

# HUMIDITY, ITS EFFECT ON ELECTRONIC INDUSTRY AND SOLUTIONS

Uday Chakravarty, Sales Manager-Int'l. Agency Division  
Arctic India Sales

## Introduction

Humidity has been a problem for many engineers to grasp because :

- a) Temperature - we can feel.
- b) Vibration - we can both see and feel.
- c) Humidity - is nothing but just little moisture which can't be seen or felt but always present in the surrounding air or on the surface.

The moisture present in the air along with temperature has a long term and devastating effect on man, machine and material. Every industry of the mechanised world is affected by humidity both in terms of material and money.

Some of the effects of humidity are explained in the following transparencies which we encounter in our day to day life .

## **Moisture / Humidity . . . . . The Problem Identified !**

Rust, mold, mildew, rot, decay, warping, stretching, lumping, caking, agglomeration and decomposition are all common enough problems encountered in our daily life.

It is interesting to note that the root cause of all these problems and many more, is the presence of moisture or humidity in the air.

The storage, manufacture and transportation of material often takes place in a humid environment which is not suited to the moisture sensitivity of the material, leading to deterioration of stored material, machinery, equipment and reduced product appeal.

## **Problems in the Pharmaceutical Industry**

In the Pharmaceutical Industry, chemists have common problems of decomposition and difficulty in compression of tablets leading to breaking of tablets; lumping and caking of dry powders, improper adhesion under pressure of tablets, improper drying of gelatine capsules.

The presence of high humidity in the air is the cause of all these problems.

## **The Food Industry**

Potato chips, dry breakfast cereals and soda crackers exhibit an affinity for water when exposed to high humid conditions and will become soggy and unappetizing.

In processing of powdery foods such as cocoas, gelatines, the sticking or lumping of powder prevents its flow in the manufacturing process, and this is due to high humidity conditions.

## **The Electronic Industry**

In the electronic industry, printed wirings get corroded due to presence of high humidity. Transistors may break down or suffer a decrease in longevity and the uniform growth of crystals is unachievable.

## **The list is endless**

Humidity makes for mushy transfers in the printing industry and irregular operating of packaging machines.

Seeds lose their germinating power and dry fertilizers agglomerate. In pumping stations and high

voltage rooms, expensive installations may rust as a result of unchecked condensation.

Hence, Humidity causes waste, if left unregulated.

### **How Humidity Effects Industry ?**

Humidity is a constant threat to production efficiency and product quality.

The damage which can be caused by excessive relative humidity are principally—

- corrosion of steel and metals
- deteriorated characteristics of hygroscopic material
- increased harmful activity of micro organisms.

**Corrosion:** Corrosion is defined as destruction of a metal or alloy by chemical or electrochemical reaction with its environment. In most instances, the reaction is electrochemical in nature: a flow of electricity between certain areas of a metal surface through a solution capable of conducting an electric current. This electrochemical action causes destructive alteration (eating away) of a metal at areas.

Though corrosion is a complex function of many factors, the three most important are—

- a voltage differential between pure and impure areas
- physical conditions of temperature and humidity
- and oxygen in the air.

Higher humidities may lead to higher condensation of water on the metal surfaces. The concentration of molecules of water vapour increases with increasing RH. This molecular thickness of the layers of water eventually permits **ionic** conduction which accelerates the rate of corrosion.

With iron or steel, the ferrous ion may react with hydroxyl ion in water to form ferrous hydroxide and with oxygen to produce ferric hydroxide (rust).

The figure shows the rate of corrosion in relatively clean and polluted air. The critical humidity level which is at 45%, is approximately same for clear and polluted air, however the rate of corrosion is faster where surfaces are exposed to polluted air in combination with high relative humidity. Industrial pollutants like sulphur dioxide enhance the corrosion rate.

Corrosion or rusting of stored material can be seen in every Industry—Defence, Marine, Precision parts.

