Daisuke Fujisawa / Regional Market Manager / Vaisala / Tokyo, Japan

Humidity measurement in cleanrooms

Choosing the right type of measurement instrumentation is important in order to reach the best humidity measurement results. Calibration should also be carried out regularly, and to traceable standards.

Products manufactured in cleanrooms cover a wide range, including pharmaceuticals and semiconductors. Humidity, temperature, particles and pressure are often controlled, as these parameters can have serious effects on product quality and production efficiency.

Relative humidity

Relative humidity (%RH) describes the amount of water vapor that exists in a gaseous mixture of air and water. It is a ratio of the amount of water vapor present compared to how much could be present at a given temperature. Issues at production sites, such as expansion and contraction, and hardening and softening of material, change in viscosity of liquid, growth of microbes, increase in static electricity, and corrosion and rust, are largely affected by humidity.

Dewpoint

Dewpoint (Td) is a temperature at which dew, or condensation, forms on cooling a gas. Dewpoint is a parameter suitable for expressing very small water content in a gas like air. In the micromachining of semiconductors the conditions are very dry as water molecules are regarded as contaminants. In this condition relative humidity is practically stagnated at 0 %RH but dewpoint scale is still sensitive for water content changes in the measured gas.

Different applications, different needs

A pharmaceutical manufacturing plant often has a large number of cleanrooms. The control and recording of temperature and humidity is strictly designated by GMP (Good Manufacturing Practice). The most important feature required from humidity sensors is small deviation. It is important to be able to perform precise calibration to check that the sensor does not drift over the long-term.

In food processing plants, it is necessary to keep the manufacturing site at or below certain humidity. For example, 40% or below seems to be a commonly used value. This helps in restricting the growth of germs and bacteria that can cause food poisoning.

In semiconductor and electronics product plants, the generation of products changes more and more rapidly. As a result, the control of humidity and dewpoint in the manufacturing process has become stricter. In the manufacturing mini-environments, very high level control with an accuracy of +/-1%RH is often required.

Humidity control is also important at liquid crystal display plants and paint plants. In this case, the durability and accuracy of the humidity sensor is very important. These plants generate various gases, which can affect sensor elements.

Humidity and dewpoint sensor technologies

Humidity sensors, which measure water content in the air, are broadly divided into two types. One measures humidity and the other dewpoint. In an atmosphere where the humidity level is at least 10%RH, humidity measurement is often used, while in low humidity, dewpoint measurement is preferred. In some cases it is convenient to use

dewpoint measurement even in high humidity conditions.

Humidity and dewpoint sensors include:

1. Psychrometer
2. Mechanical hygrometer
3. Lithium chloride dewpoint indicator
4. Resistance type hygrometer
5. Capacitance type hygrometer (dew indicator)
6. Mirror dewpoint indicator

Sensors 1-6 can measure general humidity levels. Sensors 5 and 6 are also used for low dewpoint measurement. The principle of each technology is described briefly in the following.

1. A **psychrometer** is a simple form of a hygrometer, which consists of two thermometers. One has a dry bulb and the other a bulb that is kept wet to measure wet-bulb temperature. The wet bulb cools by evaporation of the water. The amount of evaporation, as well as cooling of the thermometer, depends on the humidity of the atmosphere. This data, together with humidity tables or calculations, is used to determine the vapor pressure of water in the surrounding air, and relative humidity. This is a method often used in laboratories and humidity and temperature test chambers.
2. A **mechanical hygrometer** measures and records humidity using an instrument that expands and contracts with humidity changes, such as human hair. This type of measurement has been used for a long time. The accuracy of the method is not very good.
3. A **lithium chloride dewpoint indicator** is a measurement principle based on the hygroscopic characteristic (ability of a substance to attract water molecules) of lithium chloride. The sensor consists of a reel covered with an absorbent fabric and a bifilar winding (two insulated wires, with currents traveling through them in opposite directions) of inert electrodes. The reel is coated with lithium chloride. An alternating current is passed through the winding and the lithium chloride solution, causing resistive heating. As the reel heats, water evaporates from the lithium chloride solution at a rate which is controlled by the vapor pressure of water in the surrounding air. When the reel begins to dry, the resistance of the lithium chloride solution increases, and less current flows through the winding. This allows the reel to cool. This heating and cooling of the reel reaches an equilibrium point where it neither takes on nor gives off water, and the equilibrium temperature is directly proportional to the dewpoint of the surrounding air.
4. A **resistance type hygrometer** utilizes the principle that electrical resistance varies in a material that absorbs moisture. Special sensors are used to measure the resistance to a current passing between wires. This type of sensor is suitable for mass production and seems to be most used for home appliances and consumer products. However, it may not measure accurately in very low or very high humidity environments.
5. A **capacitance type hygrometer** measures humidity by detecting the change in capacitance of a thin polymer film. This type of sensor can easily achieve sufficient accuracy, and is mostly used in industry. The patented HUMICAP® humidity sensors manufactured by Vaisala use this technology.
6. A **mirror dewpoint indicator** utilizes the occurrence of dew at dewpoint temperature when air containing water vapor is cooled. A mirror is cooled until it reaches the dewpoint of the gas in question. As dew condensation forms, it changes the light reflected from the mirror. When the mirror surface reaches an equilibrium state whereby evaporation and condensation are occurring at the same rate, the temperature of the mirror is equal to the dewpoint temperature of the tested gas. This type of sensor is often used in research institutes.

