AirBorn, Inc.

PTB30

APPLICATION NOTE

CONTACT “FRETTING” OF MIL-DTL-55302 CONNECTORS
DURING RANDOM VIBRATION TESTING

AirBorn receives occasional requests for assistance from customers who have encountered intermittent electrical contact problems with connectors which have been exposed to random vibration testing, usually as part of a reliability demonstration test program during which the entire system is being tested. The purpose of this application note is to explain the cause of these problems and to suggest some possible solutions.

A variety of connectors have been examined (both connectors manufactured by AirBorn as well as similar connectors manufactured by other suppliers) having been returned from customers as a result of detection of intermittent contact during or following exposure to random vibration testing. Invariably the pins on the plug connectors show varying degrees of very localized “fretting” wear at the points where the pins make contact with the multi-fingered springs in the socket contacts. By comparison, there is generally relatively little visible wear of the contact points in the socket contacts.

The worn contact points are easily visible as dark black spots on the otherwise shiny gold surface of the pin even without the aid of a microscope. When examined under magnification the black spots are seen to be composed of a "powdery" substance which can easily be removed with a relatively soft probe (a pencil eraser for example). Once the black powder is removed, it is obvious that both the gold plating and the nickel plating have been worn away and the base metal from which the pin is made is exposed. In severe cases, a significant amount of the base metal may have been worn away as well. Chemical analysis of the black powdery substance has shown that it generally contains a combination of copper and nickel oxides, both of which are very good electrical insulators. These insulating particles in the contact area are the cause of the intermittent electrical contact between the pin and the socket.

Even a small amount of insulating material in the contact area can cause intermittent contact during vibration, thermal cycling, or other events that cause the pin and socket to move slightly with respect to one another. The socket contacts used on the receptacle connectors in question all contain independent, redundant, spring contact elements (3 on the W-Series receptacles and 4 on the R-Series). Whenever *all* of the socket contact points ride simultaneously over an insulating particle, electrical contact will be lost momentarily. Whenever *one* of the contact points moves off of an insulating particle and again makes contact with a clean, gold plated area, electrical connection will be reestablished (momentarily at least). If a high speed storage oscilloscope were used to monitor current flow through the contacts during vibration, “glitches” would be seen in the oscilloscope trace indicating that the electrical connection is intermittent. However, when the same contact is checked for continuity after removal from the vibration test it is likely to appear functional, although its contact resistance will probably be higher than expected. If sufficient insulating material is accumulated in the contact area, total loss of contact will occur (open circuit) even when the contacts are not moving relative to each other. In this case, even an ohmmeter will detect an open circuit.

The insulating material which accumulates in the contact area is the result of oxidation of "wear debris" which is generated as a result of small amplitude, back and forth rubbing motion (typically .002" - .010") that occurs between the pin and the socket contact during the vibration test. This is termed “fretting” wear. This relative motion between the pin and socket is caused by the complex motion of the printed wiring boards (to which the connectors are attached) during relatively high level vibration exposure. It is important to note that this is generally a problem only in “motherboard to daughterboard” applications, not in “cable to board”, or “cable to cable” applications. In many such applications, the motherboard (or backpanel) is attached to the bottom of the chassis, and the daughtercard is held in the side rails of the chassis using clamps that hold the edges of the board rigidly in place (theoretically at least). When the chassis is subjected to vibration, both the circuit cards and the backpanel flex, bend, or “oil can”. The maximum displacement of the daughtercards is generally perpendicular to that of the backpanel. Since the right angle plug connector is generally attached to the daughtercard and the receptacle connector is attached to the backpanel, the two connectors are *forced* to move slightly with respect to each other as the boards move. Although this small motion doesn't constitute a full engagement and disengagement cycle, it produces friction and wear at the contact point nonetheless. In some respects, the wear is worse than that which occurs during a full mating cycle, because the wear debris particles don't get pushed out of the contact area as they would during a full mating cycle. Instead, they accumulate in the worst possible location - the contact area.