### **Deteriorated Characteristics of Hygroscopic Materials**

The figure shows the equilibrium moisture content for some hygroscopic materials.

Certain materials require extremely low or high moisture contents during manufacture or storage.

In **the Food Industry**, dry foods such as potato chips and powders exhibit an affinity for water when exposed to relatively high humidity conditions. Although, the product quality *per se* is not affected, these foods becomes soggy and hence undesirable.

Powdered foods tend to agglomerate or lump together. The result is that their movement through the manufacturing or packaging process is greatly inhibited. In addition humidity may interfere with their processing and packaging as well.

Similarly, in the **Pharmaceutical** Industry chemicals and compounds on absorbing moisture lose their medicinal value and even decompose.

Powder will not adhere properly nor lend itself to compression in the form of tablets if the humidity is high.

In the **Fertilizer Industry**, dry fertilizers may agglomerate in presence of high humidity.

Excessive Relative Humidity reduces the resistance of electrical insulation material.

The mechanical strength of many materials like paper, deteriorates when RH is high.

Excessive RH is dangerous to explosives.

An excessive moisture content in a material can give rise to a change in its dimensions as e.g. in wood and plastics.

### **Injurious Activities of Micro Organisms**

An excessive moisture content can indirectly contribute, to the destruction of organic material by increased microbial activity.

Mold, mildew and fungi are all different types of bacteria. Outdoor air is well endowed with this bacteria which are small enough to be carried indoors and which will settle on materials. The spores lie dormant until suitable conditions of temperature and humidity are achieved. In general, the spores will not germinate below 60% RH. The actual temperature conditions for germination may vary widely between different types of molds.

Once germinated, the mold prospers and the speed of growth is a function of temperature and humidity. The condensed moisture on materials acts as a medium conducive to the growth of bacteria. Moreover, at high temperature the activity of the micro-organisms increases but a certain amount of activity occurs even at very low temperatures.

This micro-organism growth is injurious to materials; as it not only results in decomposition but also mechanical weakening of the products. In most cases, bacterial growth can be arrested if RH is maintained below 45%.

The effects of humidity can be illustrated and presented endlessly but today's topic is restricted to effects of humidity on electronic equipments.

## **2. Environmental effects on the Humidity level**

**The Variables that Affect Humidity :** The number of variables that interact and affect the humidity levels in the environment are myriad. Changes in the water vapour content in the atmosphere not only varies with the time of day and latitude but also is affected by seasonal changes.

## **3. The Sources of Moisture**

***Various failure modes or deterioration in operability of electronic equipment exists because of the combined influence of both temperature and humidity.***

**Sources of Moisture w.r.t. to Electronic :** there are three main sources of moisture within an electronics unit that must be carefully considered :

**(i) Ingress through the seal imperfections :** It is possible for moisture to enter a unit through imperfections in the environmental seal. The diffusion rate at which the ingress occurs will depend on the type and size of the leakage path.

Providing the length / diameter ratio is greater than 40:1 the rate of diffusion will be very small.

There are two basic mechanisms whereby leakage occurs.

(a) Capillary Action : water covering the leakage point may enter by capillary action alone.

(b) Pressure Differentials : The force that results in water vapour ingress is the vapour differential pressure between the low pressure inside the box and the high vapour pressure outside. Changes in barometric pressure or thermal gradients can cause the pressure differentials which result in the ingress of moisture.

**(ii) Ingress through the seal :** Ingress through the actual sealing material due to the moisture vapour transition rate (MVTR) of the polymer sealing compounds. The rate at which the ingress occurs will depend on :

(i) the sealing material

- (ii) the method of fitting
- (iii) the number of screws utilised to secure the lid

(a) Moisture vapour transmission rate (MVTR) : As all plastics are hygroscopic and have a vapour transmission rate careful consideration of the MVTR for the materials utilised must be given. Although this is not as important as the sealing efficiency it can effect the ingress medium.

