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# PRESSURE DEW POINT MEASUREMENT WITH CCC*-SENSOR

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*ABSTRACT: Humidity in compressed air is one of the most important problems in industrial and non industrial processes. The compressed air contains humidity despite of the drying process realized by the refrigeration dryer. The reason for that are located in the uncompleted separation process or in leaks along the compressed air pipes. For reasons of the energy and quality management a multiplicity of measurement principles has been developed for this application. But these technical and economical demands require more and more humidity measurement sensors with higher accuracy and long term stability. The best solution would be a direct and absolute humidity measurement system. It can be stated generally that the dew point principle is a (absolute measurement of humidity) favourable solution for such problems due to the measurement at the equilibrium state of condensation and evaporation. The developed monolithic integrated CCC*-dew point sensor bases on this thermodynamic principle and utilizes as a typical microsystem the cost advantages of the batch processes. This paper describes the most innovative CCC*-dew point sensor which is specified for the measurement of the pressure dew point temperature.*

*Keywords: Humidity, Dew Point, Compressed Air*

## 1 INTRODUCTION

Compressed air is a compressed mixture of several gases like Nitrogen, Oxygen, Carbon dioxide, Hydrocarbon and many other trace gases. Besides such gases compressed air contains foreign substances like water, dust and oil. An air dryer is normally necessary to reduce the content of water. In such a case the absolute content of water has to be reduced to guarantee good conditions for technical processes. In case of higher humidity several damages or other disadvantages can happen.
Condensed water causes rust within the pipe or in valves and reduces the long term stability. Not-air-tight valves cause leaks and an endangering of the environment. In such pneumatic systems moisture in combination with the contaminations like oil reduces precision and disturbs control mechanisms. The costs for maintenance and service are increasing considerably.

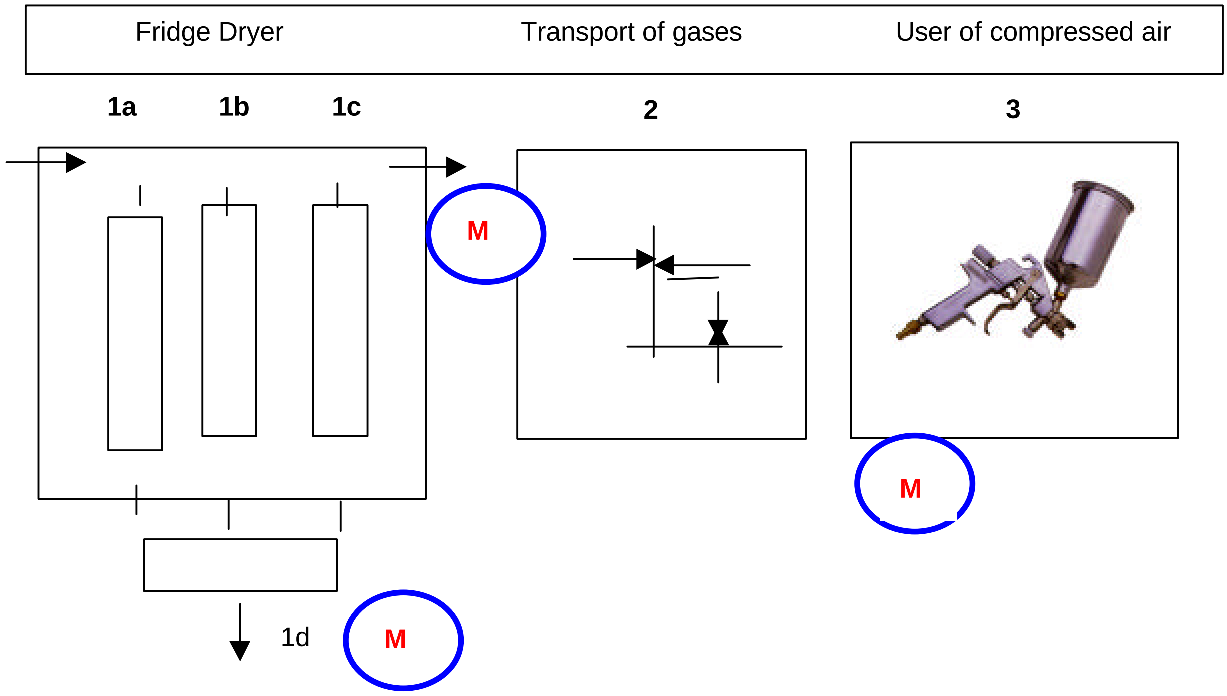
Water based painting processes and powder coating technologies use for example the compressed air as an active gas medium. The amount of water determines the percentage of water within the whole mixtured gases. Depending on the guarantee of the accuracy and the guarantee of the required water content in (compressed) air the quality of the process and the quality of the final product is more and less in good quality.

