ANALYSIS

From The Lab

By Bob Neves

It's a Jungle Out There

A sign that reads "Welcome to the Jungle" greets me as I walk into our wet environmental test area. I feel like Elvis in Graceland when I walk into our "Jungle." But unlike Graceland, our environmental test area is not painted green with tacky, wooden furniture; it's high-tech white and filled with the latest in temperature/humidity chambers and test equipment. The primary use for the chambers in the "Jungle" is to torture test parts while simulating a variety of temperature and humidity (jungle) extremes.

In general, jungle simulation testing is done to check for degradation of the integrity in a material's system. Loss of integrity can include decreases in dielectric strength, loss of adhesion of conformal coating or solder, electrolytic corrosion, or electrochemical migration. The causes of these failures can be attributed to a material's loss of integrity, poor manufacturing practices, or improper cleaning of parts. If the subject of jungle testing interests you, a thorough explanation can be found in "IPC-9201 Surface Insulation Resistance Handbook." I highly recommend this handbook, and I have stolen some of the details in this column from it.

SIR Testing

Surface Insulation Resistance (SIR) testing has prompted much discussion and disagreement within the electronics community. SIR test patterns are usually interweaving combs of conductors. These combs consist of one to four sets of coupons for the measurement of insulation resistance on a surface. SIR testing is a tool which can (if used properly) detect the presence of surface contaminates and/or the lack of integrity of an insulating material.

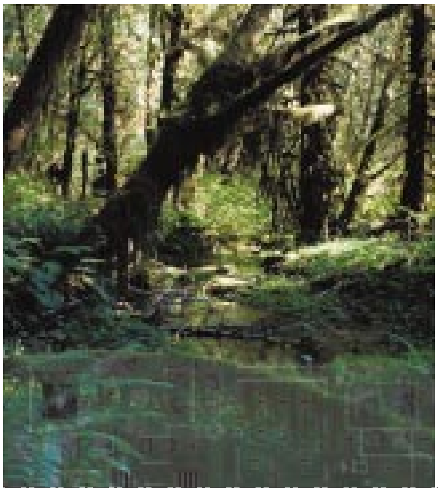
The three-letter acronym "SIR" has become the "go-to" term which represents all types of accelerated temperature/humidity testing. Other terms which have fallen out of favor are MIR, "Jungle test," temperature/humidity (TH) and temperature/humidity bias (THB).

SIR test patterns come in all shapes, sizes and placements. They can be big or tiny, and are sometimes placed under large footprint devices (such as LCCs or ASICs) to show the effects of entrapped flux or residue in shielded or difficult-to-clean areas.

The Testing Bias

Most of today's temperature/humidity testing methods require the application of a testing potential or bias to the test pattern during exposure. Typically, the electric potentials used are direct current (DC) potentials in the range of 40-100VDC. There has been some recent experimentation into the use of alternating current (AC) as a test bias (we'll see how that flies).

The test voltages applied typically have a direct effect on the levels of insulation resistance obtained from the test. If a low voltage level is used as the forcing mechanism, the resulting current flow is more susceptible to noise and are, consequently, less stable. If a high level of voltage is used, especially on a pattern with narrow spacings, the voltage could exceed the dielectric strength of the material, causing flash-over, spark-over, and sample carbonizing.



Steam Room or Sauna?

Next time you are at the gym, take a board, power supply and megohm meter into the steam bath for testing (you'll save a lot of money). Steam bath testing should not be confused with sauna testing. The people you see with electrical test equipment in the sauna are doing "Desert" and not "Jungle" testing. Sauna testing differs from steam room testing in that there is a distinct lack of humidity in the sauna. I'll leave the discussion of sauna testing for another column.

The moisture content of steam room air is expressed in terms of relative humidity. Relative humidity is defined as the ratio of actual water vapor in the air to the amount of water vapor which would saturate the air (rain/condensation) at a given temperature. As temperature increases, the air's ability to hold moisture and its "saturation level" also increases. This means that an increase in temperature requires the addition of more water vapor to remain at a given relative humidity. The relative humidity present during sample exposure affects the amount of water vapor capable of mixing with and mobilizing contaminants on a board surface. Low relative humidity during a test will generally limit electrochemical migration, whereas high levels of relative humidity will saturate the test sample, allowing the possibility of electrochemical migration to happen.

Higher temperatures also affect the activity and mobility of ions on the surface. It would seem that "more is better" in this case, but you must be careful as many con-

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taminant materials evaporate or sublimate at elevated temperatures, giving you a false sense of security.

Industry Solutions

The choice of cyclical or static test environments—high temperature/high humidity or low temperature/high humidity—for jungle testing is dependent on what kinds of surface problems you're trying to bring to light. Cyclical tests are typically used to simulate an end-use environment and test the capability of the materials used. Steady state temperature/humidity tests are most often used to test for electrochemical migration or electrochemical corrosion.

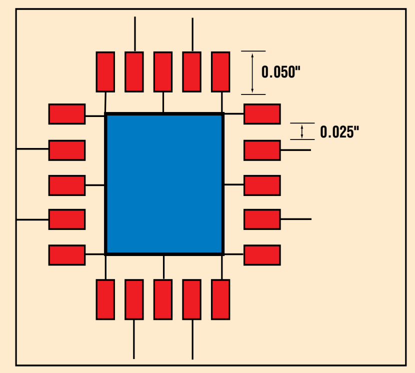
Temperature/humidity testing comes in several "Industry Standard" flavors (as well as custom company flavors):

- IPC-TM-650, method 2.6.3.1 and 2.6.3.2. This test method is a simulation of a condensing environment. The temperature varies from 25°C to 65°C and 90%RH three times per day for about seven days with the test patterns biased with 100VDC throughout.
- MIL-STD-202, method 106. This test method is similar to the one above, but only has two cycles per day. In place of the third cycle, an eight-hour ambient soak is used. In some cases, an exposure down to 10°C is included during the eight-hour period.
- IPC-TM-650, method 2.6.3.3A. This is a seven-day exposure to 85°C and 85% RH, under a DC voltage bias. There are those who claim (based upon Arrhenius assumptions) that each week of exposure simulates a year of tropical service.
- Bellcore TR-NWT-000078. Tests for one to four days at 35°C and 85%RH with no bias voltage applied.

