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IDENTIFICATION OF AN ELECTRO-MECHANICAL
ASSEMBLY CONTAMINATION PROBLEM

EP 41182-11, Topical Report

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IDENTIFICATION OF AN ELECTRO-MECHANICAL ASSEMBLY CONTAMINATION PROBLEM

BDX-613-1625 (Rev.), UNCLASSIFIED Topical Report, Published March 1977

Prepared by L. C. Jackson, D/814, under EP 41182-11

Present clean room technology has achieved a high level of cleanliness capability. Beyond the limits of particle detection, however, surface characterization of microquantities of organic contaminants has not been feasible. Recent advances at Bendix Kansas City now permit measurements of organic residues to be made in this uncharted area. This study is related to the organic contamination portion of the problem for its potential contribution in causing excessive electrical resistance at the output switch contacts of an electro-mechanical assembly.

The basis of this investigation was to characterize the contamination and find the source of the organic residue found in failed units. Contaminant characterization was determined using four quadrant chart analysis based on solubility parameter principles and Meseran Surface Analyzer data, mass spectrometer, Auger electron spectroscopy, and contact angle measurements. Potential contaminants introduced by maintenance, production, and inspection as process aids were investigated. Analysis was made on component parts and fixtures associated with the assembly. Ten contaminants hitherto considered acceptable are described and analyzed; three were selected by analysis to be potentially major contributors to the electrical resistance problem.

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SUMMARY

Present clean room technology has achieved a level of cleanliness in terms of particle size and count measurement. Beyond this detection limit, however, are the organic contaminants deposited by impingement, condensation, or precipitation by various contaminant carriers. Technical advances within the last year or two now provide a means of organic contaminant detection in micro-quantities, as well as characterization, and therefore provide the potential for contaminant source identification. Thus, this work was applied to an assembly investigation beyond that of present clean room environmental control technology. As a result, the concept of acceptable materials is now being revised.

This work was done to identify the source of organic residue contamination potentially responsible for output switch assembly failures. Four methods were used to identify the type of contaminant and its sources: four quadrant chart analysis (Meseran Surface Analyzer), Auger electron spectroscopy, mass spectrometer, and contact angle measurements. Adhesive and plastic components were evaluated but this study indicates that they were not responsible for the hydrocarbon type of contaminant found in the MC 2946 units. A variety of fixtures and process aids, however, could contribute to the contamination problem. Contact angle measurements on components in the manufacturing area indicated contamination existed on a number of parts as a nonpolar type contaminant or as a detergent.

Contamination could have been introduced by any of nine candidate contaminants. Although all could contribute, three sources were considered most likely: WD-40, GC Circuit Cooler, and OX-140 Micro Oil. Recommendations are given for improved solvent cleaning processes, detergent rinses, material access control in the manufacturing department, and for alternate component carrying container materials.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this work is to identify the type of organic residue contamination found in failed units for their potential in causing excessive electrical resistance at the output switch contacts using technology hitherto unavailable. In addition, the identification of the source of the contaminant was required for subsequent controls.

ACTIVITY

Identification of a contaminant on a production part is not always feasible since analytical methods may restrict the size of the test unit that can be measured or because detection is beyond the limit of the instrument. Introduction of this new technology would minimize intuitive solutions sometimes directed at solving the wrong problem.

The technology of solubility parameter and of evaporative rate analysis have been combined to establish a fundamental relationship pertaining to surface characterization of organic molecules. It is based on the relationship between the polarity or nonpolarity of surfaces and the Meseran radioactive carbon-14 tagged chemicals used as surface energy probes.¹

Contaminant Characterization Methods

Contact Angle

The contact angle that a drop of water makes with a surface is a general indication of the nature of the wettability of that surface. Since water, chemically, is highly polar, a nonpolar surface will result in a very high contact angle, in the vicinity of 90 degrees. On the other hand, a more polar surface will yield contact angles that may range from 30 to 70 degrees. Contact angles of less than 10 degrees are usually found on low surface tension surfaces caused by the presence of a detergent, for example.

Four Quadrant Chart Analysis

The four quadrant chart analysis technique is based on solubility parameter principles using three radioactive chemical surface energy probes, having different types of nonpolarity-polarity, with the Meseran Surface Analyzer.¹ Unknown contaminants on surfaces can, therefore, be identified according to their polarity type.

