ProofCap as moisture barrier

Moisture followed by corrosion is one of the key factors influencing the reliability of electronic equipment. This article explains some of the basic facts about humidity, moisture absorption and diffusion followed by a description of how ProofCap technology will protect equipment in humid environments.

Article by Mr. Björneklett, Are, Ph.D. Physics, at ERICSSON, Sweden, 99-09-07

Introduction

Modern electronics tend to migrate into applications which are exposed to out-door climatic conditions. Automotive electronics, marine electronics, remote sensors, control systems, radio transmitters for cellular phone systems, radio links and other communications systems are all examples of equipment exposed to high levels of humidity.

Furthermore, modern electronics is based on components with high clock rates, low voltage levels, high impedance and sensitive radio-frequency circuits. These factors make them very sensitive to moisture ingression and absorption.

Cost effective protection against high humidity and moisture ingression is badly needed and ProofCap technology is one possible solution to the problem.

Humidity in the atmosphere

Vaporized water is a natural constituent of the atmosphere. Air can hold a certain amount of vaporized water called the saturation concentration. Any excessive vaporized water above the saturation concentration will precipitate as condensed water. The saturation concentration is strongly temperature dependent, see Figure 1. At 0°C it is 4.84 grams/m^3, at 50°C it is 82.7 grams/m^3 and at 100°C it is 589.4 grams/m^3 (all values are valid at sea-level atmospheric pressure). A common measure of humidity is ***RH or Relative Humidity***. This is the ratio of the of water vapor concentration to the saturation concentration. For instance at 25°C the saturation concentration is 23 grams/m^3.
If RH is 50 % and the temperature is 25°C, the water vapor concentration is 11.5 grams/m^3.

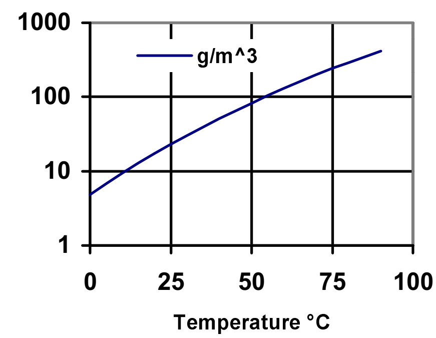

Figure 1. The saturation concentration of water vapor in air as a function of temperature. The unit is grams per cubic meter.

Moisture absorption in materials

Materials used in modern electronic components include various types of plastic materials which can absorb considerable amount of moisture. Such materials are called ***hygroscopic***. Non-hygroscopic materials may have hygroscopic surface treatments. The ***Absorption*** of water in hygroscopic materials is a two-step process, first ***Adsorption*** and then ***Diffusion.***

Adsorption is the process where free water molecules in the air attaches to the surface of a material. Most materials at temperatures typical for electronic equipment will have a film of water molecules on the surface. The thickness of the film is typically from a few atomic diameters up to a few hundred. The film is in thermodynamic equilibrium with the humidity in the air and the thickness is mainly depending on the humidity of the air, the temperature and the physical properties of the surface.

Diffusion is the process where water molecules are transported from the surface to the interior or bulk part of the material. The diffusion process is time and temperature dependent. The typical diffusion time for moisture in plastic materials of typical dimensions used in electronic equipment is from a few hours up to a few days.

The moisture uptake in plastic materials is usually inversely proportional to the temperature at constant water vapor concentration.

This effect will help reduce moisture problems. For instance, a high relative humidity created by a temperature drop may be compensated by increased absorption in plastic materials.

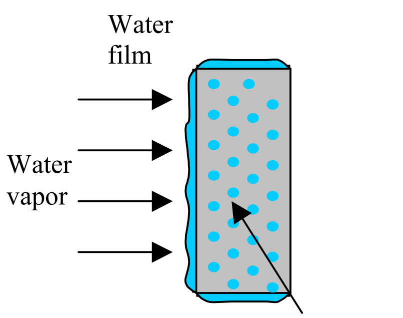

Figure 2. The principle of water absorption in hygroscopic materials. Free water molecules in the surrounding air is attracted to the surface of the material (adsorption) thus forming a thin film of water molecules. The water molecules can then diffuse from the film into the bulk of the material.

