METER

TEROS 21 Gen 2

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ABSTRACT

Developing a water potential sensor that can accurately measure the full water potential range has been a challenge for all sensor manufacturers. Finding a way to evaluate the sensor performance in the dry range (<-100 kPa) has been even more challenging. The objective of this paper is to find a suitable method for evaluating the dry-end performance of a water potential sensor and evaluate the wet end and dry end performance of the TEROS 21 Gen 2 (METER Group, Inc.). The temperature effect, wet range performance (0 to –80 kPa), and dry-end performance (-1000 to –10,000 kPa) were evaluated on 9 TEROS 21 Gen 2 sensors. The dry-end performance was evaluated against a chilled mirror water potential laboratory instrument (WP4C, METER Group, Inc.). Test data show that the TEROS 21 Gen 2 read within ± 5 kPa throughout the wet range and an approximate accuracy of ± 25% down to –4,000 kPa. The tests also showed that an equilibration technique evaluation of the dry-end performance of the water potential sensors vs the WP4C laboratory instrument was a valid approach.

INTRODUCTION

The TEROS-21 Gen 2 is an improved version of the original TEROS-21 (MPS-6) matric potential sensor. A new circuit design and measurement methodology is implemented with the same form factor as the original version. The improved circuit design provides less sensitivity to cable manipulation and environment, a more stable raw reading, and enables a semi-empirical temperature correction on the raw data. The new measurement methodology allows extended range measurements at both the wet and dry ends of the water potential range. The outcome is more stable and repeatable readings across an increased sensor measurement range. Methods and results from TEROS-21 Gen 2 performance testing are presented below with a focus on the internal temperature correction, wet end performance (-5 to -80 kPa), and dry end performance (< -1,000 kPa).

TEMPERATURE COMPENSATION

The raw output of the new circuit design is known to fluctuate with temperature and must be accounted for. The temperature compensation is particularly important in the dry range. Small temperature-induced fluctuations of raw readings result in artificial fluctuations of sensor water potential readings. For a given change in the raw reading, the magnitude of matric potential change systematically increases as matric potential decreases because of the logarithmic conversion equation.

To isolate the temperature effect of the circuit (and not real water potential changes with temperature), artificial loads were applied to the circuit that simulate air dry and saturated loads. Sensors were then equilibrated at 5 discrete temperatures from 3 to 40 degrees C. The temperature compensation reduced the fluctuations in raw readings across this range from a worst case of roughly ± 8% to ± 0.5% (Figure 1). Application of this correction on all sensors greatly reduces the dry end temperature sensitivity.

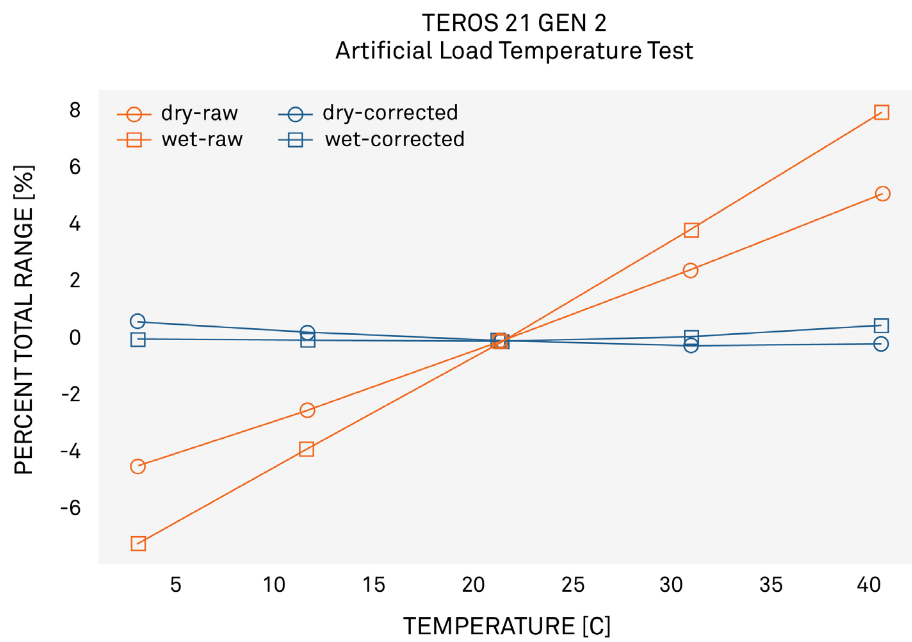

Figure 1. Percent of total sensor range as a function of temperature with and without temperature correction applied on two sensors with artificial loads simulating wet and dry conditions.