Moisture can contaminate the product followed by any chemical reactions.

To avoid such disadvantages the refrigeration dryers are able to remove water vapor down to a pressure dew point temperature of about 2°C. In case of these refrigeration dryers compressed air passes the air-air-exchanger (Figure 1). In the following air-heat exchanger the air temperature of the compressed air is reduced to the required dew point temperature. The heat is removed from the compressed air by evaporation of the cooling medium. The cooled air passes through a separator. This separator discharges the water drops from the air. This air is heated up again by passing the air-air-exchanger contacting the incoming hot air.

Defect separators (1d), defects of the pipes (2) or other events after maintenance (3) cause considerable deviation of the required pressure dew point temperature. Due to this fact there can be stated a loss of quality of the product and technology. Measurement of the pressure dew point temperature at the marked points (see Figure 1) is the best way to avoid any unwished problems.

*Condensate controlled capacitance according to HEINZE




1a air-air-heat exchange
1b air-heat exchange
1c fridge machine
1d separator
M measuring point

Valves connection

Painting process
Meteorological equipment
Drying process
Storage

**Figure 1.** Scheme of drying, transport and using of the compressed air

## 2 REALIZATION OF THE REQUIRED MEASUREMENT SYSTEM FOR ABSOLUTE HUMIDITY

The maximum content of water (g/m$^3$) in air depends on the air temperature. In case of a defined air pressure and a defined absolute humidity the air is able to take in water until a temperature sink. Below this limited temperature liquid water condense and flow away. This limited temperature is named as dew point temperature. The measurement of humidity is actually the measurement of the partial pressure of the water vapor component of a mixture of gases.

One of the most common ways of measuring this partial pressure is by measuring the condensation temperature of the water vapor component of the gas known as the dew point temperature. There is a one to one correspondence between dew point temperature and water vapor partial pressure.

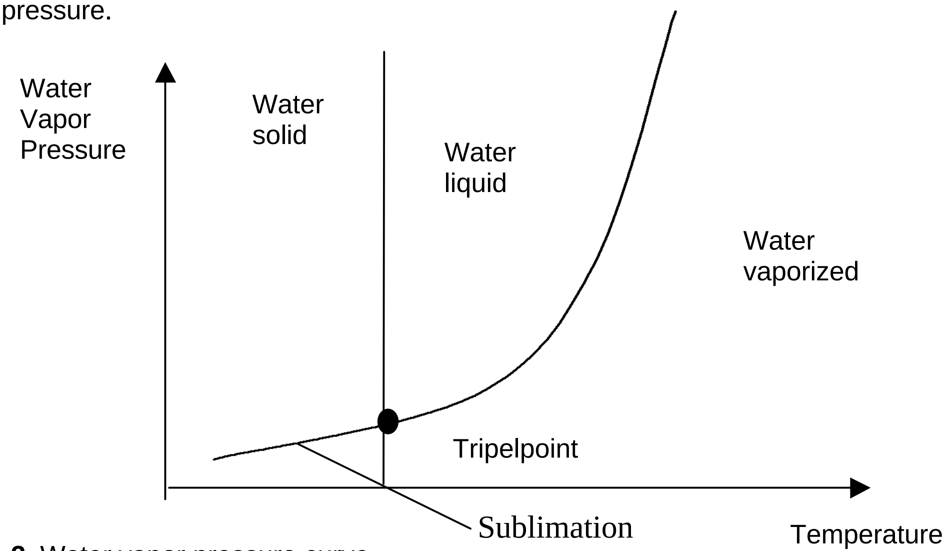



**Figure 2**. Water vapor pressure curve

The Magnus formula describes the connection between water vapor pressure and temperature /2/

