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AddGlobe GFM 2.0 Assessment

Prepared By

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AddGlobe participated in a previous study by CSU under CARB funding by providing their GFM 1.0 instrument for testing. AddGlobe solicited CSU to perform a similar battery of tests on their updated GFM 2.0 instrument under a separate agreement. This document describes the performance testing of the AddGlobe GFM 2.0 instrument (hereafter "GFM").

Introduction

Following the test procedures used during the CARB study, four categories of testing were performed: Lower Detection (LDL), Quantification Accuracy, Gas Composition Response, and Practical Use. LDL testing attempted to identify the lower useful limit of the instrument by metering pure methane directly into the GFM using precision critical orifices. Quantification Accuracy testing aimed to both identify the upper useful limit of the instrument, and to assess its accuracy between the lower and upper useful limits. Gas composition response evaluated the instrument response to various hydrocarbon gas blends, when calibrated on standard methane calibration gases, as is standard practice in practical field use throughout the intended market. Practical Use testing evaluated the performance of the GFM on several "real-world" emission points at CSU's METEC facility. In addition to test results, observations (and opinions) on the ease of use, effectiveness, reliability, and other factors will be discussed.

Comparisons throughout this report were made in standard liters per minute (SLPM). All "reference" flowrate readings made at CSU for this testing were calibrated or corrected to standard conditions at 1013.25 mBar and 25 °C. The GFM 2.0 device reports in actual liters per minute. Device readings were converted to SLPM using temperature and station pressure readings from the Fort Collins Weather Station[1].

Lower Detection Limit

LDL testing was performed in a laboratory setting. Pure methane (CP Grade, Airgas Inc.) was introduced to the GFM using the precision gas blending and metering system shown in Figure 1. Gas is metered by precision critical orifices controlled by upstream pressure regulators. The metered flow was confirmed using volumetric provers (Bios DryCal,Defender 530+) or "DryCal(s)" of various sizes, appropriate for the

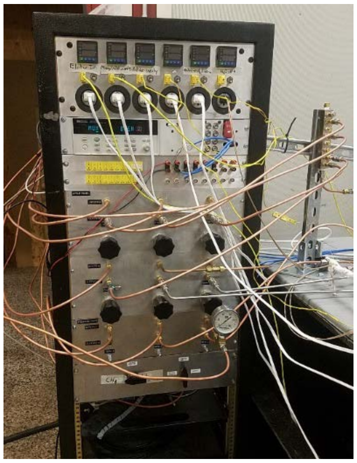

Figure 1: Precision gas blending and metering system.

flow range in use. The DryCals include pressure and temperature sensors that are used to correct the flow to standard conditions. The metered gas was delivered into the GFM instrument by inserting ¼” nylon tubing 8-10” directly into the GFM sample hose opening; thus, complete capture was assured. The range of flows delivered by the reference meters ranged from 0.01-1.06 SLPM.

Immediately prior to testing the GFM was purged with a sensor reset, by pressing the circular arrow button. Leak and Background methane sensors were set to zero, and O_2, leak and background sensors were set to 20.9 %. A “test” was made, using 2.5 % CH_4 in air, and 50 % CH_4 in N_2 (Gasco, Inc.). The 2.5 % CH_4 registered 2.4 % and 2.42 % on the back and leak sensors, respectively. The 50 % CH_4 registered 49.55 % and 49.0 % on the back and leak sensors, respectively. Both sensors were then calibrated for high and low gas readings.

