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Canada

ALBERTA INNOVATES

CERIN
Canadian Emissions Reduction Innovation Network

CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title: **Ventsentinel® Flow Metering – Part 2 of 2**

Emissions Reduction Scope: The quantification of instrument air (Phase 2) and other atmospheric points sources containing methane (Phase 1) alone does not reduce emissions. Better quantification provides opportunity to determine baseline, enable carbon credit generation for mitigated emissions, and more detailed metrics needed to make informed decision for the business case solution that improves environmental outcomes.

Applicant (Organization): Ventbuster Instruments Inc.

Project Completion Date: Mar 22, 2023

2. EXECUTIVE SUMMARY

Existing meters for measuring greenhouse gas (GHGs) emissions have been insufficiently accurate or prohibitively expensive. As a result, there is little information on flow rates from a variety of sources. It is important to know flow rates of these sources because they represent either methane being released to the atmosphere or negation of the same.

New metering technologies, such as those offered by Ventbuster Instruments Inc. were tested to help fill this technological gap. Phase 2 of this project focused on quantifying instrument air flow rates to determine the utility of the prototype Ventsentinel® and its accuracy over its calibrated flow range, at varying flow rates, both in laboratory situations and in actual field installations. This effort was follow-up on reported Phase 1 efforts that targeted atmospheric point sources emissions from near atmospheric pressure tanks and compressor packing vents. Laboratory testing was carried out at InnoTech Alberta and field testing was carried out at Bonavista Energy field sites. Further analysis of the data captured in the atmospheric tank use case from Phase 1 was also carried out.

Testing of the Ventsentinel® on the bench and in the field was done to determine if the measurements were accurate to within 10% of each other and to within 15% of the reference (Alicat in this case) flow meter, and that they would remain accurate in field use application. It was anticipated that these meters will be used in ambient conditions, varying from -40 Celcius to + 40 Celcius with source pressures just above atmospheric pressure to 655 kPag as is more commonly found as instrument air header pressure for pneumatic control loops. These meters are designed to be used to measure gas emission rates where high quality information is required such as generating carbon offset credits in Alberta or determining if point source emissions at sites remain below site limits.

From bench testing at InnoTech Alberta, the Ventsentinel® prototype meter shows excellent performance in compensating for changes in line pressure as the average error remained within +/- 3.6 Sm3/d as the pressure increased to the situational 655 kPag. As the flow rate increased from 5 to the situational 180 Sm3/d, the Ventsentinel® prototype meter followed a trend of under-predicting to over-predicting the compressed air flow rate. Test results are not indicative of commercial performance and are being used by Ventbuster Instruments Inc. engineers to develop more robust calibration algorithms with span that exceeds the prototype calibration range.

The Ventsentinel® used in atmospheric tank vent measurements provided a cumulative flow rate over a 26-minute period equivalent to 84 m3/d, while the Fox thermal mass meter measured 67 m3/d. Relative error was 24.5%. Further calibration efforts are in progress for the final Ventsentinel® commercial device.

Metering with Ventsentinel® technology provides opportunity to generate carbon offset credits if the measurement is representative of actual with minimal error. Atmospheric point sources remain the focus for this technology going forward. Further calibration efforts are needed for the prototype to be used in instrument air applications with header pressures up to 655 kPag.

Overall, taking into consideration the Phase 1 test results, the Ventsentinel® prototype meter demonstrates encouraging potential for field instrument air flow measurement applications.

3. KEY WORDS

Methane, instrument air, quantification, Flow rate

4. APPLICANT INFORMATION:

Applicant (Organization): **Ventbuster Instruments Inc.**

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5. LEAD CONTRIBUTING PARTNER INFORMATION:

Organization: Spartan Controls Ltd.

Address: 305 27 Street SE

Representative Names: Brian Van Vliet / Dean St. Amant

Title: Manager, Environment Solutions / Technical Specialist

6. PROJECT PARTNERS

Thanks to the team, which included:

- Cenovus Energy Inc. (Morgan Wrishko)
- Bonavista Energy Corp. (Kendell Esau)
- Tangent Design Engineering (Chris Parker, Josh Abbott, Simon Schmitt)
- InnoTech Alberta (Neil Yaremchuk)
- PTAC (Brian Spiegelmann)

A. INTRODUCTION

Oil and Gas Sector

Canada has set goals to achieve 45% methane emission reductions in the upstream oil and gas industry by 2025 and 75% reductions by 2030. To achieve this, oil and gas field venting limits have been applied to upstream assets. Site limits for new infrastructure put in service after Jan 1, 2021 in British Columbia and Jan 1, 2022 in Alberta are now significantly reduced. To achieve reduced emissions, the business-as-usual approach of using fuel gas to operate pneumatic instruments has been a focus area, which has required existing instruments in service to be reduced from high bleed to low bleed (steady state vent rate less than 0.17 m3/h fuel gas). New sites need to conserve or control, which means going one step further and collecting remaining emission sources from assets such as atmospheric tanks, pneumatic instruments, pneumatic pumps, compressor packing vents, reducing and eliminating fugitive emission sources, eliminating emissions from surface casings, mitigating fuel gas blow-through associated with combusted sources, converting pneumatic systems to be operated on non-GHG media such as air or nitrogen and use of electric and electrohydraulic control loops instead of pneumatic. Through this effort to reduce methane emissions, industry continues to focus on the aforementioned areas and is evaluating the most cost-effective means of reduction by knowing the magnitude of emission source and the cost to eliminate or mitigate it. Not knowing the magnitude of the achievable emission reduction presents a barrier to achieving improved environmental outcomes.

Knowledge or Technology Gaps

While the Ventsentinel® prototypes were made with intention on being used on atmospheric point sources, being able to use this meter technology to quantify air flow rates that displace fuel gas pneumatics was also considered to be valuable. The impact of backpressures up to 700 kPag had not been investigated before for this meter. One specific use case, metered instument air flow rates, is a requirement in the generation of carbon offsets in Alberta where instrument air is used instead of fuel gas pneuamtics.

Technology Description

The Ventsentinel® uses patented flow channel technology and is designed as an economical low to ultra-low flow gas metering device used to measure flow rate, flow temperature, flow pressure, shut-in pressure, and is intended for ongoing measurement and reporting of vented emissions (by design) and fugitive emissions (not by design) to atmosphere.

It was developed for installation on wellheads, production tanks, produced water tanks, relief valves, vented underground tanks, compressor seals, instrument air compressors, fuel gas lines, flare lines or incinerators. It is mounted in-line to any hydrocarbon point source to measure and record emissions accurately and in real time.

As a major concern and a requirement of many atmospheric vents, the unique Ventsentinel® design does not restrict gas flow, resulting in virtually zero backpressure. In addition, its design allows atmospheric vents to "breathe". This is particularly important with vented tanks where back pressures are not tolerable. The Ventsentinel® allows both positive and negative flows into and out of the tank which is ideal for operating safely.

It is designed to be installed in-line on the vent assembly and continuous measurements are transmitted to an IoT Platform via a "gateway" or SCADA communication device. The unit utilizes either supplied plant power or can operate with an external 12V @ 100 mA battery. Its flow range has been designed to meet all anticipated ranges from zero to 6,000 m3/d.

A summary of its attributes is provided in Table 1.

ATTRIBUTES	THE VENTSENTINEL® 1"	THE VENTSENTINEL® 2"
Weight	2.8 kg	5.3 kg
Operating Temperature	-40°C to 55°C	-40°C to 55°C
Inlet Connection	1" NPT (25.4 mm)	2" NPT (50.8 mm)
Flow Range	6 m^3/day - 720 m^3/day [720 m^3/day - 1200 m^3/day*]	7.2 m^3/day - 720 m^3/day [720 m^3/day - 6000 m^3/day*]
Flow Error	<10%	<10%
Back Pressure at Maximum Flow	<1 psi (6.9kPa)	<1 psi (6.9kPa)
Pressure Range #	5000 kPag (720 psig)	5000 kPag (720 psig)
Operating Pressure #	0 - 5000 kPag (0-720 psig)	0 - 5000 kPag (0-720 psig)
Pressure Error	<5%	<5%
Sensor Module	IP54	IP54
External Power	12 or 24 VDC	12 or 24 VDC
Hazardous Area Classification	VS100 SCADA Comms Unit: US: [AEx ia Ga] IIB Canada: [Ex ia Ga] IIB VS 200 Sentinel Unit: US: Class I Zone 0 Aex ia IIB T3 Ga Canada: Ex ia IIB T3 Ga	VS100 SCADA Comms Unit: US: [AEx ia Ga] IIB Canada: [Ex ia Ga] IIB VS 200 Sentinel Unit: US: Class I Zone 0 Aex ia IIB T3 Ga Canada: Ex ia IIB T3 Ga

* High flow limit calibration pending; # Rated pressure for exposure

Project Objectives

Phase 2 of this project focused on quantifying instrument air flow rates to determine the utility of the prototype Ventsentinel® and its accuracy over its calibrated flow range, at varying flow rates, both in laboratory situations and in actual field installations. Laboratory testing was carried out at InnoTech Alberta, and field testing was carried out at Bonavista Energy field sites. Further analysis of the data captured in the atmospheric tank use case from Phase 1 was also carried out.

