DEW POINT MEAS IN METAL HEAT TREATING

Accurate measurement of a gas or atmosphere dew point can have a significant effect on quality and process yield in heat treating. Several measurement methods and instrument types are available.

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Metal heat treatments such as annealing, carburizing, and carbonitriding require furnace atmospheres that have controlled water vapor concentrations. Measurement of atmosphere dew point temperature is widely used to provide meaningful data to help heat treaters monitor water vapor concentration and optimize the process. Condensation (optical chilled mirror) hygrometers, metal oxide sensors, and thin-film polymer sensors are among the available technologies.

Common heat treating terms are defined in the sidebar. Some of them describe processes in which atmosphere control is a distinct “science.” Metallurgists have the knowledge and ability to change a process “recipe” to alter the characteristics of the material being heat treated, and the moisture parameters of the process are very important to final properties. Repeatability also is required: Every time the product is heated, the energy used must produce the desired result. Dew point monitoring of these processes is critical since expenditures for the gasses and energy needed to maintain their atmospheres are primary cost drivers. Reworking a product rejected due to an incorrect atmosphere analysis is often not an option.

A heat treating furnace is not an ideal environment for dew point monitoring sensors and probes. The temperatures involved are beyond the operating limits of most sensors, and the furnace environment may outgas or entrain chemical vapors and contaminants such as oils, salts, and particulate. Special sampling systems typically are required to enable dew point sensors to be used for furnace atmospheres. Sensors also require a program of periodic calibration against a reference standard.

This article compares the major dew point measurement techniques and provides additional information about atmosphere sampling, system maintenance, and instrument calibration.

A Dew Point Primer

Dew point temperature is defined as the temperature to which a gas mixture at a given pressure must be cooled to achieve the saturation point of the water vapor contained in the mixture. At the saturation point the gas is holding the maximum amount of water in the gaseous state (water vapor). Any water in excess of the saturation point will condense to liquid. In addition, any surface that is below the dew point temperature will acquire condensation. Below 0°C (32°F), frost (ice crystals) will form on surfaces colder than the saturation temperature.

The dew point temperature can be directly correlated to the partial pressure of water vapor contained in the gas. Equation 1 yields the vapor pressure over water, while Eq. 2 yields the vapor pressure over ice. Since there are differences between the two saturation vapor pressures and because supercooled water can exist below 0°C (32°F), the two terms dew point and frost point are differentiated. However, the general practice in industry is to refer to either measurement as “dew point.”

$$e_{sw} = (1.0007 + 3.46 \times 10^{-6}P) \times 6.1121\exp[17.502T/(240.97 + T)] \qquad \text{Eq. 1}$$

$$e_{si} = (1.0003 + 4.18 \times 10^{-6}P) \times 6.1115\exp[22.452T/(272.55 + T)] \qquad \text{Eq. 2}$$

e_s = Saturation water vapor pressure, millibars (e_{sw}, water; e_{si}, ice)
P = Barometric or process pressure, millibars
T = Temperature, °C

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Inserting the dew point or frost point temperature, respectively, in Equation 1 or 2 yields the existing water vapor pressure, e. Inserting the ambient temperature in the equations yields the appropriate saturation water vapor pressure (Fig. 1). The measurement of dew point and its conversion to water vapor pressure is commonly used to derive other humidity parameters when the gas composition, temperature, and pressure are known. A discussion of basic humidity parameters follows:

