$19.99

Guide to Meeting the Standards for Moisture Sensitive Components in Electronic Manufacturing Environments

MSD - ESD

QUALITY SOLUTIONS
ECD
SINCE 1964

World Headquarters
North & South America, Europe
4287-B S.E. International Way
Milwaukie, Oregon 97222-8825 U.S.A.
Tel: +1 503 659 6100 | +1 800 323 4548
Fax: +1 503 659 4422
Email: sales@ecd.com | ecd.europe@ecd.com
Website: www.ECD.com

Asia
ECD Asia/Pacific
Singapore
Moble: +65 9692 6822
Email: ecd.asia@ecd.com
ecd.china@ecdchina.cn
Website: www.ECD.com

ECD Europe/Africa/Middle East
Mobile: +48 512 659 100
E-Mail: ecd.europe@ecd.com

TABLE OF CONTENTS

Introduction

Much has been written on the subject of electrostatic discharge (ESD) and moisture and their destructive impact on sensitive electronic devices. With today's ever-increasing densities and shrinking package sizes, damage is caused by even lower potentials and less moisture than ever before. It's time to take a renewed look at the issues and consider better ways to monitor and document the environment in the electronics manufacturing industry.

Moisture is in the air we breathe and is a necessary and somewhat unavoidable fact of life. We run humidifiers to add moisture in dry conditions and dehumidifiers in wet conditions to maintain a healthy, comfortable environment. Too much of either – too wet or too dry – can be unhealthy and uncomfortable. While the proper amount of moisture in the air is critical to good health, it can be a serious hazard in an electronics manufacturing environment. This guide will explain the issues surrounding moisture in the electronic manufacturing environment and provide a deeper understanding of the systems used to measure moisture content, typically relative humidity (RH). In addition, the guide will offer practical approaches to preventing the devastating effects of over- or under-exposure to humidity.

The Benefits of Moisture

Human comfort

Most people find that a relative humidity below 25% feels uncomfortable because of the drying effects on the skin and sinuses. On the other end of the scale, relative humidity levels above 60% feel wet or sticky and can promote mold growth and other airborne hazards. So, a relative humidity somewhere between 25% and 60% is a good range for most people, depending on regional adaptations. Also, this rule of thumb only applies at or about 21ºC (70ºF), because people are sensitive to the actual amount of moisture in the air, and, as the name implies, relative humidity is a measure of the amount of moisture in the air "relative" to the temperature. More on this later.

ESD reduction

ESD concerns include: electrical damage to unprotected components and the mechanical attraction to components of ever decreasing size known as Electro Static Attraction (ESA).

Electro Static Discharge (ESD) is naturally reduced when the moisture content in the air increases. This is because the conductivity of the air is increased (or the resistance is lowered), giving the otherwise static electrons a means to move about, reducing the chance for a buildup of electrons in one area (potential difference). If you live where it's cold in the winter, you're aware of the effects of cold, dry air on ESD events. The shock you feel as you reach for a metal door or as your car key approaches the door lock are quick reminders of ESD. These static discharges from one object to another are naturally reduced as the air warms and moisture in the air rises to a more comfortable level.

However, even high moisture levels and their dampening effect on ESD cannot fully protect the ever-increasing sensitivity of electronic components. There is no substitute for a well-maintained and comprehensive program for the prevention of ESD.

The Drawbacks of Moisture

There is moisture everywhere - we need it to survive and it helps reduce the threat of ESD on the electronics manufacturing floor. However, these levels of moisture -- or humidity -- are a real threat to many components because of their "moisture sensitive level" and oxidation (corrosion) of the soldering surfaces.

Corrosion

Moisture in the air promotes corrosion of components' soldering surfaces. This is true for the printed circuit boards (PCB), wires, component leads, bumps, connectors and many other device elements that are typically considered immune to moisture. What's more, the prescribed process to dry out most components that have experienced moisture overexposure (baking), can exacerbate the corrosion process because the hotter it is, the faster oxidation can occur. Corrosion (oxidation of the soldering surfaces) reduces the solderability of those surfaces and will lead to poor soldering quality.

It's not just the manufacturing floor that's susceptible to moisture's destructive effects. The storage areas are also at risk. Maintaining and monitoring temperature and humidity is the only certain approach to ensuring overexposure to moisture does not occur. These levels, as recommended by certain industry standards, will be discussed further in the "Moisture Sensitive Level of Components" section of this guide.

Effects on Solder Paste

There are a multitude of solder paste formulations on the market, all of which can be impacted by moisture and temperature in the processing area. To what extent moisture affects the material's application and function varies widely depending on the paste selected. Some fluxes are formulated for higher-moisture environments, while others are better suited for low-moisture environments. Paste specification sheets should be consulted to determine in which environment a paste will perform at its optimum level. For the best results, the solder paste should be selected based on typical manufacturing floor conditions. However, there are two general cautions regarding the effects of moisture on solder paste:

1. Too much moisture in the air will cause some fluxes to absorb moisture, increasing its "slump", or its tendency to spread beyond where it was deposited, and can thin or dilute the flux chemistry rendering it less effective.

2. Too little moisture can hasten evaporation of the liquid components in the flux, drying it out faster than expected.

The only way to avoid either of these issues is to monitor the environmental conditions of the solder paste processing area, including storage.

Moisture Sensitive Level of Components

Older, bulkier packages did not absorb moisture as fast as today's miniaturized devices and were never significantly threatened by non-optimized moisture levels. As packages have gotten thinner or smaller with thinner walls, the rate at which they can absorb moisture increases and the amount of moisture that could saturate the component decreases.

