The importance of manufacturer-independent ground checks for observations using balloon-borne in-situ sounding instruments

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Introduction

The GCOS Reference Upper-Air Network (GRUAN) currently provides reference observations for temperature and water vapour using radiosondes (e.g. Vaisala RS92) and other sounding instruments. Since these observations are used for long-term climate, a concern is that for almost every observation a new instrument is used.

Production variability and larger changes in the instrumentation directly impact the measurement series. Therefore an operational characterization of all instruments prior to launch is essential.

Several sites within the GRUAN network are providing additional manufacturer-independent ground checks (e.g. SHC) in order to characterize the instruments and their uncertainty prior to launch. This dataset is essential to improve confidence in the long-term trends and estimates of climate change. These ground check data provide important information, which has previously not been available.

Default ground checks

Some manufacturers require ground checks to be done before every sounding. Vaisala uses their ground check as a one point recalibration. For humidity measurements this recalibration is detrimental (Fig. 1).

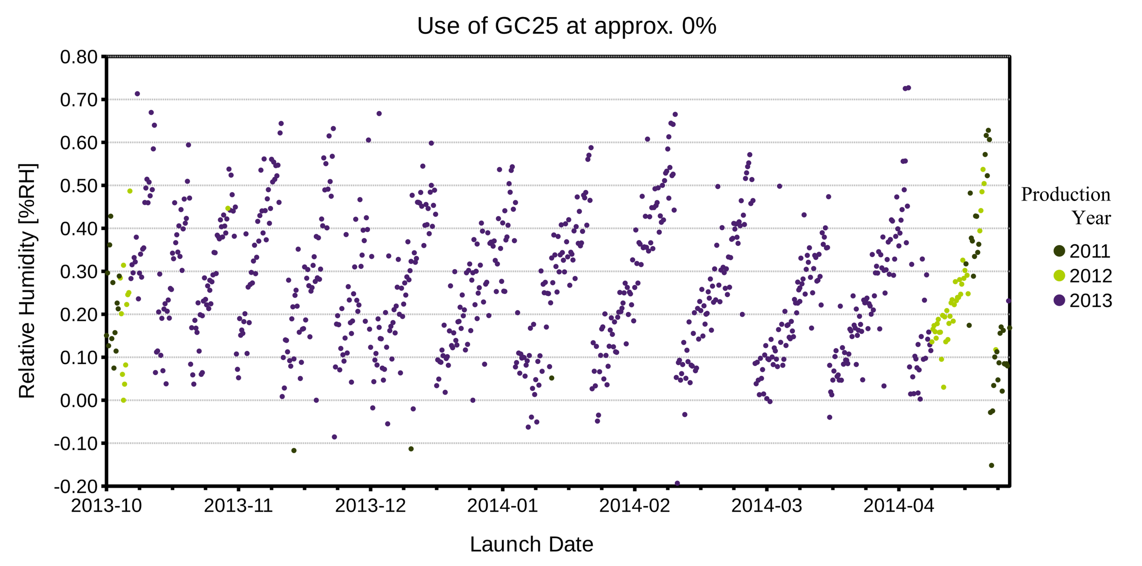

Fig. 1: Vaisala RS92 relative humidity measured in the default Vaisala GC25 ground check tool at Lindenberg. The pattern represents the biweekly change of the desiccant.

Other manufacturers may (or should) use the ground check purely for instrument characterisation.

Importance of ground checks

1) Sondes, which do not meet manufacturer specifications can be identified and rejected prior to use.

2) Small changes in the manufacturing process, which may not have been communicated by the manufacturer, but which may impact the measurement accuracy, may be identified.

3) For large changes in the observing system, such as changes in radiosonde suppliers, this information can be used to reduce the discontinuity between the observations of these different instruments.

4) Estimate the instrument-specific uncertainty budget

All sensors should be checked prior to launch.

Standard Humidity Chamber

A couple of sites within GRUAN currently use a standard humidity chamber (SHC). The standard humidity chamber (Fig. 2) holds air at saturation, and provides SI traceable references for temperature and humidity. Ventilation ensures uniform humidity and temperature as well as a ventilation speed comparable to a typical sounding. Before each launch the radiosonde sensors are checked against saturation and the reference temperature. In contrast to the 0 %RH check, the humidity check at saturation is highly sensitive to variations in the sonde production (Fig. 3).

