Circuit Card Assembly and Materials Task Force Test Results for the Validation of Alternatives to Lead Containing Surface Finishes, for Development of Guidelines for Conformal Coating Usage, and for Qualification of Low VOC Conformal Coatings

Phase 1: Electrical Performance
&
Phase 2: Reliability

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Executive Summary

Introduction. The Circuit Card Assembly and Materials Task Force (CCAMTF) was formed in September 1995 to develop and conduct a joint test program for evaluating the reliability of new manufacturing technologies and materials used in the production of circuit card assemblies. The CCAMTF program is not a research and development effort. Rather, it focuses on both understanding developed and emerging technologies and determining how these technologies apply to state-of-the-art, performance-on-demand military and high-end commercial electronics with respect to electrical performance, product reliability, and pollution prevention.

The CCAMTF combined the joint efforts of 36 individuals representing 22 industry, military, and government organizations. The project was funded by in-kind contributions of the participating organizations and by the Joint Group on Pollution Prevention (JGPP). The complete list of individual participants and their organizations is given in Section 1 of this report.

Goals of the CCAMTF. The CCAMTF formulated the following goals for its test program.

1. Qualification of lead-free organic and metallic printed wiring board (PWB) surface finishes
2. Validation of guidelines for intelligent use of conformal coating
3. Qualification of low-VOC conformal coatings (low-VOC is defined as less than 420 *g* of VOC/ liter of mixed coating (3.5 *lbs/gal*))

Background on Alternative Surface Finishes. Surface finishes are applied to PWBs to prevent oxidation of exposed copper conductors on the board, thus ensuring a solderable surface when components are added later. The most widely used processes are HASL with solder mask and reflowed tin-lead. In both processes, tin-lead is fused on exposed copper surfaces. In the HASL process, the PWB is fluxed and then dipped in liquid solder. After dipping, the excess solder is removed with hot air knives (hot air solder leveling). In the plated and reflowed SnPb process, SnPb is plated on the copper conductors and then reflowed by dipping in a hot oil bath. Besides being a source of lead waste in the environment, a major concern associated with these processes is their inability to provide a level soldering surface. Planarity is extremely important in placing fine pitch components, which are becoming more prevalent in surface mount operations. The fused tin-lead surface finish is a limiting technology with respect to planarity.

Background on Conformal Coating. Conformal coating is widely applied to circuit cards to protect against adverse operating conditions. The application process is costly and time consuming. It is also the source of up to 40% of volatile organic compounds (VOCs) produced in some high-volume manufacturing operations and requires the use of pollution prevention equipment. Many manufacturers believe that conformal coating often adds unneeded cost to their processing that could be eliminated in specific applications without lowering quality or performance. A reduction in the use of conformal coatings without primers, would decrease manufacturing costs, simplify rework, and reduce pollution at the source.

Phases of CCAMTF Evaluation. The CCAMTF initially conducted a screening program to select surface finishes and conformal coatings for evaluation. The screening phase is documented in Iman, Koon, et al, 1997. The screening program led to the development of the following two-phase test program.

Phase 1: Environmental exposure	**Phase 2: Reliability testing**
Three weeks at 85°*C* and 85% relative humidity	Thermal shock
Condensing atmosphere	Thermal cycling
Branch water	Accelerated life
Salt fog	Vibration
Diesel fuel	Mechanical shock
Hydraulic fluid	Branch water

This report documents the functional test results for Phases 1 and 2.

CCAMTF Test Vehicle. The CCAMTF selected the functional PWA designed by the Low-Residue Soldering Task Force (LRSTF) as the primary test vehicle for its evaluation. The LRSTF used this PWA as its primary test vehicle for evaluation of low-residue soldering for military and commercial applications (Iman, et al, 1995). The CCAMTF's selection of the LRSTF PWA as its test vehicle was based on its belief that this test vehicle is representative of approximately 80% of the circuitry used in military and commercial electronics (although admittedly subjective, the 80/20 rule was the goal of the original design). The CCAMTF also had a wealth of baseline data on this test vehicle from the LRSTF study and the cost and time for developing a new test vehicle was avoided with this choice.

