4.1 A NEW HIGH ACCURACY, LOW MAINTENANCE ALL WEATHER PRECIPITATION GAUGE FOR METEOROLOGICAL, HYDROLOGICAL AND CLIMATOLOGICAL APPLICATIONS

Heikki Turtiainen *, Pauli Nylander and Pekka Puura
Vaisala Oyj, Helsinki, Finland

Risto Hölttä
Vaisala Inc, Boulder, Colorado

1. INTRODUCTION

Accurate measurement of precipitation is a challenge, especially in climatic conditions where both liquid and solid precipitation occur. In principle weighing gauges are the most suitable point precipitation gauges for these conditions. However, the accuracy of conventional weighing gauges is degraded by a multitude of errors. Wind effects, evaporation and wetting error tend to cause systematic underestimation. In winter conditions instrumental errors related to accumulation of snow and ice on rim and funnel parts of the gauge - including complete filling of the gauge with snow - may result in gross errors. These problems are only partially solved by using antifreeze solution in the container and with rim heating.

The new Vaisala all weather precipitation gauge VRG101 (fig. 1) is a result of careful study of the existing solutions and new technical innovations. It provides higher quality of measurement and lower life-cycle cost in all weather conditions.

This paper describes the gauge design and presents field test results obtained at the observatories of the Finnish Meteorological Institute in Jokioinen and in Sodankylä. Preliminary results from field tests by NADP (National Atmospheric Deposition Program) are also discussed.

Fig. 1. Vaisala all weather precipitation gauge VRG101 with wind shield VRS111.

* Corresponding author address: Heikki Turtiainen, Vaisala Oyj, PB 26, FIN-00421 Helsinki, Finland; e-mail: heikki.turtiainen(at)vaisala.com.

2 VRG101 DESIGN

2.1 Design principles

VRG101 is designed as a reliable and accurate all-weather precipitation gauge, with special emphasis on easy maintenance and extended service intervals. The electronics unit includes a processor with embedded algorithms for calculation of cumulative rainfall and intensity. Versatile interfacing options guarantee easy interfacing to various data collecting systems.

The main features of VRG101 are presented in table 1.

Gauge type	Weighing precipitation gauge
Parameters measured	- Cumulative precipitation (mm) - Precipitation intensity (mm/h) - Temperature (°C), optional
Sensor element	Single point load cell
Collecting area	400 cm2 (62 in2)
Capacity	650 mm (25 in)
Resolution	0.1 mm
Accuracy	0.2 mm - precipitation event > 0.5 mm
Dimensions	Height 950 mm (37 in) Diameter 400 mm (16 in)
Power consumption	- Without heating 30 mW - With heating 100 W max
Serial I/O	- RS232 and RS485 lines for gauge output and configuration. - Polled or automatic message
Data message parameters	- Gauge status - Cumulative precipitation mm - Precipitation intensity mm/h - Air temperature (option) - Container mass g - Electronics temperature - Supply voltage
Options and accessories	- Pulse output - Rim heating - Air temperature sensor - Wind shield (types Alter, Double Alter and Tretyakov available) - Pedestal - Field check kit

Table 1. VRG101 main features.

2.2 Mechanics

VRG101 utilizes the latest high-accuracy, temperature compensated load cell technology. The single point - type load cell is designed for direct mounting of the weighing platform. Eliminating levers and flexures, this allows simple, robust and low cost mechanics.

The load cell is insensitive to eccentric loading unlike some other types of weighing gauges. Thus unsymmetrical distribution of snow in the collecting bucket (typical for winter conditions) does not introduce measurement errors.

The gauge volume and geometry have been optimized for good performance in all weather. Its wide 400 cm2 collecting area is advantageous when measuring light rain and the large 650 mm net capacity decreases the risk of overflow. The deep container, together with the constriction formed by the inlet funnel decrease the evaporation error and outblowing of collected snow.

Another error source that is eliminated by the advanced mechanics is the underestimation caused by water and snow sticking to the inner surfaces of the gauge inlet funnel. In conventional designs this mass is not measured and eventually evaporates. In Vaisala's design the funnel element rests on the collector container. All water and snow on it’s surface is therefore included in the measured mass.

The hinged upper part (rim and collecting funnel) and detachable enclosure door allow easy access for maintenance or adding antifreeze solution, as well as easy removal of the collector container (see fig. 2).

The electronics unit, including the load cell is field-removable (fig. 3). Replacement of the electronics is straightforward and quick. Data loss is kept to a minimum as there is no need to transport the whole gauge to the laboratory for calibration. On-field checking of the gauge accuracy can be done using a dedicated field check kit.

Fig. 2. The gauge with enclosure opened.

Fig. 3. Electronics unit and load cell are situated under the weighing platform.

2.3 Software and interfacing

The gauge software uses advanced algorithms to filter out noise, spurious signals (e.g. vibration by wind, mechanical impacts and rubbish or other objects entering the collecting container) and to compensate for evaporation.