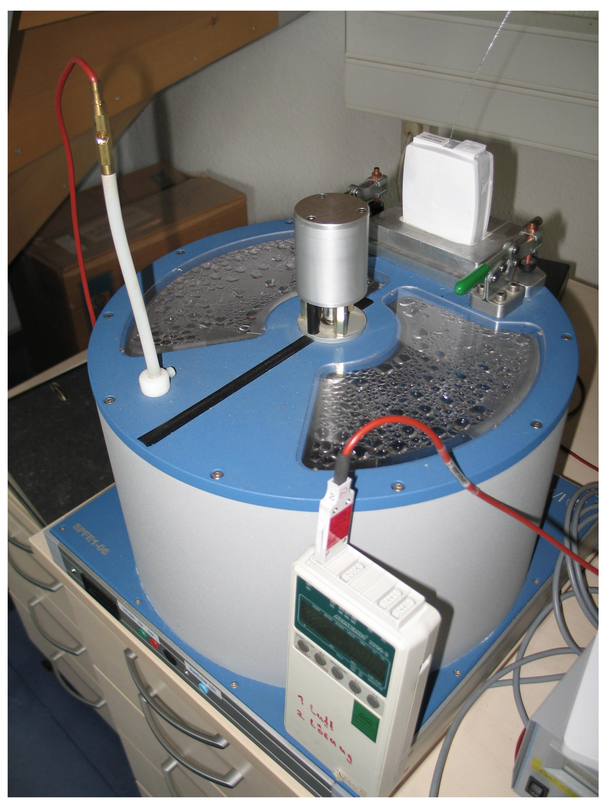

Fig. 2: Standard humidity chamber

Tab. 1: Possible level of relative humidity for the use in the standard humidity chamber

RH [%]	Uncertainty [%]	Description
100.0	±1.5	Pure single distilled water
97.6	±0.5 (at +20°C)	K_2SO_4 salt (a saturated Potassium Sulphate solution)
75.0	±1.5	NaCl salt
33.0	±1.2	$MgCl_2$ salt
11.0	±1.3	LiCl salt
0.0	+0.2	Desiccant (2.5 to 3.0 litre for 15 litres chamber volume)

It is possible to use other reference level of relative humidity than air at saturation with the SHC (Tab. 1).

Ground check at Lindenberg

Figure 3 and 4 show a comparison between ground check at 0% (using GC25) and at 100% (using SHC) for more than 8 years operational soundings with Vaisala RS92 radiosonde.

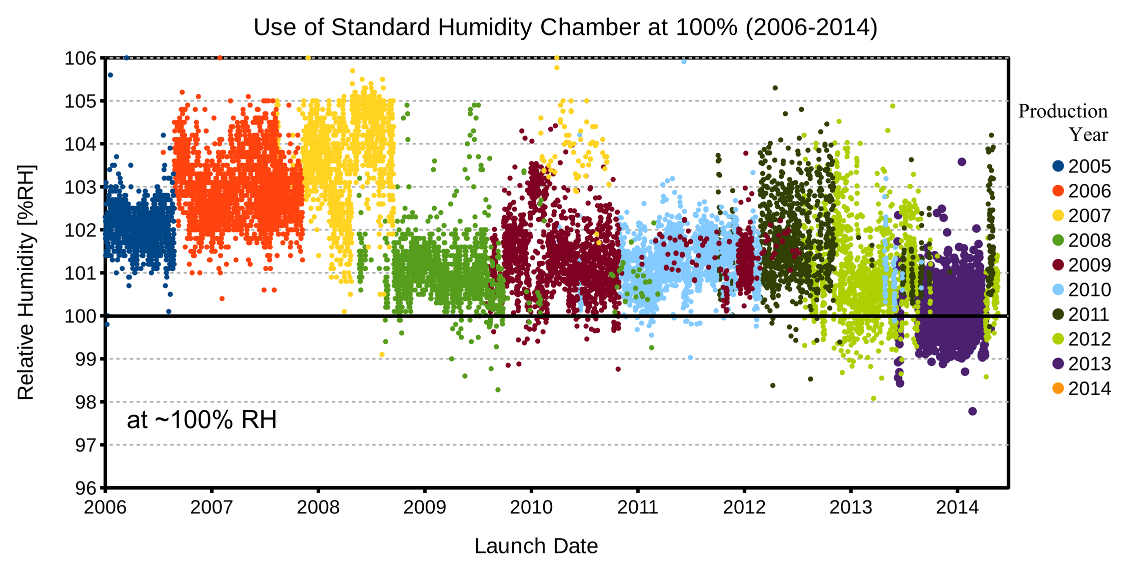

Fig. 3: Vaisala RS92 relative humidity measured in the standard humidity chamber at Lindenberg since 2006. Batch-dependent variations in this ground check are clearly detectable.