The LRSTF PWA was designed to test *process effects* resulting from changing materials and processes and to mitigate as much risk as possible in process change. The PWA is vintage 1994 technology and does not incorporate today's state-of-the-art circuitry; however, it would be next-to-impossible to have a test vehicle keep pace with today's rapid changes in circuit technology. The LRSTF PWA and the test/data analysis methodology that the CCAMTF employed have proven to be excellent discriminators in comparing processes whether it be fluxes, surface finishes, conformal coatings, or other process technologies.

The LRSTF PWA test vehicle was designed to be representative of a variety of extreme circuits: high voltage, high current, high speed digital, low-leakage current, and high frequency circuits. A designer can use the resulting measurements to make some analytical judgments about the *process* being tested. It was not intended to be a "production" board, which would typically be too narrow in breadth to represent a wide variety of these circuit extremes. Even though some technology complexities/advancements are not duplicated, the basic types are represented, and comparison of baseline technologies can be extrapolated to more current technology by analysis. The PWA is divided into six sections, each containing one of the following types of electronic circuits:

High current low voltage (HCLV)
High voltage low current (HVLC)
High speed digital (HSD)
High frequency (HF)
Other networks (ON)
Stranded wire (SW)

The components in the HCLV, HVLC, HSD, and HF circuits represent both PTH and SMT technology. The other networks (ON) were used for current leakage measurements: 10-mil pads, a socket for a PGA, and a gull wing. The two stranded wires were hand soldered. The LRSTF PWA provides 23 separate electrical responses from these groups of circuits. Raytheon in McKinney, TX designed an Automated Test Set (ATS) to perform automatic testing of the LRSTF PWA. All testing was performed by the Raytheon facility. Test results were compared to Joint Test Protocol (JTP) acceptance criteria (see reference 3 and Table 1.1 in Section 1).

Phase 1 and 2 Test Matrix. Results of the screening experiments were used to guide the development of the CCAMTF Phase 1 and 2 test plan, which requires PWAs to be used in the following five sets of sequential tests.

Test Sequence		
1	**DF-HF**	Diesel fuel – Hydraulic fluid exposure
2	**BW-SF**	Branch water – Salt fog
3	**85/85-TS**	85°*C* and 85% relative humidity – Thermal shock
4	**CA-TC**	Condensing atmosphere – Thermal cycle
5	**AL-Vib-MS-BW**	Acc. Life – Vibration – Mech. Shock – Branch water

The LRSTF PWAs were divided in four groups with each group receiving one of the following surface finishes:

HASL with solder mask (control)
Benzimidazole
Immersion Ag
Immersion Au/Pd

Each surface finish was divided into two groups. One group was processed with a halide free low-residue flux and the other with a halide containing water-soluble flux. The PWAs for each surface finish/process combination were divided into four equal sized groups for purposes of coating: uncoated, parylene coating, low-VOC silicone coating, and low-VOC urethane coating. Five PWAs were produced for each surface finish/ coating/flux combination (4 surface finishes × 4 coating conditions × 2 flux types × 5 PWAs = 160 PWAs for each of the five test sequences).

Summary of Test Results for Exposure to Diesel Fuel and Hydraulic Fluid. Following Pre-test, 160 PWAs were twice dipped in diesel fuel (DF) for 10 *min*, dried, and retested. Next, they were twice dipped in hydraulic fluid (HF) for 10 *min*, dried, and retested. As is true of all test environments, 3680 electrical measurements were recorded at each test time and compared to the JTP acceptance criterion (see Table 1.1 in Section 1). Sixteen of the 23 circuits on the LRSTF PWA survived exposure to DF and HF with no anomalies while the remaining seven circuits had only 14 anomalies. Table 1 provides a summary of the yields (percentage meeting the JTP acceptance criteria) for each test environment. This table shows that the yields were quite high (98.2% to 100%) for all circuits throughout the DF-HF test sequence.

