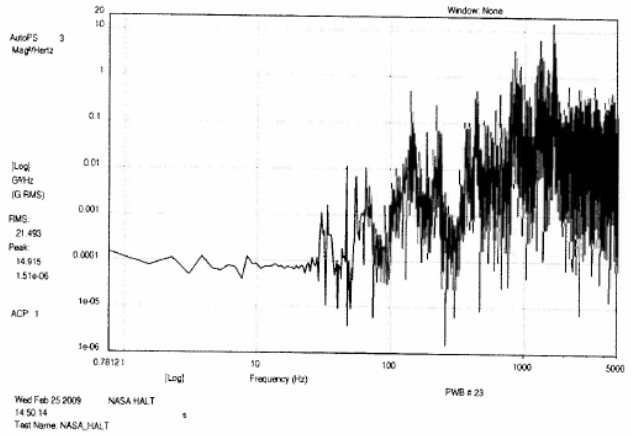

Average: Exponential @(1/10)
Window: None
AutoPS 7
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
45.625
Peak:
10.594
0.00016
ACP: 1
Frequency (Hz)
PWB # 119
3x
Wed Feb 18 2009
NASA HALT
15:40:36
Test Name: NASA_HALT

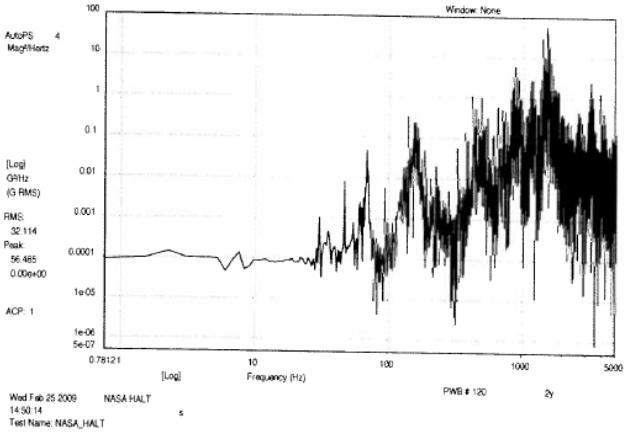

Average: Exponential @(1/10)
Window: None
AutoPS 8
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
27.443
Peak:
3.183
0.00034
ACP: 1
Frequency (Hz)
PWB # 21
3y
Wed Feb 18 2009
NASA HALT
15:40:36
Test Name: NASA_HALT

25 g_{rms}

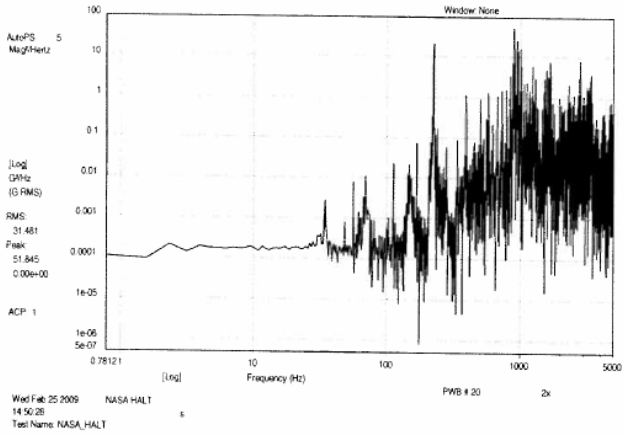

Window: None
AutoPS 1
Mag/Hertz
[Log]
g/Hz
(g RMS)
RMS:
23.840
Peak:
10.962
0.00e+00
ACP: 1
Frequency (Hz)
Control Point Under Table
Wed Feb 25 2009 NASA HALT
14:50:13
Test Name: NASA_HALT

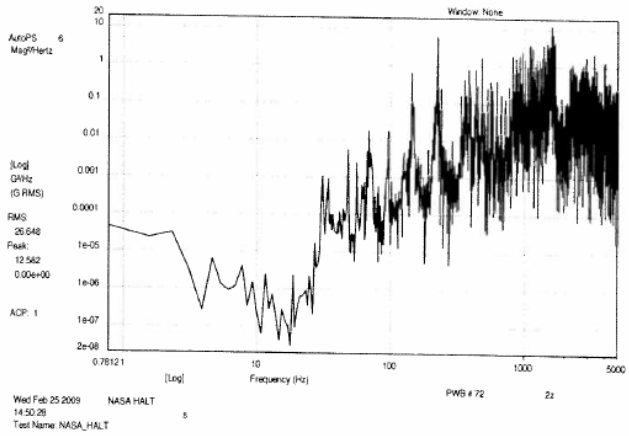

Window: None
AutoPS 2
Mag/Hertz
[Log]
g/Hz
(g RMS)
RMS:
28.345
Peak:
51.369
0.00e+00
ACP: 1
Frequency (Hz)
Rel. Top of Table Center
Wed Feb 25 2009 NASA HALT
14:50:14
Test Name: NASA_HALT

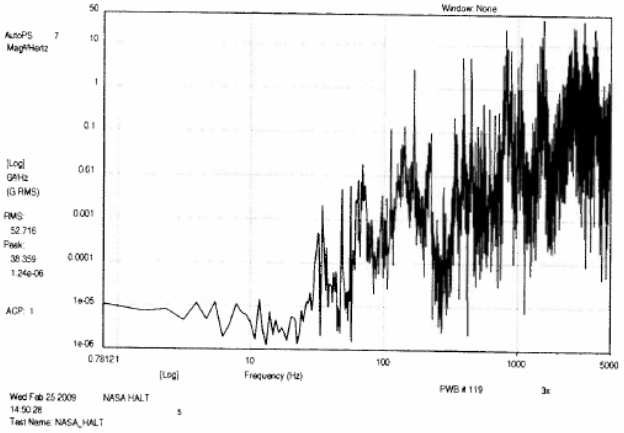

Window: None
AutoPS 3
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
21.493
Peak:
14.915
1.51e-06
ACP: 1
Frequency (Hz)
PWB # 23
Wed Feb 25 2009 NASA HALT
14:50:14
Test Name: NASA_HALT

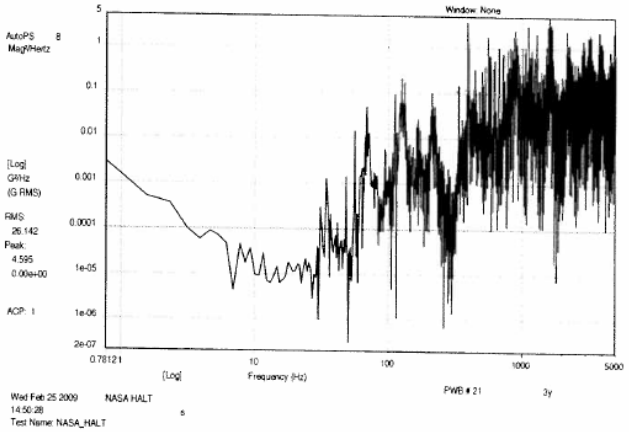

Window: None
AutoPS 4
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
32.114
Peak:
56.485
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 120
2y
Wed Feb 25 2009 NASA HALT
14:50:14
Test Name: NASA_HALT