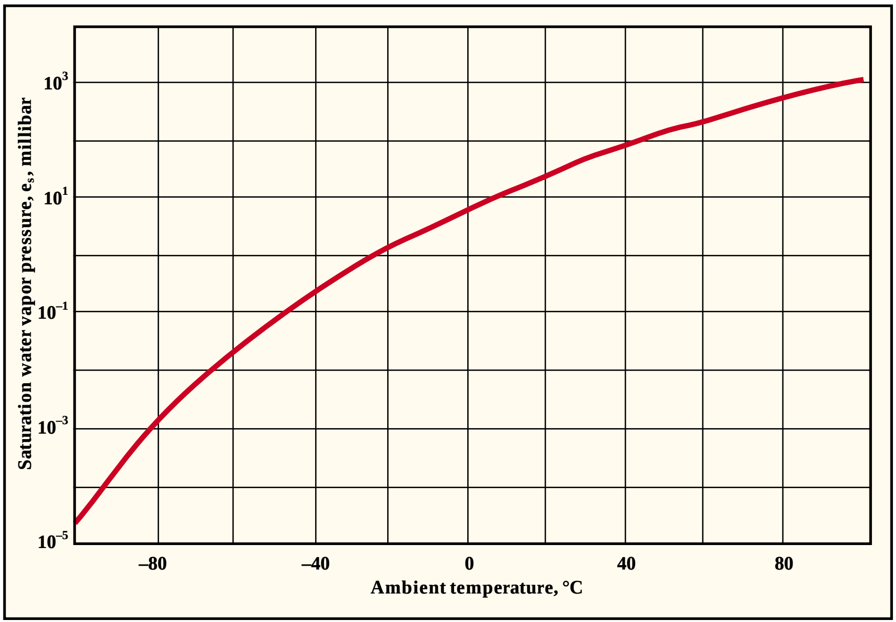

Fig. 1 — Plot of ambient temperature vs. saturation water vapor pressure.

Relative humidity (%RH): The ratio of the existing water vapor pressure, e, to the saturation water vapor pressure, e_s, both in millibars. The parameter is dimensionless and commonly expressed as a percent.

$$\%RH = (e / e_s) \times 100 \qquad \text{Eq. 3}$$

Absolute humidity ("AH"): The mass of water vapor per unit volume. Common absolute humidity units are g / m³ or grains / ft³ (1 grain = 1 / 7000 lb, or ~65 mg).

$$AH, g / m^3 = 216.7e / (T + 273.16) \qquad \text{Eq. 4}$$

Volumetric mixing ratio ("VMR"): The ratio of volume of water vapor to dry carrier gas. The parameter is dimensionless. Common units are ppm_v (parts per million by volume).

$$VMR, ppm_v = [e / (P - e)] \times 10^6 \qquad \text{Eq. 5}$$

Mass mixing ratio ("MMR"): Also called specific humidity, this is the ratio of the mass of water vapor to the mass of the dry carrier gas. The parameter is dimensionless. Common units are ppm_w (parts per million by weight).

$$MMR, ppm_w = [18e / MW(P - e)] \times 10^6 \qquad \text{Eq. 6}$$

MW = Molecular weight of the carrier gas, g / mole (MW_{air} = 28.96 g / mole)

Dew point preferred: In the heat treating industry, dew point is the parameter of choice because it provides meaningful data. For example, an error of only a few degrees Celsius in a dew point measurement can represent an error of 0.1 to 0.2% in the carbon potential, which can result in a deviation in the carbon content of the final product of as much as 25%.

The focus of this article now shifts to dew point measurement methods.

Condensation Hygrometers

Condensation (optical chilled mirror) hygrometers represent a direct method of measuring dew point or frost point. The basic design consists of a condensation target (the mirror) that is cooled until dew or frost is detected. Feedback control maintains the condensation surface at an equilibrium point such that the mass of dew or frost is constant. The resultant temperature of the con-