Table 1. Summary of Yields (percentage) by Circuit Group for Each Environmental Test (shaded entries designate low yields)

	HCLV	HVLC	HSD	HF LPF	HF TLC	ON	SW	Totals
Diesel Fuel-Hydraulic Fluid Exposure								
DF	99.1	98.1	100.0	99.2	99.4	100.0	100.0	99.4
HF	100.0	100.0	100.0	98.2	99.3	100.0	100.0	99.6
Averages	99.6	99.1	100.0	98.7	99.4	100.0	100.0	99.5
Branch Water-Salt Fog								
BW Vertical	98.4	10.3	6.9	98.9	49.8	34.8	100.0	61.4
BW Post Vertical	99.7	97.5	99.7	99.6	97.5	99.5	100.0	99.0
BW Horz Backside Up	99.7	38.1	78.1	93.3	40.5	49.4	100.0	69.2
BW Post Backside	99.7	97.8	100.0	99.2	97.4	99.4	100.0	98.9
BW Horz Comp Up	99.1	6.9	83.1	99.2	90.3	34.5	100.0	76.6
BW Post Comp	99.7	98.4	100.0	99.7	97.6	96.6	100.0	98.6
Salt Fog	84.7	9.7	48.1	68.2	72.3	39.4	95.0	61.0
Averages	99.4	58.2	78.0	98.3	78.9	69.0	100.0	84.0
85/85-Thermal Shock								
85/85	99.7	96.9	100.0	99.4	99.5	98.1	100.0	99.1
Thermal Shock	99.7	96.9	100.0	98.8	99.4	99.4	100.0	99.1
Averages	99.7	96.9	100.0	99.1	99.5	98.8	100.0	99.1
Condensing Atmosphere-Thermal Cycle								
CA Cycle 10	100.0	58.8	98.4	99.7	93.5	64.1	100.0	88.5
Thermal Cycle	99.1	99.4	100.0	99.5	98.3	99.1	99.4	99.2
Averages	99.6	79.1	99.2	99.6	95.9	81.6	99.7	93.9
Accelerated Life-Vibration-Mechanical Shock-Branch Water								
Accelerated Life	100.0	99.7	100.0	99.7	97.5	100.0	100.0	99.3
Vibration	99.1	99.7	99.7	99.7	95.1	100.0	100.0	98.7
Mechanical Shock	99.4	95.6	99.7	99.3	97.5	99.7	100.0	98.8
BW Vertical	99.1	15.0	11.9	98.6	88.6	49.7	100.0	73.3
BW Post Vertical	99.1	90.9	99.7	99.4	95.1	97.2	100.0	97.4
Averages	99.3	80.2	82.2	99.3	94.8	89.3	100.0	93.5

Only two test measurements were of sufficient magnitude relative to the JTP acceptance criteria to be considered for failure analysis. In addition to these anomalies, there were 13 HSD circuits that did not respond. Failure analysis revealed that the damage sustained in the HSD section was due to electrical overstress (EOS), which damaged either the active components or the circuit traces. The source of the EOS was likely from the adjacent ON (leakage current) section of the PWA, which was biased with 100V.

Statistical analysis showed no relationship between the number of anomalies and surface finish in the DF-HF test sequence. Conformal coating was not beneficial relative to the JTP acceptance criteria taken over all 23 circuits. This is not to say that coating would not be beneficial to some circuits in some instances, but rather coating was not an important factor in determining the number of anomalies that did not meet the JTP acceptance criteria in the DF-HF test sequence. Likewise, flux type was not an important factor relative to the number of anomalies.

Summary of Test Results for Exposure to Branch Water and Salt Fog. Following Pre-test, a second set of 160 PWAs was sprayed with a detergent solution and tested while wet and again after drying. In the first part of the Branch water (BW) test, both sides of a PWA were sprayed while it was in a vertical position. After testing, the PWA was placed in a horizontal position with the backside up and only the uppermost side was sprayed. This test was repeated with the component side up. Following the BW test, the PWAs were exposed to an extremely harsh environment consisting of 83 cycles in a salt fog chamber, which took 500 *hr* to complete.