Auger Electron Spectroscopy (AES)

The Auger spectrometer can determine the atomic elements present on a surface. The presence of organic residues is indicated by carbon atoms.

Mass Spectrometer

The mass spectrometer probe heats the sample and identifies the outgassing constituents by chemical type.

Assembly Contamination

The failure mode of the output switch was first identified as occurring upon exposure of the unit to cold temperatures; it was later found to also occur at ambient, high temperature, and after vacuum bake-out cycles. The contact resistance problem is primarily concerned with a contact header. However, the problem of contamination throughout the unit, before and after assembly, is widespread. Analysis of the many components served to provide contamination information.

Meseran data was obtained by testing the inside of the outer cylinder of a failed unit after it had been opened. Characterization of the nature of the contaminant was obtained by four quadrant chart analysis (Figure 1) as being nonpolar. Similar measurements were made on three other failed units. It is of significance that the location of the four unknowns are aligned along a common line which may be a function of concentration (Table 1).

Contact angle measurements of the four units surfaces were all 90 degrees, indicating a highly nonpolar surface (Table 1). Mass spectrometer analyses of the four units show basically hydrocarbon patterns.²

Auger electron spectroscopy (AES) analysis of the header and rotary contacts from reject units showed a gross amount of carbon contamination. AES analysis of the header after the cleaning process, however, showed very little carbon contamination.

Sources of Contamination

As a result of the characterization of the unknown contaminant being nonpolar, investigations were conducted to evaluate plastic components, fixtures, and production maintenance and inspection process aids for their potential contribution to the contamination problem.

Two cured adhesives and three plastic components were sandwiched between clean metal plates (standards) and exposed to 135°C under

Figure 1. Unknown Assembly Contaminant Characterization Based on Meseran Data

Table 1. Unknown Assembly Contamination Analysis Data

Inside Cover Measurements	Cover Identification			
	2262	2236	2269	2278
Contact Angle (Degrees)	90	90	90	90
Meseran Data				
Tridecane	109	31	48	30
Tetrabromoethane	6	5	33	30
Diethylsuccinate	0	0	25	38
Type	*	*	*	*
Mass Spectrometer	**	**	**	**

*Nonpolar all columns

**Hydrocarbon all columns

Auger spectrometry analysis showed gross quantity of carbon detected on the header/rotary contact

vacuum for 16 hours: Tefzel wire (fluorocarbon), coil (epoxy), washer (Mylar), A-2/E adhesive (epoxy), and EC2214 adhesive (epoxy).

Meseran and contact angle measurements of material were made on the top and the bottom plates (Table 2). All contact angle measurements were low (30 to 45 degrees). Meseran data (tridecane) showed there were no volatile nonpolar contaminants coming from the assembly components. There were indications of some volatilization of a polar nature. However, for all intents and purposes, these analyses showed that these components were not responsible for the type of contamination found in the units, it was not a built-in design problem.

A contact angle measurement analysis, made on a variety of metal and ceramic components used in the miniature electro-mechanical assembly area, showed all components were contaminated to a degree (Table 3). In addition to the high contact angle (non-polar contamination) found on most parts, there were several instances where the contact angle was less than 10 degrees, indicating the presence of a detergent from one of the cleaning operations.

Table 2. Components Contamination Potential Analysis Data
on Aluminum Plates

Components	Meseran Data*			
	Tridecane (Nonpolar)	Tetrabromo- ethane (Weak Polar)	Diethyl- succinate (Moderate to Strong Polarity)	Contact Angle (Degrees)
Tefzel (SS-304401)				
Top Panel	0	0	40	30
Bottom Panel	0	0	67	30
Coil (293942)				
Top Panel	0	0	73	30
Bottom Panel	0	0	24	30
Coil (293951)				
Top Panel	25	0	0	45
Bottom Panel	0	0	2	30
Mylar Washer				
Top Panel	0	16	3	30
Bottom Panel	0	0	1	30
Armstrong A-2				
Top Panel	2	0	29	30
Bottom Panel	0	0	55	30
EC2214				
Top Panel	0	33	27	30
Bottom Panel	10	0	0	30
*Radioactivity Counts in 112 Seconds				