A Pattern in the Jungle

There are a lot of different test patterns out there for insulation resistance testing (IPC, Bellcore, Military, etc.), and the question arises: can results from one test pattern be correlated to another test pattern? The attempt at correlation depends upon the concept of "Ohms/Square." The "square" portion of this equation is not defined in terms of cross-sectional area (i.e., $inch^2$ or cm^2). The "square" is defined by two electrodes sides of length "X" which are separated from each other by the same distance "X." So a pair of 1 inch long circuits separated by 1 inch spacing is 1 square, and a pair of 1 cm circuits separated by 1 cm is also 1 square

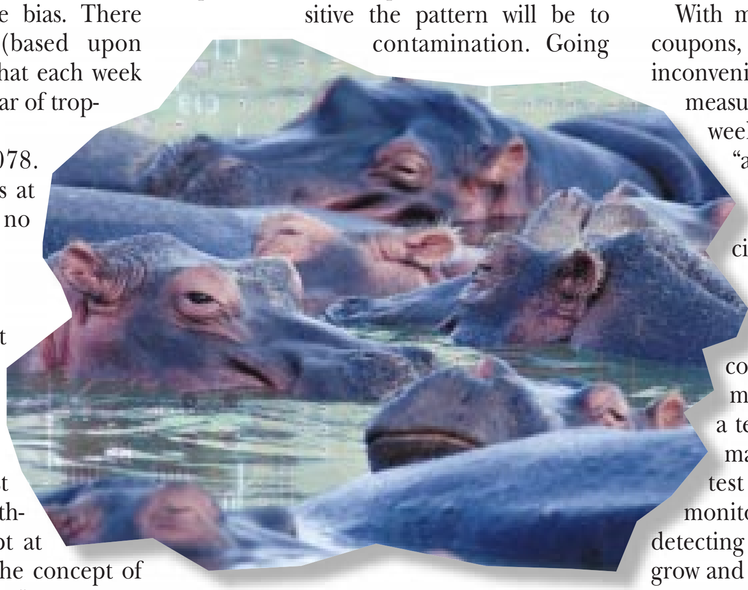
Figure 1.



(see Figure 1). If your pair of circuits is 10 mm long separated by 1 mm spacing, you have 10 squares. Since each "square" is a dimensionless unit, normalization of resistance data to an ohms/square value theoretically makes the electrical test data independent of test pattern configuration or geometry. This square philosophy makes the assumption that the entire test pattern is homogenous. This can be a big problem if localized contaminate is on the surface.

For reference, the MIL-STD-275 "Y" pattern has a square count of 120 squares. The IPC-B-36 board comb pattern has a square count of 3583 squares. The IPC-B-24 has a square count of 1020 squares. The Bellcore pattern has a square count of 440 squares.

Designers may ask how large to design a test pattern, or how many "squares" to design into a pattern. The higher the square count of the pattern, the more sensitive the pattern will be to contamination. Going



above 4,500–5,000 squares can make the test pattern too sensitive. Going too low in square count would lead to a situation where nothing but the grossest of contamination would be detected.

Growth in the Jungle

As high temperature/humidity and sunlight promote the growth of plants in the jungle, high temperature/humidity and electrical potential promotes metal growth on the PWB. The general term for this growth is electromigration. Electromigration is defined as "the current induced transport of metal ions in a metal conductor." Basically, the electrons which are conducting the electricity scatter metallic ions in the direction of current flow. Electromigration is typically accompanied and accelerated by ionic contaminates (typically chlorides) present on the surface.

Another form of metal migration is electrochemical corrosion. Corrosive residues left on the surface from fluxes or other cleaning materials can attack the metal of a circuit, placing metal ions into the moisture/residue solution on the surface. If the solution is in contact with dissimilar metals which are electrically connected (e.g., the boundary between a gold plated connector and copper or solder), an electrical cell is formed which can provoke metal corrosion. As the metals deplate from a test circuit, the resultant electrical filament forms a temporary short. This short typically cannot handle the resulting current and is destroyed, much like a fuse. The result is often a carbonizing of the board surface in the outline of the filament. For long-term tests, this filament growth and death can be an almost continuous operation.

When Do You Measure?

With manual measurements of sample coupons, frequent measuring is costly and inconvenient. For this reason, many test measurements call only for daily or weekly measurements and represent "a snapshot in time." Such a measurement scheme will not pick up the changes in resistance associated with dendritic growth. More modern instrumentation has provided the capability of measuring more frequently (e.g., constant monitoring) in an automated fashion. Frequent polling of a test pattern will yield better information about the behavior of any test pattern over time. Frequent monitoring increases the chances of detecting the conductive filaments which grow and die.

The Law of the Jungle

As you can see, there is life and death in the jungle. The life of your product can be determined by accelerating the environmental exposure. Surface cleanliness and performance will continue to be an issue, so be prepared to take your journey into the "Jungle."