There were 1420 anomalies during the BW vertical position. As shown in Table 1, the BW anomalies were mainly associated with HVLC, HSD, HF TLC, and ON circuits. Uncoated PWAs had significantly more anomalies than coated PWAs. On the other hand, the anomalies were uniformly spread over surface finishes and flux types. Table 1 shows the yield in the vertical position was only 61.4%. Following the vertical position test there were only 37 anomalies (yield = 3643/3680 = 99.0%).

There were 1134 anomalies during the horizontal position with the backside up. The reduction in the number of anomalies was due to correcting a software problem involving the correct cable length factor in the CCAMTF ATS for total propagation delay with HSD circuits. There were 780 (780/1134 = 68.8%) carry over anomalies from the BW vertical position test. The median number of anomalies was 7 and the average number of anomalies per PWA is as follows for each coating state: uncoated (9.9), parylene (4.8), silicone (7.9), and urethane (5.9). Uncoated PWAs again had significantly more anomalies than coated PWAs while the anomalies were again uniformly spread over surface finishes and flux types. Table 1 shows the yield in the horizontal position (backside up) was 69.2%. Following the horizontal position there were only 41 anomalies (yield = 98.9%).

There were 860 anomalies during the horizontal position with the component side up. This is a reduction of 560 from the vertical position and 274 less that in the horizontal position with the backside up. This latest reduction was due to the HF TLC circuit, which utilizes transmission lines on the backside of the PWA, which do not get sprayed in this position. There were 546 carry over anomalies from the vertical and horizontal (backside up) positions. Every PWA had at least two anomalies and the median number of anomalies was 5. The average number of anomalies per PWA is as follows for each coating state: uncoated (6.9), parylene (5.7), silicone (4.3), and urethane (4.5). Both uncoated and parylene coated PWAs had significantly more anomalies than either silicone or urethane coated PWAs while the anomalies were again uniformly spread over surface finishes and flux types. Table 1 shows the yield in the horizontal position (component side up) was 76.6%. Following the BW horizontal position there were 50 anomalies (yield = 3630/3680 = 98.6%).

Following the BW test, the LRSTF PWAs were subjected to a salt fog (SF) test to determine the resistance of a conformal coating film to accelerated, deleterious effects of exposure to a sulfur dioxide/salt fog. The PWAs were tested after 500 *hr* of SF exposure. Testing was quite difficult as the connectors were corroded, the uncoated boards arced during the HVLC and current leakage testing, and the HF tests showed abnormal waveforms. In addition, the ammeter over ranged or could not stabilize during many of the tests, which created unstable readings. Due to these concerns, anomalous measurements were not retested after SF as they were in all other stages of the CCAMTF test program. The SF test clearly presents an extremely harsh environment and not surprisingly, there were a large number (1435) of anomalies. In fact, every PWA had at least 2 anomalies and the median number of anomalies was 9.

The average numbers of anomalies per PWA for surface finishes after SF are: HASL (8.5), benzimidazole (9.2), immersion Ag (9.3), and immersion Au/Pd (8.9). The mean number of anomalies do not differ significantly for surface finishes. However, uncoated PWAs with an average of 11.2 anomalies per PWA had significantly more anomalies than coated PWAs. Urethane, with an average of 9.3, had significantly more anomalies that silicone with an average of 7.1, but was not significantly more than parylene with an average of 8.3. PWAs processed with either LR or WS flux each had an average of 9.0 anomalies per PWA.

Summary of Test Results for Exposure to 85/85 and Thermal Shock. Following Pre-test, a third set of 160 PWAs was subjected to a test sequence consisting of three weeks exposure in an environmental chamber with the temperature and relative humidity set to 85°*C* at 85%, respectively. This test was followed by a thermal shock (TS) test where all PWAs were mechanically rotated between chambers set at -50°*C* ± 5°*C* and 125°*C* ± 5°*C.* The TS test lasted for 200 cycles each cycle taking approximately 1 *hr*.

