Validation of the Environmentally Conscious Manufacturing Integrated Demonstration Hardware

Kansas City Division

Rick D. Carter

KCP-613-5307

Published November 1993

Final Report

Approved for public release; distribution is unlimited.

RECEIVED

DEC 09 1993

OSTI

Prepared Under Contract Number DE-ACO4-76-DP00613 for the
United States Department of Energy

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America.

This report has been reproduced from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, Tennessee 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Rd., Springfield, Virginia 22161.

**A prime contractor with the United States
Department of Energy under Contract Number
DE-ACO4-76-DP00613.**

**AlliedSignal Inc.
Kansas City Division
P.O. Box 419159
Kansas City, Missouri
64141-6159**

KCP-613-5307
Distribution Category UC-706

Approved for public release; distribution is unlimited.

**VALIDATION OF THE ENVIRONMENTALLY
CONSCIOUS MANUFACTURING
INTEGRATED DEMONSTRATION HARDWARE**

Rick D. Carter

Published November 1993

Final Report
Rick D. Carter, Principal Investigator

Project Team:
T. A. Davis
D. E. Gentry
K. Laoruangroch
H. C. Striffler
A. B. Sunseri
S. M. Vaughn

Technical Communications
Kansas City Division

MASTER

AlliedSignal
AEROSPACE

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *ds*

Contents

<i>Section</i>	<i>Page</i>
Abstract	1
Summary	1
Discussion	2
Scope and Purpose	2
Prior Work	2
Activity	3
Electrical and Environmental Testing Sequence	3
Test Results and Statistical Analysis	5
Accomplishments	8
Reference	10

Illustrations

<i>Figure</i>	<i>Page</i>
1 Programmer Final Assembly	3
2 Programmer Disassembly View	4

Tables

<i>Number</i>	<i>Page</i>
1 Unpotted Baseplate Level Environmental Stress Screening and Functional Testing	5
2 Final Level Environmental Stress Screening and Electrical Testing	6
3 Final Level Environmental and Electrical Testing	7
4 PT3554 ECM ID Test Numbers Yielding Data With Cpk's Less Than 1.33	9

Abstract

Electrical and environmental testing were performed on the Environmentally Conscious Manufacturing Integrated Demonstration (ECM ID) units. An analysis of the testing data comparing the ECM units with units processed using traditional processes showed that there was no statistical difference in functional performance or reliability.

Summary

An earlier effort related to this project consisted of fabricating three electronic assembly Environmentally Conscious Manufacturing Integrated Demonstration (ECM ID) units. These units were built for the purpose of developing manufacturing methods that would substantially reduce the amount of hazardous materials used and wasted versus traditional fabrication methods. ECM ID processing methods were successfully developed and resulted in parts that visually and dimensionally met all product requirements.

As a follow-up to the fabrication of the ECM ID units, this endeavor was initiated to verify the reliability and electrical functionality of the units. This was done by subjecting the ECM ID units to the same electrical and environmental testing that was done on the tool made sample (TMS) built to WR-quality standards using traditional manufacturing methods. Results of the testing showed that the ECM ID units passed all electrical and environmental tests, which included substantial overtest conditions.

A statistical analysis of the testing data was also made comparing the TMS with that of the ECM ID units. Results were that there was no statistical difference between the TMS and ECM ID units for any of the test numbers. From the testing and data analysis, there is no reason to believe that the processes developed for the ECM ID units resulted in any degradation in function or electrical/mechanical reliability.

Discussion

Scope and Purpose

This project was funded as part of the FY1993 project AL-4330-01 by the DOE's Environmental Restoration and Waste Management Division's Office of Technology Development. This project was preceded by project AL-4113-01, which involved the process development and fabrication of the ECM ID hardware.

The purpose of this project was to validate the functional performance and reliability of the Environmentally Conscious Manufacturing Integrated Demonstration (ECM ID) hardware. This was done by conducting a series of environmental and electrical tests similar to those used on the Programmer TMS (tool made sample) process prove-in lot. A statistical analysis comparing the TMS testing data with the ECM ID data was done to verify that the ECM processes and materials used did not change or degrade the functional performance or reliability of the electronic assembly.

The principal benefit of this work is to provide much-needed data to support using ECM processes and materials in other, more diverse areas of manufacturing. Adopting ECM techniques globally will substantially reduce the adverse environmental impact caused by the use of hazardous materials.

Prior Work

The ECM ID hardware discussed in this report was fabricated in a prior effort during FY1992. A Programmer assembly used on

the B61-6/8 program was the assembly selected for the ECM ID project. A complete Programmer assembly is shown in Figures 1 and 2. Report number KCP-613-5132 describes the processes and materials used to fabricate these units.¹ The purpose of building the ECM ID units was to show that ECM techniques could be successfully used to build an electronic assembly that was functionally equivalent to those built using traditional (non-ECM) methods.

Most of the ECM processes and materials had been characterized separately; however, no prior effort had been made to combine these new processes into a single functioning unit. Therefore, there was no history on how these new materials and processes would interact and possibly affect the functional performance or reliability of the electronic assembly.