Vaisala's own cleanroom produces sensors for radiosondes as well as different humidity, barometric pressure and carbon dioxide measurement products.

Sensors mostly used in cleanrooms include the resistance type hygrometer, capacitance type hygrometer (dew indicator) and mirror dewpoint indicator. When selecting a suitable instrument, it is important not only to pay attention to the price and product specifications, but also to consider the measurement accuracy, manufacturer's application knowledge and services available. All these factors contribute to the actual user-experience and operational success.

Regular traceable calibration is important

One should always make sure that the data produced by the measurement equipment is reliable and accurate. Periodic calibration is absolutely essential. Typical calibration intervals can be viewed in table 1.

Table 2. presents an example of a traceability chain for installed humidity and temperature units. From a global perspective, all

measurements are based on the globally agreed International System of Units (SI). This ensures that we use the same quantities, and that measurements performed with various types of equipment in various locations are comparable.

National laboratories are responsible for maintaining and developing traceability and for providing the highest accuracy calibrations. The calibration services of the National Measurement Standard Laboratories may be limited to calibration of the highest grade primary standards.

Commercial calibration services provide calibration services for lower level standards and measurement equipment. These may be manufacturer services providing calibration services for their own products, or laboratories providing calibration services for any measurement equipment. Non-accredited calibration services are the majority service providers, including most of the measurement equipment manufacturers' calibration services and a considerable amount of commercial calibration services. Without accreditation the competence of these services is not proven. Before use, the competence should be confirmed by auditing the service.

Each calibration service provider must maintain an effective traceability chain. At the very least, the primary standard must be calibrated at an outside laboratory and then used for calibrations. Some commercial calibration services do not include uncertainty estimations in their calibration certificates if not ordered separately. Some calibration services are not able to calculate uncertainty at all. One should always consider the competence of these services.

Sometimes it is practical to maintain an in-house calibration system. This may be the case if the measurement equipment is difficult to transfer (calibration on-site) or when the amount of calibrated equipment is high. To set up an in-house calibration system, a suitable organization should be founded. The organization may contain just one person or a whole department with management and calibration staff.

Laboratory calibration is preferred to field calibration. In a laboratory, the effects caused by the environment can be minimized, and the number of factors influencing the calibration are reduced significantly.

Field calibration is a quick and easy way of checking measurement equipment without having to remove it from the process or process area. Field calibration requires a working standard as a reference. This working standard can be hand-held or some other equipment used for calibrating the instrument installed in the process. Working standards are calibrated at a higher level laboratory.

Vaisala has accredited calibration services for Vaisala pressure, temperature, dewpoint and humidity instruments. Services are available through regional service centers, and available for both already installed units and together with the delivery of new units.

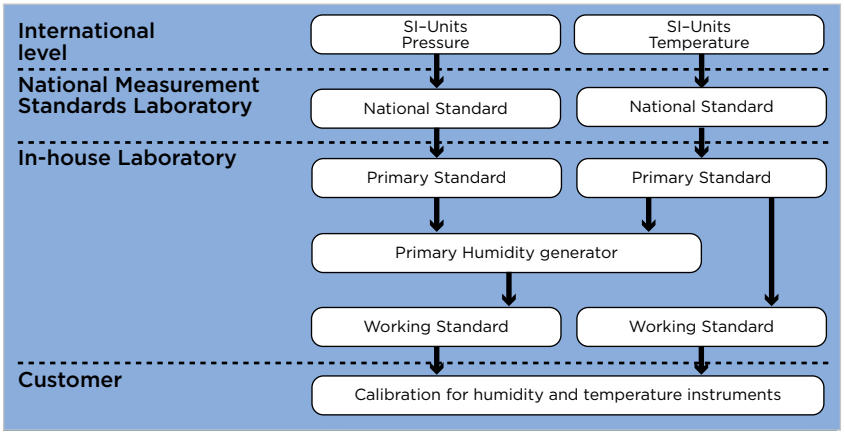
You can order your own Vaisala Calibration Book free of charge at www.vaisala.com/calibrationbook . The book contains useful information on everything you need to know about calibration.

Table 1. Typical calibration intervals for measurement equipment.

Measurement equipment	Month					
	6	9	12	24	36	60
Mechanical pressure meters				■	■	
Precision barometers	■	■	■			
Barometers		■	■	■		
Liquid-in-glass thermometers					■	■
Resistive temperature sensors and thermoelements/thermometers	■	■	■	■		
Dewpoint meters			■	■		
Humidity meters	■	■	■			
Active electrical meters			■	■		
Passive electrical meters				■	■	■
Lenght measurement equipment			■	■	■	■
Lenght measurement equipment with electrical display	■	■	■	■		

■ suitable calibration interval

Table 2. Example of a traceability chain for installed humidity and temperature measurement units.



Further information:
www.vaisala.com/humidity
www.vaisala.com/dewpoint

References:
Arun S. Mujumdar; Handbook of Industrial Drying (2006)
Vaisala Calibration Book (2007)