The outputs include RS232 and RS485 serial lines with polled or automatic messaging. Configuration of the gauge is also done through the serial lines. An optional pulse output (tipping bucket emulation) with programmable tip size is available.

In addition to cumulative rainfall the gauge data message also includes precipitation intensity, supply voltage, electronics internal temperature, gauge status with error flags and air temperature (if the optional Pt100 sensor is connected). Complete raw data (weight of the container) is also available to be used for diagnostic or research purposes.

2.4 Heating option

Optional rim heating is recommended whenever solid precipitation needs to be measured. Heating prevents accumulation of snow and ice on the rim and the collecting funnel. To prevent extraneous evaporation error caused by heating and to minimize power consumption, the heating is controlled by the gauge's software. The intelligent control algorithm is based on ambient temperature and precipitation conditions.

2.5 Wind shields

Use of a wind shield is essential for high accuracy, especially when measuring snow or sleet. There are two types of basic shields available for the VRG101: Tretyakov and Alter. For climatological stations and other applications requiring the highest accuracy, a Double Alter shield is recommended.

2.6 Other options and accessories

Other options and accessories include pulse output, air temperature sensing kit (a Pt100 temperature sensor with a radiation shield), field check weight, gauge pedestal and screw pole foundation.

Automatic draining option will be available in spring 2006.

3. TEST RESULTS

The gauge has undergone extensive testing at Vaisala's own test field, in the Finnish Meteorological Institute's (FMI) observatories in Jokioinen and Sodankylä, and by various pilot customers. Here the results obtained from FMI field test facilities and the National Atmospheric Deposition Program (NADP) test field are presented.

In the FMI Jokioinen Observatory, Southwestern Finland trial, VRG101 was compared with the FMI's double fence intercomparison reference (DFIR): a high accuracy weighing gauge with it's orifice height set at 3 m and surrounded by an octagonal vertical double fence.

The comparison was started in August 2004 and still continues. The results presented here are from the period August - November 2004 (Turtiainen et. al. 2005). Figure 5 shows the observed relation between VRG101 and the FMI reference gauge. Table 1 shows daily total values divided into three categories (light rain, rain and heavy rain).

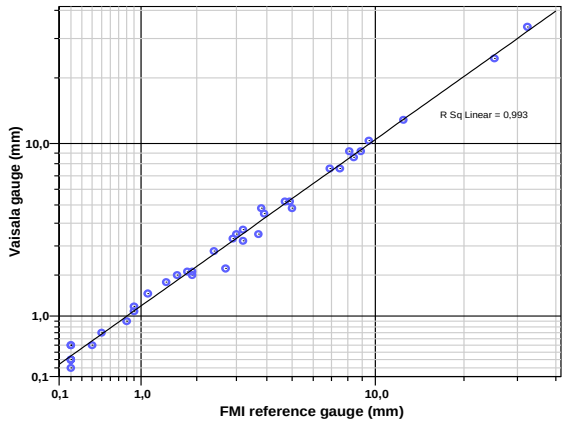

Fig. 5. Daily totals, Vaisala gauge versus FMI reference gauge (DFIR)

Overall, the Vaisala gauge caught slightly more precipitation compared to the FMI gauge, the difference being highest for light rain events. The difference is believed to be caused at least partially by the designs of the the inlet sections of the gauges. The inlet funnel of the the Vaisala gauge is a part of the instrument weighing system, whereas this is not the case for the reference gauge. Therefore water droplets caught on the surface of the inlet of the FMI gauge are likely to cause wetting error, and consequently an underestimation especially in light rain.

Daily rainfall	Nbr of days	FMI reference gauge (mm)	VRG101 (mm)
< 1 mm	10	4.5	6.2
1 - 4.4 mm	15	38.5	43.0
> 4.4 mm	12	133.9	138.9
TOTAL	**37**	**176.9**	**188.1**

Table 2. Summary of liquid precipitation measurements at FMI Jokioinen Observatory, August - November 2004.

Daily rainfall	Nbr of days	FMI gauge (mm)	VRG101 (mm)
< 1 mm	4	2.0	1.2
1 - 4.4 mm	7	14.1	14.1
> 4.4 mm	4	35.4	34.3
TOTAL	**15**	**51.5**	**49.6**

Table 3. Summary of snowfall measurements at FMI Sodankylä Observatory, February - April 2005.

Another, identical gauge was installed in the FMI Sodankylä Observatory in Northern Finland. Snowfalls are more abundant in Sodankylä and extend further into spring than they do in Jokioinen. The gauge was equipped with rim heating and a Tretyakov type wind shield. The reference used in Sodankylä was a standard FMI precipitation station: a manual gauge and a Tretyakov type wind shield.