25 g_{rms}

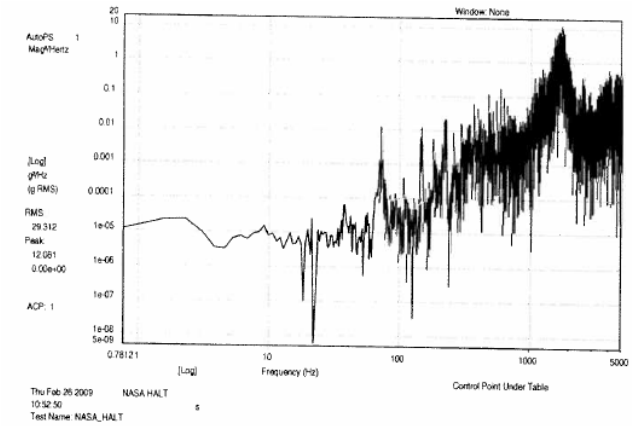

Window: None
AutoPS 5
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
31.481
Peak:
51.845
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 20
2x
Wed Feb 25 2009 NASA HALT
14:50:28
Test Name: NASA_HALT

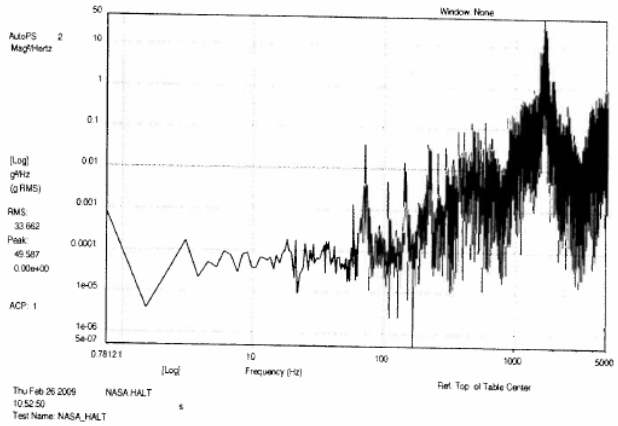

Window: None
AutoPS 6
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
26.648
Peak:
12.562
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 72
2z
Wed Feb 25 2009 NASA HALT
14:50:28
Test Name: NASA_HALT

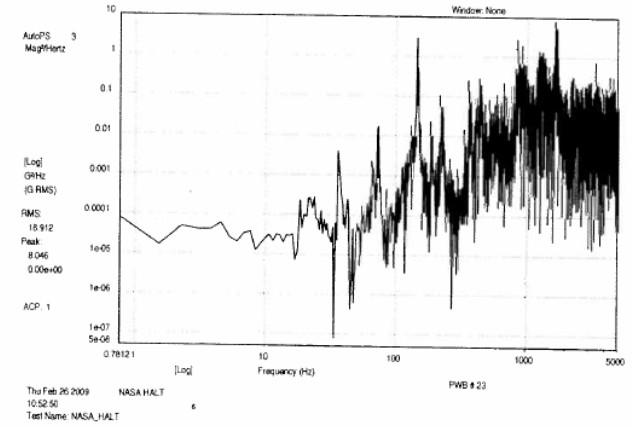

Window: None
AutoPS 7
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
52.716
Peak:
38.359
1.24e-06
ACP: 1
Frequency (Hz)
PWB # 119
3x
Wed Feb 25 2009 NASA HALT
14:50:28
Test Name: NASA_HALT

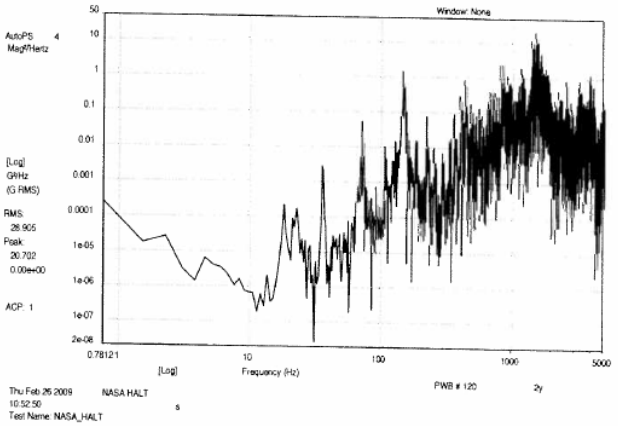

Window: None
AutoPS 8
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
26.142
Peak:
4.595
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 21
3y
Wed Feb 25 2009 NASA HALT
14:50:28
Test Name: NASA_HALT

30 g_{rms}

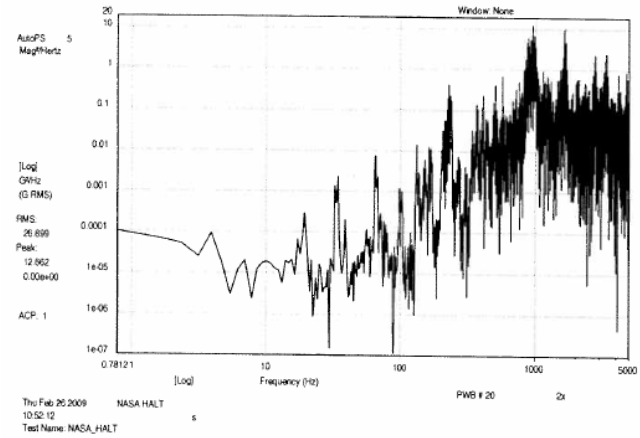

Window: None
AutoPS 1
Mag/Hertz
[Log]
g/Hz
(g RMS)
RMS:
29.312
Peak:
12.081
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
Control Point Under Table
Thu Feb 26 2009
NASA HALT
10:52:50
Test Name: NASA_HALT

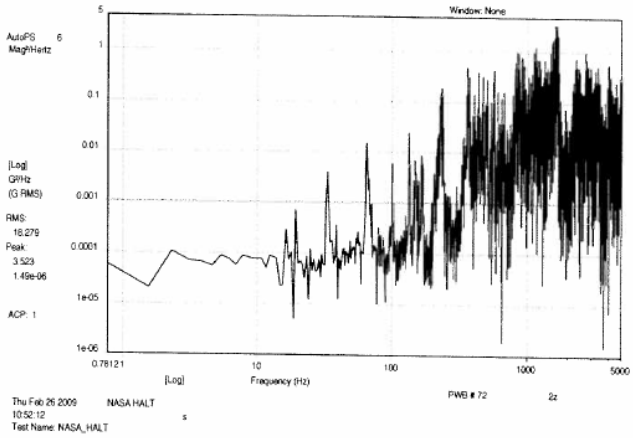

Window: None
AutoPS 2
Mag/Hertz
[Log]
g/Hz
(g RMS)
RMS:
33.662
Peak:
49.587
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
Ref. Top of Table Center
Thu Feb 26 2009
NASA HALT
10:52:50
Test Name: NASA_HALT

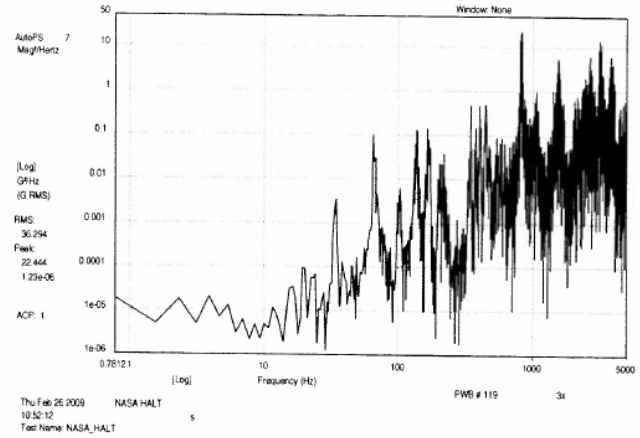

Window: None
AutoPS 3
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
18.912
Peak:
8.046
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
PWB # 23
Thu Feb 26 2009
NASA HALT
10:52:50
Test Name: NASA_HALT

