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Q4425 GENERAL REPORT SUMMARY SHEET

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8. OUTLINE, TABLE OF CONTENTS, SUMMARY, OR EQUIVALENT DESCRIPTION

This report summarizes the cracking of components caused by the shrinkage of conathane conformal coating.

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9. SIGNATURE <i>R. S. Harper</i> R. S. Harper	10. CONTRACTOR NWC/CL	SUBCONTRACTOR ARINC
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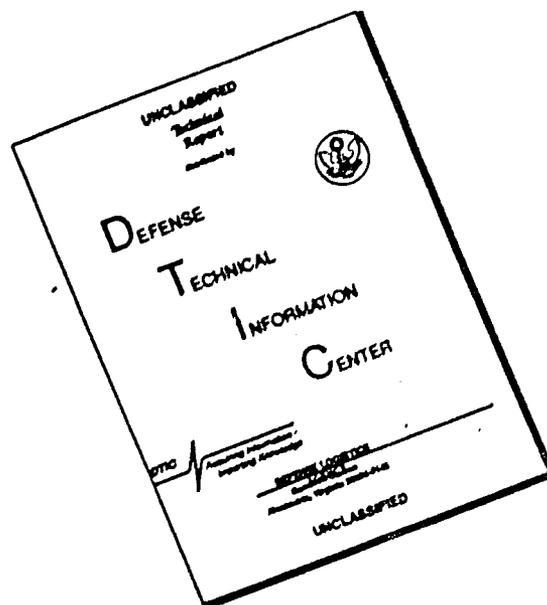
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technical notes

INVESTIGATION OF COMPONENT CRACKING
AFTER CONATHANE CONFORMAL COATING

28 November 1966

Prepared for
U. S. NAVAL ORDNANCE TEST STATION
China Lake, California

Under
Contract N123(60530)52939A
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Prepared by



K. A. Reynolds
Project Supervisor

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TRD



TECHNICAL NOTE

Investigation of Component Cracking after Conathane Conformal Coating

Introduction

A recent problem has occurred at Sperry Farragut (S.F.) in the production of AGM-45A-3 Computer Module PC Boards which results in longitudinal cracking of electronic components after conformal coating. The condition was discovered when computer trays which had previously passed all tests (including thermal cycling) were returned for some rework. The longitudinal cracks occurred in RLO7 resistors, RN series resistors, and in glass diodes. S.F. reports that the inspection of 75 printed circuit boards which had passed computer level testing and been in bond for 3 weeks to 3 months revealed 60 boards which contained approximately 100 cracked components. The quantity of components which contained visible cracks ranged from one to twelve per board. The cracks extended through the conformal coating and through the resistor coating (or glass envelope on the diodes). The resistor spiral on the substrate was apparently not affected electrically consequently the units would still meet electrical specifications.

Analysis

Two boards (Module 3 S/N 128 and Module 8 S/N 260) each of which contained several cracked components were obtained from S.F. These were inspected under a microscope and several major cracks in RLO7 resistors, RN series resistors, and one glass diode were visible. Most cracked components were observed in the areas in which the close spacing of the components had resulted in large fillet buildup or bridging of the conformal coating. Some cracked components were observed in a position in which there was no actual bridging of the conformal coating to an adjacent component. The boards were also examined under black light. The coating appeared to provide excellent coverage over all surfaces and components as evidenced by the white dye in the coating, which is visible only under black light. Some recent Texas Instruments (TI) boards were examined under black light for comparison purposes. It was evident that the coating was considerably thinner and that no bridging had occurred between components on the TI boards.

The evaluation of the problem revealed the following relevant facts:

1. The assembly drawings on the computer trays specify a brief coating procedure (see Appendix #1).

2. The conformal coating specified is MIL-I-46058, Class A, type PUR.

3. The QPL for MIL-I-46058 lists only two qualified vendors whom we could locate. Both SHRIKE contractors (SF and TI) have procured all of this material from CONAP, Inc. (The CONAP instructions for application are included as Appendix 2.)

4. The assembly drawings call for two coats of Conathane and are in accordance with the Note 8 of the CONAP instructions.

5. The instructions from CONAP do not indicate the amount or type of thinner to be used. This has since been recommended by CONAP as 20 parts of S-8 thinner maximum added to the 100 parts of CONAP 1155A and 70 parts of CONAP 1155.

6. The SF method of applying the conformal coating is different from the drawing but basically agrees with the CONAP instructions. SF pours the coating into the assembled tray and then pours it out and allows the tray to drip from an inverted horizontal position. Verbal concurrence was obtained from NOTS/CL before instituting this process at SF.

