Materials Engineering Branch

TIP*

No. 090 Fatigue Cracks in Solder Joints

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The information provided here supplements that previously reported in TIP 064 that the reader is encouraged to review.

A recent high voltage power supply failure that occurred after a yearlong thermal cycle test was attributed to an open solder joint. The power supply was potted with a polyurethane and although it was assumed, by some, that potting stresses were the cause of the failure it is a known, but easily overlooked, fact that solder fatigue plays a major role in such failures. Solder fatigue is caused by joining together and thermally cycling materials that have coefficients of thermal expansion (CTE's) significantly different from one another. This can occur independent of, but is usually aggravated by, potting materials, especially when the thermal cycle encompasses the glass transition temperature (see TIP 062 and TIP 089).

Several extensive studies conducted by IBM, ESA and others have shown that the primary cause of solder joint failures in printed circuit boards is <u>low cycle solder fatigue.</u> The fatigue is a result of the cyclic strain that eventually manifests itself in cracking of the solder. Cyclic strain is produced during thermal cycling by the large differences in the CTE's of materials in the joint. For example, a typical G-10 printed circuit board material has a CTE φ 60 ppm/°C, while the Kovar lead material is about 5 ppm/°C.

When flight hardware is thermally controlled within a narrow temperature range, such mismatched material configurations usually do not result in failure. Without thermal control, which is often the case, it is not unusual for flight hardware to experience thermal cycling over a temperature range large enough to strain cycle solder joints. When thermal excursions are large and material CTE's differ widely, failures (cracking) can occur within tens or hundreds of cycles. Cracking can also occur with thermal cycling, over a smaller temperature range if enough cycles are experienced.

It is important to note that a typical solder joint fatigue failure will look like, and may be mistaken for, a cold solder joint. Obviously, if such failure is incorrectly assessed, the wrong corrective action will be taken and the failure will recur.

Consider Space Station, which is to have an indefinite lifetime. Assuming a thermal cycle every 90 minutes, printed circuit boards could have 5,840 cycles per year and 58,400 cycles in 10 years. Depending on the temperature extremes, the fatigue limits of many solder joint configurations commonly used in electronic assemblies could be

exceeded. Unless proper precautions are taken, this will result in solder cracking of numerous joints.

To minimize effects of thermal fatigue, the following precautions are among many that should be taken.

- Match the CTEs of materials as closely as possible. Note: many materials (e.g.. graphite reinforced fiber plastics) have anisotropic properties.
- Select potting and conformal coating materials so that the low temperature extreme of the thermal cycle is above the glass transition temperature of the material.
- Exercise good engineering practices to prevent process defects such as contamination, intermetallics, and voids.
- Provide an adequate test program to evaluate the design by appropriate thermal cycling.