Table 1 shows that yields were quite high (96.9% to 100%) for all circuits throughout the 85/85-TS test sequence. The overall yield was 99.1% following both tests. The yields for surface finishes ranged from 98.6% (immersion Ag) to 99.6% (benzimidazole) at Post 85/85 and from 98.5% (immersion Ag) to 99.7% (benzimidazole) at 200TS. The corresponding ranges for coating categories were 98.6% (silicone) to 99.6% (parylene) and 98.7%

(uncoated) to 99.3% (silicone). Perhaps the most surprising result was how well uncoated PWAs fared. This group was slightly better than silicone coated PWAs at Post 85/85 and was only 0.7% behind the best performance recorded by parylene. Uncoated PWAs have the lowest yield at 200TS, but again are only 0.6% behind the best performance recorded by silicone.

At the conclusion of the 85/85 test, there were 33 anomalous measurements that did not meet the JTP acceptance criteria. Twenty of these anomalies carried over to 200TS. There were 14 new anomalies at TS200, bringing the total to 34 at the conclusion of the 85/85-TS test sequence. These 34 anomalies occurred on 24 PWAs. Of the 34 anomalies at 200TS, 21 were severe enough to be candidates for failure analysis. These 21 anomalies occurred on 16 PWAs with eight of the 21 anomalies occurring on just three PWAs. The 16 PWAs with severe anomalies included all surface finishes, coating status, and flux.

In addition to these anomalies, there were 27 HSD circuits that did not respond after 200TS. These failures are typically attributable to damage sustained in the HSD section as previously explained. The 27 damaged HSD circuits occurred on 18 PWAs and were spread over all surface finishes, coating conditions, and flux types.

Summary of Test Results for Exposure to Condensing Atmosphere and Thermal Cycling. Following Pre-test, a fourth set of 160 PWAs was subjected to a test sequence consisting of 10 cycles in a condensing atmosphere (CA) chamber. This test was followed by a thermal cycle (TC) test where the temperature cycled between -55°*C* and 100°*C.* The TS test lasted for 500 cycles with each cycle having taking approximately 122 *min*.

The circuit yields in Table 1 range from 58.8% to 100% during Cycle 10. The HVLC (58.8%) and ON (64.1%) circuits had the lowest yields during Cycle 10 while all other circuits had yields of at least 93.5%. The overall yield during Cycle 10 was 88.5%. At 500 TC the yields ranged from 98.3% to 100% with an overall yield of 99.2%.

The yields for surface finishes ranged from 87.1% (HASL) to 90.4% (benzimidazole) during Cycle 10 and from 98.6% (immersion Ag) to 99.7% (benzimidazole) at 500TC. The yields for coating categories during Cycle 10 were uncoated (75.5%), urethane (87.3%), parylene (95.0%), and silicone (96.3%). At 500TC, the coating yields were very close with a range of 98.9% for silicone to 99.3% for both uncoated and parylene.

There were 422 anomalies that did not meet the JTP acceptance criteria during Cycle 10. The number of anomalies was reduced to only 30 at 500TC. Most of the decrease at 500TC was due to improvements in the performance of the HVLC and ON circuits. Statistical analyses showed no relationship between the number of anomalies and surface finish either during Cycle 10 or at 500TC. However, there was a strong relationship between the number of anomalies and coating status during Cycle 10 with uncoated and urethane coated PWAs having significantly more anomalies than either parylene or silicone. This relationship did not hold at 500TC. In addition to these 30 anomalies, there were nine HSD circuits that did not respond after 500TC. These failures are typically attributable to damage sustained in the HSD section as previously explained.

Summary of Test Results for Accelerated Life, Vibration, Mechanical Shock, and Branch Water. Following Pre-test, a fifth set of 160 PWAs was subjected to a test sequence consisting of accelerated life (AL) test, vibration (Vib), and mechanical shock (MS). Details of the test protocols are given in Section 6 of this report. The purpose of these tests was to determine if these environments would compromise the integrity of the conformal coating. Following this test sequence, the PWAs were subjected to the worst case of the BW test (PWAs in a vertical position).