Moisture's greatest threat to a component is not damage from the moisture itself; it's the buildup of moisture over time, and the inevitable expansion, vaporization and release during the soldering process. This is where damage to the component and those around it can occur. Unfortunately, most of the ill effects of moisture during soldering are not visible. Moisture-induced defects include delamination of the plastic from its lead-frame, die damage, wire bond damage, and internal cracking. All of these are issues which may not be revealed in the test process, but may likely cause a decrease in reliability or, the worst case scenario, complete and premature failure. That's not to say all moisture-related issues aren't apparent. In some cases, the cracks will reach the component's surface and be visible. In extreme cases, the component may expand and explode, or "popcorn," as it is often called. Even if the component successfully vents the moisture, the release of vapor (steam) may upset surrounding components and even move them from their desired location during reflow.

Illustration 1: Visible MSDs Damaged During Reflow Solder

Moisture Absorption in Printed Boards

Just like with moisture sensitive components, moisture absorbed into the laminate of printed boards (AKA: printed circuit boards, printed wiring boards, circuit boards, bare boards and other names) will expand quickly as heated during the solder process. The sudden expansion of the water vapor can cause delamination, separation of the internal layers, and stress on through hold walls. In addition, long term exposure to humidity will degrade the solderability as well. Printed boards are in affect a component and should be protected from moisture.

Illustration 2: Printed Board Delamination

Standards for Electronics Manufacturing

There are numerous standards that manufacturers use to ensure compliance for various products and applications. There are in-house quality standards such as QMS, GMP or QS.

There are specific requirements mandated by certain industries like the Military, FDA, NASA, Aerospace, Medical, Telecommunications, or Automotive industries. And, there are standards produced by industry associations and organizations including ISO, ITAR, AS, IPC, AMS, JEDEC, and others.

Below are several of the more well-known standards organizations and the ESD and MSD standards they have developed for the electronics industry:

Organizations

IPC

Now known as the Association Connecting Electronics Industries, IPC was formerly called the Institute for Printed Circuits (hence the acronym) and was founded in 1957. It is now accredited by the American National Standards Institute (ANSI) as a standards developing organization. The IPC focuses on standards for inspection, acceptability, design, material specifications and testing of electronics components and assemblies.

JEDEC

The Solid State Technology Association previously known as the Joint Electron Devices Engineering Council, was established in 1958. Associated with the Electronic Industries Alliance (EIA), a trade association, JEDEC's main goal is to develop standards for semiconductor device packaging, testing and marking.

EIA

Also founded in 1957, the Electronics Industries Association was established as an alliance between several associations including JEDEC and TIA, among others. It was renamed in 1997 as the Electronics Industries Alliance because of the ever-changing industry. Its main purpose as a standards and trade association was to develop standards for interconnection of electronic components and equipment in the United States. In 2011, the EIA officially disbanded, leaving these tasks to the many divisions it once headed. EIA still has its name on many standards, and will for some time to come.

ESDA

The Electrostatic Discharge Association was founded in 1982 and is responsible for many standards on the subject of electrostatic sensitivity, protection and testing. An all-volunteer group, this US-based trade association reports to Europe's International Electrotechnical Commission (IEC) and is affiliated with the American National Standards Institute (ANSI).

Standards

ESD

Referenced by many other standards, ANSI/ESD S20.20-2007, entitled "For the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)", is the go-to standard for setting up Electrostatic Discharge (ESD) Protected Areas (EPAs) within the manufacturing environment. It's impractical and unnecessary to maintain an entire building as an EPA, so this standard outlines the requirements for designating specific areas for handling parts and equipment without ESD protective packaging. The standard covers what's needed and how to test to make sure an EPA is adequate for the task. Included are items such as: the signage, work surface, wrist strap, foot grounders, flooring, seating, ionization, shelving, mobile equipment, garments, and a few others. Manufactures of these devices have taken care that their devices meet this standard. It is up to you to make sure the EPAs are properly maintained and respected.

Components in packages, trays, reels, tubes, or carriers labeled as below (see illustration 3) can only be handled using the required ESD prevention equipment outlined in ANSI/ESD S20.20-2007, section 8.

Illustration 3: Typical ESD Sensitive Device Label

MSD

The main source of standards for electronic manufacturing in the United States and many other parts of the world is the IPC. Although many other organizations like the JEDEC publish standards, and still others are produced jointly (AKA: Joint standard or J-STD), the IPC does a good job of organizing and distributing most all of the applicable standards electronic manufactures should require. However, this does not mean other standards that an electronic manufacturer's customer may demand can be ignored. Often, these other standards, when referring to electronics manufacturing practices, will reference standards of the IPC, JEDEC, or a J-Std.

The overall standard that directly applies to electronic manufacturing is the IPC/EIA J-STD-001C, "Requirements for Soldered Electrical and Electronic Assemblies". This standard describes the materials, methods, and acceptance criteria for soldering electronic assemblies. A close companion is the IPC-A-610, "Acceptability of Electronic Assemblies", which further address the acceptance criteria.

