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# Determination of overall self-heating of automatic weather stations

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# Determination of overall self-heating of automatic weather stations

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**Abstract.** Measurements of temperature are a critical part of meteorology and climate studies and the knowledge of used sensor's key parameters that affect the resulting measured temperature values is of high importance. This paper focuses on the platinum resistance sensors used within automatic weather stations (AWS), which form a basic unit of the meteorological and hydrological services. Self-heating of the these thermometers are the subject of this study that originates not only from the temperature sensor itself, but also from the additional electrical components housed together with these sensors. The purpose of this study and the conducted measurements is to show the temperature change in the close vicinity of the sensors over a time period of more than 66 hours with an electric current and voltage supply recommended by the sensor manufacturers. Furthermore, the temperature change after increasing the voltage supply levels up to 80% of the maximum voltage recommended by the respected manufacturer is presented as well. In the presented study, the measured difference from the initial measured temperature can be high as +0.32°C when elevated voltage levels are used.

## 1. Introduction

Meteorology is a scientific field that deals with processes and phenomena happening within the atmosphere with the main purpose of weather forecast. As weather directly affects the environment in which man lives, it plays an important role in our everyday lives. Therefore precise and reliable measurements of key meteorological factors with the associated uncertainty are of high importance. As many automatic weather stations (AWS) today measure air temperature using platinum resistance thermometers (PRT), there are multiple effects that may affect the resulting measured air temperature. As these sensor types rely on the resistance measurement principle of temperature [1 - 3], they need to be supplied by a constant and stable source of electric current. This is caused by the need to measure resistance, which is only possible when electric current is present. This measurement principle can potentially cause the heating of resistance element by the passing current that can result in artificial and undesired increase of measured temperature. This effect commonly called "self-heating" is well known and has been discussed and analysed in numerous publications [4 - 8]. Further details of this effect are presented in following sections. Most of the AWS sensors that are used today, house together in a compact space multiple sensors (most commonly

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humidity sensor) the voltage levels supplied to this sensor have a potential effect on the increase of temperature within the AWS sensor housing. This can cause an artificial increase of temperature that is indicated by the temperature sensor. Therefore it is important to determine the magnitude of this effect.

Quantities like temperature, humidity, wind speed, precipitation, solar radiation etc. are crucial for accurate weather predictions. To ensure the relevance of data, measurement methods and sensors' characterisation, together with the possible influential factors on the measurement process, needs to be analysed and defined. This information will help to supply the best possible data that will be used for weather forecast and climate related analysis. Quantity that is most commonly measured in meteorology, is without a doubt air temperature. Although temperature measurements are believed to be well characterised, there are multiple undefined factors that indirectly or directly affect these measurements. These factors may originate from the environment that the sensors are exposed to or from the used measurement devices and sensors themselves.

## 2. Self-heating of PRT used in AWS

PRT are commonly used types of thermometers in AWS. As these sensors are in constant and continuous use, the possibility of self-heating over an expanded periods of time increases. Based on this knowledge, the following section will be focusing on the measurement procedure to determine the PRT self-heating that originates solely from the sensor measurement element.

Self-heating effect is usually determined by extrapolating, to zero current. This means that the thermometer resistance values with different electrical currents are measured at a stable and fix temperature. Typically, two current method is applied to determine the self-heating effect.

To determine the self-heating error of the PRT the measurements were done using the two current method at temperatures from -40 °C up to 0 °C in air. From the measured self-heating for individual sensors we can assume, that for the sensors used for this study the self-heating levels originating solely from the PRT sensor doesn't exceed 0.1 °C.

## 3. Overall self-heating of temperature sensors used in AWS

Previously presented research of PRT self-heating, has shown a relatively small effect. Based on these findings a further investigation has been conducted, in order to explore the possible heating of temperature sensors used within AWS, not only by the sensors sensing element itself, but also by the accompanying electronic housed together within the thermometer casing.

The measurement process described in this section was developed and used to determine the self-heating of selected AWS sensors and the accompanying electronic housed within the measurement unit.

In order to determine the maximal potential level of "overall self-heating" generated by the electronics housed within the tested AWS sensor, it needs to be thermally isolated from the temperature stable environment that the sensor is going to be exposed to. This can be done by covering the tested sensor`s body with an insulation material that will minimise the heat exchange between the body of the sensor and the thermally stable environment. The material type used within this study was interlaced foam based on synthetic rubber with a low conductivity $\lambda$ 0 °C $\leq$ 0.033 (at 0 °C).

In order to have reliable data that can be used for the possible "overall self-heating" characterization, the thermal stability and homogeneity of the testing environment (climatic chamber, dry well etc.) is needed for its inclusion in the uncertainty budget. For the purpose of measuring the testing environment`s thermal stability a calibrated PRT sensors which will be exposed to the same temperature conditions [9] (position within the environment, temperature, air flow speed etc.) as the tested sensor housed within the insulation housing was used.