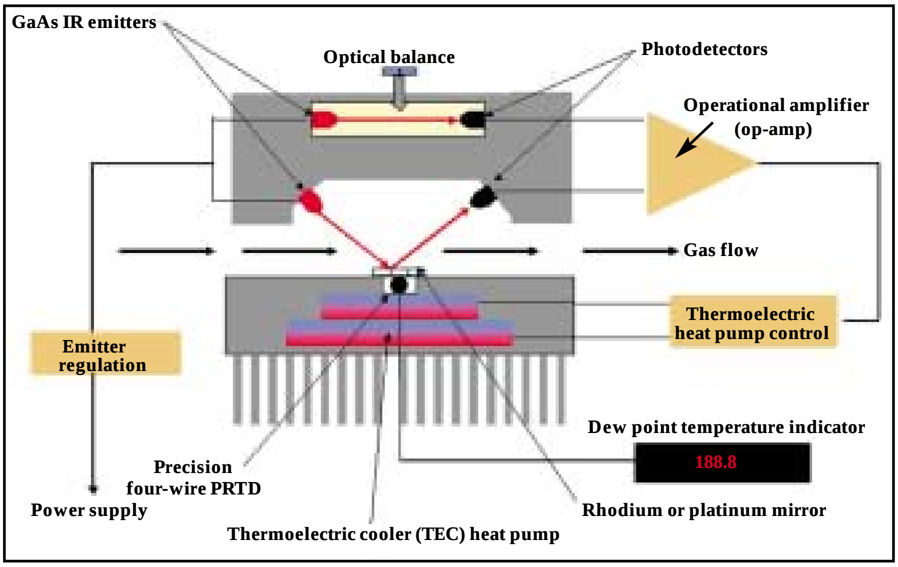

Fig. 2 — Schematic of a two-stage, optical chilled mirror dew point sensor (condensation hygrometer). They can measure dew points from –80 to 85°C (–110 to 185°F).

Fig. 3. — Chilled mirror hygrometers are available with a variety of sensors designed for specific measurement ranges.

Chilled mirror hygrometers are precise and repeatable. The wetted components are inert and the sensors do not drift over time. Typical accuracy is ±0.2°C (±0.4°F) dew/frost point.

densation target is, by definition, equal to the dew or frost point temperature. These hygrometers have the ability to measure dew point from –80 to 85°C (–110 to 185°F). The specific range is governed by the amount of cooling and the ability to heat the sensor for measurement to high dew points.

Details: The optical chilled mirror hygrometer (Figures 2 and 3) utilizes a solid-state thermoelectric heat pump, which may be augmented with liquid coolant or refrigerant to cool a metal mirror (typically made of rhodium, platinum, or stainless steel). A four-wire platinum resistance temperature detector (PRTD) is thermally coupled to the mirror. An infrared (IR) emitter illuminates the mirror at a 45° angle and a photodetector positioned at a complimentary 45° angle receives the light reflected by the mirror. When the mirror is dry, virtually 100% of the IR signal is received by the photodetector. As dew or ice condenses on the mirror the reflected light scatters, decreasing the amount of light received by the photodetector. A closed-loop controller regulates the light received by the photodetector to a constant value by controlling the heat pumped away from the mirror. When the light signal is controlled to a constant value, the mass of dew or frost on the mirror is also constant. The resultant temperature is equal to the dew or frost point.

Chilled mirror hygrometers are very precise and repeatable. The wetted components are inert and the sensors do not drift over time. Typical accuracy is ±0.2°C (±0.4°F) dew/frost point. This explains why they are used as reference standards for calibrating other types of humidity instruments.

Maintenance: The condensing surface (mirror) must remain clean. There are two basic types of contaminants: soluble (salts) and insoluble physical contaminants. Soluble contaminants will dissolve in the dew/frost layer and increase the vapor pressure of the condensate, resulting in higher dew point readings. Physical contaminants will either scatter or adsorb the light signal. Cleaning the mirror and rebalancing the reflected light signal against a reference emitter/detector pair can mitigate the effects of contaminants.

GE developed the PACER system for automatically cleaning and rebalancing chilled mirrors. The PACER cycle first utilizes rapid cooling to develop a thick dew/frost layer, and then rapid heating to flash evaporate some contaminants. Any contaminants that remain will accumulate in discrete "islands" such that approximately 85% of the mirror is clean. The optical control system is then "balanced" against a reference IR emitter/detector pair, which effectively negates the effect of the residual contaminants. While the PACER works very well to mitigate contamination, eventually the mirror will need to be manually cleaned. The instrument's optical circuitry alerts the user to the need for manual cleaning by monitoring the gain ratio of the photode-

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atmosphere controlled furnaces. In many heat treating operations, the atmosphere must be controlled to prevent workpieces from oxidizing and / or decarburizing. Steel becomes more active as the temperature increases, and severe oxidation of carbon steel begins at about 425°C (795°F). Above 1200°C (2190°F), the oxidation rate increases exponentially. At high temperatures the carbon in steel also can react with the atmosphere to lower the carbon content.

carbon potential. A measure of the ability of an environment containing carbon to alter or maintain, under prescribed conditions, the carbon level in steel. Control of carbon potential is important in carburizing furnaces. Excessive carbon will permeate the grain structure of the alloy, causing embrittlement and eventual component failure. Preheat or burn-off muffles require good atmosphere control to flush out these contaminants.

products of combustion. These result when fuel mixed with air is burned. If fuels such as methane and propane are burned in optimized proportions with air, the by-products might be ideal for certain heat treated products. If an excess of air exists (a lean atmosphere), loose scale may form. When an excess of fuel is used (a rich atmosphere), a tight, adherent oxide forms. Note that water vapor is a by-product of combustion.