7. SF has determined from IRC that Conathane coating would not adversely affect the cracked resistors (i.e., no reaction would occur with the deposited resistance element or substrate).

8. SF has repaired approximately 25 of the boards on which the most cracks have been observed by replacing those cracked components visible under 10 power magnification.

9. SF has used this coating on AGM-45A-3 missiles from S/N 114 on.

10. SF has taken 2 boards each containing several cracked components, coated them with a thin coating of Conathane, and subjected them to thermal cycling from -55°F to $+160^{\circ}\text{F}$. The boards have shown no degradation of performance and no visible evidence of new cracks.

11. SF has run a humidity test on one board coated with Conathane by the current process. It has shown no degradation in performance.

12. SF has coated ten boards with Conathane single, thin coats by their new process and are subjecting them to evaluation testing.

13. TI has used this coating from manufacturing sequence number 217 and subsequent as well as on any reworked units prior to S/N 217.

14. TI has processed parts in accordance with their shop process which has been reviewed and has had no known problems.

15. TI estimates that their rate of withdrawal of printed circuit boards from the conformal coating is approximately 1 foot/second.

16. TI hangs boards in a vertical position suspended by one of the narrow ends of the boards.

17. The TI procedure is in accordance with but goes far beyond the specified drawing requirements. It includes measuring viscosity by means of Zahn Cups and logging viscosity readings every hour.

18. There has been no reported component breakage with TI boards due to conformal coating.

19. The Conathane coating should have a thickness of approximately .0015" per coat.

20. The Conathane coating contains 60% solids and 40% solvents and is therefore said by CONAP to have a 40% shrinkage factor during curing.

21. Recommendations were obtained from CONAP in answer to specific questions. These recommendations are contained in Appendix #4. It should be noted that these viscosity measurements are not given for a Zahn Cup. According to "Viscosity and Flow Measurements" by Waxer, Lyon, Kim, & Coball, the minimum recommended range for the Zahn Cup is approximately 20 seconds. The approximate equivalent to the CONAP readings on the #4 Ford Cup would require measurements down to approximately 13 seconds on the #3 Zahn Cup. Consequently, the use of the Zahn Cups #3 or #5 is not recommended by ARINC Research.

22. Both contractors (SF and TI) have used CONAP coating entirely. No use has been made to date on SHRIKE of the alternate MIL-SPEC supplier "Better Finishes and Coating Co."

Conclusions

1. The cracking of the components is caused by the shrinkage of the Conathane conformal coating, all of which does not occur during the prescribed cure time, at least in the areas of heavy build-up.

2. The cracking is due to too thick a coat of Conathane, especially abnormally thick fillets and some bridging of the coating between components.

3. The thickness of the conformal coating is greatly affected by:

- i) the technique of application
- ii) the speed of withdrawal
- iii) the viscosity of the mixture (therefore the amount of the solvent used)
- iv) the dripping time and position of the boards during dripping.

4. Units containing cracked components should not be used due to the reliability hazard. In the event that other program considerations necessitate use of such units then they should be suitably coated to provide a humidity sealing coat which will not affect the electrical functioning of the parts into which it penetrates and a test program performed in accordance with recommendation #3 to verify that their mechanical and electrical characteristics have not been degraded.

5. All units produced by SF subsequent to S/N 114 may contain cracked components.

Recommendations

In view of the foregoing ARINC Research recommends:

1. An OD be prepared specifying the critical elements of the process. This OD should then be called out as a mandatory requirement on all applicable drawings.

2. SF be requested to prepare from our OD specification a detailed in-house procedure which assures effective implementation of the requirements.

3. Ten boards which now contain cracked components should be subjected to the coating procedure and sequence of tests outlined in Appendix 3. The results of these tests will enable a decision to be made on the balance of the boards produced by SF using Conathane coating prior to the recent modification to their process.

In the event that prolonged exposure to a humid environment can be avoided in missile deployment the risk of failure is decreased and the test plan of Appendix 3 may not be needed.

4. A program be started to evaluate "Better Finishes and Coating Co." type 91-81 which is the alternate MIL-SPEC supplier of Class A, Type Pur material. This should be completed before an OD is prepared to ensure that both materials are adequately covered.

