Radiation Protection Enclosure (RPE) according to Paetz –Prof. Miegel®

Contents

1. Introduction

The causes of erroneous temperature recordings in measurement stations cannot always be traced back to the sensors or to the positioning of the station. Inadequate radiation protection as well as the positioning and handling of the temperature sensors may also be the cause. It can be assumed that the causes of increased errors in the recording of temperatures are the same both in Germany and internationally.

With the development of a new radiation protection enclosure (RPE), we are providing climatologists with a system that will allow them to prove the existence of global warming on our planet. With its new radiation protection enclosure (RPE), Anemometerbau GmbH, which has been developing innovative meteorological products since 1875, presents its latest creative development which gives us the possibility of eliminating the impact of radiation on temperature sensors in ground-based measuring stations.

2. Explanation of the innovation with reference to the latest technology

The temperature has a significant influence on meteorological events, making the measurement of the temperature of the air, ground and water an essential prerequisite for the analysis of weather events. At the same time there are a whole range of interdependencies with other indicators such as humidity and pressure.

Alongside the Stevenson screen, which for 150 years was the most common radiation protection screen for measurement stations, in the past 30 years the cylindrical screen of multiple round cones with active ventilation has established itself internationally in independently operated climate monitoring stations.

All new developments known to us are comparable technically to the Stevenson screen, which is reflected in the measurement results.

The investigation of current screen types identified three main sources of errors in the measurement of temperature.

1. Direct radiation influences on the sensors
    a. Global radiation (short-wave)
    b. Reflection radiation (short-wave)
    c. Heat radiation (long-wave)
2. Convective transfer of heat between the measurement medium and the screen components
3. Ohmic loss resulting from continual electrical operation of the sensor module

Radiation influences on the sensors

While nearly all investigated Stevenson screens and screens of multiple round cones offered good protection from global radiation when the sun is high in the sky, a difference in temperature of up to 5°C could be detected during sunrise and sunset compared to shaded sensors.

A further frequently overlooked aspect is global radiation that is diffusely reflected from the surface of the ground and infiltrates the screen from below, thus having a direct impact on the sensor. This is particularly relevant in measurement locations whose surrounding surfaces have strongly reflective properties. These include above all surfaces with high albedos, such as snow (0.45–0.9) or desert (0.3). However, this is not only relevant for measurement locations in the polar, subpolar and subtropical climate zones, but also in the temperate climate zone at specific times of the year. A majority of the investigated Stevenson screens and screens of multiple round cones available on the market were found to have significant shortcomings in the protection of the sensors from reflection radiation, in some cases due to a lack of protective elements on the underside.

Thermal energy found in the ground or surrounding objects is emitted as long-wave heat radiation (sensible heat flux). As highlighted above, there are no products available on the market that sufficiently protect the sensors from the infiltration of radiation from below and from the sides. Depending on the temperature, thermal capacity and emissivity of the ground and other surrounding objects, the result is a further not insignificant error component. There is to date no radiation protection system on the market that sufficiently protects the temperature sensors from radiation.

Convective transfer of heat onto the measurement medium

Despite their highly reflective properties, global radiation inevitably leads to a warming of the radiation protection elements above the ambient temperature. In order to nonetheless be able to measure the ambient temperature, in accordance with the current technology stations are provided with forced ventilation that directs ambient air towards the sensor. Such radiation protection screens and screens of multiple round cones with forced ventilation can minimise measurement errors but not eradicate them completely, since the airflow is directed along the heated radiation protection elements to the sensor. The resulting convective transfer of heat from the screen elements to the sensors can be significant.

Ohmic losses at the sensor module

Through the continuous electrical operation of the sensor, warming occurs in the sensor itself and in the surrounding cabling through ohmic losses. This is fully included in the measurements due to the good thermal conductivity properties of the electrical components.

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Market research has found that most data loggers and sensor systems provide a permanent flow of current to the sensors, even when measurements are only taken periodically.

All new developments known to us can be compared structurally with the Stevenson screen. This is also reflected in the measurement results.

3. Detailed description of the approach, the target parameters and the necessary work steps

The screen we have developed has a consistent radiation protection concept and decouples the incoming measuring air from any elements exposed to radiation and the corresponding heat transfer. This means that the new construction cannot be compared with the Stevenson screen or the screen of multiple round cones and therefore represents a new solution that much more closely meets the requirements of the World Meteorological Organization.

The intended development consists of an independent measurement system with which weather and climate data can be recorded extremely accurately, even under adverse ambient conditions. In order to ensure this, the following prerequisites must be satisfied.

1. A screen that protects the temperature sensor from direct and indirect radiation
2. Avoidance of the warming of the measurement medium through convective transfer of heat (sensible heat flux)
3. Avoidance of warming through ohmic losses at the sensor

4. Meteorological precision of the effectiveness of the radiation protection enclosure (RPE)

In order to meet the high demands of the sensor technology before the creation of the documentation, the sensors were tested by the Leibniz Institute for Baltic Sea Research in Rostock/ Warnemünde (see table 2 for the protocol). To furnish proof that the radiation protection enclosure, through the elimination of all radiation influences, measures the air temperature to a precision of $\leq 10^{-3}$ K, three different measurement methods were used.