WET END RANGE EVALUATION

TEROS-21 Gen 2 are individually calibrated in a chamber that can control potential from 0 to -80 kPa. We tested the accuracy of nine previously-calibrated sensors by reinstalling them in the chamber and equilibrating at 10 discrete water potentials from -5 to -80 kPa. The results indicate that the sensors are within specified accuracy from -5 kPa, which is an extension of the wet end range compared to the original sensor version, to -80 kPa (Figure 2). There is one sensor that does not fall within specified accuracy at -7 or -10 kPa but falls back within range at drier points (Figure 2). The reason for this is that the sensor did not reach its air entry point until after -10 kPa in this instance. This behavior can be encountered when sensors are drying down from saturation for the first time which is a known limitation of the solid matrix equilibration measurement method.

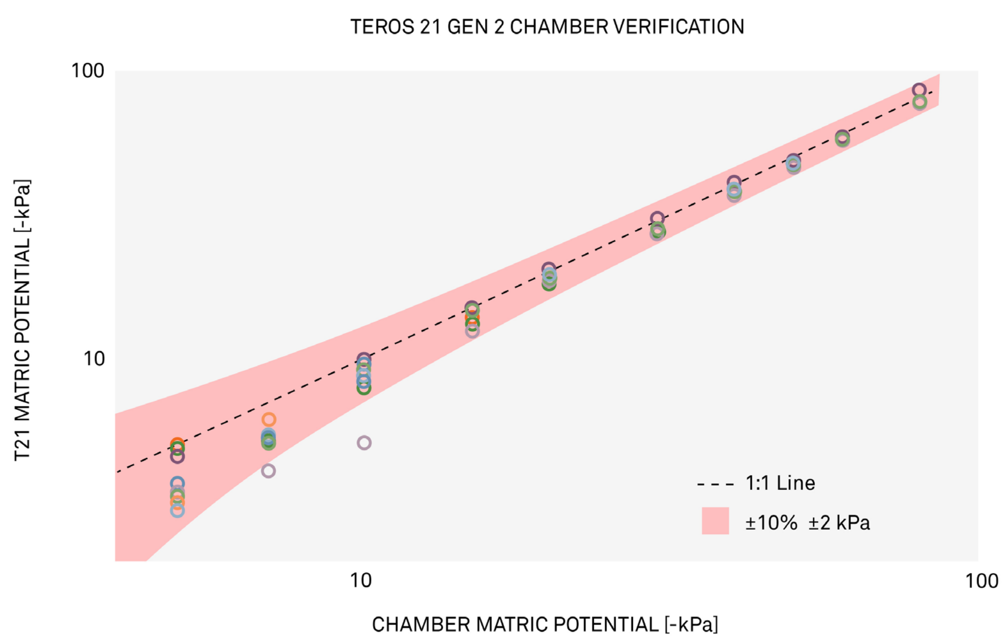

Figure 2. TEROS-21 Gen2 matric potential as a function of chamber matric potential for 9 sensors with the specified accuracy range highlighted in red.

DRY END EVALUATION

Sensor testing and verification in the dry end (< -1,000 kPa) is notoriously difficult. The chosen evaluation method for this study is comparison against a chilled mirror water potential sensor (WP4C) in equilibrated soil. The methodology works well for evaluating dry end performance of matric potential sensors with the main downside being a long equilibration time requirement.