Performance Metrics

The goal for the Ventsentinel® in Phase 2 was to be able to measure instrument air sources with metered results repeatability within 10.0% as well as be within 15.0% of a reference flow meter. The meter would also need to remain accurate with warmer temperature processes as would be expected downstream of an air compressor. To be able to provide flow rates in standard conditions, the flow meter also needed to be able to accurately measure temperature and pressure. To be a success, this meter needed to be able to obtain flow measurements with acceptable uncertainty that are representative of the sources measured.

B. METHODOLOGY

Bench Testing – InnoTech Alberta

The test setup consisted of pressure-regulated laboratory air or pure compressed methane supplied to two Alicat Mass Flow Controllers (MFCs) installed in a parallel flow pattern. Additional detail on the work completed at InnoTech Alberta is included in Appendix A.

Flow through the meters was varied between 0 to 180.0 Sm3/d. To ensure fully developed flow, 24-inches of straight 1-inch Sch. 40 pipe was installed upstream and 12-inches of straight 1-inch Sch. 40 pipe was installed downstream of the Ventsentinel®. Shown in Figure 1, a throttling valve followed by a diaphragm-type dry test meter (DTM) was installed downstream of the 12-inch straight section. To ensure proper operation of the sensor, the ground wiring from the flow meter assembly was connected to a reliable ground source within the lab. The MFCs and Ventsentinel® communicate with a data acquisition system to digitally record the flow and pressure measurements.

As noted by Tangent Design Engineering, the Ventsentinel® was calibrated to transmit flow data corrected to the standard temperature and pressure (STP) of 101.3 kPaa and 25°C. The Alicat MFCs were consistent in this setting. The DTM measured the cumulative volume of flowed gas at actual conditions. DTM flow rates were recorded visually at the beginning and the end for cumulative volumes over a measured time interval and were used to calculate the average, actual flow rate. The outlet of the DTM was vented directly to atmosphere in the fume hood and the pressure drop through the meter was negligible; therefore, it could be assumed that gas flow was at atmospheric pressure. This value was measured and recorded by the Alicat MFCs was compared against an in-house barometric pressure transmitter for confirmation. The Alicat MFCs were also used to measure and record the temperature of the flowing gas which was compared against a handheld thermocouple reader for confirmation. Combined with the ideal gas law, these measurements were then used to convert the average, actual DTM flow rate measurement to consistent STP conditions.

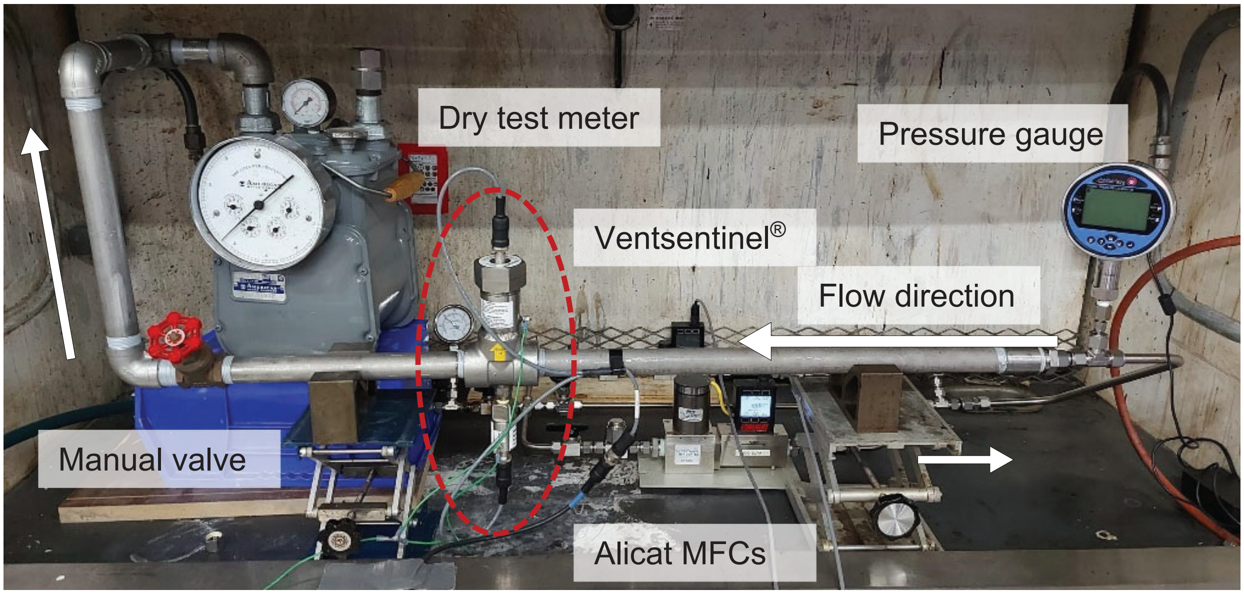

Figure 1: Flow Test Setup - Alicat Mass Flow Controllers and 1-inch Ventsentinel® installed in fume hood

Atmospheric Tank Testing – Bonavista

Figure 2: Ventsentinel® meter installed on 400-bbl tank with remote monitoring infrastructure to remotely data log the ongoing flow measurements and other measurement variables

Spartan Controls and CEI installed a Ventsentinel®. With completion on May 5, 2022, the flow measurements began logging from the 400-barrel atmospheric storage tanks. Similar to Phase 1 testing at CMC RI, the Ventsentinel® was hooked up to the discharge piping at the top of the tank. This tank was in service as a production site in west central Alberta and was selected to baseline emissions as preparation for vent gas capture to a combustor. For that reason, a pressure vacuum relief valve was installed to ensure that the operating pressure in the tank stayed between its minimum and maximum allowable working pressures.

Air Compressor Testing – Bonavista

On Oct 18, 2022, Spartan Controls installed a 1-Inch Ventsentinel® downstream of an air compressor with the needed upstream and downstream straight pipe lengths. As shown in Figure 3, the meter was oriented with flow passing down vertically through it. That was considered to be acceptable for the anticipated flow rates. If the flow rates were much closer to zero, it would have been oriented horizontally instead as was done for the atmospheric tank installation. Flow measurements were logged.

Figure 3: Ventsentinel® meter installed on discharge from air compressor with remote monitoring

C. PROJECT RESULTS AND KEY LEARNINGS

Bench Testing – InnoTech Alberta

As found in Phase 1, the Ventsentinel® metered test results compared quite favourably with those of the Alicat MFC with no applied backpressure. Error increased in magnitude though as flow rates were increased. Tables 2 and 3 summarize the error magnitude and the relative error as defined in Appendix A. Note that Standard conditions as referenced in these tables is 101.325 kPa and 25 C, not 15 C. Using a reference of 25 C was less common. The more common reference of 15 C would be referenced if these efforts were repeated.

Table 2. Summary of error (Sm3/d) in the standard measurements of the Ventsentinel®

		Line Pressure (kPag)									
		0	**207**	**276**	**345**	**414**	**483**	**552**	**621**	**655**	**Avg**
Air Flow Rate (Sm3/d)	**5**	-0.6	-1.5	-2.1	-3.1	-3.8	-4.2	-3.9	-4.0	-4.3	**-3.0**
	10	-0.6	-1.6	-2.0	-4.2	-3.0	-6.5	-5.5	-5.5	-8.1	**-4.1**
	15	-0.7	-1.7	-2.2	-2.0	-2.4	-4.3	-5.0	-4.5	-6.8	**-3.3**
	20	-0.3	-1.5	-1.8	-1.8	-3.0	-3.7	-4.8	-4.6	-5.1	**-2.9**
	25	0.2	-1.0	-1.2	-2.2	-16.7	-3.0	-3.2	-9.2	-2.5	**-4.3**
	50	2.7	5.5	5.3	-29.8	-28.5	-27.2	-24.3	-24.2	13.1	**-11.9**
	90	3.5	6.9	6.7	7.4	8.2	10.1	13.2	13.2	14.2	**9.3**
	130	4.2	7.7	7.1	8.7	15.4	13.5	12.7	12.7	15.7	**10.9**
	180	20.0	7.8	7.5	10.4	10.0	13.7	15.9	15.9	16.5	**13.1**
	Avg.	**3.2**	**2.3**	**1.9**	**-1.8**	**-2.6**	**-1.3**	**-0.5**	**-1.1**	**3.6**	

Table 3. Summary of relative error (%) in the standard measurements of the Ventsentinel®