Table 3. Contact Angle Measurements of Components and Fixtures Prior to Assembly

Component, Fixture	Contact Angle (Degrees)
Bonding Fixture	
Top Plate	20
Bottom Plate	35
Teflon Spacer	105
Pin Inside Cylinder	90
Constant Rotor Hub	
Side A	95
Side B	90
Contact (SS296650)	
Ceramic Center	<10
Back Side Gold	80
Back Side Ceramic	<10
Alumina Rotor (SS296640)	
Side A	80
Side B	<10
Housing and Coil Assembly (SS298272)	
Coil	90 (both sides)
Center Post	90
Actuator Housing Pole	105/80
Side of Housing Pole	45
One End Various Spots	Variable, 45 to 105
A Header	
Gold Over Rhodium	80
Gold Over Kovar Rim	80
Alumina Backside	<10
B Header	
Ceramic	30
Rim	105 and Zero*
Outer Metal Rim	90
Ceramic (Pin Side)	45

Table 3 Continued. Contact Angle Measurements of Components and Fixtures Prior to Assembly

Component, Fixture	Contact Angle (Degrees)
Cover	
Inside	25
Outside	60
Mylar	60
*Same rim opposite side	

Process Aids

Based on the new concept of contaminant detection capability, a large number of production and inspection process aids (spray containers and plastic fixtures) were evaluated for their potential as a contaminant as shown in the following listing.

Teflon cylinders are used as spacers for bonding fixtures.

Deep white polypropylene containers with 15 holes are used to hold components.

Shallow white polypropylene containers with variable holes are used to hold components.

Yellow polypropylene containers with 15 holes are used to hold components.

Shallow white polypropylene containers with 15 holes are used to hold components.

Polyethylene bags are used for component storage.

WD-40 Spray, WD-40 Company, is used for the Instron and all test equipment.

OX-140 Micro Oil, Webber Gage Division of the L. S. Starrett Company, is used for storage of actuator assemblies to prevent rusting.

Lubri-Bond A, Electrofilm Incorporated, is used for lubrication of counters and air motors.

MS-230 Contact Re-Nu, Miller-Stephenson Chemical Company, is used to clean contacts on all equipment.

MS-200 Magnetic Tape Head Cleaner, Miller-Stephenson Chemical Company, is used on a tester, Sabre II magnetic tape recorder.

GC Circuit Cooler, GC Electronics, is used for the tester (to isolate printed circuit board problems).

Glitter Glass Cleaner, Century Laboratories, Incorporated was used for cleaning windows.

Mass spectrometer analyses² of the indicated items, compared with the unknown contaminant in the unit, showed matching spectra (hydrocarbon) with polypropylene, polyethylene, MS-200, WD-40, Lubri-Bond A, GC Circuit Cooler, and OX-140 Micro Oil.

Meseran analysis, although confirming mass spectra data, differentiates between the various candidate contaminants according to the temperature and/or vacuum process conditions used. The primary candidates, therefore, by four quadrant analyses, under room temperature conditions (not vacuum baked), are shown in Figure 2 to be Lubri-Bond A, MS-200, GC Circuit Cooler, WD-40, OX-140 Micro Oil, and Glitter Glass Cleaner. Contact angle and Meseran data are given in Table 4.

After these materials were vacuum baked for 16 hours at 135°C, the potential contaminants are reduced to WD-40, GC Circuit Cooler, and OX-140 Micro Oil. The four quadrant chart analysis is shown in Figure 3; contact angle and Meseran data are given in Table 5.

It is possible for the Teflon spacer used in the bonding fixture to transfer to other materials. Contact angle measurements show this occurs to the bonding fixture pin (Table 3). However, mass spectra reading shows chlorine-fluorine contamination is not in the unit. The polypropylene carrying container can also be shown to transfer by contact angle measurements. Tests were made on the polypropylene sandwiched between clean aluminum Meseran test panels after 16 hours vacuum bake at 135°C. Meseran data and contact angle measurements are given in Table 6. This data, however, show no contaminant transfers under these latter conditions. These plastics, therefore, show variable contaminant transfer depending upon the conditions.