Table 1 shows that all but four cases had yields of at least 99.1% during the AL-Vib-MS test sequence. The lowest yield during this sequence was 95.1%. On the other hand, the BW vertical position had a very adverse affect on HVLC, HSD, and ON. There were no differences in yields due to surface finishes during the BW vertical position as these yields ranged only from 92.6% (immersion Ag) to 93.7% (immersion Au/Pd). The yields for coating status were also quite close during this test time with a range of 92.4% (uncoated) to 94.9% (parylene).

There were 96 anomalies that did not meet the JTP acceptance criteria at the conclusion of the AL-Vib-MS-BW test sequence, which occurred on 67 PWAs. There was no significant difference due to either surface finish or flux type, but there was a strong significant difference due to coating status, with the uncoated PWAs having significantly more anomalies and parylene having significantly fewer. In addition to these 96 anomalies, there were 13 HSD PTH and 32 HSD SMT circuits that did not respond at Post BW. HSD PTH anomalies were always accompanied by a HSD SMT anomaly.

Table 2. Average Number of Anomalies by Surface Finish for Portions of the Five Test Sequences

Test Sequence		HASL	Benzi	Imm Ag	Imm Au/Pd
1	**DF**	0.05	0.13	0.30	0.08
	HF	0.08	0.08	0.10	0.10
2	**BW Vert**	9.13	8.68	8.75	8.95
	Post BW	0.28	0.23	0.40	0.35
	SF	8.50	9.18	9.28	8.93
3	**85/85**	0.25	0.10	0.33	0.15
	200TS	0.15	0.08	0.35	0.28
4	**Cycle 10**	2.98	2.20	2.70	2.68
	500TC	0.10	0.08	0.33	0.25
5	**AL**	0.15	0.08	0.30	0.08
	Vib	0.25	0.25	0.23	0.45
	MS	0.53	0.15	0.23	0.25
	BW Vert	6.05	5.90	6.80	5.83
	Post BW	0.68	0.53	0.68	0.53
	Averages	2.08	1.98	2.20	2.07

Conclusions Relative to Surface Finish. The CCAMTF found only isolated instances where surface finish was a significant factor in circuit performance. The summary in Table 2 gives the average number of anomalies per PWA by surface finish for portions of each of the five groups of test environments. This summary shows little difference in almost all cases and the overall averages given in the last row are very similar. Hence, all surface finishes that were evaluated appear to be viable choices. However, the CCAMTF recommends that any decision by the reader regarding modifications to materials or processes should be supported by confirmatory tests conducted on specific products and environments.

Conclusions Relative to Conformal Coating. The summary in Table 3 gives the average number of anomalies per PWA by conformal coating status for portions of each of the five groups of test environments. Nine of the 14 cases (DF, HF, Post BW, 85/85, TS, TC, AL, Vib, MS) and possibly the second listing of Post BW showed that conformal coating provided little, if any, improvement in performance and as such, is probably not cost effective in these environments. However, some types of conformal coating clearly helped in some test sequences (BW Vertical, SF, Cycle 10), but they did not necessarily prove to be a panacea for these environments.

Table 3. Average Number of Anomalies by Coating Status for Portions of the Five Test Sequences

Test Sequence		Uncoated	Parylene	Silicone	Urethane
1	**DF**	0.05	0.33	0.08	0.10
	HF	0.05	0.18	0.03	0.10
2	**BW Vert**	11.65	8.20	7.90	8.25
	Post BW	0.68	0.20	0.13	0.25
	SF	11.20	8.30	7.10	9.28
3	**85/85**	0.43	0.13	0.15	0.13
	200TS	0.30	0.20	0.15	0.20
4	**Cycle 10**	5.63	1.15	0.85	2.93
	500TC	0.15	0.15	0.25	0.20
5	**AL**	0.18	0.10	0.18	0.15
	Vib	0.40	0.23	0.25	0.30
	MS	0.53	0.20	0.25	0.18
	BW Vert	7.00	4.73	6.78	6.08
	Post BW	1.05	0.25	0.58	0.53
	Averages	2.75	1.73	1.76	2.06

For example, during the BW vertical position in the BW-SF test sequence every PWA had at least four anomalies. Table 3 shows that coated PWAs have an average of approximately 3 less anomalies per PWA at BW vertical in the BW-SF test sequence, but they all have an unacceptably high level of anomalies. Hence, coating did not provide a satisfactory level of performance. Following SF, parylene (8.30) and silicone (7.10) have lower averages than uncoated (11.20) and urethane (9.28), but again coating still does provide a satisfactory level of performance in this extreme environment. Note that uncoated and urethane have almost the same averages after SF.