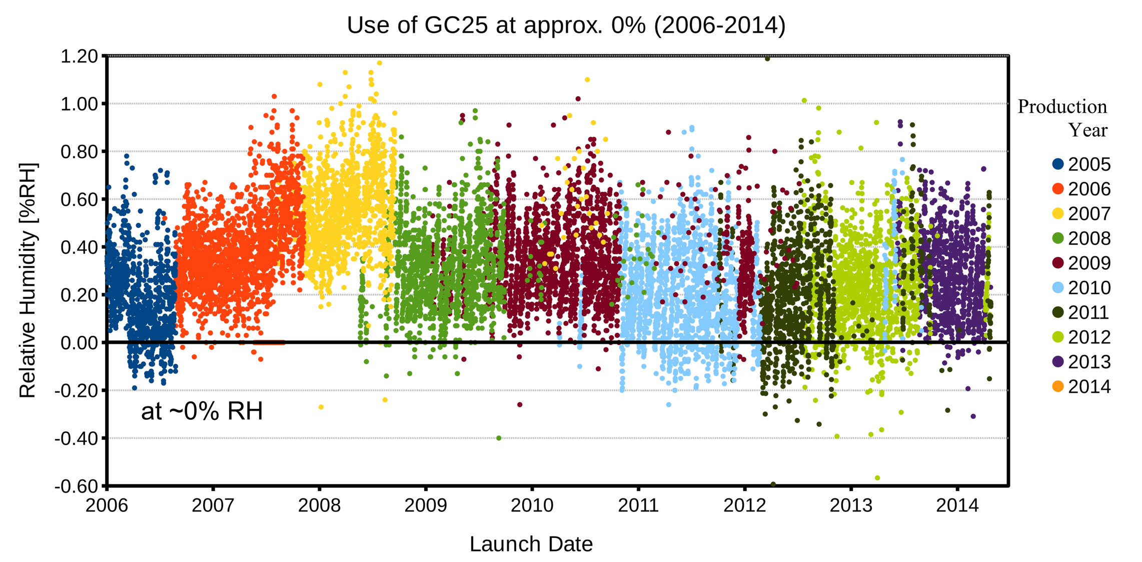

Fig. 4: Vaisala RS92 relative humidity measured in the default GC25 ground check tool at Lindenberg since 2006. The variation shows mostly the condition of the desiccant and is improperly used for recalibration of the humidity sensors.

Ground check at Ny-Ålesund

Figure 5 and 6 show same comparison of daily operational soundings with Vaisala RS92 radiosonde at polar station Ny-Ålesund.