PROCESSES

annealing. A generic term for heat treatment that consists of heating to and holding metal at a suitable temperature then cooling at a suitable rate to remove stresses, to induce softness, to alter ductility and toughness, to produce electrical, magnetic, or other physical properties, to refine the crystal structure, to remove gases, or to produce a specific microstructure. The temperature of the annealing operation and the rate of cooling depend upon the material being heat treated and the purpose of the treatment.

brazing. Proper control of the furnace atmosphere is also important to the life of alloy components. For example, poor control of the dew point in aluminum brazing can allow excess moisture and condensation of highly corrosive fluxes, leading to failure due to corrosion.

bright annealing. A process usually carried out in a controlled furnace atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright. In order to limit oxidation, the water vapor concentration must be limited. Bright annealing environments are typically purged with inert gases such as nitrogen, argon, or dry air. Typically, the dew point temperature must be less than –50°C (–60°F).

carbonitriding. A process in which ammonia (NH_3) added to a gas carburizing environment dissociates to produce hydrogen (H_2) and nitrogen (N_2). The addition of nitrogen has three important effects: inhibits the diffusion of carbon, which favors production of a shallow case; enhances hardenability, which favors production of a hard, wear-resistant case that is easily polished; and forms nitrides, which further enhance wear resistance.

carburizing. A process in which ferrous metal is brought into contact with an environment of sufficient carbon potential to cause absorption of carbon at the surface, and by diffusion to create a carbon concentration gradient between the surface and the interior of the metal. Carburizing is usually done at 850 to 950°C (1560 to 1740°F) in an atmosphere consisting of any of several carrier gases, principally nitrogen, carbon monoxide, and hydrogen, to which hydrocarbon gases (or vaporized hydrocarbon liquid) have been added. Methane or natural gas (CH_4) is the most commonly used source of carbon. For carburizing in the range of 0.8 to 1% C, the dew point temperature of the carrier gas is optimized at –7 to –1°C (19 to 30°F). Dew points below –12°C (10°F) may lead to accelerated sooting of generator catalyst. For low surface concentrations of carbon, the dew point may be adjusted to 0°C (30°F) or higher.

ATMOSPHERES AND GASES

argon: Provides an excellent inert atmosphere. It is used for gas-shielded arc welding and for heat treatment of "exotic" alloys. Generally, argon must be delivered at a dew point of less than –60°C (–75°F) and an oxygen content of less than 20 ppm.

blast gas. Used in the steel industry to oxidize (burn) the coke that melts the ore to produce molten metal. Blast gas has to be moist in order to carry heat from exhaust gasses into the furnace and to maintain burn efficiency. Steam is typically added to control this mix, which means the gas must be analyzed for moisture content. The absolute humidity range is typically 7 to 50 g / m^3 (3 to 22 $grains / ft^3$), or dew points of 0 to 35°C (30 to 95°F).

commercial nitrogen atmospheres: Nitrogen is used in many heat treating applications, sometimes replacing endothermic atmospheres. Nitrogen serves as a pure, dry, inert gas that can provide efficient purging and blanketing. Typical specifications require the nitrogen to be delivered at dew point temperatures between –60 and –80°C (–75 and –110°F). Nitrogen is also used as a carrier gas for carbon control atmospheres in many commercial heat treating applications. Nitrogen is mixed with hydrogen in a 90-10 blend, where the hydrogen serves as a reducing gas.

dissociated ammonia. Dissociated ammonia ($N_2 + H_2$) is produced from anhydrous ammonia (NH_3) by raising the temperature to 900–980°C (1650–1795°F) in a catalyst filled retort. The gas is then cooled for metering and transport. Dissociated ammonia atmospheres are about 75% H_2 and 25% N_2, with less than 300 ppm residual ammonia at a dew point below –60°C (–75°F). The atmosphere provides a dry, carbon-free source of reducing gas. Uses include bright copper and silver brazing, bright heat treating of carbon steels and selected nickel and copper alloys, and bright annealing of electrical components. Dissociated ammonia is also used as a carrier gas in certain nitriding processes.