For this testing, the upper limit of LDL testing was considered 1 SLPM. The testing spanned the range of two DryCal meters, as shown by circle (0.005-0.5 SLPM) and triangle (0.05-5 SLPM) markers in Figure 2. The operator’s manual for the GFM 2.0 states that the minimum detectable leak rate is 0.15 LPM. In Figure 2 , the left panel shows the flow measured by the reference meter on the x axis, and the detection of the meter flow by the GFM on the y axis. If the reference meter flow was detected, the measurement was assigned a detection value of 1, regardless of accuracy. If the GFM did not detect the flow a value of 0 was assigned. A logistic regression was fit to the data, which showed a 50 % probability of detection at 0.01 SLPM, an 80 % probability of detection at 0.15 SLPM, and a 95 % probability of detection at 0.21 SLPM. The right panel of Figure 2 shows the same data in an ordinary least-squares regression without intercept. Another common metric for limit of detection is 3 times the standard error of regression. Using this metric, the minimum detectable leak rate would be 0.23 SLPM, which aligns well with the trend shown in the right panel of Figure 2. The minimum detectable leak rate as stated in the operator’s manual seems reasonable when compared to either of these metrics and considering the maximum flowrate capability of the device.

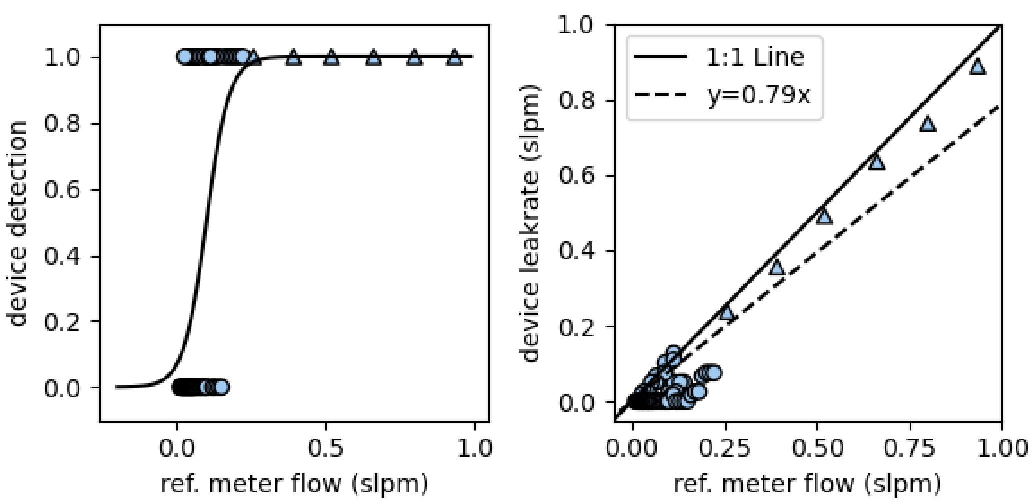

Figure 2: Lower Detection Limit (LDL) test results.

Quantification Accuracy

Quantification accuracy tests were performed on two occasions (Round 1: May 11-13, 2022, and Round 2: June 1-2, 2022). A second round of testing was performed after a firmware update. In the updated firmware, when the concentration reads 100 %, the reported leak corresponds to the device flowrate. The update also added a user-selectable gas density correction capability which increases the accuracy of the measured flowrate at high gas concentrations.

The low range (1-12 SLPM) of quantification accuracy testing was performed both in the laboratory, using the same test setup described in Lower Detection Limit, and at the CSU METEC facility using the apparatus shown in in Figure 3. Tests performed at the METEC facility used utility-delivered natural gas. Gas was metered by the control box and delivered to the expansion nozzle shown in the foreground (Figure 3). The "bag" attachment of the GFM was used to block the wind and help direct the emission into the sample hose. The bag was draped loosely over the expansion nozzle and the hose was supported with a stake. Throughout testing, the apparatus was observed with an OGI camera to ensure that the emission source was captured completely. Flowrates from 3-235 SLPM were tested.