		Line Pressure (kPag)									
		0	**207**	**276**	**345**	**414**	**483**	**552**	**621**	**655**	**Avg**
Air Flow Rate (Sm3/d)	**5**	-11.3%	-28.8%	-41.6%	-61.9%	-76.4%	-84.4%	-77.5%	-79.3%	-100%	**-62.3%**
	10	-5.7%	-16.4%	-19.9%	-41.4%	-29.6%	-64.9%	-55.0%	-55.1%	-82.6%	**-41.2%**
	15	-4.5%	-12.3%	-14.4%	-12.8%	-15.8%	-28.6%	-33.1%	-29.9%	-52.9%	**-22.7%**
	20	-1.3%	-7.5%	-8.7%	-8.8%	-14.7%	-18.3%	-23.7%	-23.1%	-25.4%	**-14.6%**
	25	0.9%	-3.8%	-4.8%	-8.7%	-66.8%	-11.9%	-12.4%	-36.8%	-10.5%	**-17.2%**
	50	5.4%	11.0%	10.5%	-59.6%	-57.0%	-54.4%	-48.6%	-48.5%	26.2%	**-23.9%**
	90	3.9%	7.6%	7.4%	8.2%	9.1%	11.3%	14.7%	14.6%	15.6%	**10.3%**
	130	3.2%	5.9%	5.4%	6.7%	11.8%	10.4%	9.8%	9.8%	12.2%	**8.4%**
	180	11.1%	4.3%	4.2%	5.8%	5.6%	7.6%	8.8%	8.8%	9.9%	**7.3%**
	Avg	**0.2%**	**-4.4%**	**-6.9%**	**-19.2%**	**-26.0%**	**-25.9%**	**-24.1%**	**-26.6%**	**-23.0%**	

Predominantly a volume flow device
Predominantly a mass flow device
Calibration range of tested device

In Table 3, the green dashed line highlights the calibrated range of the commercial prototypes. The orange-coloured squares are the regions where the Ventsentinel® is operating primarily as a volume flow meter without pressure compensation. In the blue-coloured range, the Ventsentinel® is operating predominantly as a mass flow meter and has a similar error (around 10%) across the range, which can be reduced. The errors shown in Table 3 are expected in the out of calibrated operating range of the meter. To be pressure and gas species independent, this data is being used to augment the prototype calibration. It is anticipated that the commercial version of the meter will retain accuracy over the full range shown in Table 3.

Figure 4 shows the measurements plotted with 345 kPag backpressure test where the Alicat MFC and Ventsentinel® were subjected to randomly adjusted air flow rates between 0 and 180.0 Sm3/d. 345 kPag could have been any pressure representative of instrument air header pressure. 345 kPag was reasonable as header supply to regulators providing pneumatic media to 41-207 kPag (6-30 psig) control loop instruments.

The Ventsentinel® responded well and tracked the step changes in the flow rate with one exception. In the last flow step change (to 50 Sm3/d), as highlighted with grey shading in Table 3 and the dashed line in Figure 4, the Ventsentinel® did not respond proportionately in all tests. The lack of response is attributed to the mode shift from a volume to mass flow device as illustrated in Table 3 and will be corrected with further calibration development of the prototype.

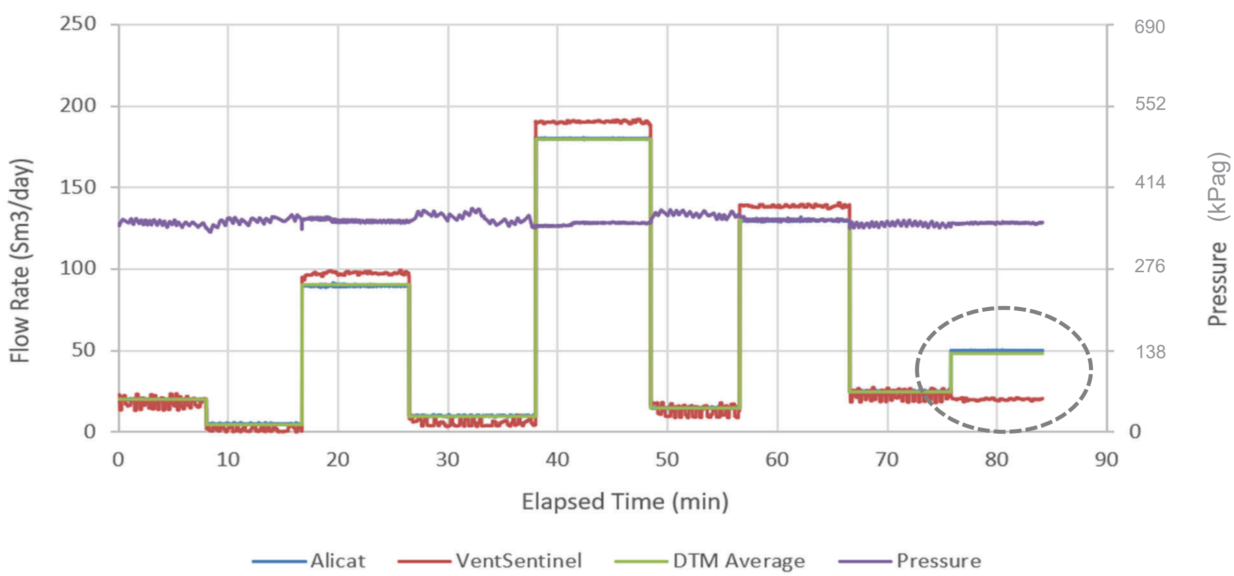

Figure 4: Standard air flow rate (Alicat, Ventsentinel®, DTM) with 345 kPag (50 psig) backpressure

Further analysis was carried out using the InnoTech Alberta Table 2 and Table 3 data to make Figure 5. The Ventsentinel® average absolute relative error, without the outlier data at 50 Sm3/d included, was found to be 5.4% with no backpressure and 38.6% at 180 Sm3/d with backpressure of 655kPag. This larger error at higher pressure is expected because the meter does not compensate for line pressures in volumetric mode. In mass flow mode, the device had smaller relative error (%) without being calibrated for anticipated line pressure. Therefore, it is anticipated that the accuracy of the system can be further improved through simple pressure compensation when the unit is in volumetric operating mode.

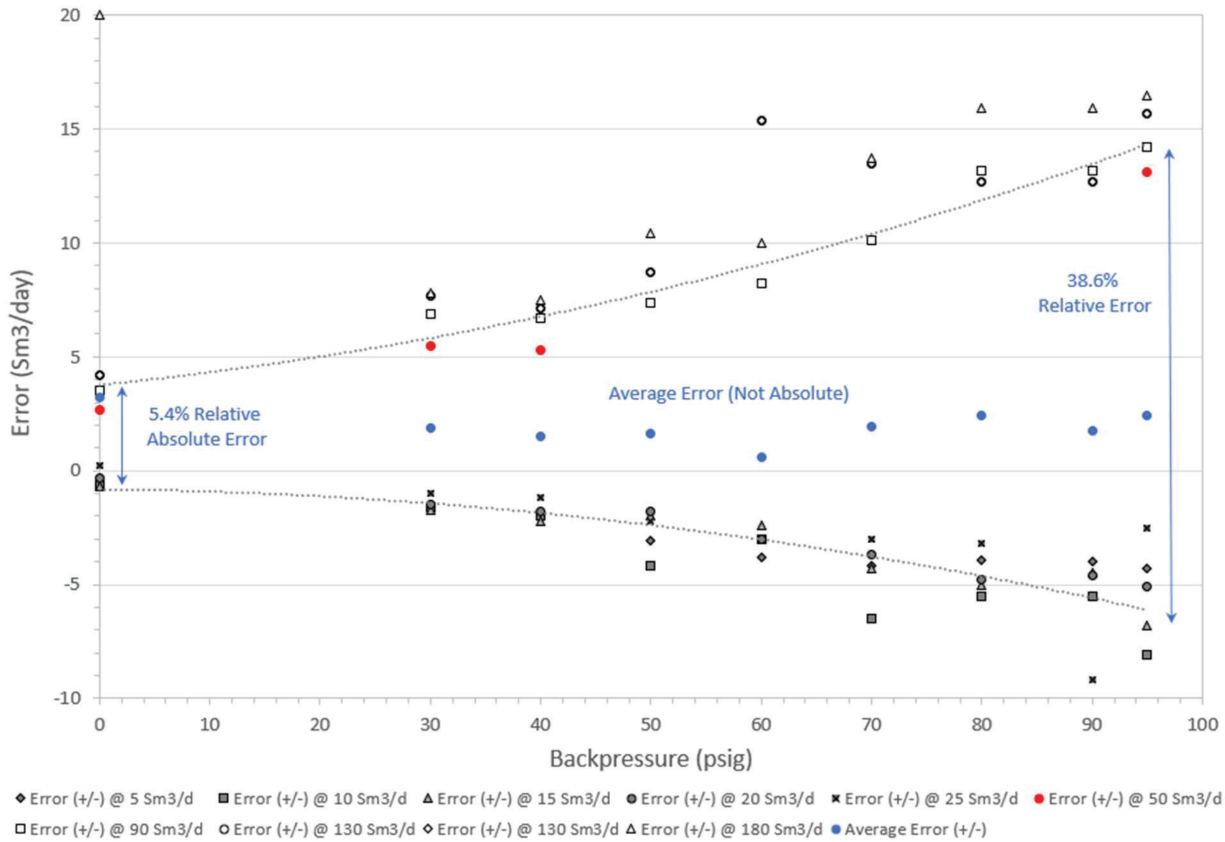

Figure 5: Ventsentinel® Prototype Error (+/-) compared to Alicat MFC

The Ventsentinel® prototype meter showed excellent performance in compensating for changes in line pressure as the average error remained within +/- 3.6 Sm3/d as the pressure increased to 655 kPag. As the flow rate increased from 5 to 180 Sm3/d, the Ventsentinel® prototype meter followed a trend of under-predicting to over-predicting the compressed air flow rate.

