HUMIDITY THEORY

Fundamental terms of humidity measurement

Water vapor density (absolute humidity)

This is the amount of water vapor (kg) contained per volume unit (m^3) of the gas mixture. In a gas mixture the water vapor generates a certain partial pressure that is part of the total barometric gas pressure. The vapor pressure can only rise to its saturation limit which is determined by the temperature. Thereafter condenses as dew or frost. The maximum pressure is called saturation pressure and is temperature dependent. The temperature dependency is, however, not contained in the term of absolute humidity.

Relative Humidity

Relative humidity is the relationship between the actual water vapor pressure and the maximum possible water vapor pressure.

$$\%RH = 100 \cdot \frac{p}{ps}$$

%RH: Relative humidity in percent

p: Water vapor pressure in the gas mixture at ambient temperature

ps: Water vapor saturation pressure at ambient temperature

100 %RH corresponds to the maximum amount of water vapor a gas mixture can contain at constant pressure and constant temperature at saturation p = ps. At constant water vapor partial pressure and changing ambient temperature the water vapor saturation pressure changes and consequently the relative humidity also changes (see water vapor saturation pressure).

To obtain useful measurements of relative humidity, it is extremely important that the measurement probe and measured material have the same temperature.

Equilibrium relative humidity (ERH)

A hygroscopic material always tries to reach humidity equilibrium with the surrounding air. Equilibrium relative humidity is the free water content in a hygroscopic material after equilibrium is reached in an environment with constant relative humidity and temperature. Humidity equilibrium then prevails when the amount of water absorbed and given off is equal.

Water activity (aW)

Water activity is a measure of the freely available water in a material. Water activity is Equilibrium Relative Humidity divided by 100. The water activity value is an important indicator of the shelf life of food products and influences the incidence and propagation of micro-organisms.

Psychrometric parameters

Dew point / Frost point (Dp / Fp)

The dew point is the temperature at which the air over water is saturated with water vapor at a constant air pressure. Frost point is the temperature at which the air over ice is saturated with water vapor at a constant air pressure. The prevailing water vapor pressure is then the same as the water vapor saturation pressure.

Wet-bulb temperature (Tw)

Is the lowest temperature that can be reached by evaporative cooling. The water given off by a wet surface is then in equilibrium with the water absorption capacity of the surrounding atmosphere.

Enthalpy (H)

Enthalpy of moist air is an energetic property. It is composed of the specific enthalpies of the components in the mixture (dry air, water vapor) and is related to the mass fraction of the dry air. It is given in J/kg.

Specific Humidity (Q) in g/kg

Is the ratio of the mass of the water vapor to the mass of the complete gas mixture containing the water vapor.

Vapor Concentration (Dv) in g/m3

Is the ratio of the mass of the water vapor to the volume of the complete gas mixture containing the water vapor.

Mixing ratio (R) in g/kg

Is the ratio of the mass of the water vapor to the mass of the dry gas mixture containing the water vapor.

Water vapor partial pressure (E) in hPa

Is the fraction of the total pressure of a gaseous mixture due to water vapor.

Water vapor saturation pressure (Ew) in hPa

Is the maximum pressure that water vapor can reach over a water surface at a given temperature.

Response time of ROTRONIC sensors

ROTRONIC defines the response time of its sensors as the time taken to complete 63% of a step change in humidity. Factors such as air flow, and thermal mass can effect the response time of the sensors.

Accuracy of HC2 probes

The accuracy of the ROTRONIC humidity and temperature probes is highest at the adjustment points. The standard factory adjustment is carried out at 23 °C.
Maximum accuracy is achieved when adjustment of the probes is at the point of use. ROTRONIC offers this service (see chapter Services, page 140).

Measurement uncertainty increases the closer the measurement approaches saturation.

Contaminants/Pollutants

Some gases and contaminants/pollutants can damage the ROTRONIC humidity sensors. The contaminants/pollutants can be divided into two categories: gases without influence and gases with an influence on the humidity sensors.

For contaminants/pollutants with an influence on the sensors and therefore with an influence on the measurement result, the maximum concentration load must be known (see table below).