dry hydrogen atmospheres. Commercially available hydrogen is 98 to 99.9% pure. Cylinder hydrogen may contain trace amounts of water vapor and oxygen. Dry hydrogen is used in furnaces for annealing stainless and low-carbon steels, electrical steels, and several nonferrous metals. It is also used for sintering "hard metals" such as tungsten carbide and tantalum carbide, for brazing nickel, stainless steel, and copper, for annealing metal powders and sintering powder metallurgy (P / M) parts, and in the direct reduction of metal ores.

endothermic atmospheres: Endothermic atmospheres are produced by generators that use air and a hydrocarbon gas as fuel. The two gases are mixed, slightly compressed, and passed through a chamber filled with nickel catalyst. The chamber is heated externally, hence the term endothermic. Endothermic gas mixtures are used as carrier gases in carburizing and carbonitriding applications (they offer a wide range of possible carbon potentials). Other applications include bright hardening of steel, carbon restoration of steel forgings and bars, and sintering powder that requires a reducing atmosphere.

exothermic atmospheres. Exothermic gas is produced by combustion of a hydrocarbon fuel such as methane or propane to maintain a reaction temperature of 980°C (1795°F) for sufficient time to reach equilibrium. Heat is obtained from the reaction, hence the term exothermic. The resultant gas is cooled and water vapor is removed either by a refrigerated or desiccant dryer. Exothermic atmospheres are used for clean and bright annealing

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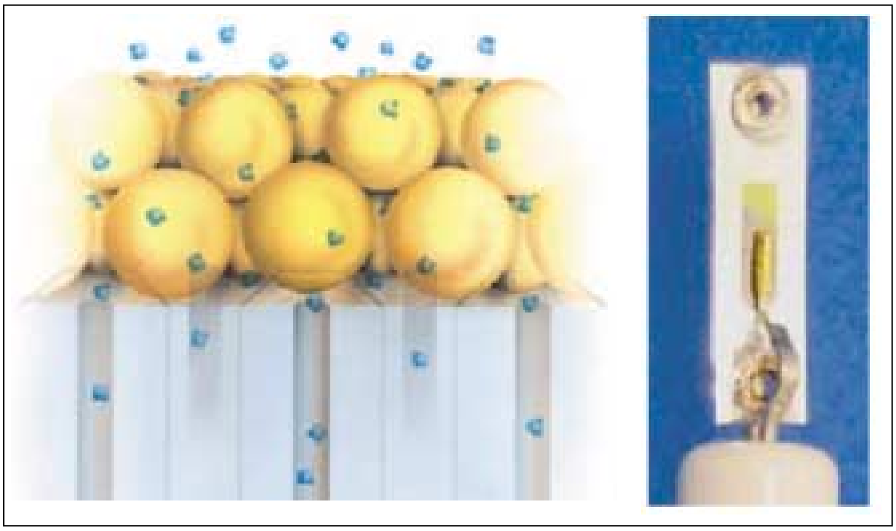

Fig. 4 — Schematic of how a metal oxide (Al_2O_3/Au) trace moisture sensor works, left. An actual sensor is shown at right.

Fig. 5 — A variety of metal oxide trace moisture instruments are used in heat treating applications. They include integrated transmitters, top; analyzers with remote probes, inset; and portable battery-operated hygrometers, bottom.

tector to the reference detector. Manual cleaning consists of heating the mirror (the analyzer has a heat switch) and wiping the metal mirror with a cotton swab dipped in a cleaning solution or distilled water. The procedure takes less than three minutes.