Table 3 shows the summary of the daily results. The Vaisala and the reference gauges were in good agreement. The difference in the total values was only 1.9 mm or 4 %.

VRG101 was also tested by several pilot customers. An example of interim results of tests performed at the test field of the National Atmospheric Deposition Program (NADP), Champaigne, IL. are presented here. The summary of the results is shown in fig. 6. In general the two gauges were in good agreement, the difference in the total cumulative rainfalls being only 2 %, with VRG101 showing slightly more.

4. CONCLUSIONS

The VRG101 belong to a new generation of weighing precipitation gauges. Simple and robust mechanics, optimized gauge geometry, the latest high-accuracy load cell technology combined with advanced measurement and heating control algorithms ensure high performance in all weather conditions.

The gauge has been field tested in co-operation with the Finnish Meteorological Institute, as well as with several pilot customers. The results demonstrate the good performance of VRG101 both in liquid and solid precipitation.

When interfaced with the Vaisala MAWS-dataloggers and communication modules the gauge can be used both as a basic stand-alone hydrometeorological station, or as a component in larger observation networks. Due to it's versatile output options, the VRG101 can be interfaced with any data collection system with a RS232/485 or a pulse input, and has a wide application area in state and national meteorological, hydrological and climatalogical networks. The precipitation intensity output also enables the gauge to be used as a reference when weather radar signals are to be converted to quantitative rainfall amounts.

Acknowledgements. The authors thank Ms Anu Petäjä from the Finnish Meteorological Institute and Roger Claybrooke from National Atmospheric Deposition Program for their kind co-operation in organizing the field tests and permission to publish the results.

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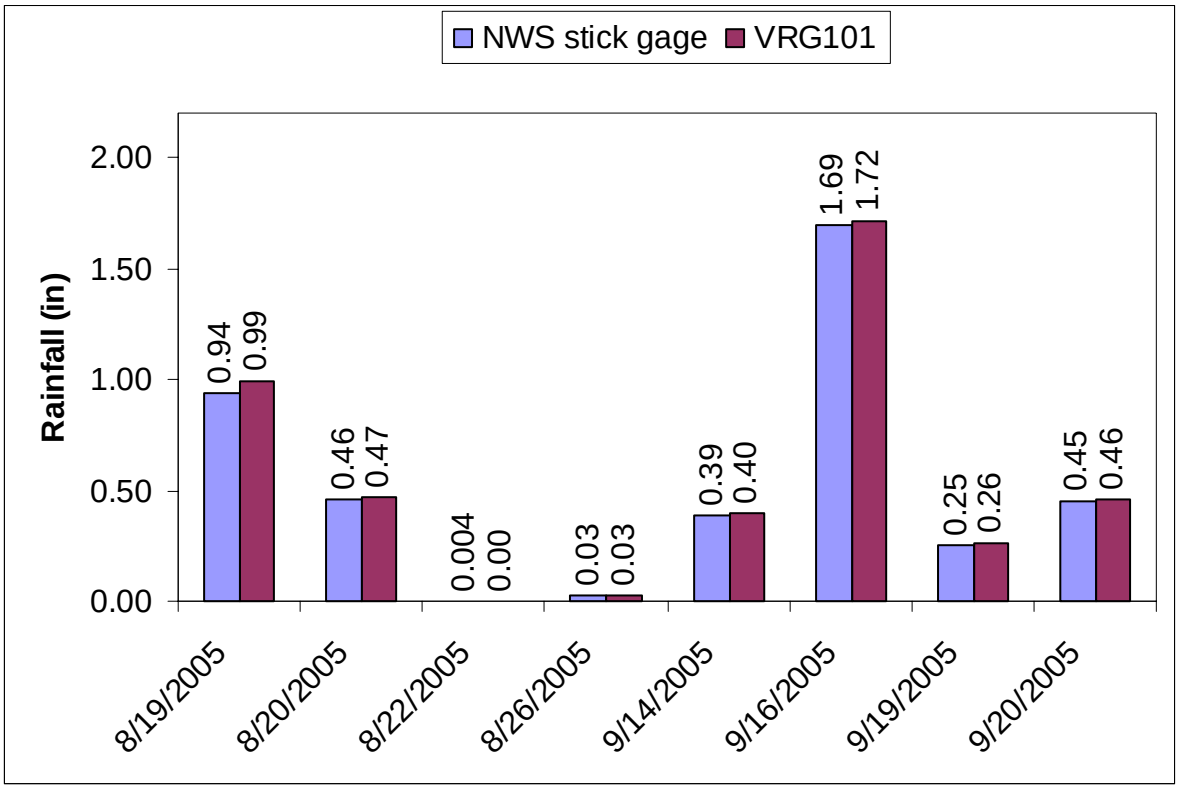

Fig. 6. Comparison of daily rainfall measured by VRG101 and NWS stick gage at the NADP test field, Champaigne, IL, from 19 August to 20 September 2005.