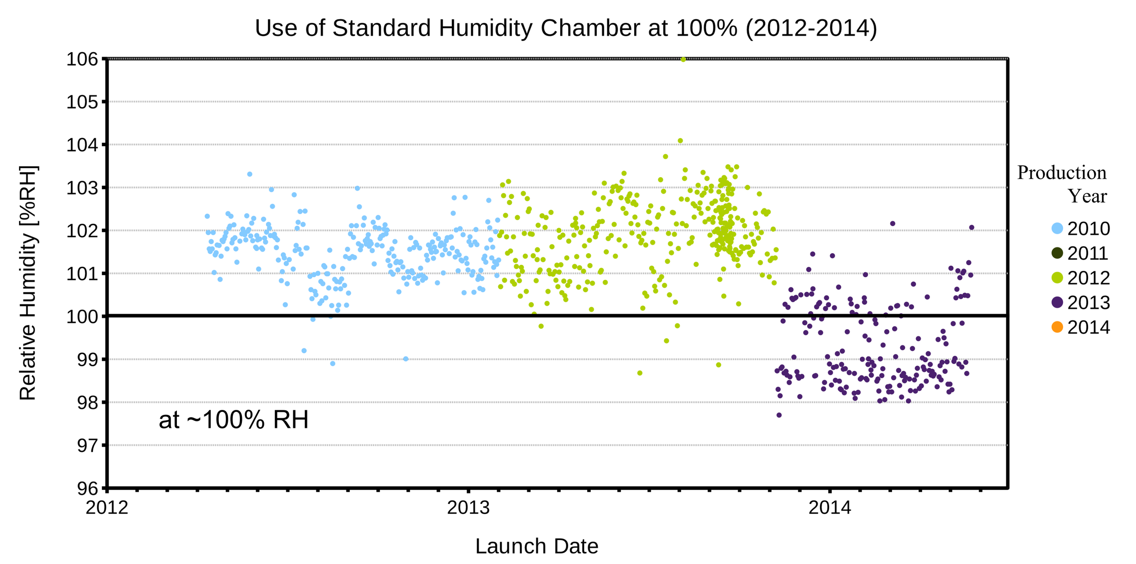

Fig. 5: Vaisala RS92 relative humidity measured in the standard humidity chamber at Ny-Ålesund. Also here, batch-dependent variations in this ground check are clearly detectable.

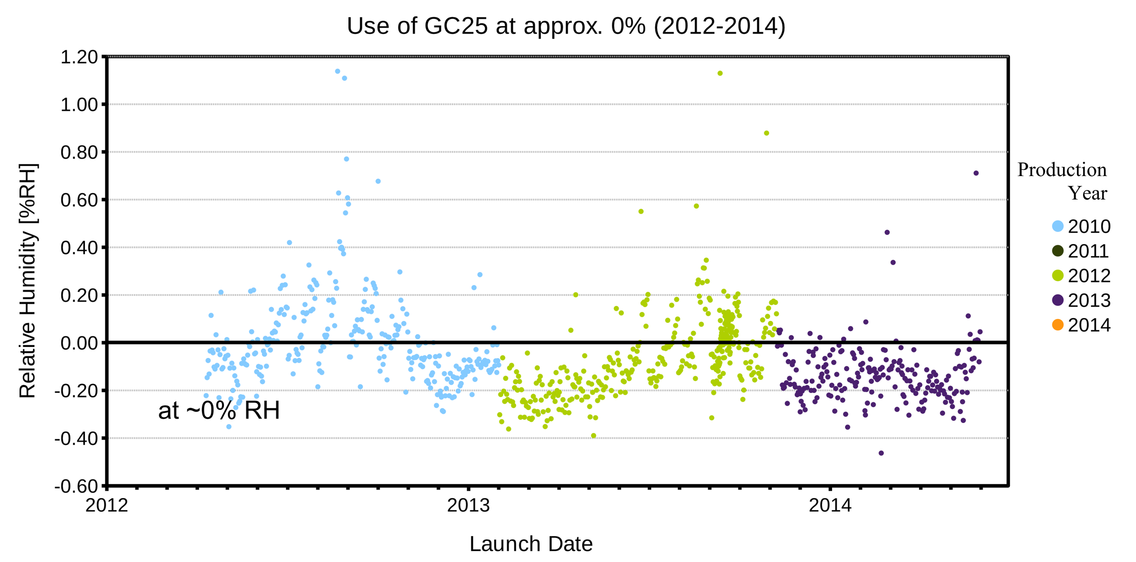

Fig. 6: Vaisala RS92 relative humidity measured in the default GC25 ground check tool at Ny-Ålesund. The variation shows dryness of desiccant. It is used for recalibration of the humidity sensors and leads to real measurement errors in the dry Arctic atmosphere.

Recalibration

At Lindenberg, a number of lab studies was done with a series of standard humidity chambers at various RH levels (Fig. 7).