Overall, taking into consideration the Phase 1 test results, the Ventsentinel® prototype meter demonstrates encouraging potential for field instrument air flow measurement applications.

Atmospheric Tank Testing – Bonavista

Preliminary qualitative insights, as shown in in Figure 6, were shared in the Phase 1 report. The Y-axis is not included in this Figure, similar to this Figure in the Phase 1 report, as it was intended to be more qualitative. More data has been gathered from this site with it staying in service as a metered installation. A more detailed view into the sampled quantitative data is shared in Figure 7.

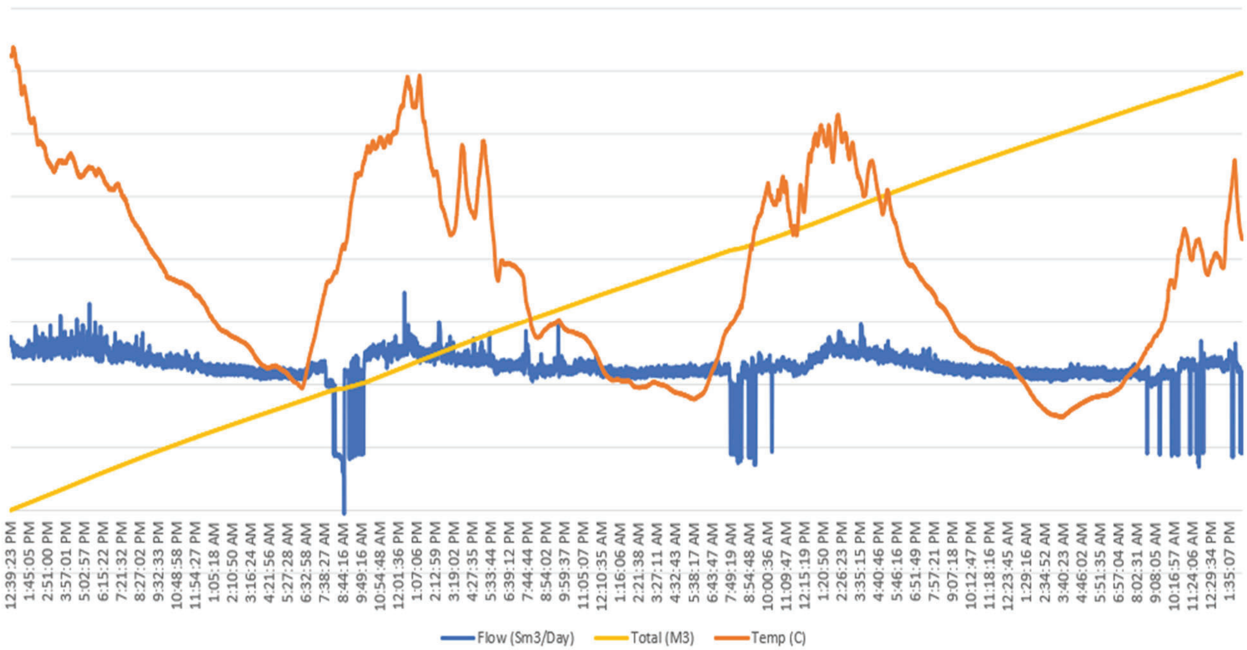

Figure 6: 400-bbl Ventsentinel® instantaneous and cumulative flow rates with process temperature

The recorded flow rates of the Ventsentinel® were corrected using the most recent temperature, pressure and gas composition corrections. Low level sensor performance values were not recorded for these tests. They were back calculated from the reported flow rates using the device calibration data. The media was assumed to be pure methane, which provided agreement with the Fox Thermal meter when comparing dynamic resolution.

Complicating this activity, the temperature recordings of the device were compromised and were incorrect as logged. Consequently, temperature from the adjacent Fox Thermal meter was used to obtain the estimated low level sensor values. Unfortunately, an unknown error was incorporated into the data due to this step.

The Ventsentinel® over this 26-minute sampled duration had instantaneous flow rates that varied between 0 and 180 Sm3/d. Those emissions are attributed to liquid volume entering the tank displacing gas in the vapour space, thermal expansion and volume that came out of solution given the lower tank pressure than the upstream process pressure.

A cumulative flow rate of 1.5 Sm3 was measured from the Ventsentinel®, where the FOX thermal mass meter measured 1.2 Sm3. This was equivalent to an average emission rate of 84 Sm3/d, where the Fox thermal mass meter measured 67 Sm3/d. Relative error, using formula presented in Appendix A, was 24.5%. In generating Figure 7, it is important to note that the temperature reading from the Fox thermal mass meter was used to convert the obtained flow readings to the same referenced standard conditions, which in this instance were 20 C and 101.325 kPa.

Aside from the tee joint to help collect any liquid carry through as shown in Figure 2, moisture was not removed from the pipe away vent line between the tank and the Ventsentinel®. Moisture in the process flow would result in a high measured flow rate than actual. Overall, taking into consideration the Phase 1 test results, the Ventsentinel® prototype meter demonstrates encouraging potential for field site GHG emission quantification on atmospheric point sources.

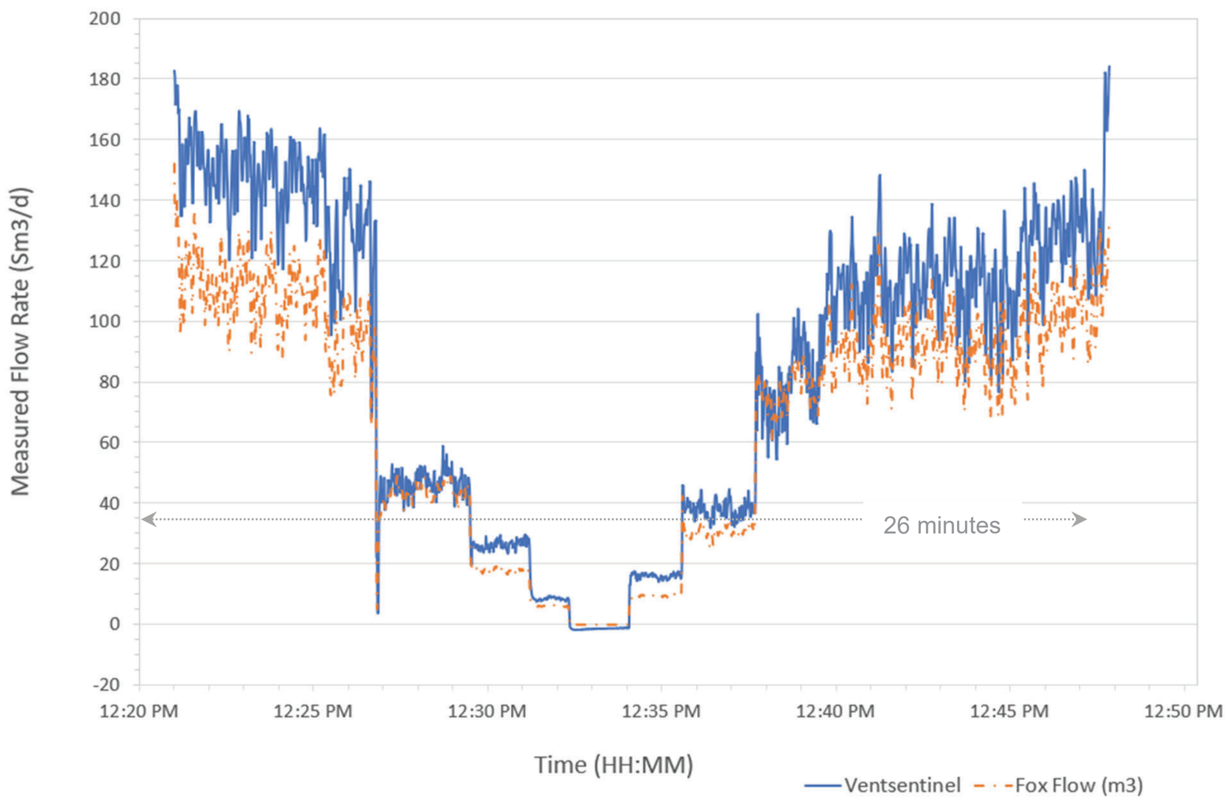

Figure 7: 400-bbl Ventsentinel® and Fox Thermal mass meter instantaneous flow rates

Air Compressor Testing – Bonavista

Low level sensor performance data was acquired from the prototype Ventsentinel® device during these tests, which allowed a direct application of the most recent temperature, pressure and gas type corrections. Data was corrected for standard pressure and temperature assuming dry air.