It is interesting to compare the amount of moisture absorbed in material compared to the amount of moisture in the air for a typical enclosure for electronic equipment. A typical PCB Printed Circuit Board may have dimensions 150 x 100 x 1.5 mm^3. Most of the PCB consists of FR4 epoxy material which absorb approximately 0.5 % water or 112.5 mm^3 liquid water which is 112.5 mg. A typical enclosure for this PCB may have dimensions 160 x 110 x 30 mm or 530 mm^3. At 25°C the saturation concentration of moisture in air is 23 gram/m^3 or 12.2 mg liquid water in the enclosed air.
In this case it is 10 times as much moisture absorbed in the material (PCB in this case) as in the air within the enclosure, see Figure 3.

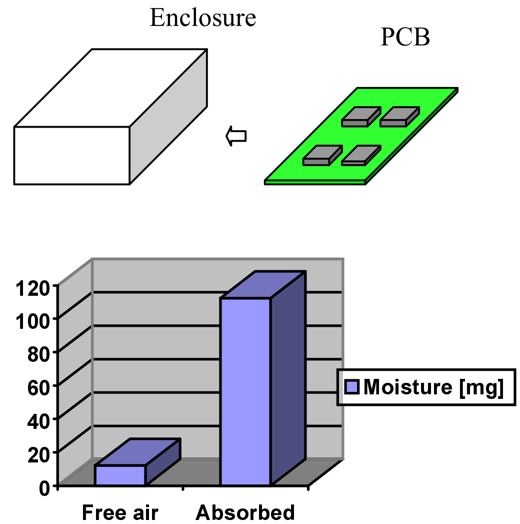

Figure 3. The moisture absorbed in the epoxy circuit board and the amount of vaporized water in the free air in the enclosure.

This example shows that it is very important to consider the absorption of moisture in plastic materials when trying to understand how an electronic enclosure behaves in humid environment.

Why is moisture a problem for electronic equipment?

Moisture may have different effects on electronic equipment. Relatively large amounts of condensed water will of course result in electrical short-circuit and large leakage currents. However the most common harmful effect of moisture is corrosion. Moisture alone is not the cause of corrosion. It is usually moisture in combination with ionic contamination on the circuit board or air pollution which result in electrochemical corrosion of the PCB and its components.

Protection against moisture

There are many techniques for protection of electronic equipment against moisture. Only a few can be mentioned here.

Hermetically sealed enclosure

The principle of hermetic sealing is that the entire enclosure is made of metal or ceramic material which will not allow diffusion of water molecules into the enclosure. It is important that all components inside the enclosure is as dry as possible before the enclosure is sealed off.

The sealing process is often made in an inert atmosphere in order to keep the initial humidity inside the enclosure as low as possible.

A major risk with hermetic enclosure is leakage caused by defects or wear-out in materials or sealing process. Moisture may under certain circumstances accumulate inside the enclosure resulting in condensed water and heavy corrosion.

Large enclosures for electronic equipment often include connectors, display, switches and buttons. Such features are very difficult to seal hermetically. Hermetic sealing is therefore mostly used for small enclosures such as packages for integrated circuits and sub-assemblies.

Breathing enclosure

Electronic enclosures may also be made fully breathing. This means that a ventilation hole or membrane permeable to air is made in the enclosure. A ventilation hole should be located in a position protected from direct rainfall or splash. A breathing enclosure will keep its interior at the same humidity as the ambient environment, but the electronic equipment will be protected from liquid water caused by rain-fall or accumulation of moisture. In those cases where the electronic equipment has a stable power dissipation and thereby a higher temperature inside the enclosure than outside, then the internal relative humidity will be reduced compared to the ambient. In such cases the breathing enclosure may be particularly attractive.

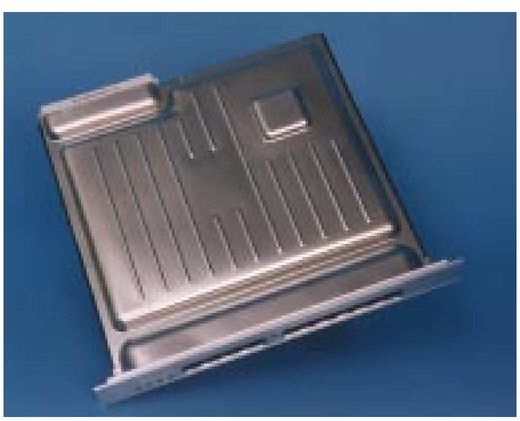

Figure 4. ProofCap applied on ERICSSON Micro Base station board.

ProofCap

ProofCap is a technology based on materials used for packaging of liquids and as such it comes very close to a sealed hermetic enclosure, but at a very low cost compared to traditional hermetic packaging.