Appendix 1

Coating Procedure:

- A. Prior to installing assembled printed circuit board into housing. Item 1 clean with alcohol item 61.
- ⓑ B. Evacuate assembled board to 27 inches of mercury and bake at $60^{\circ}\text{C}\pm 5^{\circ}\text{C}$ for 30 minutes minimum to remove all moisture.
- ⓑ C.
- ⓑ D. Mask off screw holes ($5/16 \pm 1/64$ dia) on assembled printed circuit board.
- ⓑ E. Blend compound, item 62, allow bubbles to break then dip coat assembled board into mixture. Allow board to drip for 15 minutes minimum and cure at $60^{\circ}\text{C}\pm 5^{\circ}\text{C}$ for 30 minutes minimum. Dip again, allow 15 minutes minimum for dripping and cure at $60^{\circ}\text{C}\pm 5^{\circ}\text{C}$ for 3 hours.
- F. Remove masking from assembled printed circuit board and assemble into housing. Item 1, and secure with screws. Item 57, washers, item 64 and nuts, item 58. Torque screws to 7 ± 1 inch-lbs.
- Ⓐ G. Strip lead wires and solder to housing terminal studs using solder, item 7.
- H. Brush coat lead wires and housing terminal studs inside housing twice as specified in "E" above and cure.
- I. After coating is completely cured see OD 10001-30711 for recommended electrical checkout procedure.

Appendix 2

Instructions for Application of CONAP 1155

- 1) Prepare the printed circuit board for coating by cleaning with clean solvent to remove grease, fingerprints, oil, solder flux, and other contaminants. Alcohol or Freon PC Solvent have been found to be acceptable. Recently, a very pure Freon EM has been used in critical applications with excellent results.
- 2) Dry the board at 140°F for 1/2 hour, then cool to room temperature.
- 3) Prepare the coating material by adding 70 parts by weight CONAP 1155 to 100 parts by weight CONAP 1155A.
- 4) Mix well and allow bubbles to rise and break (10 minutes).
- 5) Dipcoat parts into material. Give slow steady withdrawal.
- 6) Allow parts to drip for 10-15 minutes.
- 7) For 1 coat application, cure film at 140°F for 3 hours, (or at 212°F for 1 hour).
- 8) For multiple coat application, partially cure each coat for 1/2 hour at 140°F, cool, redip, and give final cure at 140°F for 3 hours, (or at 212°F for 1 hour).

Appendix 3

Procedure for coating and evaluating boards containing cracked components.

1. Inspect boards for cracked components using 10 x microscope.
2. Prepare list of cracked components by Module Number, Module S/N, Symbol number of cracked component, and type of component (e.g., Module 4, S/N 231, R22, RLO7). Leave Space for initial, "after coating," and "after test" comments and indicate magnitude of cracks (e.g., hairline, 1/2 body length, .001" crack, 3/4 body length, etc.) under initial comments column.
3. From above select ten boards which contain the most cracked components.
4. Perform complete tests at room temperature on each board in accordance with the appropriate module test procedure and record actual readings.
5. Select three (3) boards at random from group of ten and set them aside to remain uncoated.
6. Coat seven remaining boards with Conathane by the following method:
 - (a) Rinse boards in Isopropyl Alcohol to remove contamination (Note: Do not allow Burns pots or other parts subject to leakage to be immersed.).
 - (b) Bake the boards at 60°C ±5°C in a vacuum of 27 inches of mercury for 30 minutes minimum.
 - (c) Mask off appropriate portions of tray including mounting holes and mating surfaces which are used for ground contact. Also mask off connectors.
 - (d) Prepare the mixture by adding seventy (70) parts by weight of Conathane 1155 to one hundred (100) parts by weight Conacure 1155A and twenty (20) parts by weight S-8 thinner. Mix well and allow bubbles to rise and break.
 - (e) Measure viscosity on a #4 Ford Cup (or equivalent) and record time and reading.

- (f) Hold tray in a vertical position by one corner so that components are at forty-five degrees (45°) to the gravitational axis. Dip each tray then withdraw at a speed of approximately 1/2 foot per minute.
 - (g) Suspend each tray in the same position as used for dipping. Allow boards to drip for 15-20 minutes at room temperature.
 - (h) Transfer coated boards to an oven preheated to $60^\circ\text{C} \pm 5^\circ\text{C}$. Bake for three (3) hours minimum at 60°C .
 - (i) Remove cured modules from oven and unmask.
7. Reinspect coated boards under 10 x microscope for evidence of any changed conditions in previously cracked components or any new cracking. Note any changes under "after coating" column prepared under 2.
8. Preheat oven to $100^{+0}_{-5}^\circ\text{C}$. Place one uncoated and three coated boards in oven. Continue baking for 2 weeks (336 hours) minimum. Remove boards (one at a time) from oven and inspect for any changes in cracks or new cracks at the following intervals:
- | | |
|-----------------|--------------------------------------|
| 1st inspection* | within 24 ± 4 hours after start. |
| 2nd inspection | 96 ± 4 hours after start. |
| 3rd inspection | 168 ± 4 hours after start. |
| 4th inspection | 252 ± 4 hours after start. |
| 5th inspection | 336 hours or more - at completion. |
- Remove boards from oven and repeat item 4. Analyze documented inspection and test results.
- *Note - Inspection on each board not to exceed a total of one-half hour total time out of temperature chamber.
9. Perform the following sequence of tests on the six remaining boards (2 uncoated and 4 coated).
- (a) Thermal shock 3 cycles through temperature extremes of -55°F to $+160^\circ\text{F}$ per MIL-STD-202 test method 102, condition D.
 - (b) Repeat test per item 4.
 - (c) Repeat inspection per items 1 and 2.
 - (d) Perform humidity test in accordance with MIL-STD-202, Method 106B, except that 3 cycles only shall be performed.