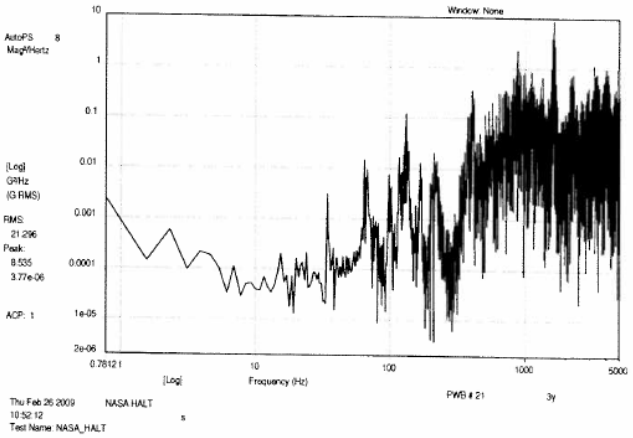

Window: None
AutoPS 4
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
28.905
Peak:
20.702
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
PWB # 120
Thu Feb 26 2009
NASA HALT
10:52:50
Test Name: NASA_HALT

30 g_{rms}

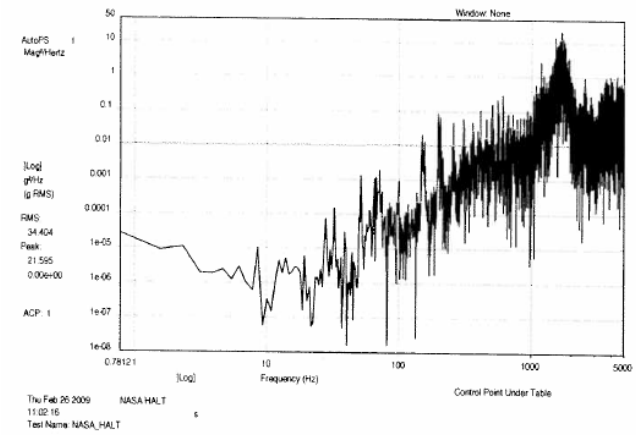

Window: None
AutoPS 5
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
26.899
Peak:
12.862
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 20
2x
Thu Feb 26 2009
10:52:12
NASA HALT
Test Name: NASA_HALT

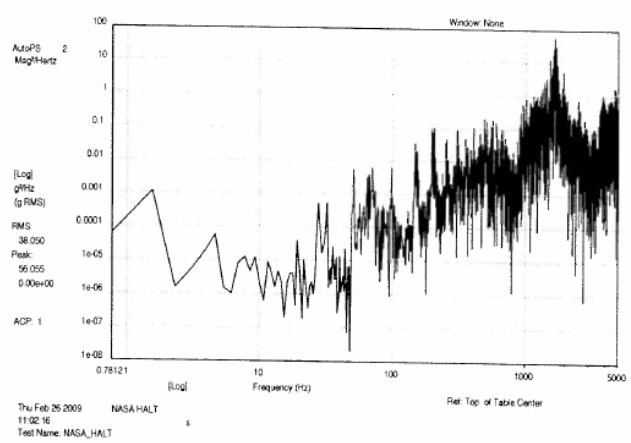

Window: None
AutoPS 6
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
18.279
Peak:
3.523
1.49e-06
ACP: 1
Frequency (Hz)
PWB # 72
2z
Thu Feb 26 2009
10:52:12
NASA HALT
Test Name: NASA_HALT

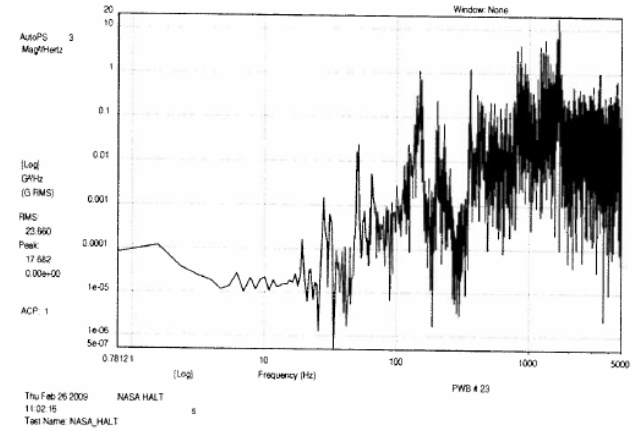

Window: None
AutoPS 7
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
36.294
Peak:
22.444
1.23e-06
ACP: 1
Frequency (Hz)
PWB # 119
3x
Thu Feb 26 2009
10:52:12
NASA HALT
Test Name: NASA_HALT

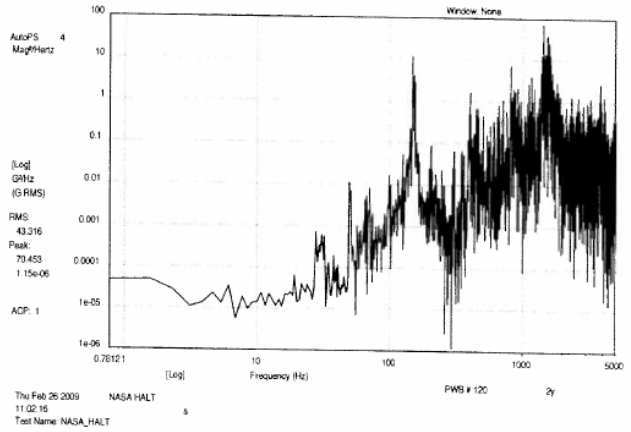

Window: None
AutoPS 8
Mag/Hertz
[Log]
G/Hz
(G RMS)
RMS:
21.296
Peak:
8.535
3.77e-06
ACP: 1
Frequency (Hz)
PWB # 21
3y
Thu Feb 26 2009
10:52:12
NASA HALT
Test Name: NASA_HALT

35 g_{rms}

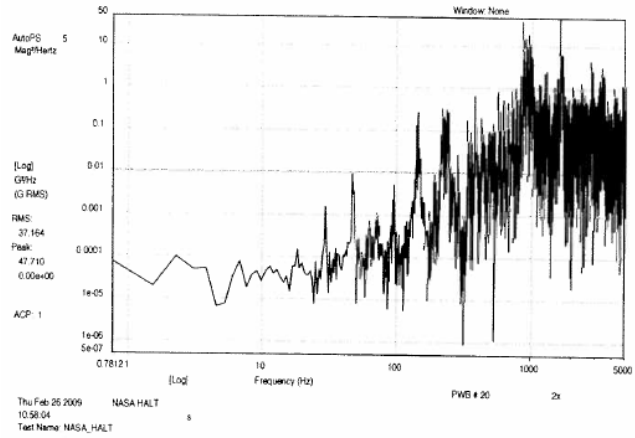

Window: None
AutoPS 1
Mag/f/Hertz
[Log]
g/rHz
(g RMS)
RMS:
34.404
Peak:
21.595
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
Control Point Under Table
Thu Feb 26 2009 NASA HALT
11:02:16
Test Name: NASA_HALT