Stabilization: Condensation hygrometers must physically cool the condensing surface to the dew point temperature. The amount of cooling at a given ambient temperature is referred to as the “depression.” The amount of depression is influenced by the sensor “body temperature,” gas composition, and gas pressure. Because condensation hygrometers are under closed-loop control, they typically take time to stabilize at a given reading. There is some oscillation before the reading “settles out.” For measurements at low frost points (less than –25°C, or –13°F), chilled mirrors must sufficiently undercool to acquire a frost coating on the mirror’s surface. This means that chilled mirrors typically must have the capability of cooling 5 to 10°C (9 to 18°F) below the lowest value measured. For dew points less than –60°C (–75°F), full stabilization may take a few hours. However, process upsets are rapidly detected because the instrument will respond very quickly to moisture.

Service life: The initial cost of chilled mirror hygrometers is generally greater than that of other dew point instruments. Offsetting the higher price tag are reliability, repeatability, and long-time drift-free service. These factors make condensation hygrometers very competitive with other dew point instruments.

The component in a chilled mirror hygrometer most likely to fail is the thermoelectric heat pump. Thermoelectric cooling performance can be measured in terms of watt density (W/cm^2). Lowering the watt density extends the life of the heat pump; however, the trade-off is giving up the ability to measure to lower moisture levels. Watt density can be lowered using refrigeration or circulation of a chilled fluid through the sensor’s base to supplement thermoelectric cooling. For example, GE's 1311 series chilled mirror sensors are equipped with thermoelectric heat pumps that are thermally bonded to a gold-plated, water-cooled heat exchanger. Circulating city water (or chilled water) through the unit lowers the watt density, extending the measurement range, and lengthening life expectancy. It is not unusual for a water-cooled chilled mirror to provide 10 to 15 years of continuous service.

Metal Oxide Sensors

Metal oxide sensors are typically used for trace dew point measurement, usually over a dew / frost point range of –90 to 10°C (–130 to 50°F). Typical accuracy is ±2 to 3°C (±4 to 5°F). The measurement technique is based on the ability of absorbed water molecules to change the capacitance or impedance of a metal oxide. Aluminum oxide (or alumina, Al_2O_3) is the one most widely used. Other sensors include silica and zirconia (SiO_2 and ZrO_2).

A thin layer of oxide is first deposited or grown on a metal base. The oxide is typically sputter coated with a layer of porous gold, which serves as an upper electrode and also protects the metal oxide. The oxide is highly porous (has a large surface area). When dry, the spaces within the oxide are filled with air, which has a dielectric constant of 1. In this state the oxide's electrical capacitance is low and its impedance is high. When water vapor (dielectric constant = 80) is absorbed, microcondensation occurs within the pores and the oxide's capacitance increases in proportion to the surrounding water vapor pressure. The pores function as microscopic parallel plate capacitors. This is shown schematically in Fig. 4, left. (When capacitors are placed parallel, the total capacitance is the sum of the capacitances of the individual capacitors.)

A metal oxide sensor's signal conditioning circuitry typically measures capacitance or impedance as frequency (or a discreet count). Probes are calibrated by recording frequency vs. dew point at multiple values across the operating range. Many metal oxide probes also include a temperature sensor for compensation purposes. Dew point calibration data are typically stored in an embedded memory chip along with temperature compensation data. Other instruments provide a frequency table that is programmed into an analyzer. Raw frequency and temperature data are reduced by microprocessor-based circuitry to provide a direct readout or linear output and display of dew point temperature. (Remember that other humidity parameters such as absolute humidity and volumetric mixing ratio can be derived from the dew point.)

Metal oxide sensors are usually calibrated against a primary reference humidity instrument such as a chilled mirror hygrometer.

Filter required: Since metal oxides such as aluminum oxide are very hygroscopic, they respond rapidly to the presence of water vapor but may take considerable time to dry out. This is why some metal oxide sensors are stored in a chamber surrounded by desiccant when not in use. A special valve introduces process air to the sensor chamber. The net result: shorter dry-out times. Generally, these sensors respond to moisture (wet-up) in a few seconds. This makes them useful for detecting process upsets.

GE-developed metal oxide sensors (Fig. 5) include those that combine an ultrathin aluminum oxide layer with a porous gold protective coating. The sensor is pre-aged, resulting in drift of less than 2°C (4°F) per year. However, drift is highly dependent on the environment being measured. Unlike temperature or pressure sensors where the sensing element can be installed in a protective sheath or diaphragm that is in thermal or pressure equilibrium with the test environment, dew point sensors must actually come in contact with that environment. Filters are a "trade-off" between protecting the sensor from contaminants and optimizing response time. GE's planar gold / aluminum oxide sensors are

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Fig. 6 — A variety of instruments based on thin-film polymer capacitive sensors are used in metal heat treating.

usually installed in a polished stainless steel housing that has a porous sintered steel filter. An industrial nonhygroscopic filter should be installed upstream of the sensor.