Figure 2. Candidate Contaminants on Aluminum Standard Substrates at Room Temperature

Table 4. Meseran Data and Contact Angle Measurements of Candidate Contaminants at Room Temperature

Contaminants	Meseran Data*			Contact Angle (Degrees)
	Tri-decane	Tetra-bromo-ethane	Diethyl-succinate	
Contact Re-Nu	0	5	0	30
Zero Mist				
Circuit Cooler	217	216	197	50
WD-40	403	253	163	30
OX-140 Micro Oil	1496	441	793	70
Lubri-Bond A	566	673	505	80
Glitter Glass Cleaner	90	72	2	<10
MS-200	304	143	212	45

*Radioactivity Counts in 112 Seconds

Cleaning Process

An unusually high level of contamination occurs when the actuator housing units are stored in plastic bags after being immersed in the OX-140 Micro Oil. Prior to use, the specifications require that these units receive a 30 second rinse in trichloroethylene as a means of removing the oil before other cleaning cycles are used. It has been demonstrated that solvent cleaning efficiency is dependent on the process and it is shown that vapor degreasing was more effective in removing oils than by using ultrasonic or spray cleaning.³ As a result, it was demonstrated on the housing that more difficult to remove contaminants could be effectively cleaned by a multi-cycle cleaning (vapor degreasing and ultrasonic cleaning) process.

The data on contact angle measurements of components (Table 3) showed several instances where less than 10 degree angles were present. Detergents provide such low angles, thereby suggesting greater rinse times are required in the process.

Figure 3. Candidate Contaminants on Aluminum Standard Substrates, Vacuum Baked for 16 Hours at 135°C

Table 5. Meseran Data and Contact Angle Measurements of Candidate Contaminants After 16 Hours Vacuum Baked at 135°C

Contaminants	Meseran Data*			Contact Angle (Degrees)
	Tri-decane	Tetra-bromo-ethane	Diethyl-succinate	
Contact Re-Nu	0	5	0	30
Zero Mist Circuit Cooler	91	43	20	45
WD-40	520	441	480	50
OX-140 Micro Oil	1097	333	382	85
Lubri-Bond A	319	604	509	80
Glitter Glass Cleaner	152	299	46	<10
MS-200	0	0	20	40

*Radioactivity Counts in 112 Seconds

Recommendations

The following recommendations are given for consideration to eliminate major and minor contamination problems associated with manufacture of the output switch to assure a high level of cleanliness potential.

The actuator housing, which is stored in oil, should be solvent cleaned using three cycles of a vapor degrease-ultrasonic trichloroethylene cleaning process followed by a vacuum bake.

Extended rinse times are required after detergent cleaning to eliminate detergent contamination.

Permit only acceptable solvents in the production area; eliminate spray cans.

All cleaning processes should be reviewed for time and process controls.

Polypropylene and polyethylene do show variable hard-to-remove contamination transfer, depending on the conditions and, therefore,

Table 6. Polyethylene and Polypropylene Transfer Capability
After 16 Hours Vacuum Baked at 135°C

Material	Meseran Data*			Contact Angle (Degrees)
	Tri-decane	Tetra-bromo-ethane	Diethyl-succinate	
Polyethylene Bag				
Top Panel	0	1	0	30
Polypropylene Sample**				
A, Top Panel	5	1	3	45
A, Bottom Panel	0	0	7	20
B, Top Panel	0	2	15	30
B, Bottom Panel	0	5	0	30
C, Top Panel	0	0	0	30
C, Bottom Panel	0	8	0	30
D, Top Panel	11	0	0	30
D, Bottom Panel	0	15	4	45

*Radioactivity Counts in 112 Seconds

**A, Yellow Polypropylene Shallow, 15 Hole, High Angle Container.
B, White Polypropylene Variable Shape, 15 Hole Container.
C, White Polypropylene Deep, 15 Hole Container.
C, White Polypropylene Shallow Hole, Low Angle Container.

are difficult to locate. Alternate material substitution is recommended if maximum contamination removal is required.

ACCOMPLISHMENTS

The contaminant found in failed output switch units is a nonpolar material such as found in hydrocarbon molecules. Four analytical methods in identification support the finding.

The plastic components of the assembly and the cured adhesives were not found to cause contamination.

There are nine process aids used by maintenance, production, and inspection which leave residues similar to that found in failed units. Detergent contamination is also present.

Mass spectra reveals there are seven sources of candidate contaminants; four quadrant analysis narrows the selection to three (WD-40, GC Circuit Cooler, and OX-140 Micro Oil).

Actuator units stored in OX-140 Micro Oil can be effectively cleaned by a multi-cycle vapor degrease-ultrasonic cleaning process.

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