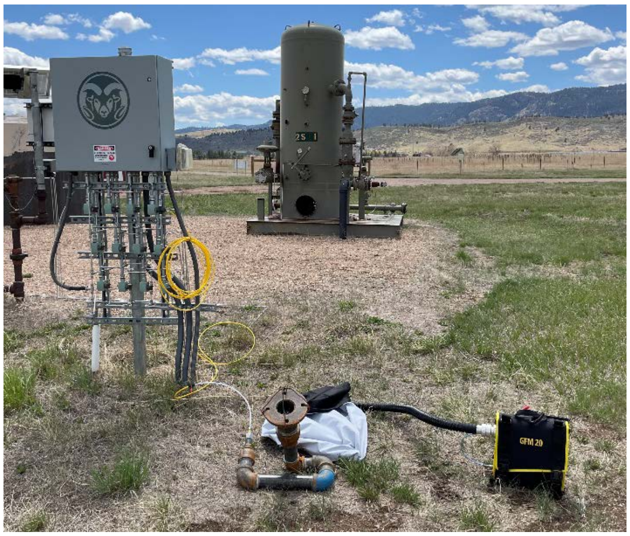

Figure 3: High range quantification accuracy test setup at CSU's METEC facility. Gas is metered by the control box on the left and delivered to the expansion nozzle.

A firmware update was performed that added the capability for density correction. This correction uses the measured gas concentration to update the device flowrate, accounting for the density difference between air and natural gas. There are 2 options for the density correction – "OFF" and "ON". As shown on Figure 4 - the density correction is "off". In Figure 5, the same test points were repeated with the density correction "on", which resulted in excellent agreement between the GFM and reference meters.

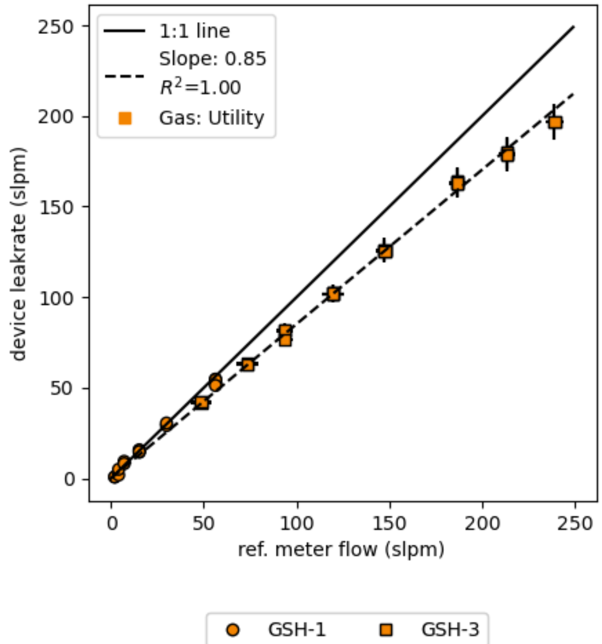

Figure 4: Accuracy Testing was repeated after a firmware update. With density correction "off" the results mirror those prior to the firmware upgrade.

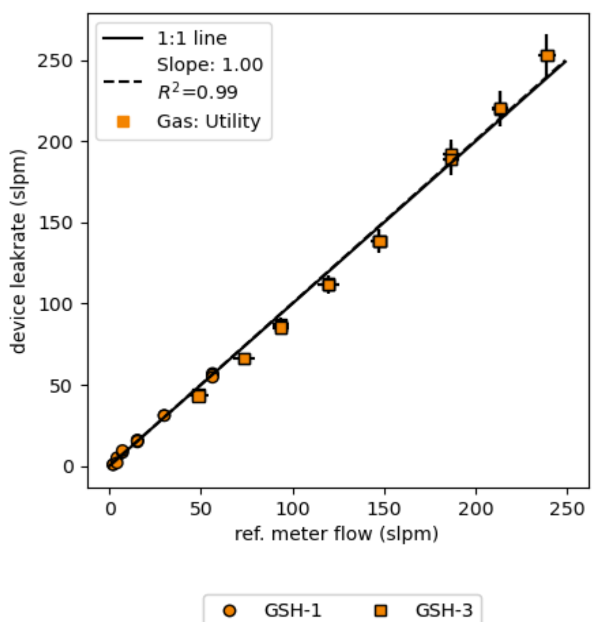

Figure 5: Accuracy Testing was repeated after a firmware update. With density correction "on" the results are improved and show excellent agreement with the reference meters.