### **(iii) Moisture Absorption, Adsorption, Desorption from the Surface**

**(A) Absorption** : This is defined as moisture diffusion through spaces in the molecular structure

**(B) Adsorption** : This is defined as a moisture layer which may only be one or more molecular layers on the surface of a material.

**(C) Desorption** : It must be recognised that the printed circuit board with components form quite a large surface area but because the boards are polymer they will adsorb a lot of moisture. When power is applied and the unit is functional the induced heat releases the moisture from the board and component surface into the air within the box which can create a high humidity.

**The cause of Failures** : As the amount of water that can be supported by a volume of air is related to the temperature. **Absolute Humidity** is defined as the amount of water vapour present at a specified temperature at a particular time and is measured in grams/cubic metre. As the temperature within a unit decreases so will the capacity of the air to retain its moisture resulting in any excess moisture condensing inside the box.

**(I) The Condensing Atmosphere** : Consider the scenario where the temperature inside a unit is at 40°C and the dewpoint temperature is at 23.8°C the Absolute Humidity will be 20.4 grams/cubic metre (this equates to a Relative Humidity of 40%). If the unit is cooled down to the outside ambient temperature of 20°C then the absolute Humidity will be 17 grams/cubic metre but the Relative Humidity will be 100%. The excess moisture cannot be carried in vapour form in the air but will condense on the inner surfaces.

Put simply this means, when the air temperature is lowered below the dewpoint temperature then water condensation is formed. An ideal condition for condensation to occur would be in computer room where the air is maintained at 20°C utilising an air conditioning unit but the outside climatic conditions are 32°C with a relative humidity of about 90%RH (hot and humid)

(a) The effects of condensing atmosphere :The major effects of condensation inside an electronics unit can be :

- (i) electrical shorts
- (ii) the binding of mechanical moving parts
- (iii) localised corrosion

## **4. The effects of moisture ingress**

The devastating effects of humidity on electronic equipment is more often both underestimated and misunderstood. The consequences of moisture ingress will vary with the materials used and can cover the following range of effects. I have deliberately split the problem in two (Primary and Secondary Effects) and looked at both separately.

**Primary Humidity Effects:** These are the direct results of humidity acting on equipment or materials and are represented by the following groupings.

**Degradation:** The presence of humidity may result in the degradation of

- (a) the performance of equipment operating in the infra-red band
- (b) some materials such as fabrics, some plastics and cellulose

**Delamination** of composite materials. This may have a devastating effect on some cheap

PCB materials.

**Dimensional Changes:** This can result in not only high stress because of bowing but also the swelling of fibrous materials.

Fibres : When exposed to humidity fibres with high moisture regain figures usually not only lose tensile strength and extensibility on the absorption of water but will also suffer a fair degree of swelling.

**Surface Resistivity:** On PCB's reduction in surface resistivity can alter timing circuits, change the frequency of oscillator circuits, change the current level in a constant current source, result in loss of sensitivity or reduce the input impedance on high impedance amplifiers.

**Outgassing from PCB Laminate:** Experience has demonstrated that many printed circuit boards assembled by a number of different Commercial Companies have experienced blow holes or voids in the solder joints from the outgassing from the resins. These defects can be traced to :

(a) Moisture : One of the main causes of outgassing during the soldering process is when moisture, absorbed by the resin during long term storage prior to assembly, is released in gaseous form during the extreme temperature during soldering, resulting in poor solder joints, pinholes, blow holes or the rupturing of plated through holes.

(b) Multilayer Technology: The rupturing of a plated through hole in multilayer boards can also create such problems as the disconnecting of internal tracks and the resultant high rework costs.

**Secondary Effects :** For easy of identification most secondary effects require contamination or an additional component before any form of action takes place.

**Warning!! Common Contaminants:** In the electronics industry poor hygiene standards may add sufficient contamination to supply the necessary nutrients to support growth formations.