Thin-Film Polymer Sensors

Thin-film polymer capacitive humidity sensors are typically capable of measuring dew points from –15 to 150°C (5 to 300°F). GE's MMR series transmitters and MDR series probes (see Fig. 6) incorporate a sensor that consists of interdigitated metal electrodes on a silicon substrate. The surface is coated with a proprietary thin-film polymer and porous metal layer. As water molecules are adsorbed by the polymer the capacitance changes in proportion to the surrounding relative humidity. The sensor is coupled to signal conditioning circuitry that produces a frequency output. A precision RTD measures temperature and provides temperature compensation for the relative humidity signal. In MMR-101 high-temperature instruments, each sensor is calibrated at multiple points across several temperatures to produce a matrix that is stored in memory.

Microprocessor circuitry, linear regression analysis, and psychometric formulas are used to convert raw frequency and temperature data to direct linear dew point and temperature signals (4 to 20 mA). Typical accuracy of a thin-film polymer capacitive sensor is ±2 to 3°C (±4 to 5°F) dew point, depending on the operating range.

Contaminants and Filters

The readings of all humidity instruments are affected by exposure to chemical and physical contaminants. For example, polar compounds such as alcohols will change the capacitance when absorbed by the sensor. If dissociated ammonia atmospheres are being used, dew point readings will be higher due to ammonia carryover. Salts such as zinc oxide (entrained from galvanizing operations) can adversely affect metal oxide sensors. Reactive or corrosive chemicals should be avoided.

In general, nonpolar compounds such as straight-chain hydrocarbon vapors or liquids have very little effect; however, heavier hydrocarbons or oils will tend to coat the surface of the sensor over time, creating a barrier to water vapor.

Many metal oxide and capacitive sensors can be cleaned with solvents, reconditioned, and placed back in service. And as previously mentioned, it is always a good practice to use a nonhygroscopic filter upstream from a metal oxide sensor. Typical filter media include borosilicate glass, silicone oils (oil bath), sintered steel, and polytetrafluoroethylene (PTFE).

Sampling System Required

Sampling systems must be used in heat treating applications. Typically, the system must extract a sample of the furnace atmosphere and cool it to the operating range of the sensor. Depending on the temperature and dew point, the cooling mechanism may simply be heat loss through a few feet of stainless steel tubing (air to air) or a "water-to-air" heat exchanger. A filter must be used to remove particulate and contaminants; however, the filter medium must not be one that will remove or add water vapor to the sample. The filter housing must also be made of hydrophobic material such as AISI type 316 stainless steel (UNS S31600).

Fig. 7 — Sampling systems extract, cool, and clean furnace atmosphere samples. The system must not add or remove water vapor from the dew point test gas. For many furnaces, a turnkey sampling system having sensors for oxygen and other process parameters in addition to those for dew point might be appropriate.

In certain cases, a vacuum pump or aspirator must be used to extract the sample and create sufficient flow across the sensor. The nominal flow in 0.25 in. (6 mm) OD tubing is 1 scfh (0.5 L / min). All sampling lines are typically stainless steel with compression fittings. For ultralow levels, internally electropolished tubing with VCR pressure fittings are used. (VCR is a trademark of Cajon Co., Macedonia, Ohio.) The sampling system might also include sensors to measure other process variables, such as oxygen, pressure, temperature, and flow rate.

In some cases the sampling system might be installed in a protective or heated enclosure (Fig. 7). If the ambient temperature at the location of the sensor is lower than the dew point of the sample gas, condensation will occur. In these applications, the sample must be heated above the dew point temperature of the process gas. The rule of thumb is to heat sample lines, filters, and the sensor body to at least 10°C (20°F) above the highest dew point encountered.