Three TEROS-21 sensors were sealed in 20x12x7 cm glass containers half full of silt loam. The soil was allowed to air dry and then the cap was placed on the container to allow the soil and sensors to equilibrate. The sensors were read by a logger and data were periodically evaluated to determine when sensor equilibration occurred. Once sensors were equilibrated, soil samples were removed using a small auger (Figure 4) and placed in the WP4C. This type of test was conducted 3 times with a total of 9 TEROS-21 sensors evaluated. It took anywhere from 3 to 11 days for sensors to equilibrate. An entire testing process for one container took 42 days to collect data at 4 different matric potential values (Figure 4).

The results of this testing indicate that the TEROS-21 Gen 2 has an accuracy of approximately ± 25% down to -4,000 kPa. This accuracy was determined by comparing the average output from the three TEROS-21 sensors to that of the WP4C (Figure 5). However, there is a noticeable decrease in precision at these drier values which accounts for the large spread in data among the 3 sensors. One component of this decrease in precision is the logarithmic conversion equation mentioned previously. A small difference in the raw reading becomes a much larger difference in matric potential in the dry range than it is in the wet range. With the noted decrease in precision, the accuracy is ± 40% for individual sensor readings down to -4,000 kPa. The TEROS-21 Gen 2 will respond to water potential changes drier than -4,000 kPa, but those measurements should not be considered quantitative.

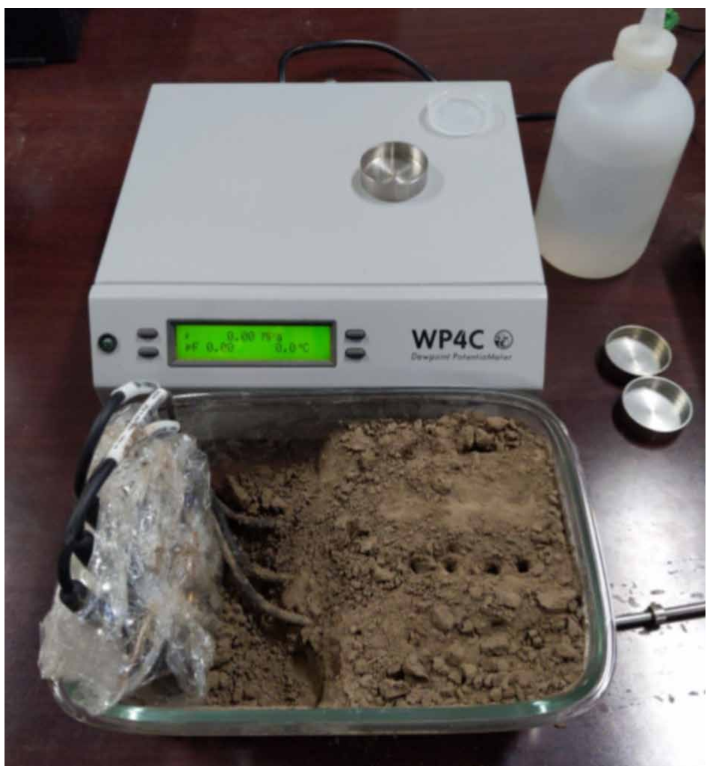

Figure 3. WP4C and soil container with TEROS-21 sensors and augered sample removed.