The standard which directly applies to moisture sensitive devices is the Joint Industry Standard IPC/JEDEC J-STD-033C, "Handling, Packaging, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices". There are at least two companions to J-STD-033C including: J-STD-020C, "Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices" and J-STD-075, "Classification of Non-IC Electronic Components for Assembly Process". These last two standards are designed to define what level of sensitivity the device has and recommends the test method used to confirm the level. So, although J-STD-020C and J-STD-075 refer to moisture sensitive components, only J-STD-033C addresses the issues of handling moisture sensitivity devices of all types on the electronics manufacturing floor. The moisture sensitive level (MSL) of a component depends mostly on the component's package type or size, as determined by the manufacturer. The manufacturer will mark the MSL on the packaging label, typically a moisture-barrier bag (MBB), which is your first indication that a component may have an MSL of concern. Illustration 4 is a typical moisture sensitive component packaging label. The MSL is shown in the upper right corner.

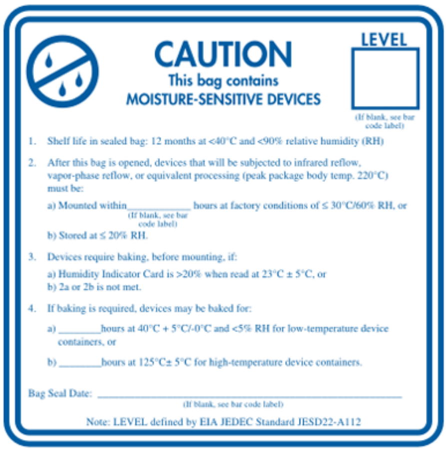


Illustration 4: Typical Moisture Sensitive Device Label

Table 1 lists the eight moisture sensitive levels which will be indicated on the package label: 1, 2, 2a, 3, 4, 5, 5a, 6, where 1 is the lowest sensitivity (or almost no concern) and 6 is the highest sensitivity (or greatest concern). The table lists the "safe floor life", which is the number of days each level can be safely exposed to a typical working environment once the components have been removed from their factory-sealed MBB and the component being soldered. This table can be found in the J-STD-033C, section 5.2, table 5-1. This applies only when the temperature is less than or equal 30 ºC and the relative humidity is less than or equal to 60 %. If the temperature and humidity levels on your factory floor are different than the specified 30 ºC/60% RH, J-STD-033C, section 7, table 7-1, indicates the expected safe exposure times. This means the safe exposure time is reduced if the typical maximum temperature and/or humidity is more than 30 ºC/60% RH. It also means the safe exposure time is longer if the typical maximum temperature and/or humidity is less than 30 ºC/60% RH.

Moisture Sensitivity Level	Floor Life (out of bag) at factory ≤30 ºC/60% RH
1	Unlimited at ≤30 ºC/85% RH
2	365 days
2a	28 days
3	7 days
4	3 days
5	2 days
5a	1 day
6	Mandatory bake before use. After bake, must be soldered within the time limit specified on the label.

Table 1: Moisture Classification Level and Floor Life, J-STD-033, 5.2

Just as moisture sensitive components have a standard, so do printed boards. The standard IPC 1601, "Printed Board Handling and Storage Guidelines" gives the best practices for storing printed boards. IPC 1601 section 5.1 recommends that you, after opening the factory sealed MMB, a) store printed boards in a dry cabinet at 10% RH or less, within 1 hour, or b) return printed boards to their sealed MMB with the original desiccant and a HIC within 30 minutes. This suggests that, although you could place printed boards in the same dry cabinet as moisture sensitive components, since their safest RH level be below 5%, you may want to have a second dry cabinet storage specifically for printed boards, since they require more space and only require a 10% RH or less.

Inventory management

Immediate knowledge of the physical location of components is vital to assessing their safe floor life time. Remember, this is only important after the moisture barrier bag has been opened. An inventory management system is only as good as the people who operate it. Make sure all parts going into and out of the dry cabinets are recorded. The floor life clock does not stop until after the components are soldered. The total of the time between opening the MBB and putting the components in the dry cabinet, plus the time between taking them out of the dry cabinet and soldering them must be less than the safe floor life for each MSD's specific MSL number. Otherwise, the component's floor life clock must be reset using the baking process described in J-STD-033C, section 4.

Components with a moisture sensitivity level (MSL) of 1 have an unlimited floor life (see Table 1) yet may still be stocked in an MBB. While components with MSL 2 through 5a are in their MBB, shelf life is a minimum of one year unless otherwise stated on the MSD label. Components with an MSL of 6 require a bake and must be soldered on or before the time (typically hours) stated on the MSD label. MBBs will be sealed at the factory with a humidity indicator card (HIC) inside (see illustration 5) to indicate the MBB's effectiveness. Components whose HIC indicates the exposure to moisture was exceeded will require a bake per IPC/JEDEC J-STD-033C, section 5.5, which effectively resets the floor life clock.

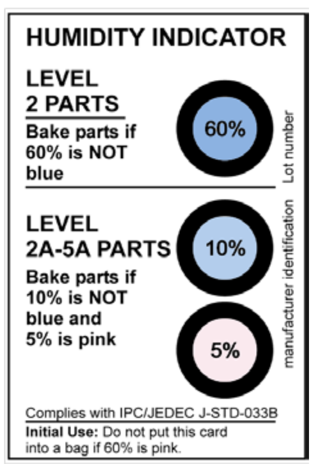


Illustration 5: Typical Humidity Indicator Card (HIC)

MMB's are typically rated for 1 year. However upon opening the MMB for the first time, the HIC must be examined to determine if the components were over exposed, following the requirements to bake the components per Table 4-1 in J-STD-033. If MMB's must be opened upon receipt for inspection, The MMB's must be replaced or resealed, including a new HIC card and desiccant. An alternative is to store the open MMB's in a Dry Cabinet.

