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Heated rain gauges

THE HEAT IS ON

Italian technology is helping to overcome the challenges associated with operating rain gauges and meteorological sensors in cold climates with limited energy sources

Accurately measuring solid precipitation in locations where there is no mains electrical power supply is extremely challenging. This is a problem that affects many automatic weather stations (AWSs), especially when they are installed in particular areas, such as high altitudes.

Many parameters affect the ability of an AWS to accurately measure physical phenomena such as snow, the deposition of ice, freezing rain and hail, and for it to maintain an adequate amount of energy to ensure the station and its transmission systems continue to work. Many systems use the same energy source to power both the basic functioning of an AWS and the heated sensors to ensure they continue to work.

A typical application for AWSs with no mains electrical power supply is a system that is powered by cyclic rechargeable batteries and solar panels. However, such as system is not always completely reliable, especially during times of prolonged bad weather and when temperatures are near or below 0°C. During these times, the weather station may not have enough energy to perform adequately, especially if it is programmed to transmit data in real time to a remote control center (typically via GPRS modem, radio or satellite).

A lack of sophisticated technology that can carefully control and monitor AWS energy use, together with inadequate attention to the realization of devices that minimize heat loss in critical climatic conditions, can result in unusable data from the automatic weather station, greatly limiting its autonomy. This can also lead to the absence of accurate real-time data for decision making and weather alerts.

Scientific studies looking at the measurement of snow precipitation demonstrate that the measure of equivalent water quantity acquired by a standard heated tipping bucket rain gauge (even if manufactured according to WMO standards) can be underestimated by up to 30-40% in places where precipitations are mainly solid during the year.[1]

Example of installation with "Single Alter" shielding system for heated rain gauge, according to WMO (Gardena Valley - Italy), together with standard AWS

This uncertainty is due to a number of factors. Strong gusts can affect the amount of snow gathered if proper shields such as the Alter windshield are not used. The formation of ice on the surface of the sensor can also affect the accuracy of measurements. Furthermore, factors such as orography, exposure and heating sensor processes can affect total uncertainty.

Standard heated tipping bucket rain gauges have some limits, mainly due to the nature of the phenomenon they measure. With this in mind, technological research has focused its attention on minimizing errors associated with the heated sensor, such as limiting water evaporation and therefore the loss of mass. Research has also looked at maximizing the efficiency of the electronic circuits so that they can be used at low electric power configurations and can withstand environmental conditions. The main aim is to develop an instrument that is suitable for both industrial and scientific use, according to WMO standards.[2]

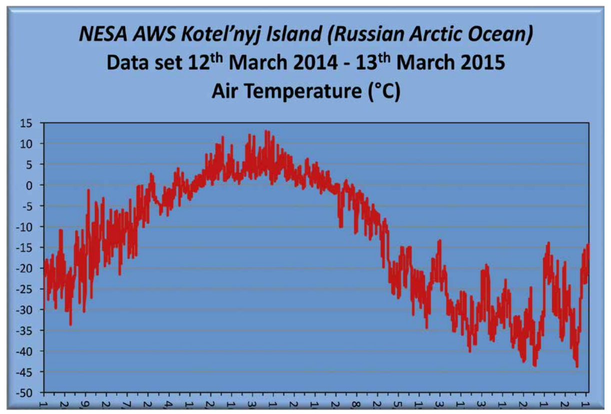

Figure 1: **Air temperature – Kotelny Island**

RESEARCH AND DEVELOPMENT

Nesa, which has designed, supplied and installed professional equipment and systems worldwide for environmental monitoring since 2004, has developed several specific solutions for tipping bucket rain gauges to make them suitable for applications characterized by reduced power availability. For one of its products, the company has even obtained a patent (number 0001385352) entitled 'Pluviometro riscaldato a basso consumo di energia' ('Heated rain gauge with low power consumption') from the Italian Patents and Trademarks Office on January 1, 2011.

Nesa's research and development department handles the technological development of new solutions and is primarily focused on looking at the energy use of AWSs. R&D is also looking at solutions aimed at minimizing water evaporation and wind effects on the rain gauge sensor to reduce systematic errors. Another area of focus is to apply the obtained results from measurement campaigns and research, which have been organized by the WMO or other scientific institutions.