It is important to note that the sensor had a lower measurements uncertainty that the sensor under test. To minimize the possible self-heating originating from the reference sensor (placed in the insulation housing), a measurement technique that includes measurements for short periods of time (typically 5 min) needs to be applied. This measurement method will cause that the duration of the current passing through the reference sensor is minimal and the heating of the sensing element of the reference sensor can be neglected. The length of the time interval during which the current passes through the reference PRT sensor should be minimal, but long enough to enable the stabilization of the reference sensor.

To be able to see the possible “overall self-heating” it is important to measure the temperature in the vicinity of the thermally insulated tested sensor before the current and voltage supply to the sensor is added. This measurement will determine the temperature of the equilibrium state (zero point) of the whole measurement setup (reference and tested sensor housed in an insulation container) and will furthermore give to the user the information when to start with the testing, by adding the power supply to the sensor under test. Measurements of the zero point should be done with the reference PRT in the same way as described in the previous section, in order to minimize the possible effect of heating by the reference thermometer. The measurements should be performed ideally in one hour intervals for at least 4 hours. If there is no continuous increase or decrease of temperature we can assume that the whole system is in equilibrium state, the zero point has been determined and the sensor testing can begin.

After the successful preparatory steps followed by the measurements of the zero point, the AWS sensor testing can start. This means that the electric current and voltage supply to the tested sensor can be applied. The level of the current and voltage supply should be selected taking into account the manufacturers recommendations (minimum and maximum levels). For the presented study the temperature measurement interval with the reference PRT was 5 min and the intervals between these measurements was set for one hour.

## 4. Results and findings

The results shown in this section were obtained using the measuring procedures described previously. The fallowing results show a change in temperature from the initial level when the sensors were used without a power source (only 1mA current was applied). The maximum positive values of temperature increase after 66 hours were, 0.05 °C from sensor No. 1, 0.07 °C No. 2 and 0.07 °C for sensor No. 3. It is important to note that the overall spread of the data is up to ± 0.06 °C around the initially measured zero point. In conclusion we can state that no clear evidence is presented to state that the usage of 1 mA current results in self-heating surpassing the measurement maximum expanded uncertainty of 0.19 °C ($k = 2$).

After these continuous measurements with only 1 mA current supply an additional voltage supply was added to the sensor. The levels of the voltage were up to 80 % of the maximum allowed values. Specific voltage levels applied were for sensor No. 1: 23.86 V, No. 2: 20.31 V and for No. 3: 20.44 V. This test was intended to show if the power supply level influences the temperature in the vicinity of temperature sensors. The previous measurements continued and the change concerned only the power supply levels. The results show a temperature difference from the zero point. The measurement results show a clear increase in temperature. This increase can be assigned to the additional voltage supply levels, as this was the only parameter changed since the previous measuring conditions. The maximum temperature difference from zero point recorded after 70 hours since adding the voltage supply were: 0.26 °C, 0.34 °C and 0.39 °C for the sensor No. 1 No. 2 and No. 3, respectively.

Temperature changes show a link to heating of the tested sensor by the additional electronic as the whole AWS temperature measuring devices were thermally insulated and any generated heat from within this insulation housing heats primarily the enclosed area which is monitored by a calibrated PRT sensor. This means that any increase of temperature originating from the inside is measured before an interaction between the surrounding environment and the sensor under test happens.

The average increase of temperature within the insulation container for all the tested sensors after the exposure to only 1mA current supply is only 0.07 °C after 66 hours with an expanded measurement uncertainty of 0.13 °C ($k = 2$). By contrast, the average temperature increase when using the 73 % and 80 % additional voltage levels was 0.39 °C after 70 hours with an expanded measurement uncertainty of 0.13 °C ($k = 2$).

The expanded uncertainty for the "overall self-heating" of the tested sensor No. 1 is 0.13 °C. Other tested sensor measurements had similar uncertainty value of 0.18 °C for sensor No. 2 and 0.19 °C for sensor No. 3. This information indicates with what uncertainty the "overall self-heating" values for individual sensors were determined.

## 5. Conclusion

The presented study investigated potential heating originating not just from the resistance temperature sensor itself, but also from the accompanying electronics and sensors (humidity etc.). Measurements with

1mA current supply solely to the temperature senor has show that there is no measureable increase in temperature in the vicinity of the temperature sensor when concerning the experiments measurement expanded uncertainty of 0.19 °C (k = 2). Addition of a voltage supply up to 80 % of the maximum recommended levels resulted in a temperature increase in the vicinity of the temperature sensor. Specifically the temperature increases were after 70 hours of continuous voltage supply: 0.26 °C, 0.34 °C and 0.39 °C for the sensor No.1 No.2 and No.3, respectively (the measurement of these results is 0.13 °C, 0.18 °C and 0.19 °C (k = 2) respectively). These values indicate that the accompanying sensors and electronics housed together with the temperature sensors generate heat by applying elevated voltage levels. In conclusion, using a standard current supply of 1mA to the sensors results in minimal or no "overall self-heating" in the vicinity of the temperature sensor. As for the additional voltage supply heating within the AWS housing occurs even when respecting the manufacturers recommended levels. Based on these finding users of AWS should take into consideration using the bottom limits of voltage supply declared by the manufacturer or alternatively minimise the time of exposure.

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