Dry cabinets can extend the floor life, per IPC/JEDEC J-STD-033C, section 5.3.3.1 and 5.3.3.2. There are two levels for dry cabinets: one where maximum relative humidity is <10% and another where maximum relative humidity is <5%. Dry cabinet storage at a maximum of 10% is considered temporary storage and does NOT replace a MBB, but can double the floor life noted on Table 1. (See IPC/JEDEC J-STD-033C, section 7 for a complete table of the extended floor life times based on 10% RH and a range of temperature and MSL values). Dry cabinet storage systems, at a maximum of 5% RH, are considered better than an MBB, effectively making the storage life unlimited.

Area	Applicable Standard			
	ESD	Spec	MSD	Spec
Factory Floor	IPC/EIA J-STD-001	> 30% RH, 18-30ºC	IPC/EIA J-STD-001	< 60% RH, ≤ 30ºC
Dry Cabinet	IPC/EIA J-STD-001	> 30% RH, 18-30ºC	IPC/JEDEC J-STD-033	≤ 10% RH, 20 to 30ºC
Dry Cabinet as MBB	IPC/EIA J-STD-001	> 30% RH, 18-30ºC	IPC/JEDEC J-STD-033	≤ 5% RH, 20 to 30ºC
Dry Cabinet for PB Storage	ANSI/ESD S20.20 (when applicable)	> 30% RH, 18-30ºC	IPC 1601	≤ 10% RH, < 30ºC
Storage Rooms	IPC/EIA J-STD-001	> 30% RH, 18-30ºC	IPC/JEDEC J-STD-033	≤ 90% RH, < 40ºC
ESD Protected Areas	IPC/EIA J-STD-001 ANSI/ESD S20.20	> 30% RH, 18-30ºC	IPC/JEDEC J-STD-033	< 60% RH, ≤ 30ºC

Table 2: Applicable Standards and the Humidity/Temperature Specification

Table 2 indicates the applicable standard and the required limits for relative humidity and temperature for common areas and within dry cabinets. A dry cabinet used for the listed purpose should be capable of maintaining these conditions to protect components from both moisture and ESD. Proper grounding of both the cabinet, its surfaces and the user's wrist or foot straps must be provided.

Records of Compliance

Without a dated record of the humidity and temperature measurements, it's as if the measurement was never taken. Records of measurements are the only proof the measurement was made. All of the areas of concern must be monitored for humidity and temperature to make sure they do not exceed the limits specified. Maintaining the historical record of those measurements will offer proof that the storage and manufacturing environments remained within the specified limits.

RH and Temperature Measurement Systems

Relative humidity is a complicated parameter to measure. It requires a very specialized sensor and is, of course, dependent on the temperature. So there are always at least two measurements and some mathematics necessary to produce a single value in percent relative humidity.

The National Physical Laboratory (NPL) in the UK has a published work called "A Guide to the Measurement of Humidity", which includes a list of seven things to keep in mind when measuring humidity:

1. **Choose the correct sensor**
2. **Follow the manufacturer's instructions**
3. **Ensure proper calibration**
4. **Keep records**
5. **Spot check performance**
6. **Be knowledgeable about the parameter**
7. **Be aware of potential external factors**

1. Choose the correct sensor

There are many ways to measure humidity. The best sensing method depends on the nature of the environment being measured. For the electronic manufacturing floor and dry cabinet component storage, the sensor type most suited is the RH sensitive capacitive type.

2. Follow the manufacturer's instructions

This is your task. The system manual is designed to help you get the best possible humidity and temperature measurements. Read the manual prior to installation; reading it after a problem is discovered may be too late.

3. Ensure proper calibration

All measurement instruments needs to be calibrated regularly, typically once per year. A calibration means the instrument was compared to a known standard and any differences between the standard and the instrument are noted. Calibrations must be done using traceable standards. In other words, the standard used must have a "paper trail" leading back to some recognized standards laboratory, such as the NIST (National Institute of Standards and Technology) in the US. A calibration may include an adjustment of the instrument to bring its measurements within the manufacturer's specification for accuracy. In addition, a calibration must show the "as received" and "as returned" calibration values so it is known whether the instrument was within specification throughout the calibration period.

4. Keep records

A recording of ALL the things that happen to an instrument is vital. Calibrations should be some of the first statistics captured. Other important factors to record are: Power loss/restore events, battery failure or replacement, instrument impact or damaging events, spot check tests and instrument repair/replacement.

5. Spot check performance

This step is often ignored. Make sure the instruments are working between calibration intervals by performing a simple test. This can be as simple as holding your hand over the instrument and noting the temperature and humidity levels change. Like all others, this test should be recorded so that the sudden changes in readings are explained.

6. Be aware of potential external factors

Temperature and relative humidity can be affected by adjacent environments that can cause "bleed-in". For this reason, it is a good idea to make sure the instruments are installed as close to the area you are monitoring and away from things that may influence their measurement. Things such as warm equipment, heavily traveled areas, outside walls and heating vents can have an impact.

Relative humidity and temperature should be measured at least every 10 minutes in open floor and storage areas and at least once per minute in enclosed solder paste process systems and dry cabinets. These last two should be measured more often because they are enclosed, and controlled environments where routine intrusions (like opening doors) occur. IPC/JEDEC J-STD-033C, section 5.3.3 requires the dry cabinet to recover from such disturbances in less than one hour. Recording every minute will provide more accurate data to show that the cabinet is recovering in that time.