Corrections were applied to two data sets: one with data at 30 second sampling intervals over two days; one with 10 second sampling interval over six hours.

Upon review of the captured data shown in Figure 8, there were concerns that the flow rates varied so much. Initial thoughts hypothesized that a PSV was lifting downstream on high pressure fill as the increase in flow happened with the air compressor cycling approximately every 25 minutes. The Ventsentinel® was grounded properly and wasn't considered to be a root cause of error.

After a follow up review with field staff, this air system had two air receivers. The meter was installed downstream of the small receiver shown in Figure 3, but upstream of another large receiver. That large receiver was put in place to provide additional volume for the compressor engine starter. Therefore, the spike in flow rate was the small receiver filling the large receiver.

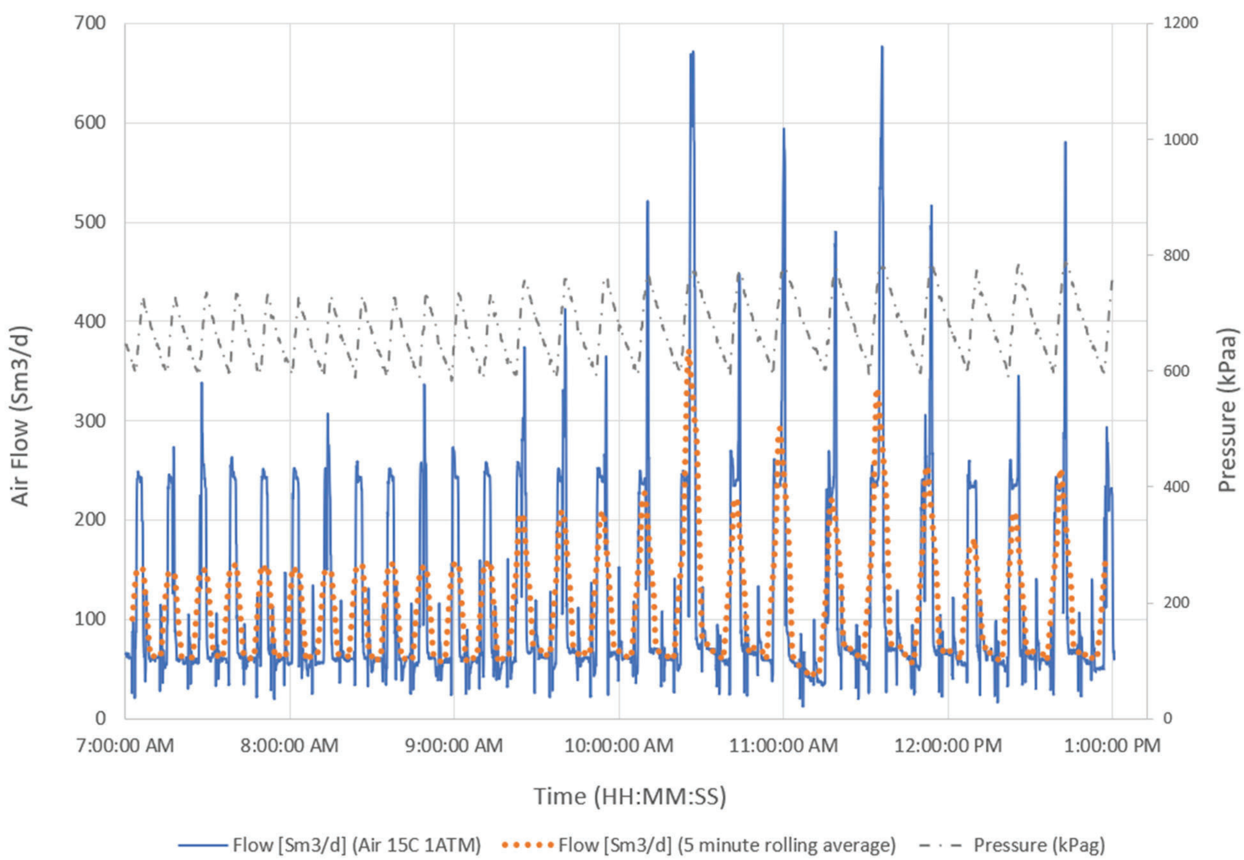

Figure 8: Ventsentinel® compressor discharge flow meter flow rates with process temperature

In comparison to earlier used positive displacement rotary meter (Dresser Roots meter), the average corrected flow rates (101.325kPa; 15C) was 113 Sm3/d. This appeared to be higher than it should have been given that the last nine-day average sampled PD meter flow was 30 Scf/d. It was difficult to confirm if the site demand had changed because both meters weren't kept in service in series at site.

Project Scope Key Learnings

- Developing a new measurement technology is challenging.
- There is uncertainty in all measurements. The Alicat MFC and the diaphragm-type dry test meter (DTM) compared well to each other in bench testing at InnoTech Alberta as did the Ventsentinel® especially with minimal backpressure.
- As the flow rate increased from 5 to 180 Sm3/d, the Ventsentinel® prototype meter followed a trend of under-predicting to over-predicting the compressed air flow rate, which is manageable.
- Overall, the Ventsentinel® prototype meter still shows excellent performance in compensating for changes in line pressure as the average error in bench testing remained within +/- 3.6 Sm^3/d for flow rates between 0 and 180 Sm3/d as the back pressure increased to 655 kPag.
- Not related to the Ventsentinel®, rather to emission sources themselves, any field measurement is only able to provide insight on what is happening if the duration is long enough to be considered representative.
- Atmospheric tanks are very dynamic and subject to emit dynamically active volumes depending on ambient conditions, the amount of light ends in the liquid stored in the tank, the liquid flow rates in and out of the tank and the ambient pressure and temperature. The Ventsentinel® allows tanks to “breathe” and does not induce a backpressure. It also captures reverse flow as negative flow rates.
- Bench tests only go so far. Field efforts are essential to ensure the needed durability, accuracy and reliability is built into the design of a flow meter. Important factors such as how well the flow meter is grounded are paramount. Other factors such as suitability to different media is important. The Ventsentinel® does not need to be recalibrated for different gas media types, where others do. Like other flow meters, the Ventsentinel® does need to be reverified over time to ensure the meter hasn’t drifted and remains as accurate as is needed.
- The measurement needs to be fit-for-purpose and cost effective – there are often considerations that are missed when flow meters are deployed in the field and that only adds cost to field deployment. The Ventsentinel® is designed to be deployed on virtually all atmospheric vents.
- Atmospheric point source measurements need to be obtained with view to the broader assembly and ease of use.

Broader Impacts

- It’s important to be mindful of some of the limitations and caveats; when carrying out a HAZOP prior to installation of flow meters on atmospheric point sources, what could happen and is there risk or negative consequence associated with that?
    - Connecting a flow meter without a drip leg in the upstream piping; liquid in the process may be detrimental to obtaining reliable field measurements.
    - Specific upstream and downstream pipe lengths are beneficial to obtaining good field data but may be difficult to obtain in all measurement situations.

  - Leaky gaskets in the process piping connection.
  - Being cognizant of other point sources that are part of the pressure boundary – flow will take the path of least resistance (PVRVs, thief hatches, ERVs, compressor crankcases, etc.).

- Achieving 45% methane reductions in the upstream oil and gas industry by 2025 and 75% by 2030 is a considerable task. Being able to achieve that outcome requires focus on all forms of atmospheric point sources through regulations, policies, and approval and permitting processes that are Specific, Measurable, Achievable, Reasonable and Timely (SMART) and predictable because uncertainty equals risk.
- Being able to optimize performance and/or verify compliance requires a good understanding of the baseline. Without such an analysis cannot be carried out, retrofit options cannot be evaluated nor can solutions be implemented.
- Not all point source emissions are large, including some atmospheric tank emissions and compressor packing vents as were field measured in this project. Similar to other atmospheric point source emission sources including, but not limited to, instruments, pneumatic pumps, cactus dryers, surface casing vent flow, engine blow-by, crankcase vents, blowdown valve leaks, valve packing leaks, flange gasket leaks, non-combusted flare volumes, the focus needs to be first on the ones that emit most often or emit the largest magnitude volumes. Tackling those first will be the most cost-effective and provide the greatest gains near term to help waste less and reduce GHG emissions.
- As learned through the Ventsentinel® efforts, there are a variety of approaches that will be considered fit-for-purpose and a good, better, best approach that merits having continuous emission monitoring of some point sources and sampling other point sources on a less frequent basis to provide needed insight.

D. PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	$131,250	Proportional to production scale
Technology Readiness Level (Start / End):	7	8
GHG Emissions Reduction (kt CH4/yr):	N/A (measurement only)	N/A (measurement only)
Estimated GHG abatement cost ($/kt CH4)	N/A (measurement only)	N/A (measurement only)
Jobs created or maintained:	2	4

E. RECOMMENDATIONS AND NEXT STEPS

The near-term plan for the commercialization of the Ventsentinel® is to continue using it at more field sites to make use of a proven technology, improve its performance and make it easier to implement. It is easier to repeat installs that have been done before as future deployments become much more cookie cutter.

The learnings from field deployment are invaluable. Next steps to be completed near term are further calibration improvements of the Ventsentinel® to allow it to capture field data that is more representative of actual flow rates. Ongoing computational fluid dynamic (CFD) calibration is underway. This new calibration model will be loaded onto the Ventsentinel® and will alleviate the concerns over accuracy. When deployed again into the field, the Ventsentinel® is expected to perform with precision.

The long-term plan for commercialization of the Ventsentinel® requires more probability that more continuous flow measurements will be needed at upstream oil and gas sites. This patented flow channel technology of the Ventsentinel® has its place in the market to help quantify atmospheric point sources. Greater adoption of its use will increase the scale or deployment and improve its cost-effectiveness.

The Ventsentinel® is an adaptation of Ventbuster Instruments' innovative technology, the Ventbuster®. Using the Ventbuster® patented flow channel design, the Ventsentinel® is built for purpose to precisely and continuously provide point-source quantification and baseline measurements for all methane emissions being vented to atmosphere. Through this latest round of field testing, the Ventsentinel® is able to achieve accurate measurement across for the needed span of methane vent installations. After completion of further CFD calibration efforts in late spring of 2023, this meter will become commercial and provide industry with an intrinsically safe, direct, and continuous real-time measurement, with digitally recorded venting methane flow rates and pressures to the atmosphere. It is designed for installation on wellheads, production tanks, produced water tanks, relief valves, vented underground tanks, compressor seals, instrument air compressors, fuel gas lines, flare lines or incinerators. Its design allows it to be mounted in-line with any hydrocarbon point source to precisely measure and digitally record GHG emissions.

With use of the proprietary CFD calibration model, the Ventsentinel® will be able to correct for different or varying gas compositions in real time at the field level. The gas component stream fed into the Ventsentinel® manually or digitally will correct the flow rate to compensate not only for the gas composition, but for the gas density too, as temperatures and pressures change. This technology will then report the "actual" flow rate to atmosphere of each component and will give an equivalent mass volume of that component in grams/hour, or tonnes/year, depending on the specific requirements of the operator.

The Ventsentinel® will be manufactured as a cost-effective solution and be made available across industries. Ventbuster Instruments will manage and archive all data through its IoT Platform and dashboard interface under a prescribed data plan. By enabling all industries to establish a scientifically accurate base line measurement on any GHG vent assembly, industry is then able to prioritize, design, engineer, budget, plan, and execute effective mitigation measures to meet or exceed government regulations. The carbon credit market would also have new precise point-source quantification technology to establish a standard to which it can value its "commodity" upon and be used to quantify Mt/y of CO2e emission reductions.

The Ventsentinel® currently meets the requirements of AER Directives in Alberta for gas measurement and monitoring.

The Ventsentinel® is expected to be available for commercial deployment by late 2023.

Natural Resources Canada
Ressources Naturelles Canada

Canada

ALBERTA INNOVATES

CERIN
Canadian Emissions Reduction Innovation Network

Appendix A: Ventsentinel® Lab Testing

InnoTech
ALBERTA
A SUBSIDIARY OF ALBERTA INNOVATES

Ventsentinel® Lab Testing - Phase 2

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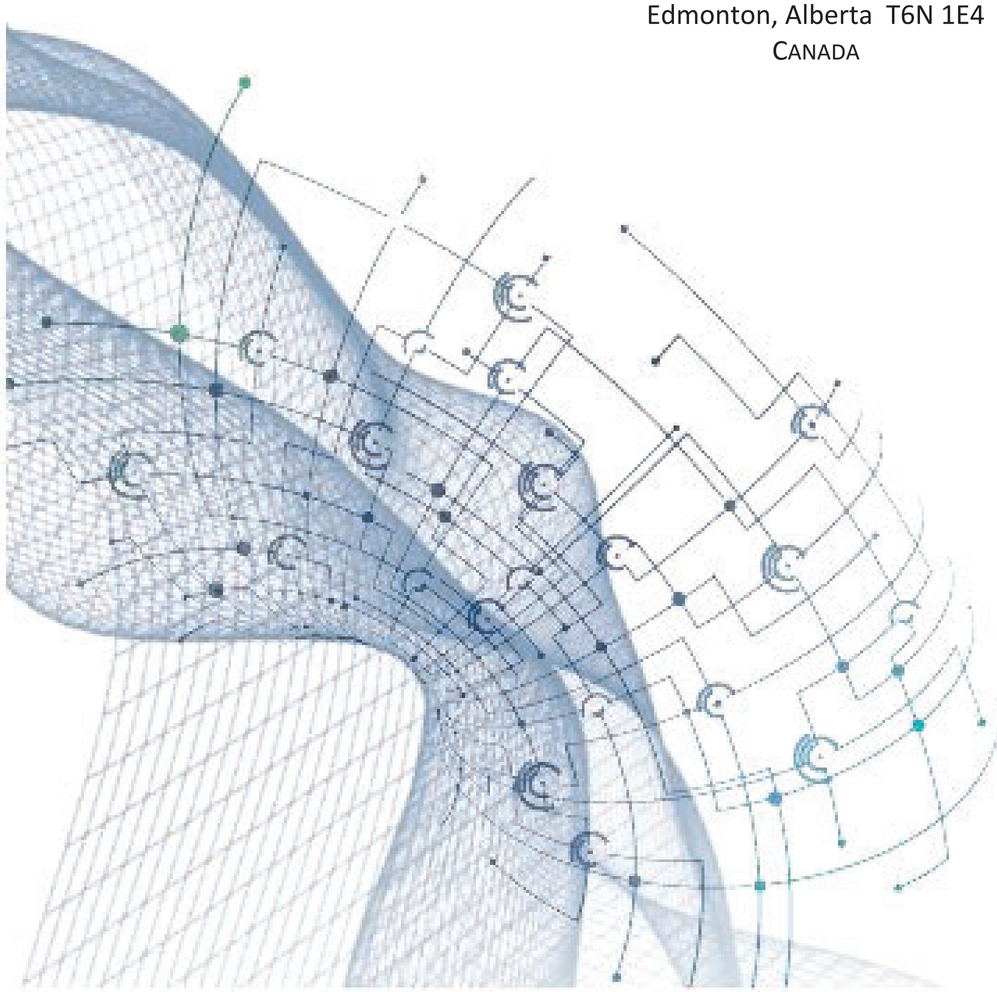

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Contract No. C2021000968

October 2022

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VENTSENTINEL® LAB TESTING- PHASE 2

NEIL YAREMCHUK

1.0 INTRODUCTION AND OBJECTIVES

Existing meters for measuring GHG emissions and other field site gases are either insufficiently accurate or prohibitively expensive. As a result, there is little information on flow rates from a variety of such sources and an opportunity exists for new metering technologies, such as those offered by Ventbuster Instruments, to fill this gap. With support from the Canadian Emissions Reduction Innovation Consortium (CanERIC) and the Petroleum Technology Alliance Canada (PTAC), this project is an extension of the previous project where low-pressure air and methane flow tests were conducted in the lab environment. The encouraging performance of the Ventsentinel® prototype flow meter during these previous tests prompted an exploration of its application in measuring supplied instrument air rates at various field sites. The objective of this project phase is to evaluate the accuracy and utility of the Ventsentinel® prototype in measuring compressed air at various flow rates and pressures.

2.0 FLOW TEST APPARATUS

As shown in Figure 1, the test setup consists of pressure-regulated laboratory air or pure compressed methane supplied to two Alicat Mass Flow Controllers (MFCs) installed in a parallel flow pattern. The two units allow for a high-flow range up to 180 Sm^3/d and low-flow range up to 7 Sm^3/d. Specifications of the two MFCs are shown in Table 1. To confirm the line pressure measured and reported by the MFCs, a digital pressure gauge was installed downstream. This is then followed by the 1” Ventsentinel® flow meter assembly. To ensure fully developed flow, 24” of straight 1” Sch. 40 pipe is installed upstream and 12” of straight 1” Sch. 40 pipe is installed downstream of the Ventsentinel®. To ensure proper operation of the sensor, the ground wiring from the flow meter assembly was connected to a reliable ground source within the lab. As shown in Figure 1, a throttling valve followed by a diaphragm-type dry test meter (DTM) was installed downstream of the 12” straight section. The MFCs and Ventsentinel® communicate with a data acquisition system to digitally record the flow and pressure measurements.