Contamination from any of the following sources can cause long term damage which may not be detected during either inspection or test. Manufacturing quality controls are sadly lacking if this type of damage is being experienced by your company.

**(I) PCB Manufacture:** Contamination may take place during the actual production of the board and is usually due to either

(a) incomplete curing of the resin

(b) badly applied solder resist

The whole situation may be further compounded by any of the following process failures

**(II) Poor Goods-in Inspection:** Where lack of training or inadequate inspection equipment allows contaminated boards to proceed into the production system.

**(III) Bad Handling techniques:** This can result in further contamination of the PCB from skin flakes, food, tobacco tar, cosmetics or any of the contaminants listed under poor hygiene.

**Poor Hygiene:** Even in commercial environments, hygiene can be critical. Where poor hygiene is tolerated in a manufacturing area serious damage can be caused to the PCB by any of the following contaminants being transferred by hand. The additional presence of humidity can result in accelerated biological activity :

**(I) Bodily Fluids:** The transfer of bodily fluids such as perspiration, spittle or urine can have spectacular effects. Where poor cleanliness standards are adhered to within an organisation the transfer of urine to a board being worked on is quite possible. The result can be corrosion and or fungal growths.

**(II) Fruit Juices:** (from citrus fruit such as oranges) The damage from corrosion in the presence of humidity can be extensive

**(III) Machine Drinks:** The spillage of tea, coffee, chocolate or drinks such as cola may either

result in corrosion or fungal growths.

**(IV) Salt from Crisps:** Being hygroscopic salt can

- (a) absorb moisture and form a liquid bridge across the gap between tracks on a PCB
- (b) give the necessary conditions to support corrosion
- (c) while the vegetable fats from the crisps can support growth formations

**Salt and Vinegar Crisps:** This corrosive combination has an additional effect, it can eat through the tin lead coating on the PCB track and produce some wonderful copper sulphate formations

**(V) No Clean Fluxes:** The input impedance of devices can also be affected by the presence of humidity vapour on any polar contamination in the flux residue.

When utilising hand soldering techniques, some modern synthetic no clean fluxes will not reach the deactivating temperature of the flux. If subjected to high humidity for a period of two to three weeks the result is a white organic salt residue which, although low in ionic contamination can easily trap moisture. This in turn can affect the surface resistivity. Due to the hygroscopic nature of these salts the problem may be further compounded as they present a perfect medium to precipitate dendritic growth when power is applied to the PCB.

**Mould Growth or fungal growth** normally requires an environment that is both warm and high in humidity. The formation of fungal growths can cause damage to Polymers and even the etching of glass but only where there are the necessary nutrients or organic salts to support growths.

During the normal metabolic process micro-organisms digest organic materials; enzymes and organic acids diffuse out of the cells and onto the materials. This may cause a range of problems such as

- (a) metal corrosion
- (b) etching glass
- (c) hardening of grease
- (d) extensive damage to some paint finishes

**Electrolytic Corrosion:** Corrosion usually requires the presence of moisture and soluble impurities which may be inherent in the materials or contained in atmospheric pollution. This solution will therefore provide the electrolyte necessary for the electro-chemical reaction of the corrosion process. This takes place where dissimilar metals are in contact or may also be initiated when the electrolyte bridges the gap between metal surfaces and current flows. It is not necessary to have visible wetting of the surface but an invisible adsorbed film of moisture is sufficient to support electrolytic corrosion.

**(1) PCB'S:** The presence of conductive electrolyte on the surface of PCB'S under voltage stress can result in surface tracking because of corrosion or in the worst case the electromigration of metal across the gap resulting in a short circuit.

**(2) Connectors:** The ingress of moisture into a connector may result in corrosion around the pins. The effects of corrosion in a connector can easily be (I) The increase of surface resistance with the possibility of over-heating culminating in loss of performance or even a fire

(II) the corrosion bonding the mating halves of the connector together which may result in:

- (a) both halves of the connector having to be replaced
- (b) long down times with high costs

## 5. **Low Humidity Problems**

Most of the effects of low humidity are evident in hygroscopic materials, the removal of moisture can in some cases change the mechanical structure and cause embrittlement. Often this is also accompanied by shrinkage and loss of weight.

