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Errors in Relative Humidity Measurements Due to Slow Temperature Response

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Summary

Relative humidity calibrations are usually completed at static conditions i.e. both temperature and dew-point temperature is stabilized prior to reading values of the device under test and references. This kind of static calibration is justified by reduced uncertainty and more simple calibration stations. Following this, humidity transmitters are usually specified in stable and static conditions, which is problematic in terms of real world non-static environments. In this work effect of humidity transmitters thermal response times are studied and two different probe types are compared. Due to change of temperature a humidity transmitter which is specified to have accuracy of 1%rh might cause measurement error of about 5 %rh depending on stabilization time, level of temperature change and other environmental conditions.

Keywords: Hygrometer, humidity, humidity sensor, temperature, temperature measurement, response time, accuracy

Introduction

Specifications for humidity transmitters are usually defined in stable and static conditions. Also, calibrations of the transmitters are usually performed at static conditions. However, in real world - unlike in calibration stations - the conditions hardly ever are static. Thus, it is important to understand error sources in changing environments.

Lately within the EMPIR HIT project emphasis was put on development of dynamic relative humidity calibration set-ups [1]. As part of the project VTT-MIKES developed such a set-up and successfully characterized it [2]. However, the VTT-MIKES calibration apparatus does not respond – at least not at yet - to demand of calibrations at changing temperature.

In this study measurement results from Vaisala's HMP9 [3] were compared to other typical humidity probe at changing environments. The results indicate that the lower thermal mass HMP9 is significantly faster in terms of thermal response than the other probe type. At the same time the HMP9 is significantly faster in terms of humidity. Additionally, measurement errors are compared to the probes specifications.

Background

Externally humidity probes are typically tubular structures with external diameter of about 10 mm as described in Fig. 1. Depending on mechanical solutions every kind of probe have unique thermal mass and thus thermal response time. However, the common thing is that every probe requires some time to measure targeted temperature. Moreover, prior to stabilized temperature is achieved, inside the filter of the probe temperature is typically differrent than at the target measurement environment. Following this, as relative humidity is temperature dependent, also measured relative humidity is influenced. This kind of error is nearly impossible to correct by calibrations as the thermal response time depends not only on the probe type but also on measurement environment. Factors such as flow speed around the probe, speed of temperature change, gas concentrations, and pressure have significant effect on thermal response time.

Fig. 1. An example of a typical humidity probe. Sensor of the probe (illustrated on the probe on red) is located inside the probe filter.

Measurements

Measurement error caused by slow temperature response was studied by measurements with two different humidity probe types from different manufacturers. Another probe was a typical about 10 mm diameter humidity probe and the other one was Vaisala's about 5 mm

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diameter HMP9. Another external difference along with the size is the material of the probe. Vaisala is using stainless steel while the other manufacturer is using plastic. Both of the probe types have accuracy specification of about 1 %rh.

The measurements were completed with 3 Vaisala's HMP9 and also 3 typical humidity probes. All six probes were placed inside a heat chamber in such way that they all were equally in front of the fan of the chamber. In addition, none of the probes touched walls of the chamber. The tests were performed by carrying out a temperature ramp presented in Fig. 2. The ramp was repeated three times. A more detailed example of the performed measurements along with measured humidity values is shown in Fig. 3.

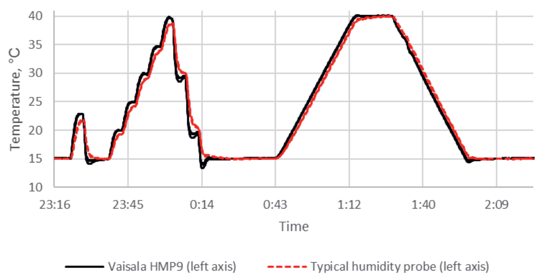

Fig. 2. During the test temperature of the chamber was varied in the range from 15 °C to 40 °C.

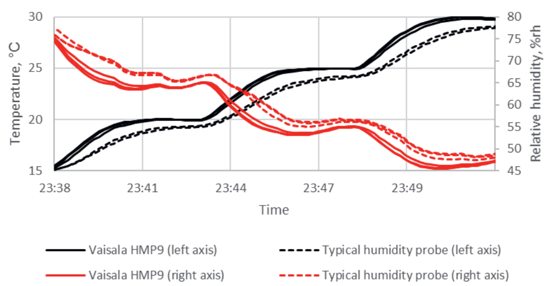

Fig. 3. As part of the test, temperature was increased 5 °C at a time in 5 min interval. Here is an example data indicating differences in response times and thus measurement errors.

Results

According to Fig. 2 and Fig. 3 typical humidity probes have slower response time in terms of temperature that can be seen also in humidity readings in Fig. 3. In the beginning of the measurement (see Fig. 3.) all temperature readings were consistent, but after the temperature increases the bigger probes indicated lower temperature readings due to slower thermal response (see Fig. 4). However, according to a separate calibration all of the probes indicated within 0.1 °C the same temperature also at elevated temperatures.

In terms of humidity the thermal response time causes also error as can see from Fig. 3. Differences between the two probe types from 15 °C to 20 °C and from about 75 %rh to 65 %rh are shown in Fig. 4. as a function of delayed time from temperature change.

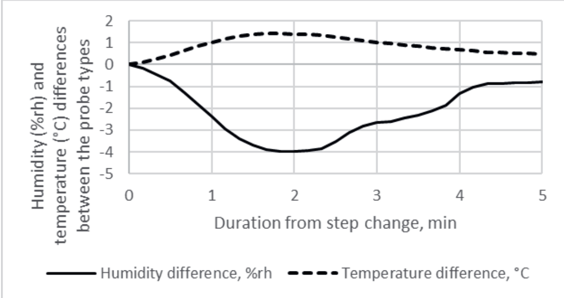

Fig. 4. Humidity and temperature differences between typical humidity probe and Vaisala's HMP9 when temperature of a heat chamber is increased from 15 °C to 20 °C.

The differences between the probe types were even greater at cooling steps. In fact, the typical humidity probes were unable to record overshoot of the heat chamber temperature (See Fig. 2 at 0:14). Maximum difference that were measured during the tests was 5.1 %rh, which is far more than what is specified in datasheets of the probes.

Conclusions

Thermal mass of a humidity probe is a key parameter when choosing the best probe type. According to this work, too large probe can cause significant error in terms of measurement accuracy. As shown in this work, in changing non-static environments measurement error can be five times greater than measurement accuracy specified in product datasheets.

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