Steps 7a and 7b are not required. Temperature extremes of +25°C and +65°C apply.

- (e) Repeat test per item 4.
 - (f) Repeat inspection per items 1 and 2.
10. Analyze all results on ten boards and perform the following under the direction of the assigned SHRIKE reliability engineer:
- (a) Troubleshoot all assemblies on which an out of specification reading was detected to determine the component responsible (Note: If doubt exists consult a circuit analyst before changing parts.).
 - (b) When parts are detected which have changed physically (as detected by inspection) or have caused electrical failure a careful inspection shall be performed on the component before any removal or probing. This inspection shall be made under appropriate magnification and repeated under ultra-violet light to determine whether continuous coverage of conformal coating is evident. Any visible phenomena of importance shall be noted and pictures taken.
 - (c) Carefull removal of defective parts (as determined above) shall be made. Techniques of failure analysis such as cross sectioning etc. shall be used as appropriate to determine cause of failure.
 - (d) The test results which are within spec shall be carefully reviewed to determine the amount of drift between readings on the same board. Repeat 10(b) and (e) on those boards which contained the most pronounced drift of parameters.
 - (e) Issue report incorporating all results as appendices and the resultant conclusions from the evaluation.

CONAP Inc.

CONTROLLED MATERIALS APPLICATIONS



November 4, 1966

Mr. Ken Reynolds
 Arinc Research Corp.
 P. O. Box 1025
 Ridgecrest, California 93555

Dear Ken:

Finally, the viscosity data arrived. Our replies to your questions are as follows:

1) Viscosity

MATERIAL	SYSTEMS - (PBW)		
	A	B	C
1155	70.0	70.0	70.0
1155A	100.0	100.0	100.0
S-8	---	10.0	20.0

VISCOSITY - TIME RELATIONSHIPS

Initial, #4 Ford Cup, Seconds	36.2	24.4	19.0
Initial, Brookfield, CPS	152	104	64
After 1 hour, #4 Ford Cup	44.3	27.5	20.5
After 1 hour, Brookfield	192	108	72
After 3 hours, #4 Ford Cup	72.5	39.2	25.2
After 3 hours, Brookfield	304	156	96
After 6 hours, #4 Ford Cup	156.5	74.2	39.2
After 6 hours, Brookfield	640	324	160

As you will note three are actual figures not ranges. The range of viscosity for the two methods of application dipping versus flow coating should be determined on the boards. However, as a guideline we will put down the range where, from what we have seen, a good coating (not too thick to eliminate bridging, nor not too thin) will be obtained:

	Dipping	Flow Coat (pour in and pour out)
Initial, #4 Ford Cup, Seconds	30-40	20-30
Initial, Brookfield, CPS	140-160	100-140

CONAP Inc.

CONTROLLED MATERIALS APPLICATIONS



As you know by thinning with fresh material or with S-8 thinner, the viscosity of the material can be maintained. We would recommend that 20 parts of thinner per 170 parts of mixture is the maximum amount of thinning. This will allow several hours working life and yet will maintain the percent solids and film thickness.

2) Repair of the current cracks in coating.

As a fresh film does have good adhesion to old film, and as the cracking problem was primarily in the bridged over areas, we suggest that a thin film be applied to seal off any cracks. The above "C" mixture is our choice for this.

3) Fillet thickness

First, we would like to eliminate the bridging. Once this is done, we think that the fillet thickness is no longer a problem. The exact fillet thickness is dependent upon several variables, and we hesitate to put down exact mils. However, we believe that fillets should be less than 15 mils.

4) Dipping procedure

A four (4) inch per minute withdrawal rate is what we have used for years. The angle of withdrawal should be at a 45 degree angle to the majority of the components to allow for run-off.

5) Accelerated testing for cracking

100°C for 7 days is our recommendation (with bridging, cracks will show up and with a uniform coating with small fillets no cracking is noted).

Sincerely,

Mark V. Goodyear
Vice President
Western Division

MVG/skw