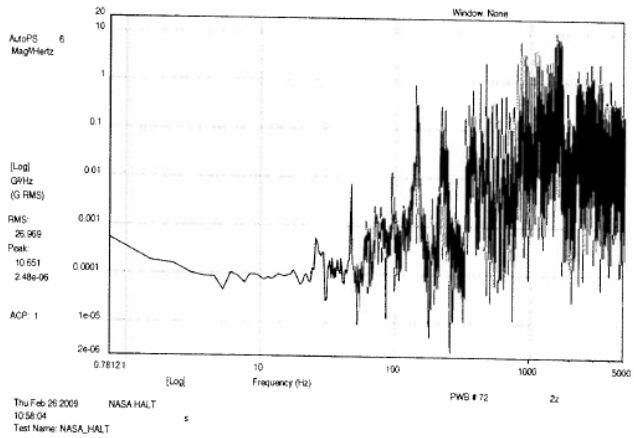

Window: None
AutoPS 2
Mag/f/Hertz
[Log]
g/rHz
(g RMS)
RMS:
38.050
Peak:
56.055
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
Ref: Top of Table Center
Thu Feb 26 2009 NASA HALT
11:02:16
Test Name: NASA_HALT

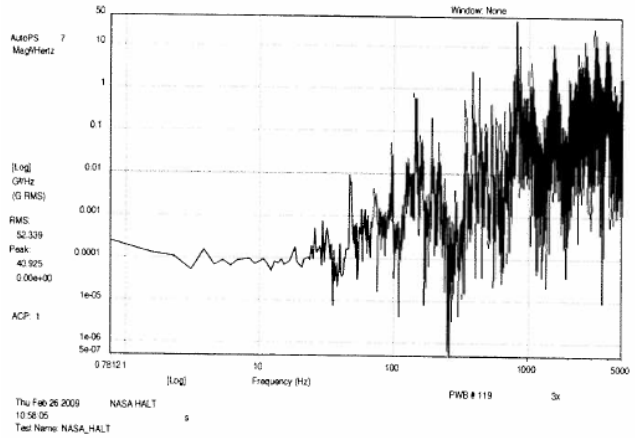

Window: None
AutoPS 3
Mag/f/Hertz
[Log]
G/rHz
(G RMS)
RMS:
23.660
Peak:
17.682
0.00e+00
ACP: 1
[Log]
Frequency (Hz)
PWB # 23
Thu Feb 26 2009 NASA HALT
11:02:16
Test Name: NASA_HALT

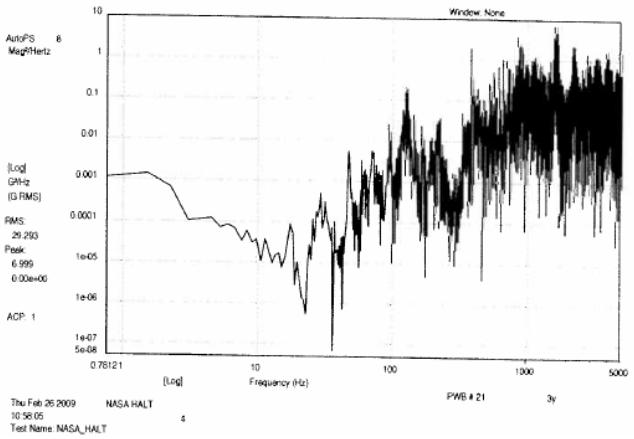

Window: None
AutoPS 4
Mag/f/Hertz
[Log]
G/rHz
(G RMS)
RMS:
43.316
Peak:
70.453
1.15e-06
ACP: 1
[Log]
Frequency (Hz)
PWB # 120
Thu Feb 26 2009 NASA HALT
11:02:16
Test Name: NASA_HALT

35 g_{rms}

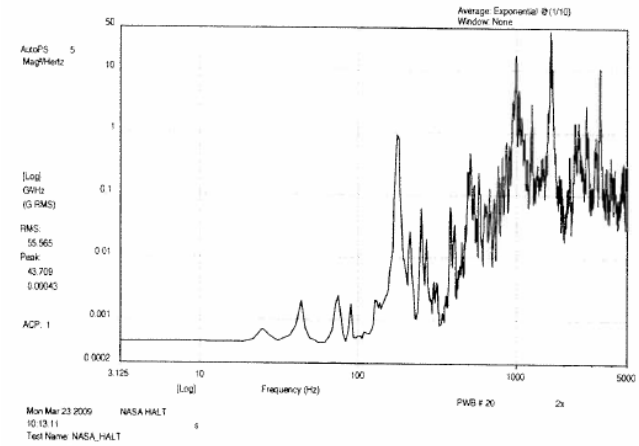

Window: None
AutoPS 5
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
37.164
Peak:
47.710
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 20
2x
Thu Feb 26 2009
NASA HALT
10:58:04
Test Name: NASA_HALT

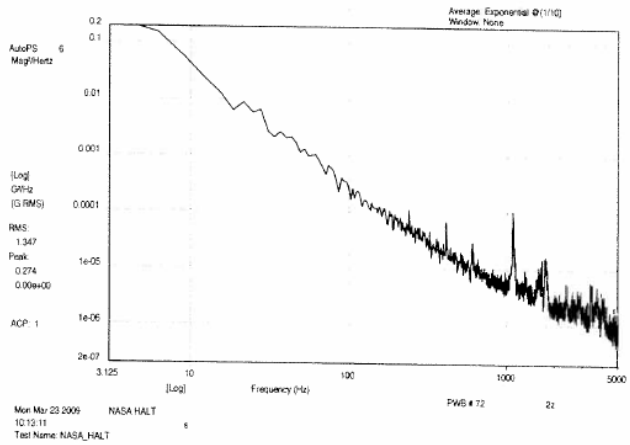

Window: None
AutoPS 6
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
26.969
Peak:
10.651
2.48e-06
ACP: 1
Frequency (Hz)
PWB # 72
2z
Thu Feb 26 2009
NASA HALT
10:58:04
Test Name: NASA_HALT

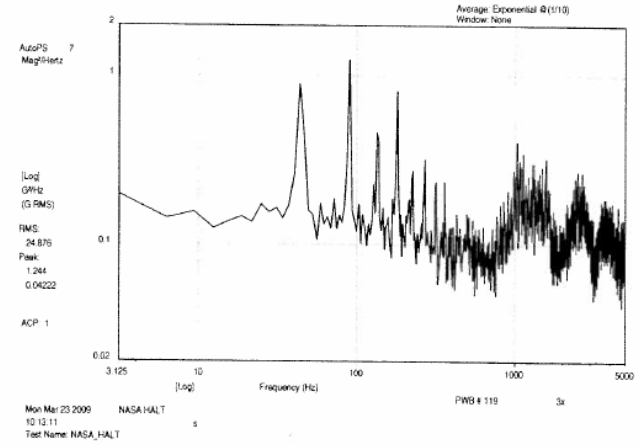

Window: None
AutoPS 7
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
52.339
Peak:
40.925
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 119
3x
Thu Feb 26 2009
NASA HALT
10:58:05
Test Name: NASA_HALT

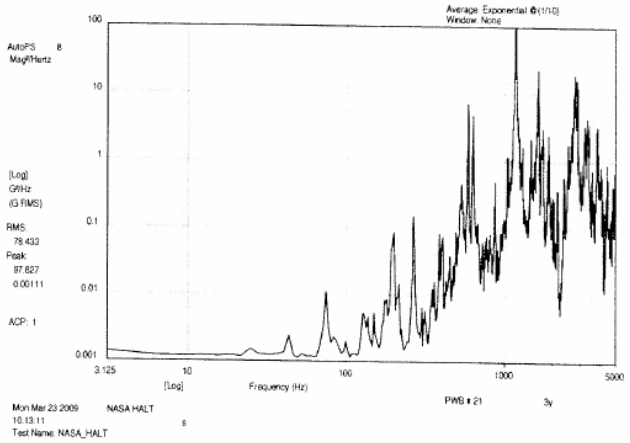

Window: None
AutoPS 8
Mag²/Hertz
[Log]
G²/Hz
(G RMS)
RMS:
29.293
Peak:
6.999
0.00e+00
ACP: 1
Frequency (Hz)
PWB # 21
3y
Thu Feb 26 2009
NASA HALT
10:58:05
Test Name: NASA_HALT