Illustration 6 shows the typical manufacturing areas and the recommended measurement interval times, as well as relative humidity and temperature measurement limits from Table 2. Measurement instruments placed at these locations should be set to record as least as often as indicated and warn if measurements are outside these limits.

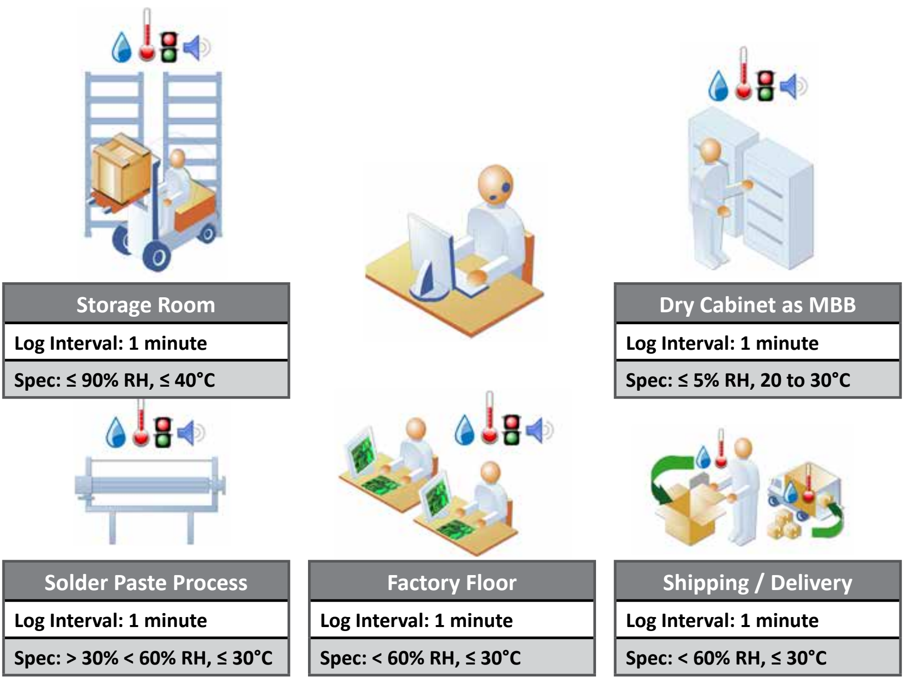


Illustration 6: Manufacturing Floor Areas with Measurement Times and Limits

Moisture Control

Larger facilities will have HVAC systems as part of the infrastructure of the building. In these environments, relative humidity should be set between 30% and 60% RH. The RH and temperature measurement system can then monitor and provide proof of these conditions.

In many cases, however, humidity is not controlled and the relative humidity is dictated by the seasonal weather conditions and the temperature in the room. In this case, an independent RH and temperature measurement system, and ind in addition to measuring and recording the current conditions, can also provide warnings should the humidity and temperature conditions reach specified limits.

Low humidity warnings should initiate running local humidifiers or air ionizers to maintain the required ESD suppression in electrostatic protected areas (EPA) and solder paste application systems. Simple residential-style ultrasonic humidifiers are a budget-conscious approach to serving these areas.

High humidity warnings, which can lower the safe floor life of exposed components, should initiate local dehumidifiers in solder paste application systems. MSDs that are not expected to be soldered within the safe floor life should be immediately returned to the dry cabinet. If the dry cabinet is producing the high humidity warning, immediate attention to its cause is required, and affected components should be transferred to a backup cabinet if needed.

Glossary

Relative Humidity (%RH) – The amount of water vapor currently in the air divided by the maximum amount of water vapor the air could hold at that same temperature multiplied by 100, expressed in percent. Cold air cannot hold very much water vapor, and hot air can hold much more. In fact, 5°C air at 100% relative humidity holds only 6.8 grams. This means that at 5°C, air will go from 0% RH to 100% RH by adding (evaporating) only 6.8 grams if water. At 25°C it takes 23 grams of water to reach 100% RH. So, the hotter the air the more water it takes to reach 100% RH, or saturation. This also means that if relative humidity needs to be lowered quickly and there is no access to a dehumidifier, raising the temperature will produce this effect. You can lower the room's RH from 70% at 20°C to 55% simply by increasing the temperature to 25°C.

At any given temperature, 100% RH is defined as the point where the rate at which water is evaporating from liquid (or ice, AKA: sublimation) to vapor (gas) and the rate at which water is condensing from vapor (gas) back to liquid (or ice, AKA: deposition) has become equal. This means that relative humidity is valid below freezing because the water (or ice) has the unique ability to go from solid to gas and back, maintaining the equilibrium necessary to achieve 100% RH. In part, this is also the reason that relative humidity measurements have no meaning over the boiling point of water, because the water (or ice) has all gone to vapor. The water is still in the air as vapor (gas), however, the small amount of vapor in the air at temperatures over the boiling point typically calculates to a relative humidity value less than 2%. So it is more meaningful to measure absolute humidity, when measuring moisture content in the air above 100°C.