(a) The cascading temperature decrease between the individual radiation protection elements including the measuring chamber was tested.

(b) The change in temperature of the airflow to be measured before entering the radiation protection enclosure and after its exit from the measuring chamber was tested.

(c) The increase and decrease in the enthalpy of the radiation protection enclosure was measured in order to detect differences from the ambient temperature profile.

(a) Cascading decrease of the radiation influence

In order to document the temperature profile, Pt100 sensors were attached between the individual radiation protection elements as far as the measuring chamber. At the first radiation protection element a Pt100 sensor Pos. 6 [S17) and a mercury thermometer were attached to the outward-facing surface in order to establish the surface temperature. A further sensor Pos. 5 [S1] was attached between the first and second radiation protection elements. The third Pos. 4 [T7] was positioned between the two ventilation cylinders of 100 mm and 75 mm diameter. The fourth Pos. 1 [S9] was to be found in the measuring chamber itself.

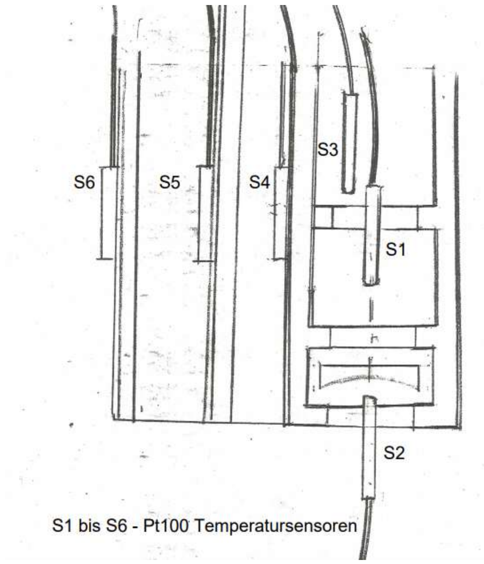

Figure 1: Configuration of the Pt100 temperature sensors for the cascading decrease

Temperature results:

Sensor	Pos. 6 [S17] Flow cylinder	Pos. 5 [S1] Flow cylinder	Pos. 4 [T7] Flow cylinder	Pos. 1 [S9] Measuring chamber	Pos. / [U21]
Position	External diameter 150 mm	External diameter 100 mm	External diameter 75 mm	Interior	Air temperature in multiple round cones
Calibration divergence from the characteristic curve	15.0366	14.9267	15.0241	15.0007	15.0334
09.08.2020 10:17:53	-	-	25.013	25.171	-
17.09.2020 09:07:40	40.6720	16.3348	15.5553	15.0093	15.1575

Table 1: Cascading decrease, all temperatures in °C

(b) Minimisation of the convective transfer of heat

In order to furnish proof that as a result of the radiation protection enclosure measurement errors through the convective transfer of heat could be eliminated to the extent that they are of no significance for meteorological measurements, the radiation protection enclosure had to be equipped with further sensors.

One sensor Pos. 3 [S16] was mounted at the entrance of the airflow into the light lock with measuring chamber, and further sensors behind the measuring chamber and at the beginning of the flow channel Pos. 2 [X2]. If the measured values of sensors Pos. 3 [S16] and Pos. 2 [X2] agree, this can be considered evidence that the inflowing air is not influenced by the radiation protection enclosure. Sensor Pos. 1[S9] can be included in the evaluation for the purposes of error analysis (see Table 2).

1	Sensor	Pos. 1 [S9] Measurement chamber	Pos. 3 [S16] Entrance to measurement chamber	Pos. 2 [X2] Exit of measurement chamber
2	Unit	°C	°C	°C
3	Calibration value	25.0029	25.0029	25.0029
4	Measured temperature 01.08.2020 11:36:57	25.0010	25.0890	24.9270
5	Difference between calibrated sensor – measured temperature (row 4)	+0.0019	−0.0861	+0.0759

Row 4: Average temperature over 10 minutes, every 20s

Table 2: Radiation influence

The measured values presented in Tables 1 and 2 have only been documented from the third digit after the decimal point to provide evidence that the gas flowing in the RPE is not influenced by radiation. The radiation measurement error in our screen was ≤ 10^{-6} and thus insignificant for meteorological records.

It is common knowledge that global warming is happening rapidly in various areas, but slower in others. However, this fact also requires that measurements must be made with greater precision. In order to achieve reliable measurement results quickly, several high-quality Pt100 sensors should be installed in our screen and flanked with reference marks.

5. Summary

Usual radiation protection housings such as the usual Stevenson screen and the climate stations with the screen of multiple round cones contain errors due to radiation effects, which influence the measured temperatures. With the radiation protection housing according to Pätz - Prof. Miegel® presented here, these systematic errors are avoided or largely minimized, so that the measured temperatures are very close to real temperatures and thus a more realistic long-term recording of global climate change regardless of local or temporary radiation effects is possible.

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