40 g_{rms}[4]



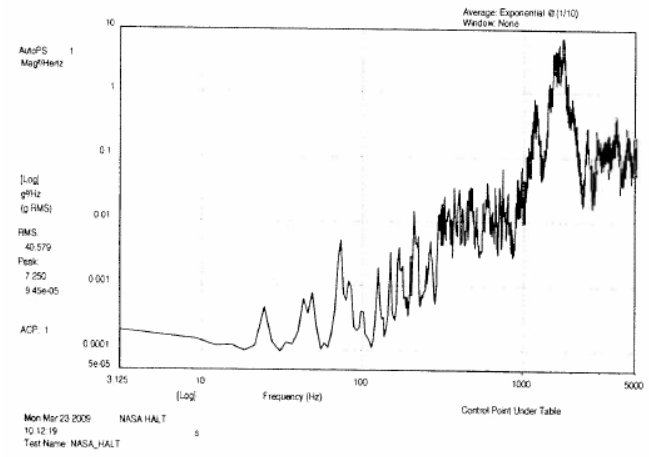


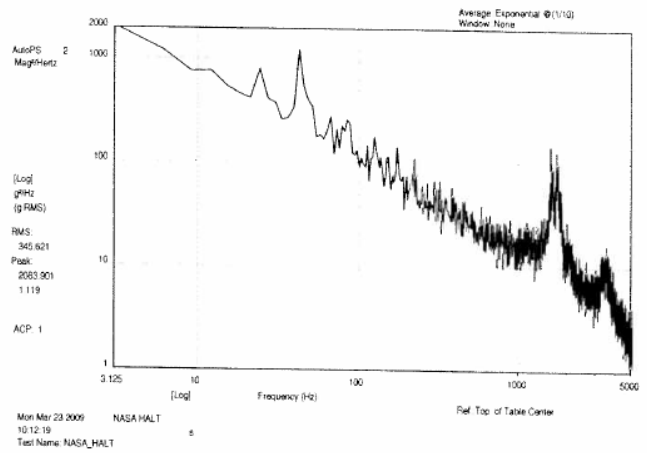


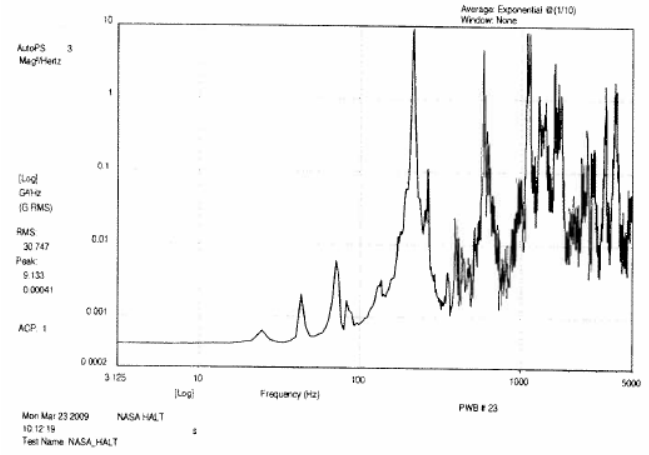


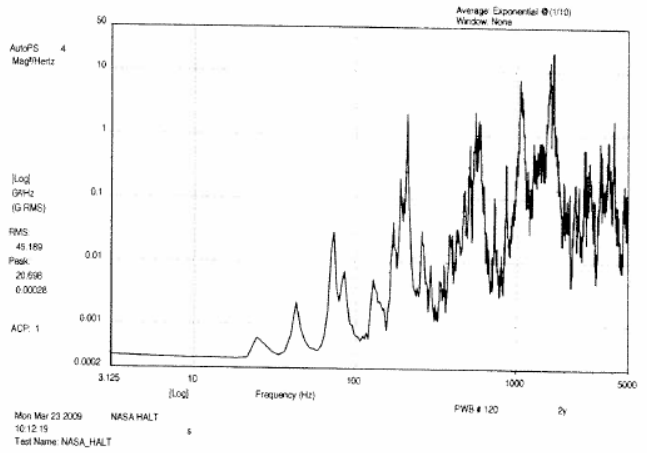
4 Accelerometer in location "PWB #72" came loose during testing and recorded a signal.

40 g_{rms}[5]



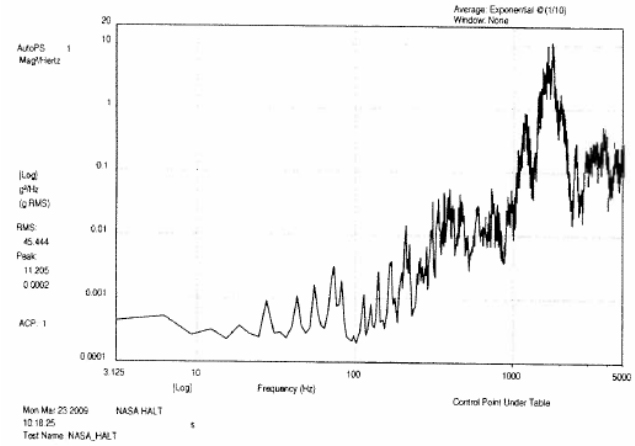


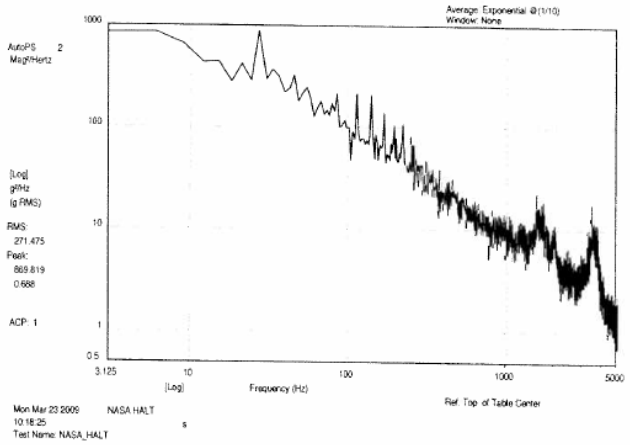


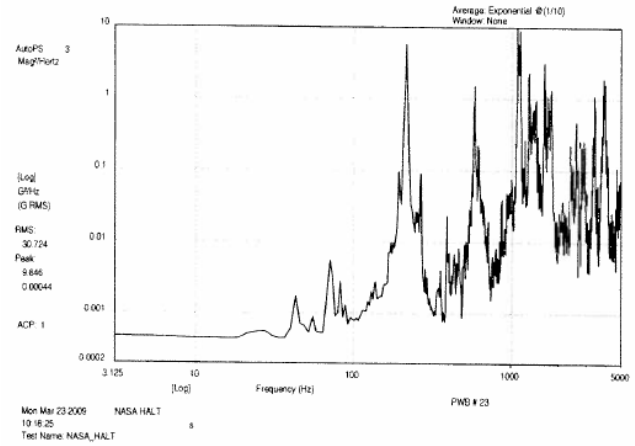


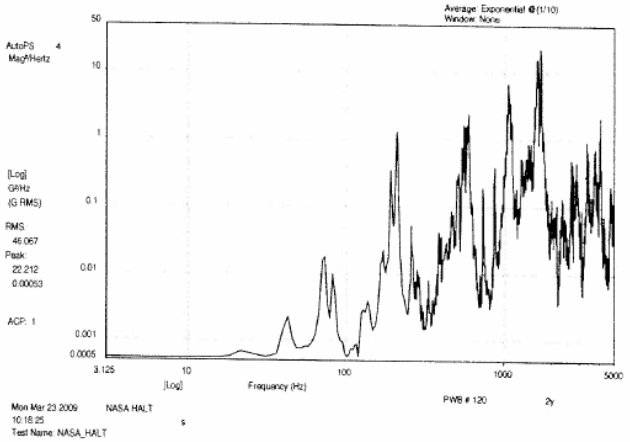
[5] Accelerometer in location "Top of Table Center" came loose during testing and recorded a signal.