$$e_w = e_{ws} \bullet \exp (a_w \bullet t_F)/(b_w + t_F) \qquad (1)$$

with the saturated water vapor pressure

$$e_{ws} = m_{wdmax} \bullet R_d \bullet T/V \qquad (2)$$

The temperature in the point on the water vapor pressure curve (Figure 2) where the state of saturation is reached. is the dew point temperature.

Since water vapor is found in gas mixtures, it behaves in accordance to the gas laws and exerts a partial pressure in a gas mixture per Dalton`s law.

According to Dalton`s law is the total pressure of a gas mixture equal to the sum of the partial pressures of the component gases. If the total pressure is increased the partial pressure increased by the same amount. Because water vapor pressure is a function of dew point temperature, when total pressure is increased the dew point increases.

As that pressure goes down, the dew point reduces (Figure 3). For calculation of dew point temperature at pressure $p_a$ a dew point temperature $t_d$ at pressure $p_a$ can be converted in a dew point temperature $t_{d1}$ at a pressure $p_{a1}$ by the following equation:

$$t_{d1} = \frac{t_d + ((b_w + t_d)/a_w) \ln(p_{a1}/p_a)}{1 - ((b_w + t_d)/(a_w \cdot b_w)) \ln(p_{a1}/p_a)}$$

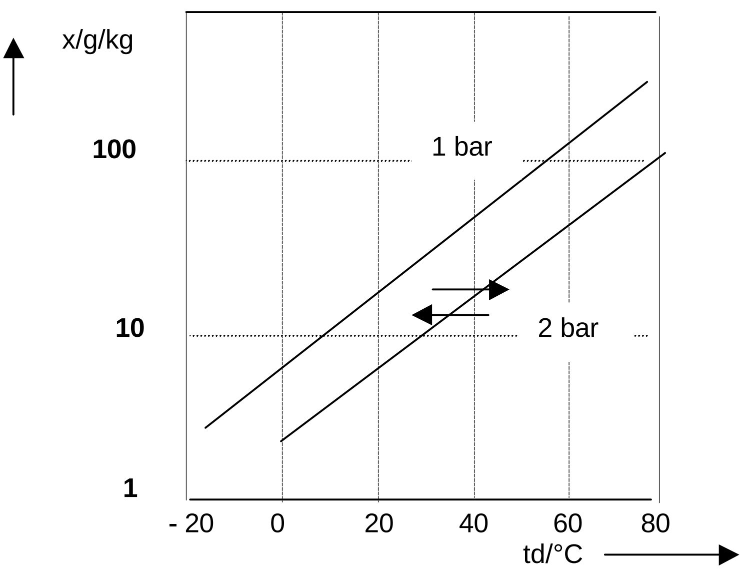



**Figure 3.** Dew point at different overall air

## 3 MEASUREMENT PRINCIPLE OF THE PRESSURE DEW POINT TEMPERATURE

The best and simplest way to measure the absolute humidity is to use a dew point hygrometer. The principle can be explained by using the water vapor curve. These dew point hygrometers work at the equilibrium state of condensation and evaporation. Therefore it is a favourable solution for such problems where accuracy and direct measurement of absolute humidity is required . Figure 4 shows a systematic /1/ which presents both physical methods for measurement of humidity - the thermodynamical equilibrium of energy between medium and sensors and absorption of energy by the water mass of medium at transmission.

Besides the most expensive dew point mirror hygrometers the CCC* monolithic integrated sensor is based on thermodynamic principle of condensation and evaporation too and utilizes the cost advantages of the microelectronic batch processes.