Three ECM units were fabricated using the same materials and processes except for the printed wiring assembly (PWA) soldering and cleaning process. The PWAs for one ECM unit were soldered using standard RMA flux, followed by agitated immersion cleaning with d-Limonene, followed by an isopropyl alcohol (IPA) spray rinse. The PWAs for the other two ECM units were soldered using an aqueous flux, followed by cleaning in a dishwasher using deionized water with a saponifier, followed by an IPA spray rinse.

Figure 1. Programmer Final Assembly

Activity

Electrical and Environmental Testing Sequence

The primary purpose of this Process Capabilities Assurance Program (PCAP) project was to test the ECM ID hardware

using the same testing sequence used for the TMS of the Programmer assembly. This testing included a combination of environmental stress screening, environmental testing, and electrical functional testing. The intent of this type of testing is to expose the electronic

Figure 2. Programmer Disassembly View

assembly to environmental conditions that induce latent defects.

In the case of the ECM ID hardware, this testing was done to ensure that the processes and materials used in the fabrication of the ECM ID did not

significantly alter the testing data from that obtained during the TMS.

Table 1 shows the testing sequence for the unpotted baseplate assembly. At this level of assembly the printed wiring assembly and cable are mounted to an aluminum baseplate prior to encapsulation. The

Table 1. Unpotted Baseplate Level Environmental Stress Screening and Functional Testing

Step	Tester	Description
1	PT3300	Room Temperature; Electrical Isolation/Leakage Test
2	PT3554	Room Temperature; Functional Test
3	PT3554	Low Temperature (1-hr soak at -55°C); Functional Test
4	PT3554	High Temperature (1-hr soak at + 80°C); Functional Test
5	TE7038	Temperature Cycling (-55°C to + 80°C, 30-min soak, 15 cycles); Monitored Electrical Test
6	PT3300	Room Temperature; Electrical Isolation/Leakage Test
7	PT3554	Room Temperature; Functional Test
8	PT3554	Low Temperature (1-hr soak at -55°C); Functional Test
9	PT3554	High Temperature (1-hr soak at + 80°C); Functional Test

purpose of this testing was to ensure that the assembly functioned correctly prior to encapsulation and also to precondition the assembly by performing powered temperature cycling.

Table 2 shows the testing sequence for the encapsulated final assembly. At this level of assembly the Programmer is completely fabricated, encapsulated, and fully functional. The purpose of this testing is to ensure that the assembly functions correctly and to perform additional environmental stress testing.

Table 3 shows the sequence of environmental and electrical testing performed following the testing shown in Tables 1 and 2. This testing sequence was developed to prove-in the TMS hardware by demonstrating that the assembly could function far beyond design requirements. This sequence consists of five environmental test cycles with

electrical testing after each environmental test.

Test Results and Statistical Analysis

All three of the ECM ID units received the testing described previously. The ECM units passed all parameters of every test performed, including all five environmental test cycles.

A statistical analysis was performed by Quality Engineering comparing data from the TMS with that of the ECM ID units. Data from the five environmental test cycles from the PT3554 functional tester was statistically analyzed to determine if there was a statistically significant difference between the TMS data and the ECM ID data.

Table 2. Final Level Environmental Stress Screening and Electrical Testing

Step	Tester	Description
1	PT3300	Room Temperature; Electrical Isolation/Leakage Test
2	PT3554	Room Temperature; Functional Test
3	PT3554	Low Temperature (1.5-hr soak at -55°C); Functional Test
4	PT3554	High Temperature (1.5-hr soak at + 80°C); Functional Test
5	TE7042	Complex Wave Vibration (X, Y, and Z, 20 min/axis); Monitored Electrical Test
6	PT3300	Room Temperature; Electrical Isolation/Leakage Test
7	PT3554	Room Temperature; Functional Test
8	PT3554	Low Temperature (1.5-hr soak at -55°C); Functional Test
9	PT3554	High Temperature (1.5-hr soak at + 80°C); Functional Test

The following method was used to determine if there was a statistical difference.

1. Calculate the average and the standard deviation from the data for each test number for both the TMS and ECM ID units.
2. Calculate process capability indices (Cpk) from the TMS and ECM ID data for each test number.
3. Identify ECM ID test numbers having data yielding a Cpk of less than 1.33.
4. For each test number with a calculated Cpk of less than 1.33, determine if a difference in average exists between the ECM ID data and the TMS data.
5. For each test number with a calculated Cpk of less than 1.33, determine if a difference in variability exists between the ECM ID data and the TMS data.

Table 4 shows the test numbers that had calculated Cpk's of less than 1.33. A Cpk of 1.33 means that 33 data points out of a sample of 1 million will fall outside of specification limits, assuming a normal data distribution. This was considered a necessary screen so as to not scrutinize data that was unlikely to fall outside of specification limits. Also indicated in Table 4 are the results of the statistical tests for differences in average and variability.

From Table 4 it can be seen that none of the test numbers with a Cpk of less than 1.33 showed a difference in average. However, three of the test numbers (A04RPD, B03MSA, and B05MSA) showed a difference in variability.