A number of GE probes and transmitters can be supplied with either explosion-proof or intrinsically safe certifications for monitoring atmospheres containing flammable or combustible gases, or for installation in them. In certain applications, the analyzers and probes are installed in explosion-proof enclosures and sampling systems are equipped with safety features such as flame arrestors. Other instruments may have intrinsic safety systems, where the probe or transmitter is operated in the hazardous zone while the analyzer is installed in the safe zone. The components are interconnected via an intrinsic safety barrier.

Calibration Ensures Accuracy

Metal oxide and polymer capacitance sensors provide secondary dew point measurement. While secondary dew point instruments do not provide the accuracy and precision of a primary instrument such as a chilled mirror hygrometer, they have a few advantages including lower initial costs. Since they do not require cooling to achieve low dew points, the sensors can be operated at relatively high temperatures, and generally are more rugged in industrial environments. Aluminum oxide-based instruments are considered industrial workhorses, but do require a program of periodic calibration to compensate for long-term drift.

One of the best ways to maintain accurate dew point sensors is to stock spare sensors and rotate them in and out of service. For example, if a heat treating facility has 20 measurement points, five spares might be stocked. After a predetermined period of service, the five spares are installed in place of five working sensors, which are subsequently recalibrated.

Calibration process: Typical calibration services consist of providing "as found" data. First, however, most calibration labs clean industrial probes prior to placing them in their calibration systems. (These systems are kept very clean, and probes returned from the field are a source of contamination.) Aluminum oxide sensors are typically cleaned in solvents such as hexane or toluene, then dried in an oven. Calibration of the dew point instrument follows. The process consists of comparing readings against a reference standard which is sampling the same air or gas. Calibrations are typically performed at multiple test points.

There are two basic requirements for a calibration system:

- A dew point generator capable of producing stable and controlled dew / frost points. Several types are available.
- A reference instrument. The one most commonly used is a condensation (chilled mirror) hygrometer.

If the devices being tested are found to be "out of tolerance," adjustments might be made at either the instrument or the analyzer by reprogramming a new "look table." After adjustment, the probes are recalibrated and verified to be within acceptable tolerances.

Heat treaters that have a significant number of probes might find it cost effective to set up internal dew point calibration systems. Suppliers such as GE offer the instrumentation, hardware, software, and training to perform calibrations. The cost and type of calibrations should be considered when selecting instrumentation. Important factors in amortizing the cost of an internal calibration system include the volume of outsourced calibrations, personnel training, and turnaround times.

In the field: In addition to calibrations in the lab, field checks on aluminum oxide probes can be performed by comparison with readings made using a portable instrument. In this case, the user typically has no control of the dew point and is simply comparing the reading of an instrument against a reference instrument having a known calibration. It is important to keep the portable instrument calibrated because it often uses the same measurement technology as the device being tested.

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and clean hardening. Rich exothermic atmospheres are useful for annealing, and for copper brazing of low-carbon steels, Cu-Ni alloys, gold alloys, and some brasses. Applications for lean exothermic atmospheres include annealing of aluminum and copper and their alloys, bluing of steel parts, silver brazing of nonferrous alloys, and nonflammable blanketing during various industrial processes.

natural atmospheres (air). Air consists of about 78% nitrogen, 21% oxygen, 0.9% argon, and other trace gases. Air at room temperature varies in moisture content from about 0.3 to 3%, nominally. Although natural atmospheres are strongly oxidizing, they may be acceptable when workpieces are to be machined after heat treating.

steam atmospheres. Steam injection into furnaces is used for scale-free tempering and stress relieving of ferrous metals in the temperature range of 345 to 650°C (655 to 1200°F). The steam causes a thin, hard, tenacious blue-black oxide to form on the surface of the part. Prior to processing in a steam atmosphere, parts must be clean and oxide-free. To prevent condensation and rusting, furnace internal surfaces and the parts in the furnace must be at a temperature above 100°C (212°F). And air must be purged from the furnace to prevent formation of a brown coating instead of the desired blue-black oxide.

vacuum atmospheres. Heating metal parts at pressures below atmospheric is used for many semiconductor components, composites, and metals. Vacuum heat treating prevents surface reactions such as oxidation and decarburization, removes surface contaminants such as oxide films and lubricant residue, degasses metals, removes dissolved contaminants from metals, and joins metals by brazing or diffusion bonding.