Among all the mechanical techniques studied by Nesa's R&D department, a decision was made to focus on the development of four main areas: the adoption of the 'knife blade' technique, made in stainless steel, which reduces weight and mechanical inertia; compliance of the inclinations of the gathering cone according to WMO norms (to reduce turbulence effects, rebound and leakage of precipitation); the use of powder coating of a reflective white color to reduce the adhesion of rain drops, the cutting of the gathering 'mouth'performed with maximum accuracy.

Together with improved mechanical characteristics, the R&D department also focused on electrical and electronic aspects. Experience gained over time has shown that if only the gathering cone is heated, thereby melting the solid precipitation, the tipping bucket of the rain gauge can freeze. Further improvements and refinements to solutions are also periodically made following suggestions and support from some research entities and universities.

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AWS for Organisation of Eastern Caribbean States (OECS) – Grenada

Automatic weather station equipped with low consumption rain gauge in Bompiano (Edolo, BS - Italy)

Automatic weather station in Bivacco Festa (2320 m), at the head of Rabbia Valley (Sonico, BS - Italy), equipped with low consumption heated rain gauge with thermal insulator

ENERGY-EFFICIENT RAIN GAUGE

The heating function of many rain gauges is only activated when the temperature of the external air or of the space near the gathering mouth drops below a certain level. In this way there may be evaporation that increases measurement error. A suitable temperature control system, however, can help manage the heating to reduce energy waste and to avoid generating excessive heat, which is the main cause of mass loss by evaporation.

Many technical solutions are available to help develop a temperature control system. On-field experience has shown that the thermosetting logic can be realized with special stabilizer circuits and precision thermostats or by associating the rain gauge with an external electronic intelligence device, such as a datalogger, that through proper algorithms can handle activation thresholds and heating time intervals (considering also residual power availability and battery charge status).

The rain gauge patented by Nesa was designed considering that energy use is minimized if the heating switches on only in the presence of precipitation (in whatever form, and also in the case of frost deposit), and not in every low-temperature condition, as with standard rain gauges.

The solution follows this procedure. The heating is activated below a certain temperature threshold for a limited time interval (typically 10 minutes). If in this interval at least one tilting is measured (indication of precipitation), then the heating continues for another time interval; otherwise it stops if no signal is recorded. Appropriate electronic circuits have to manage both heating activation and deactivation and the verification of precipitation presence. This technique is suitable for monitoring systems with limited energy availability and enables users to further refine knowledge on solid precipitation measurement in c ritical conditions.

Another benefit of the rain gauge is that it uses a special insulation that helps reduce energy consumption. This insulation is stuck on the outer side of the sensor cone and helps minimize heat loss. On-field tests show that thermal insulation has a major impact on measurement accuracy, especially with strong gusts, when the heat removal is quick and cripples any rain gauge heating system when there is limited energy available.

During professional activities and environmental monitoring network implementation, Nesa sells and installs rain gauges according to WMO standards and the Class A UNI 11452:2012 standard thanks to the specific correction algorithm implemented in the company's datalogger TMF/Evolution series.

The company can integrate many systems, products and advanced solutions to meet the needs of specific applications and project requirements. A common requirements is the supply and installation of an AWS solution that can operate reliably in a wide temperature range. A good example is the AWS that was installed on Kotelny Island in the Russian Arctic. Figure 1 shows air temperature during a year of uninterrupted measurements. Temperatures below -40°C are not rare, and precipitation is almost exclusively in solid form, except for brief rainfall during the summer. According to the database, the lowest temperature, -43.7°C, was measured on March 5, 2015. Annual average temperatures are around -13°C.

Many projects, in addition to the supply of solutions, also require on-site training and commissioning, together with after-sales service. Nesa's senior engineers meet local technicians to perform scientific training on equipment, its use and periodic maintenance, data management and correct interpretation of measurements. Experience gained in many places around the world, including in the Caribbean, central America and central Asia, enables Nesa's staff to work with members of local meteorological services and to strengthen partnerships that stimulate the professional and personal growth of staff. ■

References

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PL1000 rain gauge with calibrated gathering surface of 1000cm2 and measurement system made of tilting bucket