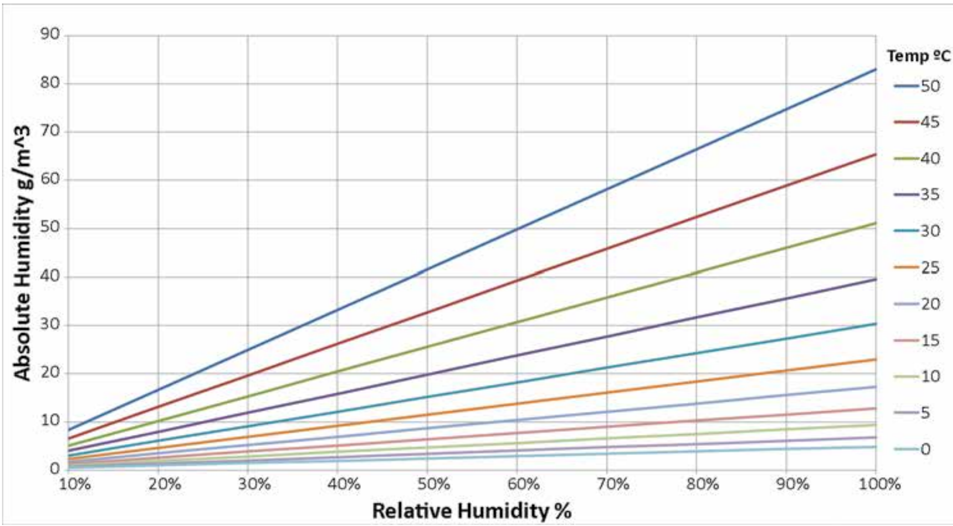
Table 3 shows the amount of water in grams per cubic meter and the dew point over a range of relative humidity and air temperature.

Temp °C	10%	20%	30%	40%	50%	60%	70%	80%	90%	100)
50	8.3	16.6	24.9	33.2	41.5	49.8	58.1	66.4	74.7	83
45	6.5	13.1	19.6	26.2	32.7	39.3	45.8	52.4	58.9	65.4
40	5.1	10.2	15.3	20.5	25.6	30.7	35.8	40.9	46	51.1
35	4	7.9	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6
30	3	6.1	9.1	12.1	15.2	18.2	21.3	24.3	27.3	30.4
25	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.7	23
20	1.7	3.5	5.2	6.9	8.7	10.4	12.1	13.8	15.6	17.3
15	1.3	2.6	3.9	5.1	6.4	7.7	9	10.3	11.5	12.8
10	0.9	1.9	2.8	3.8	4.7	5.6	6.6	7.5	8.5	9.4
5	0.7	1.4	2	2.7	3.4	4.1	4.8	5.4	6.1	6.8
0	0.5	1	1.5	1.9	2.4	2.9	3.4	3.9	4.4	4.8
-5	0.3	0.7	1	1.4	1.7	2.1	2.4	2.7	3.1	3.4
-10	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.3
-15	0.2	0.3	0.5	0.6	0.8	1	1.1	1.3	1.5	1.6
-20	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9
-25	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
50	8	19	26	32	36	40	43	45	48	50
45	4	15	22	27	32	36	38	41	43	45
40	1	11	18	23	27	30	33	36	38	40
35	-2	8	14	18	21	25	28	31	33	35
30	-6	3	10	14	18	21	24	26	28	30
25	-8	0	5	10	13	16	19	21	23	25
20	-12	-4	1	5	9	12	14	16	18	20
15	-16	-7	-3	1	4	7	9	11	13	15
10	-19	-11	-7	-3	0	1.8	4	6	8	10
5	-23	-15	-11	-7	-4.5	-2	0	2	3	5
0	-26	-19	-14	-11	-8	-6	-4	-3	-2	0
-5	-29	-22	-18	-15	-13	-11	-8	-7	-6	-5
-10	-34	-26	-22	-19	-17	-15	-13	-11	-11	-10
-15	-37	-30	-26	-23	-21	-19	-17	-16	-15	-15
-20	-42	-35	-32	-29	-27	-25	-24	-22	-21	-20
-25	-45	-40	-36	-34	-32	-30	-29	-27	-26	-25

Table 3: AH in g/m3 and Dew Point ºC given RH and Air Temp

Absolute Humidity (AH g/m^3) – The mass of water vapor, in a given volume of air, at any temperature, typically expressed in grams per cubic meter. This means it does not matter how hot the air is, the amount of water vapor in a fixed volume of air does not change.

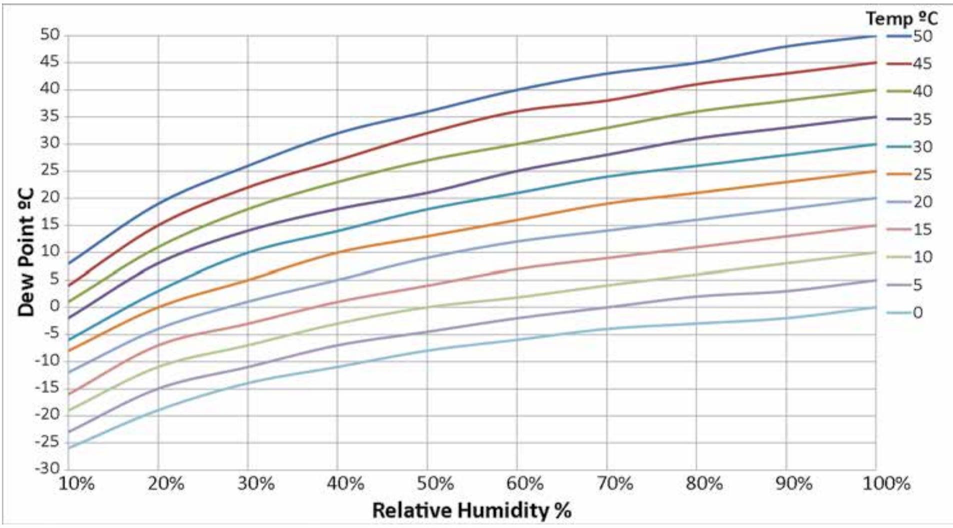
Graph 1 shows the absolute humidity given the relative humidity and room temperature.