Real Equipment

The GFM 2.0 was tested in simulated field use on 21 realistic leak locations at CSU's METEC facility. The results reported by the device generally agree with the reference flowmeters. Each leak location was monitored with an OGI camera to confirm complete capture to create an accurate portrayal of measurements on real equipment and not introduce an artificial bias to the results.

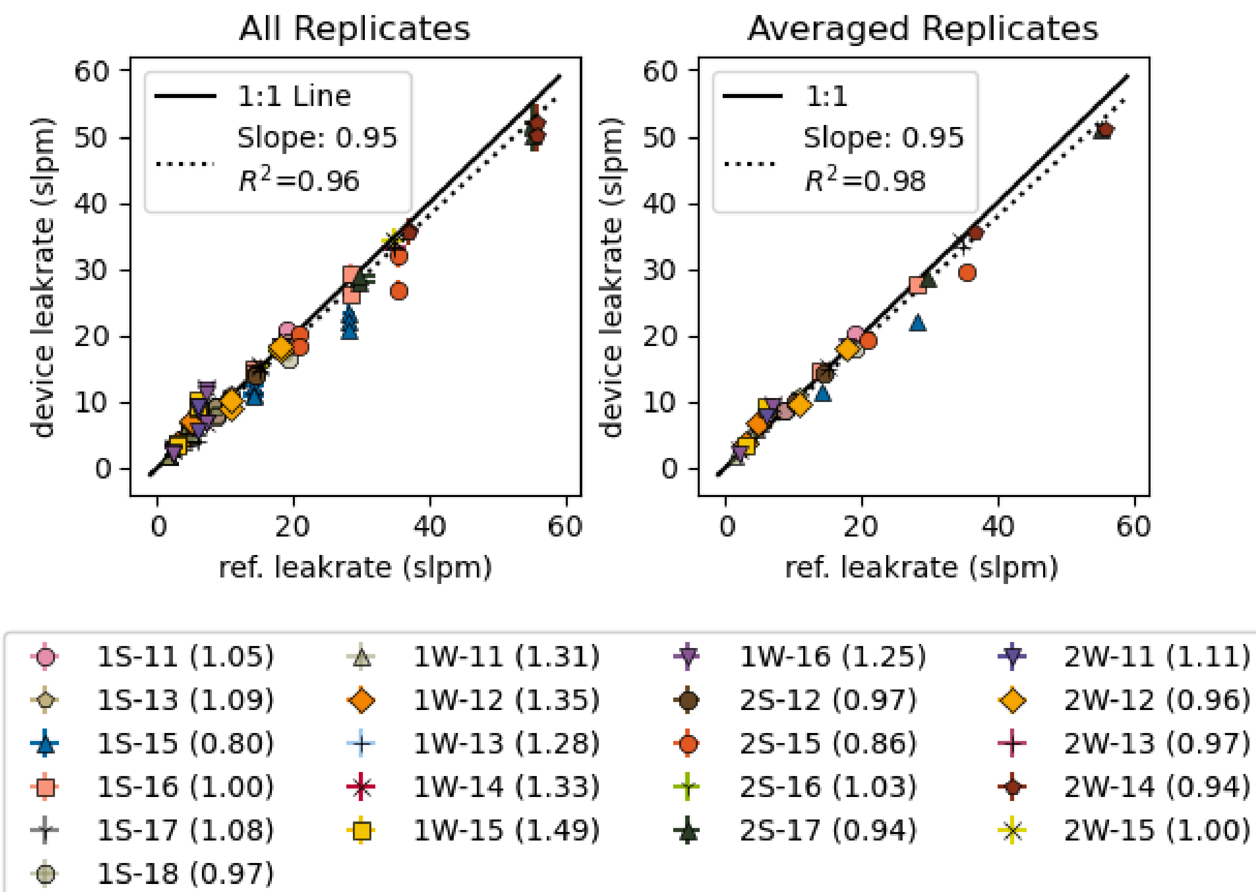

Figure 6: Real Equipment testing results. The GFM 2.0 was tested on several emission points at CSU's METEC facility.