In a sinusoidal vibration test (as required for qualification of AirBorn’s connectors to Mil-DTL-55302), the motion of the connectors generally causes no problem because the PWBs do not resonate *continuously* during the vibration test. In the sinusoidal vibration test (see Mil-Std-1344, Method 2005.1, Test condition III) the vibration frequency sweeps slowly from 10 - 2000 Hz so that little time is spent at any single frequency. Since significant PWB motion occurs only when the applied vibration frequency is very close to the resonant frequency of the boards (typically about 200 Hz for a good sized PWB), significant board movement will occur for only a small fraction of the total vibration test time.

The situation is very different in a random vibration test during which all frequencies in the 10 - 2000 Hz range are applied *simultaneously*. As a result, the boards resonate *continuously* during the random vibration test. Thus, if the board resonates at 200 Hz, and the vibration test duration is 3 hours, the contact points in the connector will be subjected to a total of over 2 million small amplitude rubbing cycles (3 hrs X 60 min/hr X 60 sec/min X 200 cyc/sec). This huge number of rubbing cycles causes the gold plating, the nickel plating, and often a significant amount of the pin base metal to be completely worn away. Wear of the gold plating occurs slowly at first as a result of the mechanism known as "adhesive wear". However, as soon as the gold is worn through and the nickel begins to wear, the rate of wear increases dramatically because of the abrasive nature of the nickel oxide wear debris particles.

In some circumstances, "surface conditioners" (specially formulated contact lubricants) have been successful in reducing the wear at the contact points in the connector to a degree that will allow the system to pass a random vibration test. However, in other cases, surface conditioners have either not been successful at reducing wear sufficiently, or their use has created new problems. At best, this approach should be viewed as a "band-aid" solution and not a long term solution. The root cause of the problem is the small relative motion that exists between the pin and socket, and the most effective way to solve the problem is to eliminate this motion, although this is often easier said than done. Board stiffeners, more rigid card guides, screw type hardware to hold the connectors together, and vibration isolation mounts for the equipment are all possible options that may help eliminate this motion.

The fretting problem is often not discovered until after the design of the equipment is complete, and pre-production units are being run through qualification or reliability testing. At this point hardware design changes to solve the problem are at best difficult, and often impossible to implement because there often simply isn't space available. For this reason, when designing systems that will have to survive a random vibration test (even if the average or RMS g-level is relatively low) we encourage users of Mil-DTL-55302 connectors to recognize and address these problems during the initial design and to do everything possible to reduce the level of vibration and the relative movement at the motherboard to daughterboard interface. Testing by others[(1)] has shown that this relative movement between the pin and socket contact must be reduced to less than 0.001" in order to eliminate the fretting problem. This is often *very* difficult to accomplish, especially on large, or massive cards (like power supply boards for example).

It is important to understand that this is not a problem which is exclusive to connectors manufactured by AirBorn. It has been our experience that Mil-DTL-55302 connectors from other manufacturers experience the same "fretting" and intermittent loss of contact when exposed to random vibration. The problem is inherent in the way Mil-DTL-55302 implements motherboard to daughterboard connectors which allows the mated plug and receptacle connectors to move with respect to one another. The problem is aggravated by the fact that qualification of these connectors to Mil-DTL-55302 requires exposure only to a *sinusoidal* vibration test, *not a random vibration test*. In addition, the plating system required by Mil-DTL-55302 (hard gold over nickel per Mil-G-45204) is inherently incapable of withstanding such severe wear. Gold is an excellent contact material in many ways, but it simply is not wear resistant enough (especially when used in a gold against gold application) to survive for the hundreds of thousands or even millions of cycles that are accumulated during the random vibration test.

References:

(1) D. Winslow, "Investigation of Avionics Module Connector Wear", Proceedings of the 1991 ASME Design Technical Conferences - 13th Biennial Conference on Mechanical Vibration and Noise; September 22 - 25, 1991; DE-Vol. 38