# CAPACITORS

## FAILURE MECHANISMS AND ANOMALIES

The relative failure modes of capacitors are shown in Table 1. As shown, the principal failure mode of capacitors is short circuits, particularly in mica, glass, and tantalum styles. Early life failures are initially caused by deficiencies in the capacitor manufacturing process, such as burred or rough foil edges, thin regions in separator paper, deficiencies in oxide films, etc., depending on the capacitor style. Failures later in life are often caused by excessive internal temperatures caused by high operating voltages or ripple currents. Some styles of capacitors are protected against failure by a self-healing process. A temporary short across a defect burns out the defect with minimal damage to the anode/cathode. The capacitor will continue operating, but in a slightly degraded mode.

Table 1. Normalized Failure Mode Distributions for Capacitors[2]

| Capacitor Style | Relative Failure Mode Probability | | | |
|---|---|---|---|---|
| | Open | Short | Value Change | Electrolyte Leakage |
| Mica/Glass | 13 | 72 | 15 | |
| Paper | 37 | 63 | | |
| Plastic | 42 | 40 | 18 | |
| Ceramic | 22 | 49 | 29 | |
| Tantalum, Chip | 32 | 57 | 11 | |
| Tantalum Electrolytic | 17 | 69 | 14 | |
| Aluminum Electrolytic | 35 | 53 | 2 | 10 |
| Variable Piston | 10 | 30 | 60 | |

A failure mechanism unique to aluminum electrolytic capacitors is safety vent failures. The purpose of the safety vent is to release internal pressures and prevent explosions of free oxygen and hydrogen that can occur at the anode. These internal pressures are created by excessive operating voltage, ripple current, reverse voltage, or from any abnormal operating condition that creates an internal temperature rise. However, safety vents can also open prematurely and unintentionally. This causes the electrolyte to evaporate, resulting in premature failure through decreased capacitance and dielectric withstanding voltage. Since the electrolyte is corrosive, leakage can also damage copper circuit board traces and surrounding components. The most likely cause of premature safety vent release is from handling damage during the manufacturing operation or degradation from cleaning solvents (especially halides). The safety vent may also release prematurely when subjected to low barometric pressures. For this reason, capacitors with safety vents are not recommended for airborne applications or any application where it may be subjected to low barometric pressures.

Wear out failure mechanisms in capacitors is usually caused by chemical effect in the dielectric and is a function of time, temperature, and voltage level. As a rule, the

[2] Failure mode data was taken from a combination of MIL-HDBK-978, “NASA Parts Application Handbook”, 1991; MIL-HDBK-338, “Electronic Reliability Design Handbook”, 1994; “Reliability Toolkit: Commercial Practices Edition”, Reliability Analysis Center (RAC), 1998; and “Failure Mode, Effects, and Criticality Analysis (FMECA)”, RAC, 1993.

time-temperature chemical degradation process doubles for each 10$^{o}$C rise in temperature (i.e., the failure rate at 100$^{o}$C will be twice the failure rate at 90$^{o}$C). Time-voltage degradation is more difficult to quantify because it is dependent on the type of dielectric. For some organic dielectrics, it can vary in proportion up to the fifth power of the voltage (i.e., the failure rate at 40 volts will be 32 times higher than the failure rate at 20 volts).