45 g_{rms}[6]



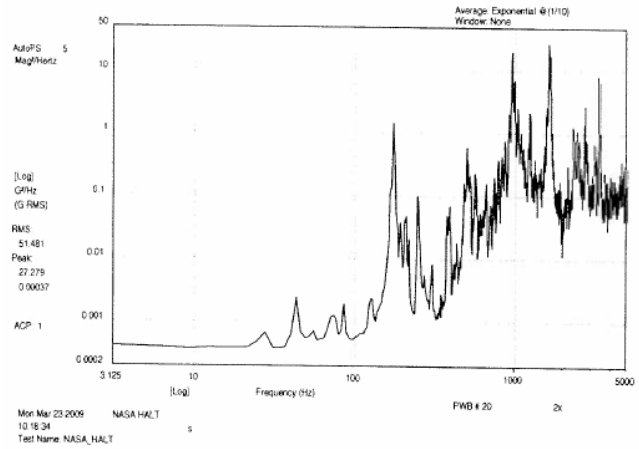


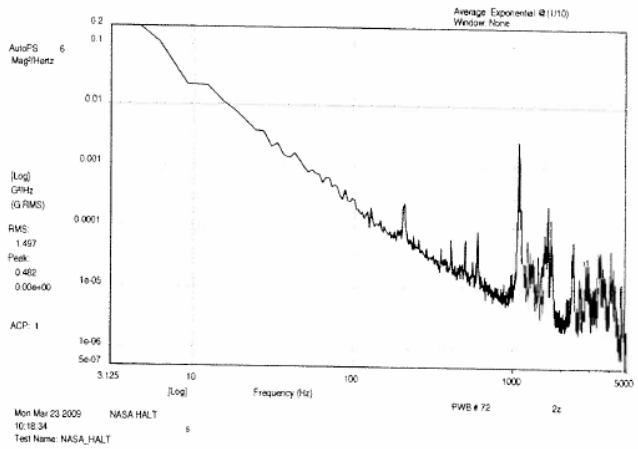


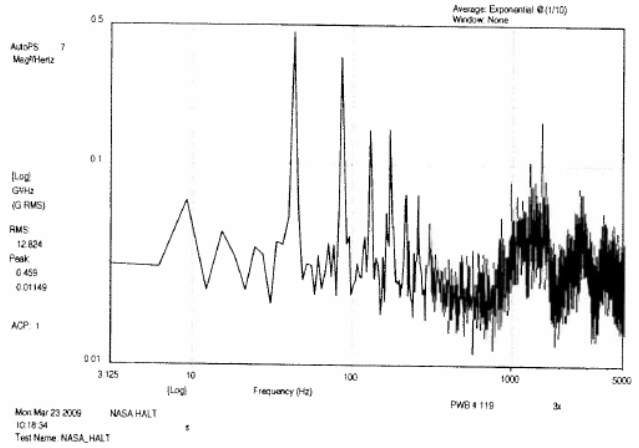


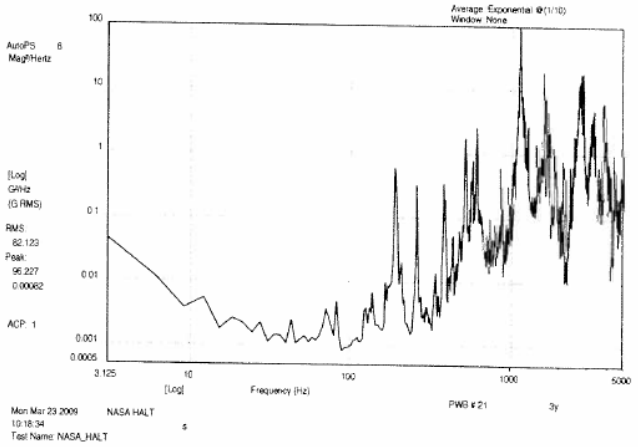
[6] Accelerometer in location "Top of Table Center" came loose during testing and recorded a signal.

45 g_{rms}[7]



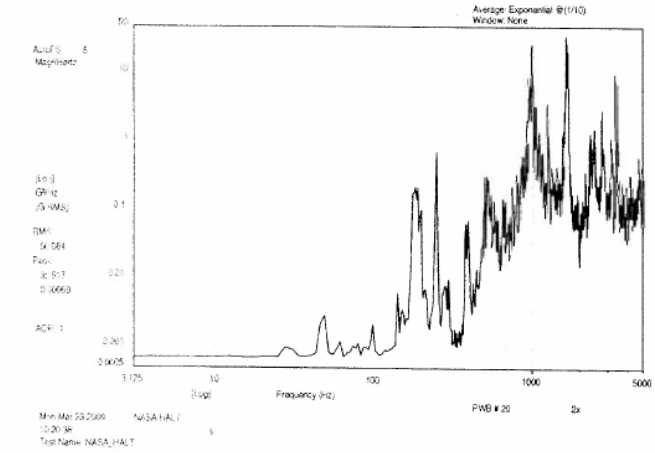


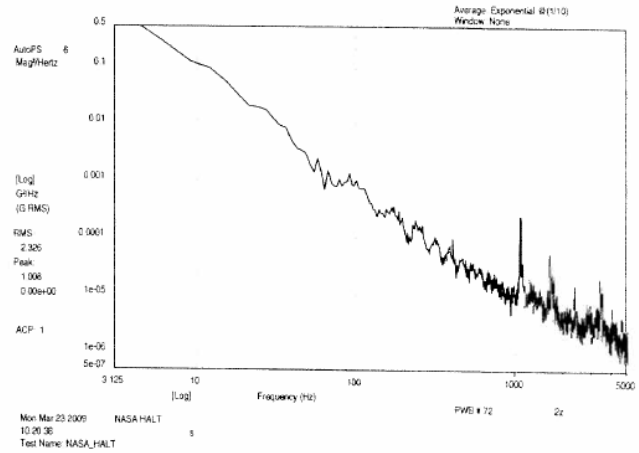


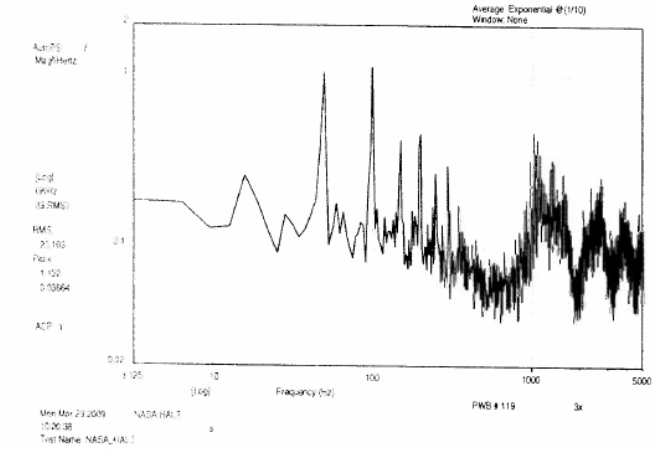


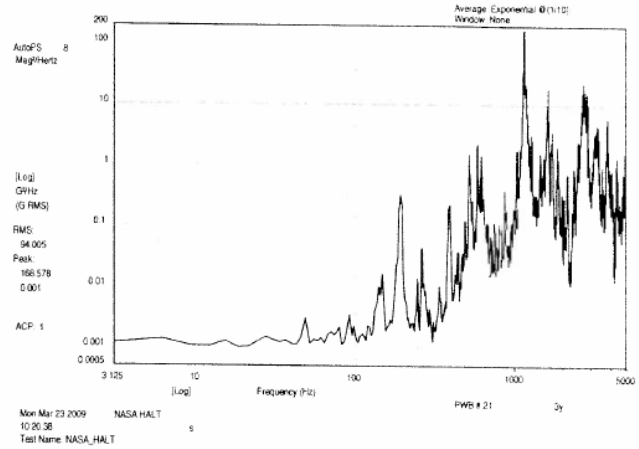
[7] Accelerometer in location "PWB #72" came loose during testing and recorded a signal.