Graph 1: AH in g/m3 given RH and Air Temp

Dew Point – The temperature value at which the air can no longer hold the amount of water vapor it contains and the water vapor (gas) begins to condense out and form water droplets or dew. This measurement is useful in predicting the weather since it highlights at what temperature dew as fog or rain will occur given the current relative humidity and the expected low temperature overnight.

Graph 2 shows the dew point given the relative humidity and the room temperature.



Graph 2: Dew Point in ºC given RH and Air Temp

Relative Humidity Sensors – There are two basic types of humidity sensors: mechanical and electrical. Both require precise measurement of one or more temperature values and, depending on the type, some other electrical property of the sensing element or physical parameter like barometric pressure. Here are some of the most common methods for relative humidity measurement:

- **Chilled Mirror (AKA: Condensation Hygrometer)**
- **Wet Bulb, Dry Bulb (AKA: Psychrometer)**
- **Aluminum Oxide Sensor**
- **Polymer Capacitor Sensor**
- **Human Hair Hygrometer (AKA: HHH)**

Chilled Mirror (AKA: Condensation Hygrometer) – This system actually measures the dew point temperature and then calculates Relative Humidity. It does so by bouncing light off the surface of a mirror. It then cools the mirror until the light is scattered by the formation of dew on the surface, or the dew point temperature. Accurate measurement of the ambient temperature (Ta) and the temperature of the mirror when the dew begins to form, (Td) or dew point temperature, enables calculation of RH using the following equation 4:

$$100 \times 10^{\left[7.5892\left(\frac{T_d}{T_d+240.71}-\frac{T_a}{T_a+240.71}\right)\right]}$$

The constants: 7.5892 and 240.71 are only good for ambient temperatures -20°C to 50°C resulting in an accuracy of about +/-0.09%.

Chilled mirror RH sensors are some of the most accurate, since they depend on the measurement of temperature only, which can be measured very accurately. This measurement is not affected by pressure or other gases in the sample, but does depend on the ambient air being a stable temperature, as the measurement takes some time to complete. If the mirror's surface is contaminated, the measurement can be adversely impacted. Since this system is mechanically complicated, bulky, and costly, its accuracy of better than 1% RH is best suited for maintaining environments for use as a calibration source for simpler RH sensing systems.

Wet Bulb, Dry Bulb (AKA: Psychrometer) – The name of this method is derived from the spinning of two thermometers through the air to take advantage of the wind chill effect on one verses the dry temperature on the other. One of the older procedures for calculating humidity, this technique measures two temperatures, one from a wet bulb and one from a dry bulb. The bulbs are the reservoir end of two glass thermometers. One bulb is kept wet with a "sock" or wick, and one is maintained at the ambient temperature (dry). The chilling effect of the evaporating water on the wet bulb reduces the temperature and the difference between the two temperatures is a function of the relative humidity. It's not a simple function, but it is one that is scientifically proven. Traditional glass thermometers are no longer used and have been replaced with the temperature sensing elements of a digital thermometer. The accuracy of the RH calculation depends on the accuracy of the temperature measurement, the purity of the water and cleanliness of the sock used to keep the wet bulb wet, and good air flow over the sensors.

Illustration 7: Typical manual Psychrometer

The current barometric pressure also has a small effect on the results so, to refine the result, measure the pressure and enter it into the %RH equation 14 where P is the pressure in kiloPascals (kPa), Td is the dry bulb temperature in ºC and Tw is the wet bulb temperature in ºC and e is the "natural" exponent value:

$$100\,\frac{e^{\left[\frac{(16.78T_w-116.9)}{(T_w+237.3)}\right]-0.00066(1+0.00115T_w)P(T_d-T_w)}}{e^{\left[\frac{(16.78T_w-116.9)}{(T_w+237.3)}\right]}}$$

The equation can be broken down into simple steps:

1. The barometric pressure (P) is assumed to be: 101.3 kPa
2. A conversion factor is calculated: A = 0.00066(1.0 + 0.00115 Tw)
3. The saturation vapor pressure is calculated at temperature Tw:
   eswb = e[(16.78 Tw – 116.9)/(Tw + 237.3)]
4. The water vapor pressure is calculated: ed = eswb – A P (Td - Tw)
5. The saturation vapor pressure is calculated at temperature Td:
   esdb = e[(16.78 Td – 116.9)/(Td + 237.3)]
6. The % RH is then calculated: RH = 100(ed/esdb)

Aluminum Oxide Capacitive Sensor – This sensor, like others, has electrical properties that change as function of humidity. It is sensitive to the water vapor pressure so more calculations are required to convert the measurement into relative humidity. The actual conversion equation is provided by the manufacture of this type of sensor.

Because it is sensitive to water vapor partial pressure, it is a good choice for moisture detection in natural gas lines and other industrial atmospheres. This sensor type must be kept dry and the gases being sampled must be clean and free of solids, which can harm the sensor.

To complete the calculation, atmospheric pressure must be accurately measured. This sensor type can also take a long time – up to 24 hours – to stabilize.