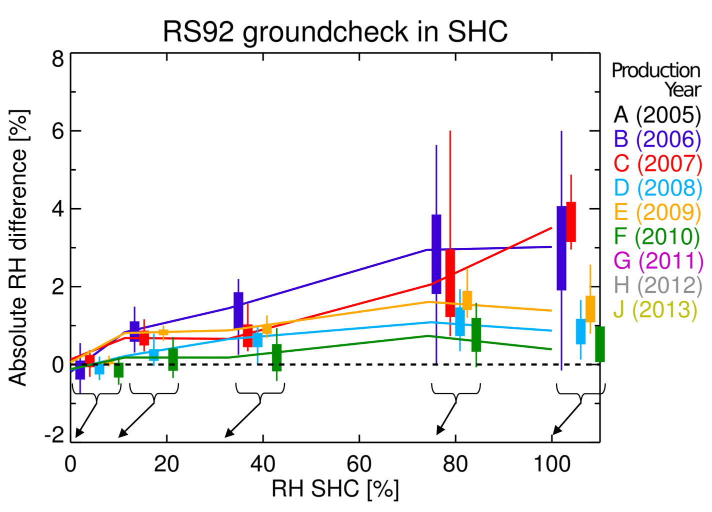

Fig. 7: The absolute difference of relative humidity at five reference levels (0%, 11%, 33%, 75% and 100%) measured using a series of standard humidity chambers.

A one-point recalibration at 100% RH may be effective and may improve the humidity measurements of RS92 (Fig. 8).

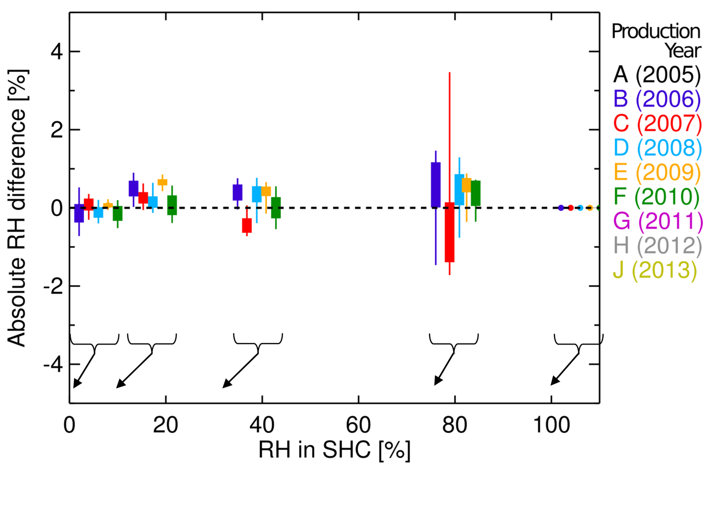

Fig. 8: The result plot shows absolute difference of relative humidity between recalibrated humidity sensor measurements (using results from 100%) and the reference levels of different chambers.

Ground check of other sondes

This time series of prelaunch ground check data (using SHC) are based on biweekly launches of the Graw DFM-09 at Lindenberg. The calibration by manufacturer for both RH and T appears to be stable (at room temperature).

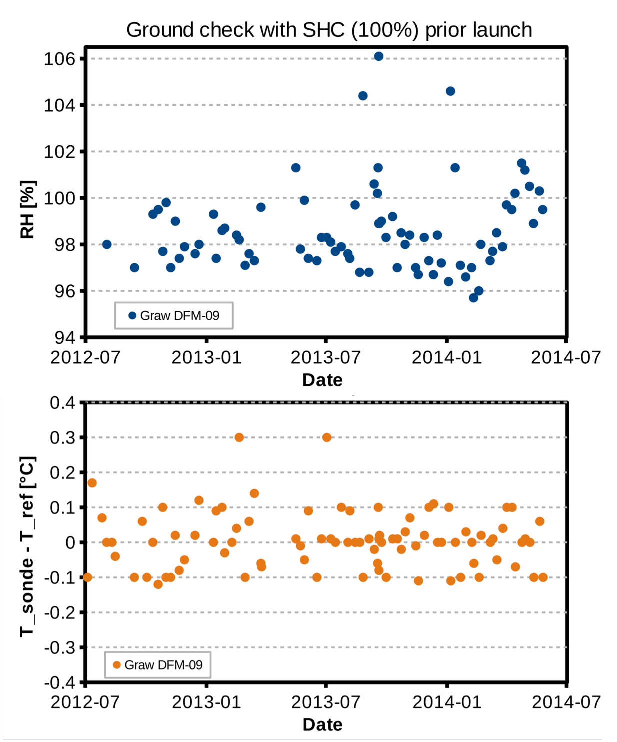

Fig. 9: Two year time series of ground check using a SHC at 100% relative humidity and room temperature. Upper plot shows the relative humidity and lower plot shows the temperature difference between radiosonde (Graw DFM-09) and reference.