The sensor system consists of the sensor chip, the cooling element and the signalprocessing for the evaluation of the condensed water mass and for the measurement of the temperature of the water drops. The dew point detector is located on the surface of the silicon chip formed as a stray field capacity and is connected with an integrated capacity-frequency converter. The detection area is cooled down by the cooling element. When water vapor condenses at the chip surface the dew point is reached. At the moment of dewing the stray field capacity is changing and so does the VCO-frequency (integrated signal preprocessor). In the same moment the temperature of the water drops is measured by an integrated monolithic temperature sensor. The signal processing (controller) guarantees a constant mass of water on the chip surface at the moment of dew point temperature measurement. The physical principle is the same used for the dew point mirror. Figure 5 shows the principle of the CCC*-dew point sensor system.

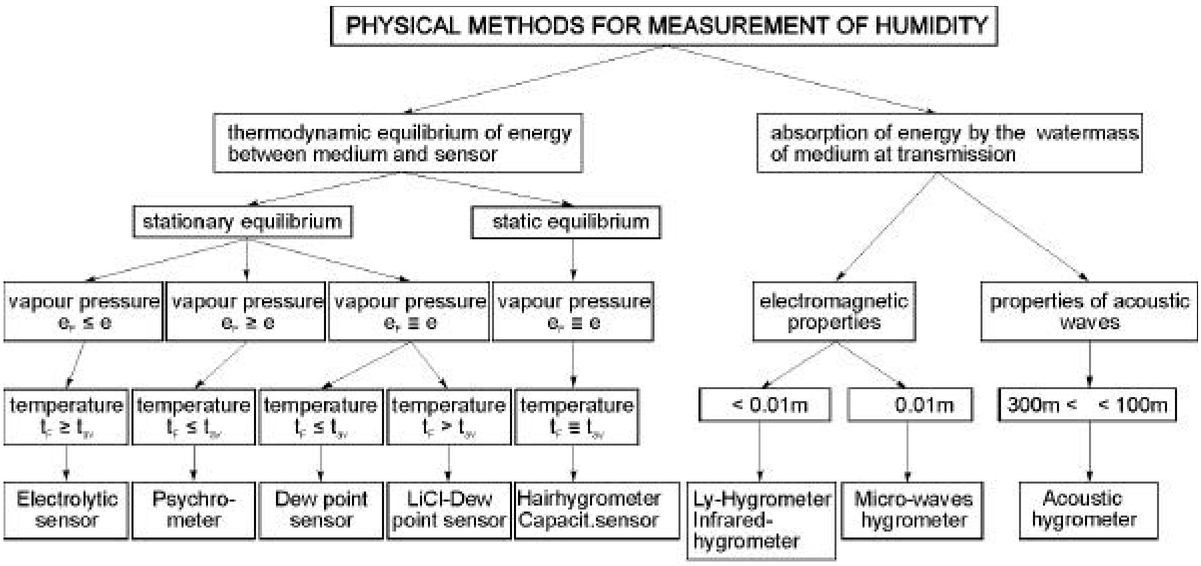



**Figure 4.** Overview on the physical methods for measurement of humidity /1/

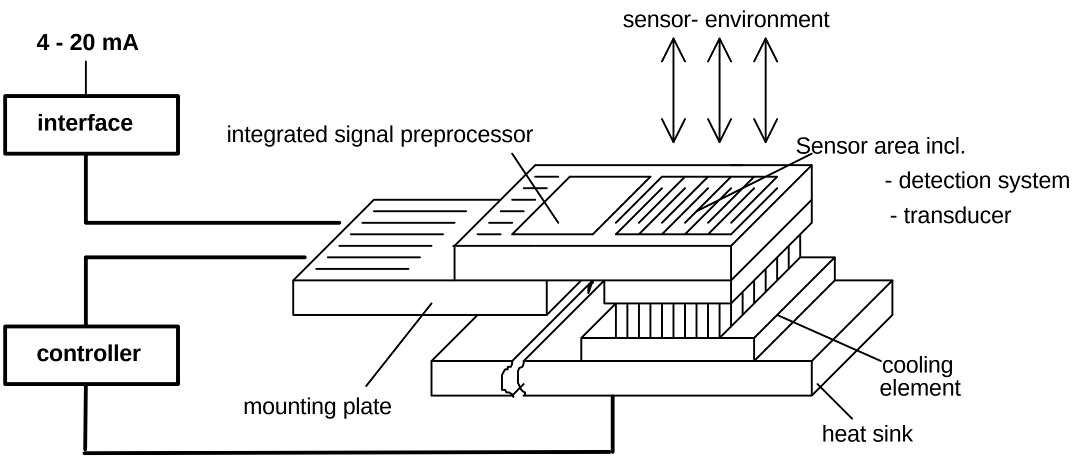



**Figure 5.** Principle of the CCC*-dew point sensor system (dimension of the sensor: 4 x 2 x 0,5mm$^3$).

The dynamic behaviour regarding the detection system is very simple. After reaching the thermodynamical equilibrium a constant water mass exists on this surface like shown in Figure 6. If the humidity of the surrounded air increase more water condenses (see Figure 7). The origin state is reached by reducing the cooling performance.

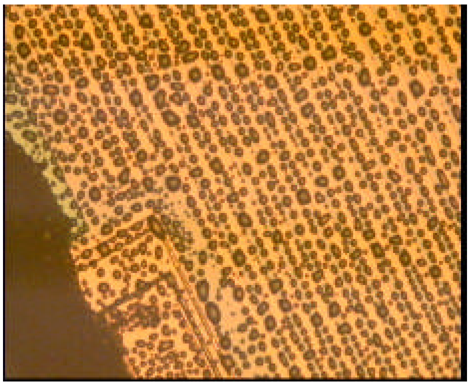


**Figure 6.** Covering of the detection area with water drops regarding the thermodynamical equilibrium

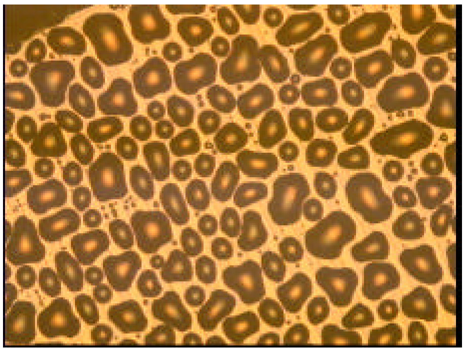