Polymer Capacitive Sensor – The most popular relative humidity electrical sensor, this device actually changes its capacitance as a function of Relative Humidity, about 0.2pF to 0.5pF per 1%RH. Again, the manufacturer provides details on converting this capacitance change to %RH. Polymer capacitive sensors are very dependent on the temperature; however temperature is one of the easiest measurements to take, so this does not present any issues.

Extremely small, this sensor type is well suited for low power, digital humidity and temperature meters often found in office and factory floor environments.

Illustration 8: Typical Polymer capacitive sensor (magnified)

Human Hair Hygrometer (AKA: HHH) – Believe it or not, human hair has the unique property of expanding in high humidity and contracting in low humidity, about 2.5% from 0% to 100%. So a ten-inch long hair will stretch 0.25" from 0% to 100% RH. Though it is not recommended for measuring humidity in your factory, this method might make a great science fair exhibit project with your school-aged children!

Accuracy – The readings given by a measurement device are said to be more accurate if there is a small (low) difference between those readings and the actual value of the parameter being measured. More accuracy is not necessarily gained just because there are a lot of digits in the reading. This just means there is more resolution and not more accuracy.

Resolution – This is the total number of significant digits in the measurement value. More resolution is generally considered better, however, more digits do not equal more accuracy.

Repeatability – No matter the accuracy or the resolution, when making the same measurement, is the result the same? The closer the readings of the same measurement are to each other (accurate or not), the better the repeatability.

References

1. "A Guide to the Measurement of Humidity" published by the National Physical Laboratory (NPL)

2. "Climate/Humidity Table" Transport Information Service (TIS) http://www.tis-gdv.de/tis_e/misc/klima.htm

3. http://en.wikipedia.org/wiki/Hygrometer

4. "Humidity Conversion Formulas" published by Vaisala Oyj

5. "Vaisala Humidity Calculator" Vaisala Oyj http://www.vaisala.com/humiditycalculator/help/index.html

6. "Humidity 101 – Best Practices in Humidity Measurement" by Bruce McDuffee and Yumi Alanoly of Vaisala Oyj

7. "Moisture-Sensitive Devices" by Austin Weber, Assembly Magazine http://www.assemblymag.com/articles/85082-moisture-sensitive-devices

8. "A Guide to Moisture Control in Electronics Manufacturing" by James of Kaisertech Ltd http://www.articlesbase.com/electronics-articles/a-guide-to-moisture-control-in-electronics-manufacturing-4141307.html

9. "Temperature Profiles: The Key to SMT Assembly Process Control" J. Maxwell, July 1990

10. "Moisture Control Measures for Epoxy Encapsulated Surface Mount Magnetic Components" published by Pulse http://pulseeng.com/file.php?3097

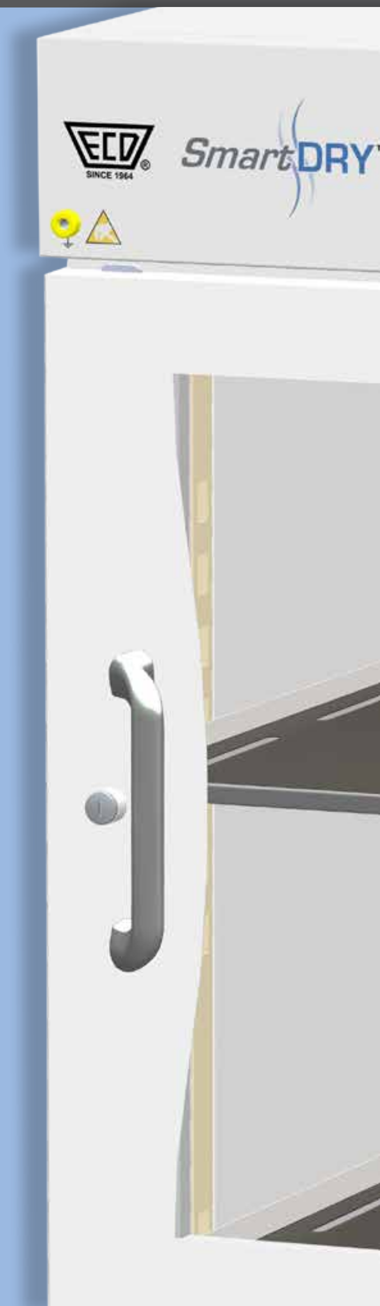
11. "Electronic Component Traceability Issues" by Bob Douglas, Innovaxe http://www.electronicsproductionworld.com/articleView~idArticle~71539_974515141712008.html

12. "Introduction to MSD Control" SMTA, MSD Council Meeting at SMTAI 2012 http://www.smta.org/msd/msd.cfm

13. "Capacitive Humidity Sensor Presentation" by Brett Nibbelink

14. "Wet Bulb Dry Bulb, A JavaScript routine that calculates the relative humidity given the wet and dry bulb temperatures" by Jeffrey Clymer http://home.fuse.net/clymer/water/wet.html

INTRODUCING INTEL



J-STD PERFORMANCE – More than *just* Compliance. Market leading recovery of <3 minutes for constant access.

EXCEPTIONAL QUALITY – Designed by ECD, Built in the USA

INTELLIGENCE AS STANDARD – Instant Visual Confirmation of Readiness, Fully Networked.

SmartDRY™

Coming Summer 2015

LIGENT DRY STORAGE

A53-3673-55

Rev-2014/12