**Static Damage:** The major difficulty with static damage is that, the results are not always immediately obvious because the resulting failure often destroys the evidence of damage. It is therefore difficult to categorically state that the failure was caused by static damage. The most critical period when damage can be inflicted is during handling before a device is inserted into the board.

Dust : By virtue of the fact that a static charge attracts dust, a build up of dust in an unsealed unit can result in malfunction by

(i) causing bad contacts

(ii) creating a path which can allow the tracking of high voltage discharges to earth such as in a TV or Computer monitor

**Electrostatic Generation:** The generation of static will be greatly affected by the levels of humidity. Voltages as high as 20KV can be generated by a person walking across a carpet when humidity levels are below 30%RH. Under high humidity conditions the same walker may only generate about 1.5KV. If this person picks up a device without following the correct anti-static procedures damage can occur.

**Static Susceptibility:** Often ignored as being irrelevant, it must be pointed out that non-catastrophic damage can be caused by a static discharge as low as 30V in some MOSFET technologies, where the gate oxide is very thin.

The critical areas within a device where electrostatic discharge damage can occur are at junctions, gates and contacts.

Analysis : The only real way to assess the damage within a device is :

(a) verify the failure exists within the device and, if possible, identify the mode of failure.

(b) send the device to a laboratory with the equipment to remove the top. The passivation will then have to be removed and the suspect area photographed utilizing a scanning electron microscope.

**Static procedures:** Installation and enforcing of a rigorous anti-static programme which will:

(a) reduce the probability of this type of damage.

(b) reduce some of the latent failures which may be due to static damage

(c) thus improve the Mean Time Before Failure of unit.

### **Conclusion:**

Hence Humidity control and testing becomes imperative for all industries in general and electronic industry in particular. Humidity control and testing is must during production, testing, calibration and storage of material, components and equipments to avoid loss in production and maintain product quality and reliability during its service life.

### **Solutions:**

This is where we at PAHWA ENTERPRISE come into picture .We are known as AIR Engineers to provide Quality Air for various application in almost all segment of industries. Pahwa enterprise is a group of companies as illustrated in the following transparencies.

Arctic India sales handles the marketing and sales of all products manufactured by the group companies. It also represents many International companies exclusively in India. It has a wide network of sales and service offices all over India.

Arctic India sales has offices and trained engineers for sales and application engineering support in all important towns in India.

In brief Arctic India Sales has the forte to provide a profitable solution to all environmental control needs-anywhere -anytime.

1. For Humidity control or conditioning of Air, one of group company BRY-AIR INDIA PVT.LTD. located at Gurgaon is manufacturing World class Dehumidifiers for all segments of industry. Dehumidifiers have wide applications in industry during manufacturing process, storage of

materials or finished products with no loss due to spoilage,deterioration or reduced product appeal.

Another group company DELAIR provides Compressed Dry Air for precision instruments in Laboratories.In addition natural gas,bio-gas,industrial gases and processed gases need be conditioned before they can be used.DELAIR compressed air dryers based on refrigerent and descicant adsorption techniques can handle all such jobs.

2. For testing and simulation of humidity conditions Arctic india sales has tied up with Angelantoni Industries -Italy to market their products in India. We provide sales and service for complete range of enviornmental test chambers manufactured and supplied by Angelantoni group.Angelantoni Industries is an ISO -9001 company and provides complete range of environmetal test chamber for testing all type of products as per National and International test specification and cater for all segments of Industry and Labs.

All reputed electronic component and equipment manufacturers subject their products to simulated Climatic testing in test chambers in order to prove that their products can withstand severe humidity conditions in our tropical atmosphere.