References

Dirksen, R. J., Sommer, M., Immler, F. J., Hurst, D. F., Kivi, R., and Vömel, H.: Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, Atmos. Meas. Tech. Discuss., 7, 3727-3800, doi:10.5194/amtd-7-3727-2014, 2014.

Immler, F. J.; Dykema, J.; Gardiner, T.; Whiteman, D. N.; Thorne, P. W. and Vömel, H., Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products. Atmospheric Measurement Techniques, 2010, 3, 1217-1231, doi:10.5194/amt-3-1217-2010.

Detected issues

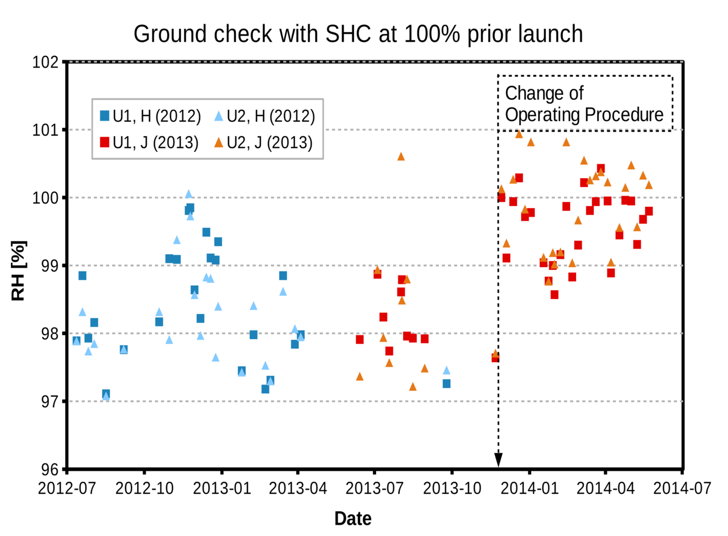

Fig. 10: Time series of SHC measurements prior launch at De Bilt (GRUAN station Cabauw). Until December 2013 all RH measurements of both sensors (U1, U2) are between 97% and 100%. It was too low in comparison to other GRUAN stations (see Fig. 3 and 5).

A small experiment identified a missing step in the operating procedure — the conditioning of humidity sensors). Now this issue is resolved and data are comparable.

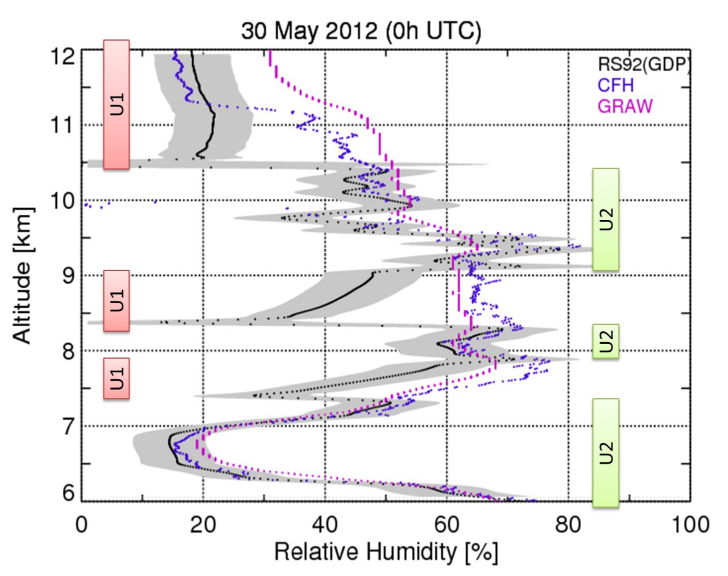

Fig. 11: Merged RH profile (U1, U2) from RS92 in comparison with two other sondes a CFH (Cryogenic Frostpoint Hygrometer) and a Graw DFM-09.

Default ground check with GC25 at ~0% shows U1=0.33% and U2=0.36%, and the additional ground check with SHC at 100% shows a different situation: U1=106.00% and U2=100.98%.

The recognizable problem with the sensor U1 was detected with the SHC ground check, not with the GC25.

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