50 g_{rms}[8]



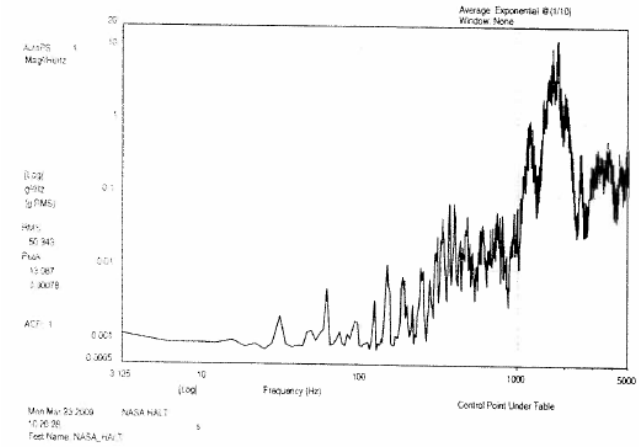


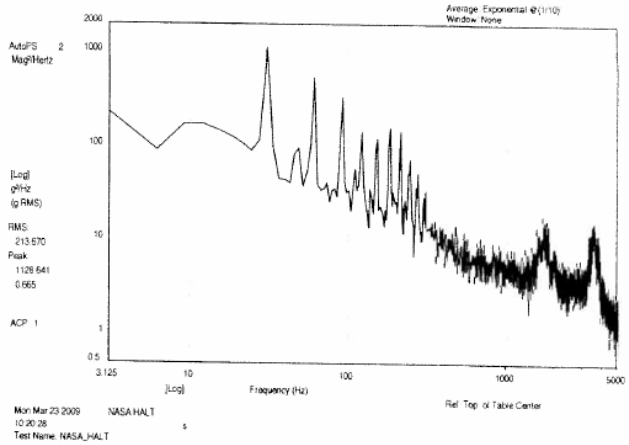


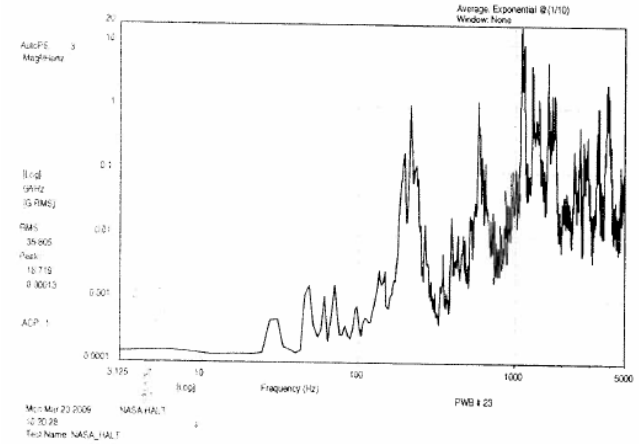


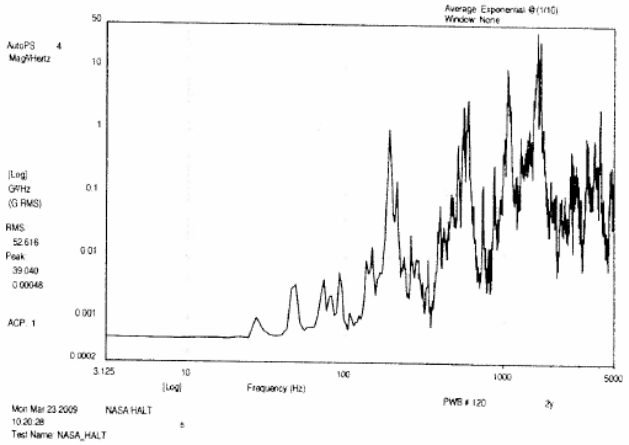
[8] Accelerometer in location "PWB #72" came loose during testing and recorded a signal.

50 g_{rms}[9]