The ProofCap enclosure consists of metal sheets which are non-penetrable for moisture. The polymer welding seam which is a very small part of the enclosure, do however not meet the full requirements of hermetic sealing. Moisture diffuses and penetrates polymer materials, see Figure 4-5.

The time constant for diffusion of moisture into a typical ProofCap enclosure is in the order of years. ProofCap therefore comes close to a hermetic enclosure.

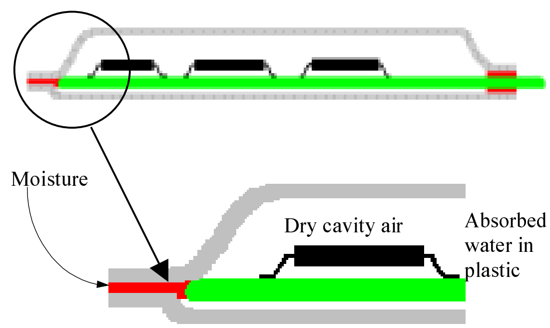

Figure 5. The sealing between the top-side and the bottom-side laminate is a point of moisture ingression because water molecules migrates in polymer materials

A typical ProofCap enclosure will also have a relatively small air volume and there will be a considerable amount of plastic materials such as the inside plastic layer of the ProofCap cover, circuit board and plastic encapsulated components inside the enclosure. As mentioned above the moisture absorption of plastic materials increase at low temperatures in a closed system with constant water vapor concentration. The risk for precipitation of condensed water is therefore reduced inside a ProofCap enclosure.
It is possible to simulate the moisture diffusion into ProofCap based on results from accelerated tests and models for moisture absorption and diffusion in plastic materials.

Some results are shown below, figure 6-7. The ambient climatic conditions in these simulations are typical for the Middle East region with very large temperature differences between summer and winter and correspondingly large differences in relative humidity. This particular type of climate was selected because it is difficult to protect equipment against moisture under such circumstances. The relatively high levels of humidity during summer time and warm days will easily condense as liquid water during cold nights.

The graphs below show the humidity inside a typical ProofCap enclosure as a function of time and ambient humidity.

Three important observations should be made from the simulation result.

1. The diffusion of moisture into the ProofCap enclosure has a time constant of several years.
2. The ProofCap enclosure protects the electronic from the extremely high humidity during winter nighttime.
3. A relatively moderate over temperature caused by heat dissipation inside the enclosure will reduce the internal humidity.

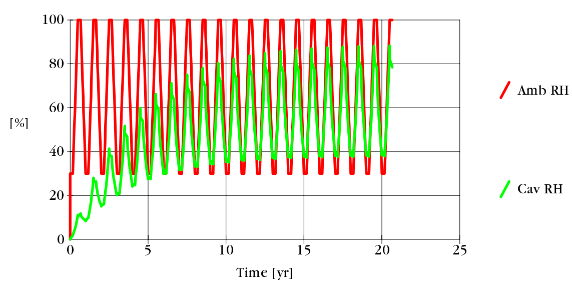

Figure 6. Relative humidity (RH) inside a typical ProofCap enclosure (green line) as a function of the ambient humidity (red line). The climate represented by the ambient RH in the simulation is representative for the middle-east countries. The maximum RH of 100 % occurs at night and the low RH of 35 % during warm summer days.

ProofCap as moisture barrier

ProofCap offers a near-hermetic barrier against moisture migration based on the very low cost technology used for food and beverage packaging (compare Tetra Pak).

The moisture diffusion rate into a ProofCap enclosure is slow, in the order of years.

The small amount of moisture which penetrates the ProofCap enclosure, will be absorbed by plastic based packaging materials typical for modern electronics.

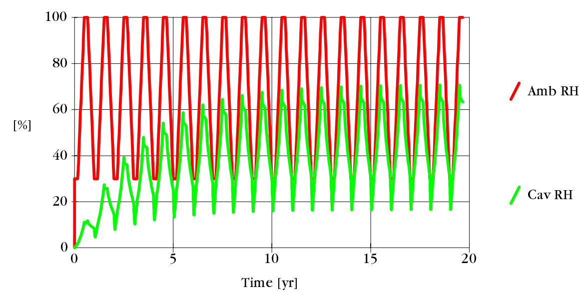

Figure 7. The same simulation as above, but with internal heat dissipation causing an over temperature of 10°C during 5 % of the time.

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ProofCap AB
Högmalmsvägen 57, SE-139 73 Djurhamn, Sweden

Tel: + 46 8 571 545 06
E-mail: k-e.leeb@telia.com

Internet: www.proofcap.se