In analyzing these test numbers more closely, the reason variability was detected was due to three factors: limited sample size for the ECM ID units, tester resolution with respect to specification limits, and zero variability of the TMS data for two of

Table 3. Final Level Environmental and Electrical Testing

Environmental Test Cycle	Tester	Test Description
First	N/A	Complex Wave Vibration (X, Y, and Z, 20 min/axis)
	PT3554	Room Temperature; Functional Test
	PT3555	Mechanical Shock (-X and + Y axes); Monitored Electrical Test
	PT3554	Room Temperature; Functional Test
	N/A	Temperature Shock (1.5-hr soak, -55°C and + 80°C, 5 cycles)
	PT3300	Room Temperature; Electrical Isolation/Leakage Test
	PT3554	Room Temperature; Functional Test
Second	N/A	Complex Wave Vibration (X, Y, and Z, 20 min/axis)
	PT3554	Room Temperature; Functional Test
	PT3555	Mechanical Shock (-X and -Y axes); Monitored Electrical Test
	PT3554	Room Temperature; Functional Test
	N/A	Temperature Shock (1.5-hr soak, -55°C and + 80°C, 5 cycles)
	PT3300	Room Temperature; Electrical Isolation/Leakage Test
	PT3554	Room Temperature; Functional Test
Third	N/A	Complex Wave Vibration (X, Y, and Z, 20 min/axis)
	PT3554	Room Temperature; Functional Test
	PT3555	Mechanical Shock (-X and + Z axes); Monitored Electrical Test
	PT3554	Room Temperature; Functional Test
	N/A	Temperature Shock (1.5-hr soak, -55°C and + 80°C, 5 cycles)
	PT3300	Room Temperature; Electrical Isolation/Leakage Test
	PT3554	Room Temperature; Functional Test

Table 3 Continued. Final Level Environmental and Electrical Testing

Environmental Test Cycle	Tester	Test Description
Fourth	N/A	Complex Wave Vibration (X, Y, and Z, 20 min/axis)
	PT3554	Room Temperature; Functional Test
	PT3555	Mechanical Shock (-X and -Z axes); Monitored Electrical Test
	PT3554	Room Temperature; Functional Test
	N/A	Temperature Shock (1.5-hr soak, -55°C and +80°C, 5 cycles)
	PT3300	Room Temperature; Electrical Isolation/Leakage Test
	PT3554	Room Temperature; Functional Test
Fifth	N/A	Complex Wave Vibration (X, Y, and Z, 20 min/axis)
	PT3554	Room Temperature; Functional Test
	PT3555	Mechanical Shock (-X and +Y axes); Monitored Electrical Test
	PT3554	Room Temperature; Functional Test
	N/A	Temperature Shock (1.5-hr soak, -55°C and +80°C, 5 cycles)
	PT3300	Room Temperature; Electrical Isolation/Leakage Test
	PT3554	Room Temperature; Functional Test
	PT3554	Low Temperature (1.5-hr soak at -55°C); Functional Test
	PT3554	High Temperature (1.5-hr soak at +80°C); Functional Test

the three test numbers. Due to these factors, and by engineering judgment, it was determined that the differences in variability for these tests were not significant.

Accomplishments

The ECM ID hardware that was fabricated in an earlier effort underwent a series of validation tests. This was done to ensure that the materials and process changes made to these units did not significantly alter the functional performance of the electronic assembly. The electrical and

Table 4. PT3554 ECM ID Test Numbers Yielding Data With Cpk's Less Than 1.33

Test Number	Test Description	Cpk TMS	Cpk ECM ID	Difference in Average (Y/N)	Difference in Variability (Y/N)
A03MSA	T-Cycle, Cold	0.78	0.77	N	N
A04RPD	T-Cycle, Cold	2.55	1.17	N	Y
A05MSA	T-Cycle, Cold	0.78	0.77	N	N
B03MSA	T-Cycle, Cold	*	0.77	N	Y
B04B2D	T-Cycle, Cold	1.52	1.04	N	N
B05B2D	T-Cycle, Cold	1.46	1.04	N	N
B05MSA	T-Cycle, Cold	*	0.77	N	Y
B06B2D	T-Cycle, Cold	1.62	1.17	N	N

*Not able to calculate due to zero variability

environmental tests performed were similar to those done for the TMS of the Programmer assembly. Results from the testing showed that the ECM ID units passed all tests and functioned equivalently to the TMS.

A statistical analysis of the PT3554 functional tester data was made comparing the data from the TMS with that of the ECM ID units. None of the test numbers showed any statistical difference when comparing the TMS data with the ECM ID data.

This study indicates that the ECM processes and materials used had no measurable effect on the functional performance or reliability of the electronic assembly. Data from this study will serve to support using ECM processes with greater confidence in other product applications.

Reference

1D. E. Gentry, *Environmentally Conscious Manufacturing Integrated Demonstration* (Final Report). Kansas City Division: KCP-613-5132, July 1993 (Available from NTIS).

END

**DATE
FILMED**

3 / 22 / 94