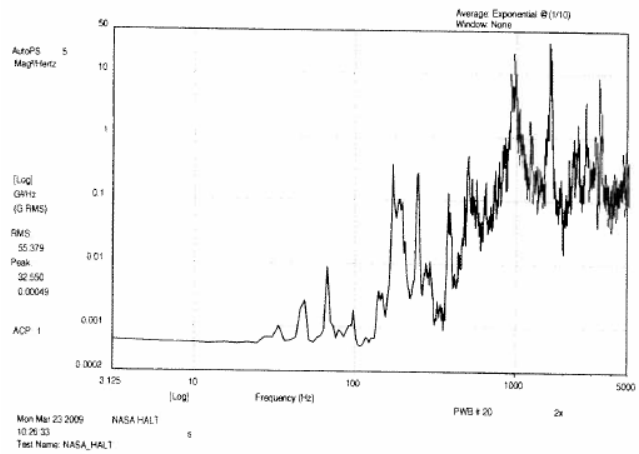


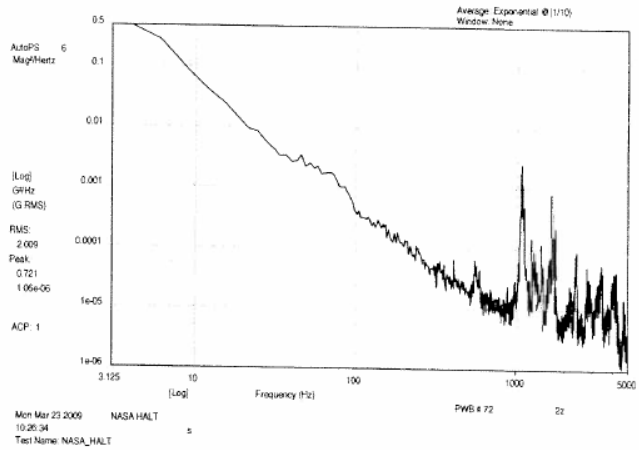


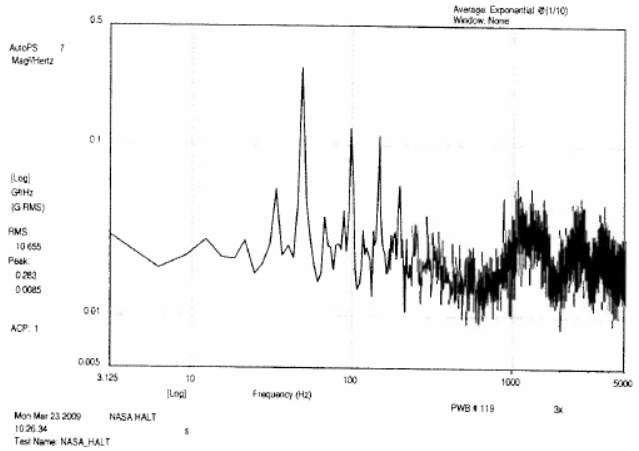


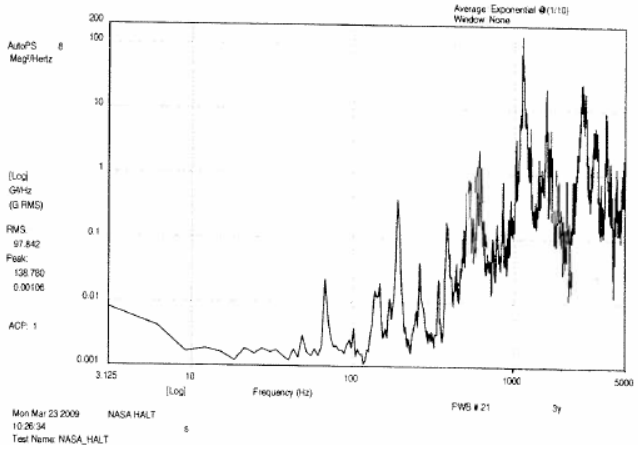
9 Accelerometer in location "Top of Table Center" came loose during testing and recorded a signal.

55 g_{rms}[10]



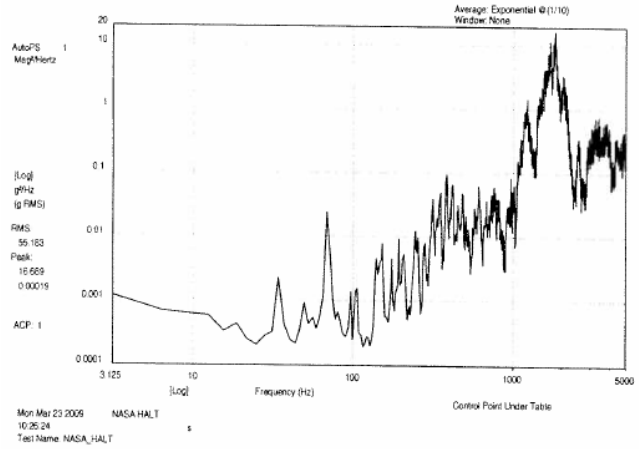


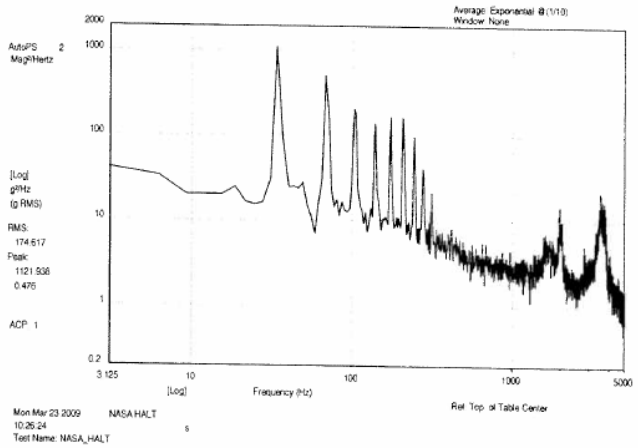


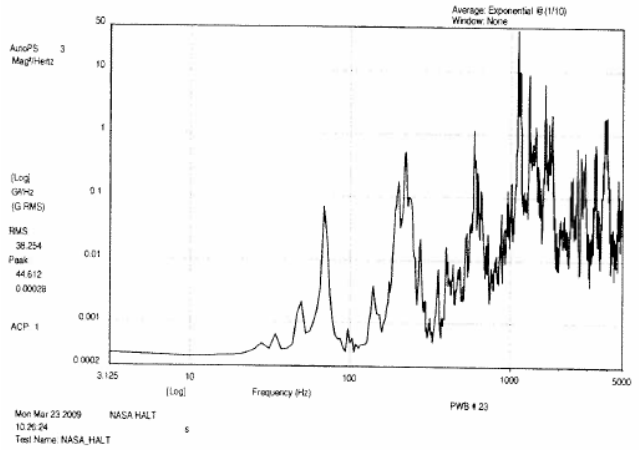


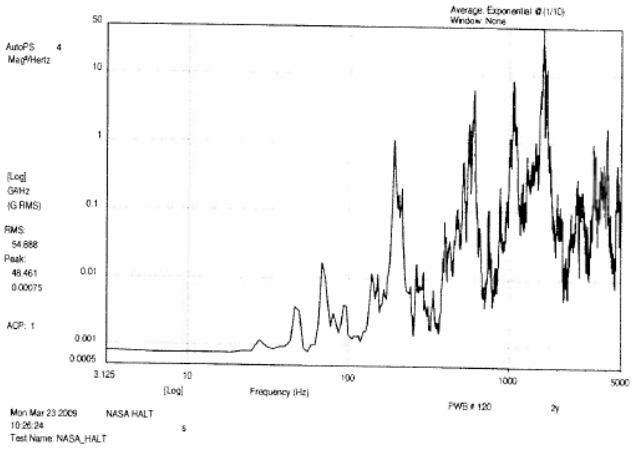
[10] Accelerometer in location "PWB #72" came loose during testing and recorded a signal.

55 g_{rms}[11]









[11] Accelerometer in location "Top of Table Center" came loose during testing and recorded a signal.

List of Symbols, Abbreviations and Acronyms

ACI	American Competitiveness Institute
Ag	Silver
AMCOM	U.S. Army Aviation and Missile Command
Au	Gold
AuPdNi	Gold-Palladium-Nickel finish
BGA	Ball grid array
Bi	Bismuth
CCA	Circuit card assembly
CECOM	U.S. Army Communications Electronic Command
CET	Combined environments test
CLCC	Ceramic leadless chip carrier
CSP	Chip scale package
Cu	Copper
DoD	Department of Defense
ENIG	Electroless nickel immersion gold
EPA	Environmental Protection Agency
ETL	Environmental Test Laboratory
HASL	Hot air solder level
HALT	Highly accelerated life test
HASS	Highly accelerated stress screen
I/O	Input/output
IST	Interconnect stress test
JCAA	Joint Council on Aging Aircraft
JG-PP	Joint Group on Pollution Prevention
JTP	Joint Test Protocol
JTR	Joint Test Report
NASA	National Aeronautical and Space Administration
NAVAIR	U.S. Navy Naval Air Systems Command
NAVSEA	U.S. Navy Naval Sea Systems Command
NAWCWD	U.S. Navy Naval Air Warfare Center Weapons Division
NCMS	National Center for Manufacturing Sciences
NEMI	National Electronics Manufacturing Initiative
Ni	Nickel
NIST	National Institute of Standards and Technology
OSP	Organic solderability preservative
Pd	Palladium

PDIP	Plastic dual-inline package
PLCC	Plastic leaded chip carrier
PTH	Plated-through hole
RoHS	Restriction of Hazardous Substances
SAC	Tin-Silver-Copper solder alloy
SMT	Surface mount technology
Sn	Tin
SN100C	Tin-Copper solder alloy
SnAgCu	Tin-Silver-Copper solder alloy
SnBi	Tin-Bismuth solder alloy
SnCu	Tin-Copper solder alloy
SnPb	Tin-Lead solder alloy
TACOM	U.S. Army Tank-Automotive and Armaments Command
Tg	Glass transition temperature
TQFP	Thin quad flat package
TSOP	Thin small outline package
WEEE	Waste from Electrical and Electronic Equipment Directive
UK	United Kingdom