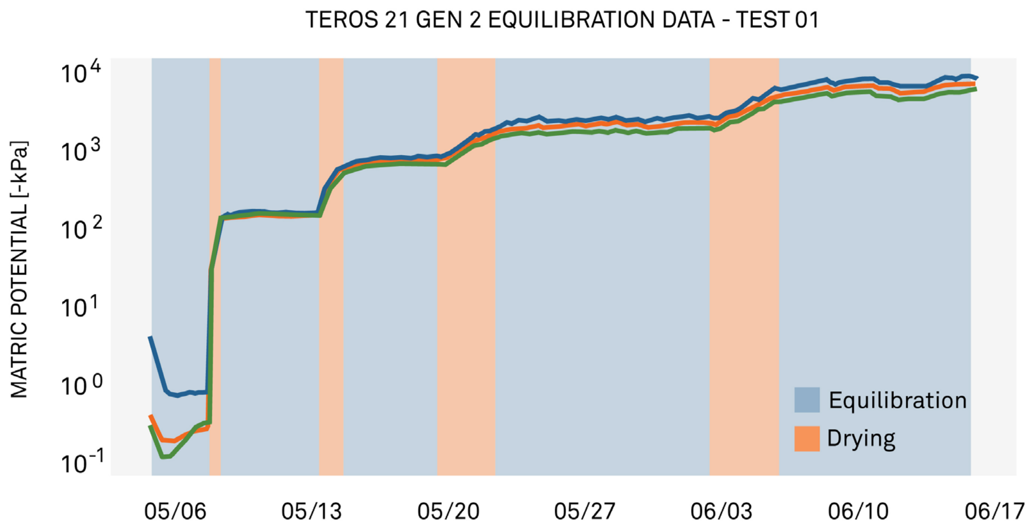

Figure 4. Example of TEROS-21 matric potential as a function of time during one of the equilibration tests.

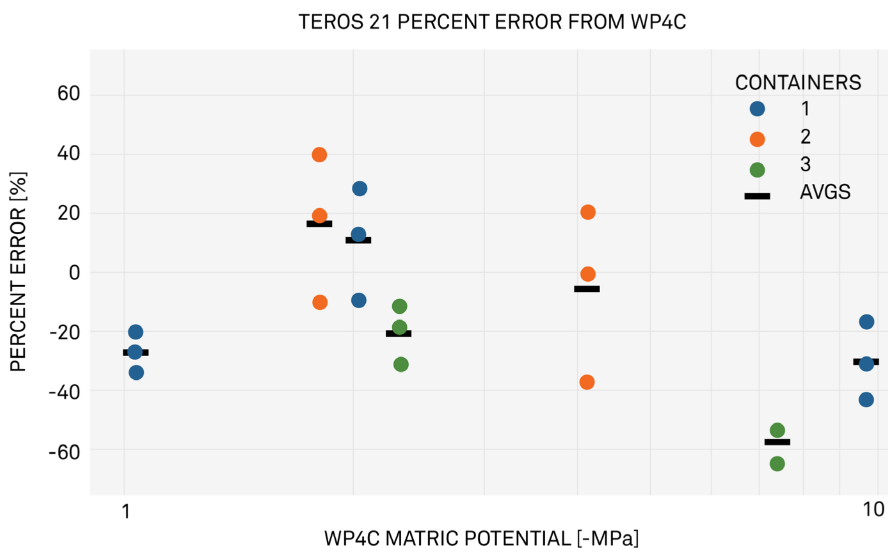

Figure 5. Percent error of equilibrated TEROS-21 matric potential as a function of WP4C matric potential for three different dry end evaluation tests.

CONCLUSION

Overall, the TEROS 21 Gen 2 performed well throughout the evaluated ranges. The temperature compensation approach utilized in the TEROS 21 Gen 2 significantly improves the sensor performance, over the TEROS 21 Gen 1, with an accuracy improvement from ± 8% to ± 0.5% in the 3 to 40 C temperature range. This improvement on the temperature correction of the circuitry will impact the dry-end performance of the sensor, as we know small temperature-induced fluctuations of the raw readings result in larger fluctuations in the water potential readings. The wet-end performance of all but one sensor outperformed the specified accuracy in the wet range with ± 5 kPa. The one sensor didn't perform well in the -7 to -10 kPa range due to the ceramic response being delayed due to a delayed air entry. The dry-end performance of the TEROS 21 Gen 2 as validated against the WP4C showed an accuracy of ± 25% down to -4,000 kPa. Beyond -4,000 kPa the accuracy decreased to ± 60%. Readings beyond this range should only be considered qualitative readings due to the decreased accuracy.

The equilibration method for validating the solid matrix water potential sensors in the dry range vs the chilled mirror water potential sensor appears to be a useful method for evaluating the dry-end performance of water potential sensors. There are improvements that can be made to the method by isolating individual sensors in a container to improve equilibration speeds. The next step beyond this is evaluating a way to calibrate the dry-end of the water potential sensors to further improve the accuracy.