Gas Composition Response

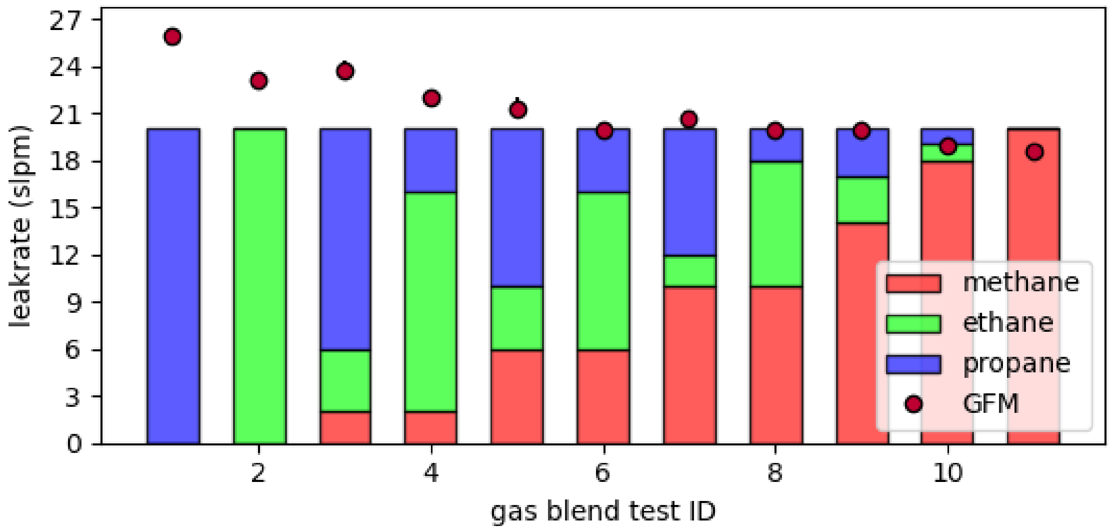

Figure 74: Gas composition response testing.

Varying mixtures of methane, ethane, and propane were introduced to the GFM at a constant flowrate to understand the affect of higher hydrocarbons on the device response, as shown in Figure 7. The GFM report leak rates between 18 and 26 SLPM for fixed reference flowrates of 20 SLPM. The GFM slightly underpredicted the reference meters at 100 and 90 % methane by volume, gave reasonable predictions between 30 -70 % methane by volume, and then began to overpredict the leak rate with decreasing methane content. Pure ethane and propane flows were tested as well, giving worst case composition-based over predations of 15 and 30 % respectively. These results indicate the likelihood of good performance when measuring typical natural gas blends.

General Thoughts

The GFM appears to be well made and suitable for field use. The ability to use any Android device as a control/display is useful/flexible. The small, relatively lightweight form factor and ability to use it with or without the backpack attachment provides operators with options to suit their preferences.

The capture bag was generously sized and easy to fit over equipment.

The Bluetooth connection between the phone and the GFM performed perfectly. It seems that a separation of 6 ft or less is required for the most reliable operation.

The battery life of both the supplied Android device and the GFM 2.0 unit itself seem to be reasonable and will likely last for an average day of testing. Some operators may only need to charge the devices overnight.

Though a methane specific detector is not employed, gas composition sensitivity does not appear to be a major issue over the range tested. Measurements of most natural gas blends encountered in the field should not be problematic.

References