During Cycle 10 of the CA-TC test sequence parylene and silicone both lead to improvement in circuit performance as does urethane to a lesser extent. Parylene is slightly better during the BW vertical test in the AL-Vib-MS-BW test sequence, but silicone and urethane are both very similar to the uncoated group. The overall averages given in the last row show that uncoated PWAs have approximately one more anomaly than parylene and silicone, and about 0.6 anomalies higher than urethane.

The PWAs were tested at the end of the 83rd cycle of SF. However, after one week (168 hours) of SF testing, two members of the CCAMTF, one of whom is an experienced corrosion specialist, performed a physical examination of the PWAs. It was their opinion that all specimens except for the parylene coated had so much corrosion that they were considered to have essentially failed at that time. Uncoated specimens were by far the worst at this point. After examination at the end of 500 *hr* of SF exposure, there was more corrosion on all specimens except for the parylene-coated specimens. Their conclusion was that the parylene-coated specimens were the only specimens that were corrosion free. Moreover, any electrical anomalies recorded for the parylene PWAs were more likely the result of corrosion of the electrical connections, the test equipment or hidden parylene voids. Their reasoning for this is the pristine appearance of the observable surfaces and the corrosion spots and salt deposits on the unprotected contacts that could obviously provide resistance during the testing. (The technician tried to clean up the contacts but this did not always give the desired results.) The obviously corroded appearance of the non-parylene coated boards after salt fog gave strong evidence of the protection of the parylene.

The reader should be aware that electrical testing was quite difficult after the SF test as the connectors were corroded (the JTP test protocol did not specify that the connectors should be masked) on all PWAs, which undoubtedly affected the test results. Uncoated PWAS arced during the HVLC and current leakage testing, and the HF tests showed abnormal waveforms. In addition, the ammeter over ranged or could not stabilize during many of the tests, which created unstable readings. Due to these concerns, anomalous measurements were not retested after SF as they were in all other stages of the CCAMTF test program. Not surprisingly, there were a large number (1435) of anomalies. In fact, every PWA had at least 2 anomalies and the median number of anomalies was 9. The uncoated PWAs had an average of 11.2 anomalies per PWA while the coated PWA had the following averages: parylene (8.3), silicone (7.1), and urethane (9.3). Statistical analysis shows that uncoated PWAs had significantly more anomalies than coated PWAs. Likewise, urethane coated PWAs had significantly more anomalies than silicone coated PWAs, but not more than parylene. Parylene and silicone were not significantly different, though silicone averaged 1.2 less anomalies than parylene.

Conclusions Relative to Flux Type. Some differences were detected in flux types that were applicable to specific circuits in specific environments. These differences were too unpredictable to make generalizations. The reader is encouraged to review the detailed report for specifics.

References

1. Iman, R. L., Koon, J. F., et al (1997). "Screening Test Results for Developing Guidelines for Conformal Coating Usage and for Evaluating Alternative Surface Finishes," CCAMTF Report, (June).

2. Iman, R. L. et al (1995). "Evaluation of Low-Residue Soldering for Military and Commercial Applications: A Report from the Low-Residue Soldering Task Force," (June).

3. Joint Group on Pollution Prevention (JGPP) Joint Test Protocol CC-P-1-1 for Validation of Alternatives to Lead-Containing Surface Finishes, for Development of Guidelines for Conformal Coating Usage, and for Qualification of Low-VOC Conformal Coatings (1998).

Table of Contents

Appendices