For accurate measurement from the Alicat MFCs, the devices rely on the user to input the composition of the flowing gas into the device’s settings and allows the specific heat capacity of the gas to be known. In this study the manufacturer-supplied presets of “Air (Clean Dry)” was used. As noted by Tangent Design Engineering, the current Ventsentinel® prototype is calibrated for instrument air. For absolutely accurate results, a full gas speciation report is required as well as diagnostic information from the meter itself. The Ventsentinel® prototype is also calibrated to transmit flow data corrected to the standard temperature and pressure (STP) of 101.3 kPaa and 25°C. The Alicat MFCs were consistent in this setting; therefore, the flowrates from all three sensors were recorded at the same STP conditions. The DTM measures the cumulative volume of flowed gas at actual conditions. DTM flow rates are determined by visually recording the beginning and end cumulative volumes over a measured time interval and calculating the average, actual flow rate. The outlet of the DTM is vented directly to atmosphere in the fumehood and the pressure drop though the meter is negligible; therefore, it can be assumed that gas flow is at atmospheric pressure. This value is measured and recorded by the Alicat MFCs and compared against an in-house barometric pressure transmitter for confirmation. The Alicat MFCs were also used to measure and record the temperature of the flowing gas which is compared against a handheld thermocouple reader for confirmation. Combined with the ideal gas law, these measurements are then used to convert the average, actual DTM flow rate measurement to consistent STP conditions.

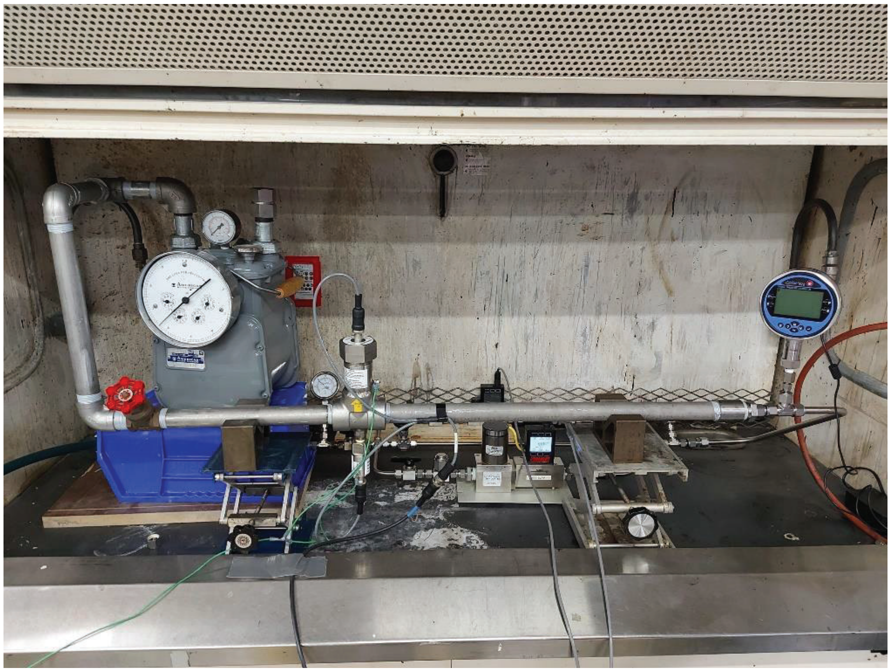

Figure 1: Flow test setup with two Alicat Mass Flow Controller and 1” Ventsentinel® installed in a fumehood.

Parameter	**Specification**
Model Number (High-Range MFC)	MCR-100SLPM-D-X/CM,CIN
Model Number (Low-Range MFC)	MC-5SLPM-D-X/CM,CIN
Flow Range (High-Range MFC)	0.5 to 100 SLPM
Flow Range (Low-Range MFC)	0.025 to 5 SLPM
Accuracy	± (0.8% of reading + 0.2% of Full Scale)
Repeatability	± 0.2% Full Scale
Zero Shift and Span Shift	0.02% Full Scale / ºCelsius / Atm

Table 1: Specifications of the two Alicat Mass Flow Controllers used in the flow tests

3.0 FLOW TESTING

3.1 ERROR DEFINITIONS

For this study, error is presented in the terminology shown below.

$$Error = Measured\ Value - Real\ Value$$

Relative error is presented in the terminology of:

$$Relative\ Error = \frac{Measured\ Value - Real\ Value}{Real\ Value} \times 100\%$$

Note: In order to allow identification of over- and under-estimation (i.e. +/- Error), the use of absolute errors values has not been applied.

Also, for this study, the Alicat MFCs are the considered the “gold standard” that which the Ventsentinel® is compared against. Therefore, the Ventsentinel® prototype flow meter measurement is defined as “measured” and the Alicat mass flow controller as “real”. The DTM was incorporated in the project as secondary confirmation or “sanity check” of the Alicat MFC measurement.

3.2 AIR – VARIABLE PRESSURE

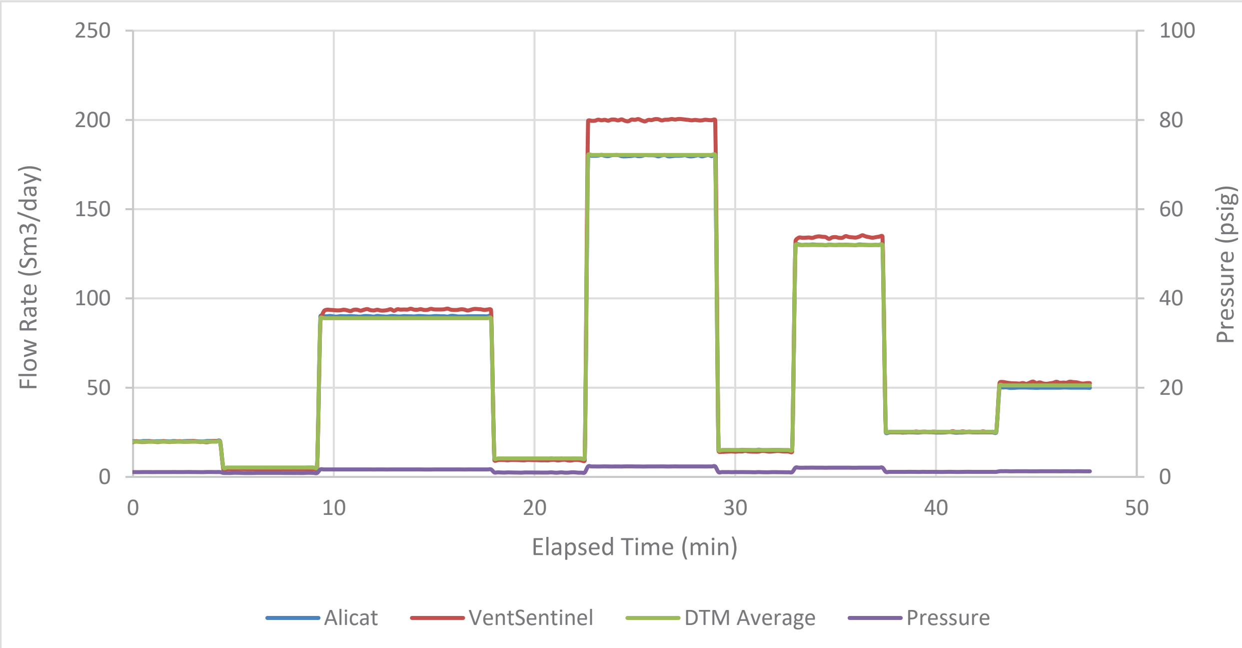

Figure 2: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 0.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-0.3	-1.3%
2	5.0	-0.6	-11.3%
3	90.0	3.5	3.9%
4	10.0	-0.6	-5.7%
5	179.9	20.0	11.1%
6	15.0	-0.7	-4.5%
7	130.0	4.2	3.2%
8	25.0	0.2	0.9%
9	50.0	2.7	5.4%

Table 2: Error in the standard measurements of the Ventsentinel® in Test 0.