Contaminants/Pollutants with an influence

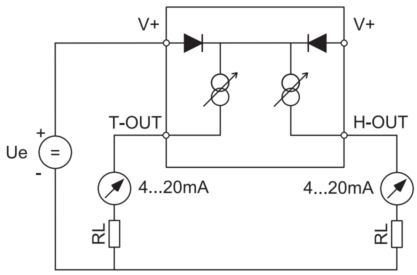
		Max. constant concentration	
Substance	**Formula**	**ppm**	**mg/m³**
Ammonia	NH_3	5500	4000
Acetone	CH_3COCH_3	3300	8000
Gasoline			150000
Chlorine	Cl_2	0.7	2
Acetic acid	CH_3COOH	800	2000
Ethyl acetate	$CH_3COOC_2H_5$	4000	15000
Ethanol	C_2H_5OH	3500	6000
Ethylene glycol	$HOCH_2CH_2OH$	1200	3000
Formaldehyde	HCHO	2400	3000
Isopropanol	$(CH_3)_2CHOH$	4800	12000
Methyl alcohol	CH_3OH	3500	6000
Methyl ethyl keton	$C_2H_5COCH_3$	3300	8000
Ozone	O_3	0.5	1
Hydrochloric acid	HCl	300	500
Hydrogen sulfide	$H2_S$	350	500
Nitrous gases	NOx	5	9
Sulfur dioxide	SO_2	5	13
Toluene/Xylene	$C_6H_5CH_3$	1300	5000
Xylene	$C_6H_5(CH_3)_2$	1300	5000

Contaminants/Pollutants without influence

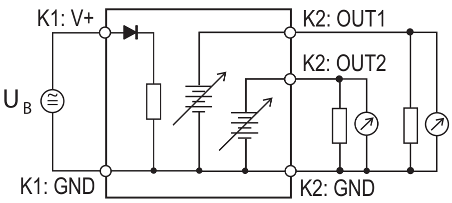
Substance	**Formula**
Argon	Ar
Helium	He
Hydrogen	H2
Neon	Ne
Nitrogen	N2
Oxygen	O2
Butane	C4H10
Ethane	C2H6
Methane	CH4
Natural gas	
Propane	C3H8

Note that the common sealing material silicon damages the sensor!
When probes are installed in, silicon must not be used!

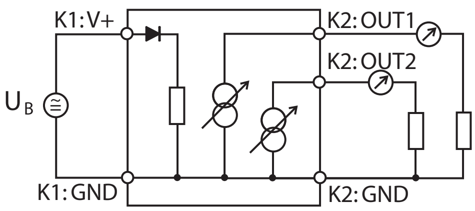
Transmitter circuits



2-wire circuit



3/4-wire circuit with voltage output



3/4-wire circuit with current output

In a 2-wire circuit the measurement output is connected to the ground wire of the power supply via a measurement resistor (load). The circuit is therefore ideal for simple wiring. However, this circuit can only provide a current output and it is not possible to integrate a protective ground in the circuit. For this reason metal probes cannot be connected to 2-wire transmitters.

The 3/4-wire circuit is characterized by the common ground of the power supply and transmitter. It is also possible to realize galvanic isolation with this circuit and ground is connected to the protective ground via the jumper B2. The jumper B2 is closed by default in all ROTRONIC transmitters with a protective ground connection. If required, the jumper in the device can be opened.
The 3/4-wire circuit is available both with voltage and current options. The measurement resistor (load) is ‹500 Ω in current circuits and ›1 kΩ in voltage circuits.

Probe use in practice

As a world leading manufacturer of humidity measurement instruments, ROTRONIC is fully aware of our responsibility to offer instruments that can withstand the harshest operating conditions, while remaining user-friendly and requiring minimal maintenance. To achieve the best possible performance from our measurement instruments we urge users to follow the guidelines outlined below.

1. Analyze the environment in which the humidity probe is used. What suspended substances and/or chemicals exist and in what concentration?
2. Install the probe at a place representative of the room climate with good airflow across the sensor.
3. Choose the right filter. Measurement is fastest without a filter. A protective open filter carrier is suggested to provide mechanical protection. For wind velocities higher than 3 m/s, however, a filter must be used. The filter protects the sensor up to airflow velocities of 40 m/s. Suitable filters must also be used in the case of contaminants/pollutants and in harsh environmental conditions.
4. Install the probe correctly to suit the application.
5. Inspect and replace the filter more frequently in harsh operating conditions. Filters can be cleaned in an ultrasonic bath. However, always keep a new filter set in stock.
6. Check that the measurement probe is working correctly by performing a calibration at least every 6 to 12 months.
7. For Calibration, use one of our calibration services or the SCS-certified humidity standards. This will insure that you have calibration traceable to national standards.