**Figure 7.** Water drops configuration after increasing of the humidity

Based on this CCC*-principle different types of probes, compact transmitter, transmitter with separate probe and dew point meters were manufactured. Probes for pressure dew point is one of the possible configuration beside such one for higher gas temperature for example /3/. The dew point measurement systems are traceable to PTB standards. All these probes and devices have been provided with CE declaration. Low cost versions consisting of dewing element only are available too.

## 4 SPECIAL ADVANTAGES OF THE CCC*-DEW POINT SENSOR

In accordance to the features of absolute humidity sensors the CCC*-dew point sensor offers several advantages in case of industrial applications. Figure 8 presents the special advantages.

| Special advantages of the CCC*-dew point sensor |
| --- |
| Measurement of pressure dew point, absolute humidity (g/m$^3$), mixing ratio (g/kg) with high accuracy |
| Long term stability |
| Fast responds |
| High reproducibility in case of high humidity |
| Direct comparison of dew point temperature and temperature of material |

**Figure 8.** Advantages of the CCC*- dew point sensor

## 5 SYMBOLS

| | |
| --- | --- |
| $R_d$ | gas constant |
| $T$ | temperature /K |
| $V$ | volume |
| $e$ | water vapor pressure |
| $e_F$ | water vapor pressure of sensor |
| $e_W$ | water vapor pressure, saturation |
| $e_{WS}$ | water vapor pressure, saturation at 0°C |
| $m_{wdmax}$ | max. mass of water vapor, saturation |
| $p_a$ | pressure of air |
| $t_F$ | temperature of sensor |
| $t_d$ | dew point temperature |
| $a_W$ | constant factor |
| $b_W$ | constant factor |

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