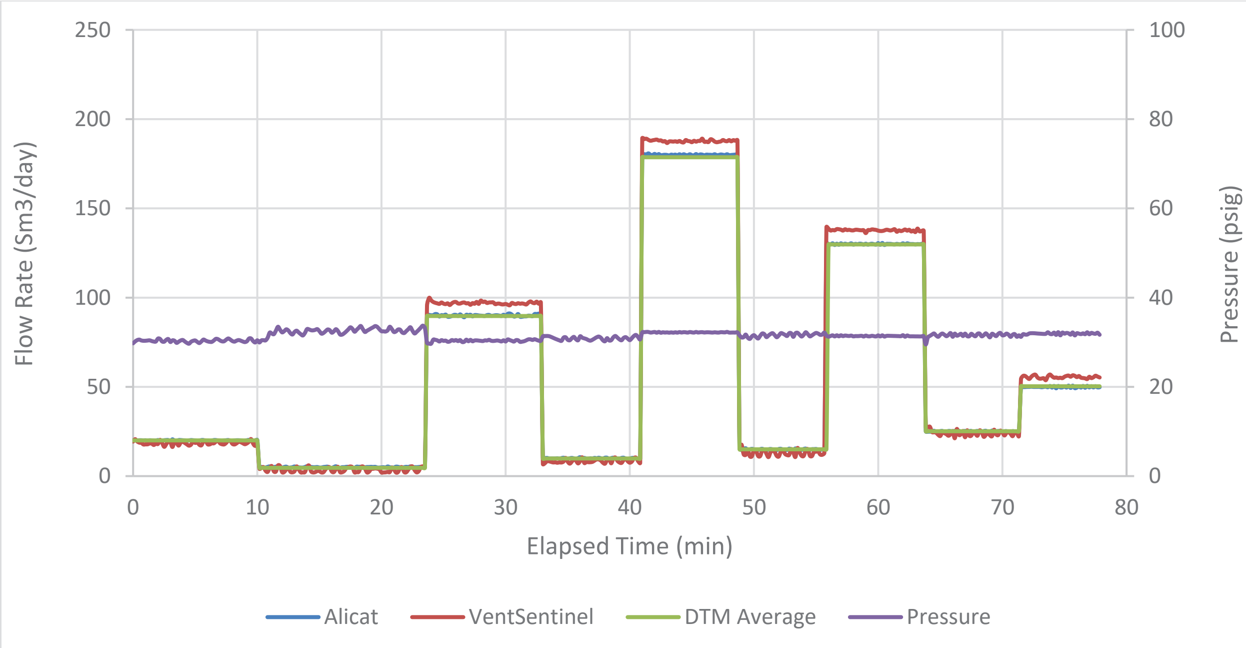

Figure 3: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 1.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-1.5	-7.5%
2	5.0	-1.5	-28.8%
3	90.1	6.9	7.6%
4	10.0	-1.6	-16.4%
5	180.0	7.8	4.3%
6	17.7	-1.7	-12.3%
7	130.0	7.7	5.9%
8	25.0	-1.0	-3.8%
9	50.0	5.5	11.0%

Table 3. Error in the standard measurements of the Ventsentinel® in Test 1.

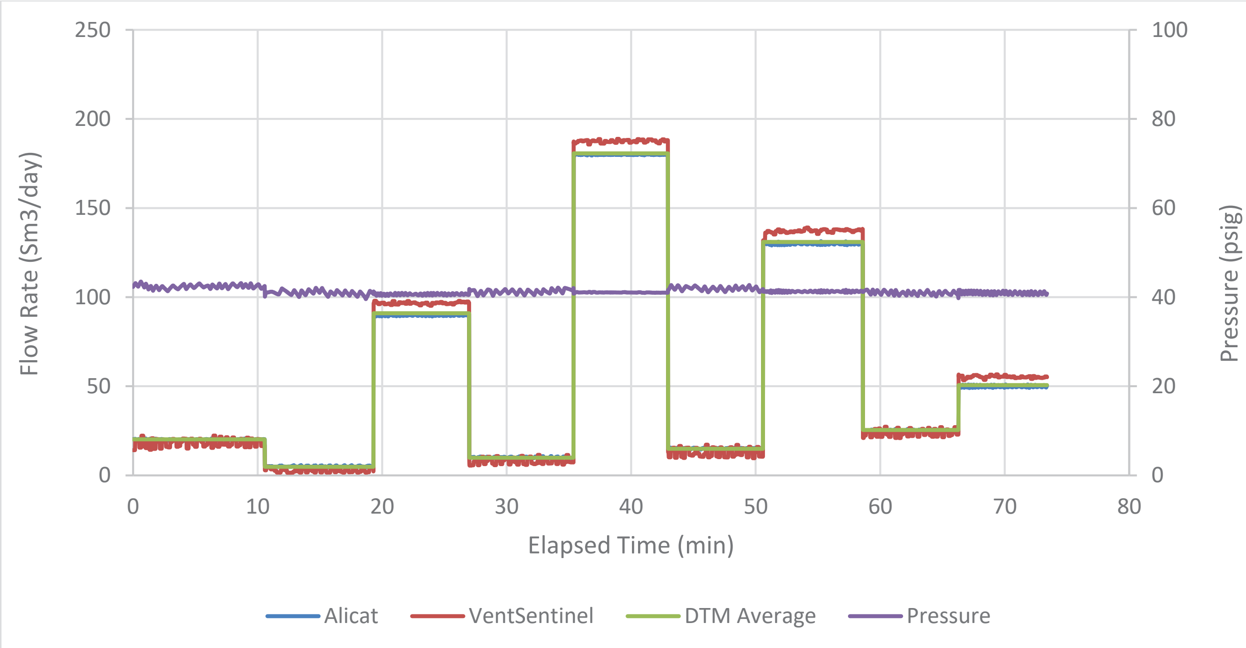

Figure 4: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 2.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-1.8	-8.7%
2	5.0	-2.1	-41.6%
3	90.0	6.7	7.4%
4	10.0	-2.0	-19.9%
5	180.0	7.5	4.2%
6	15.0	-2.2	-14.4%
7	130.0	7.1	5.4%
8	25.0	-1.2	-4.8%
9	50.0	5.3	10.5%

Table 4. Error in the standard measurements of the Ventsentinel® in Test 2.

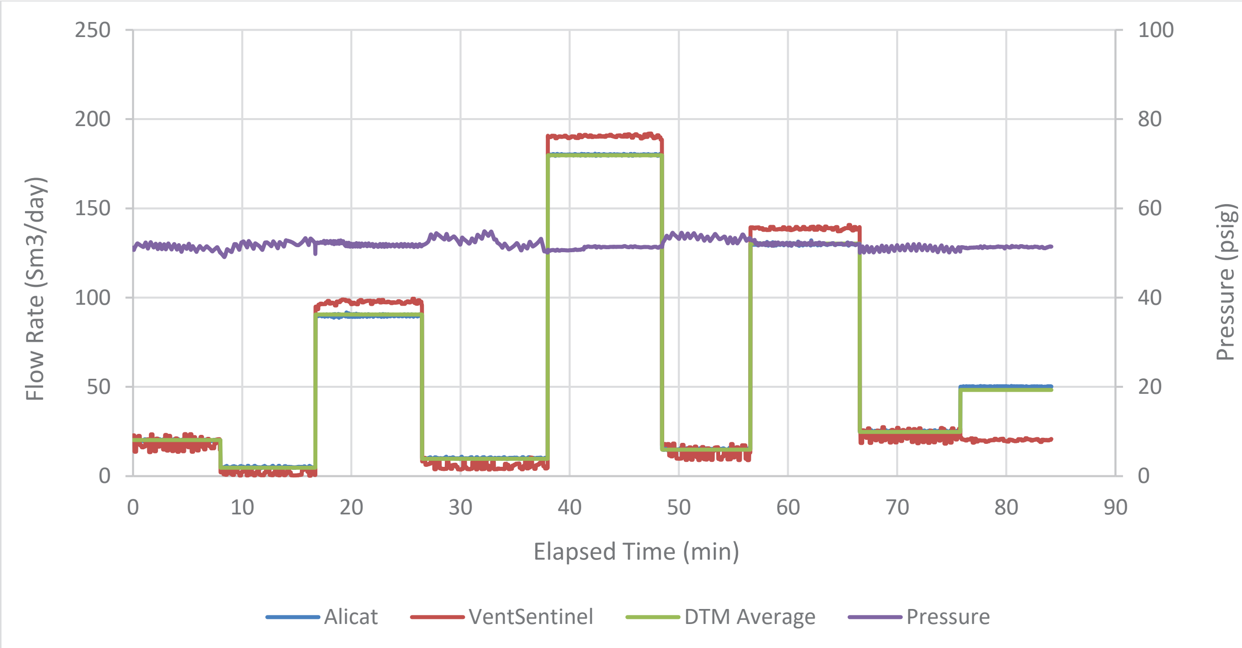

Figure 5: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 3.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-1.8	-8.8%
2	5.0	-3.1	-61.9%
3	90.0	7.4	8.2%
4	10.0	-4.2	-41.4%
5	180.0	10.4	5.8%
6	15.0	-2.0	-12.8%
7	130.0	8.7	6.7%
8	25.0	-2.2	-8.7%
9	50.0	-29.8	-59.6%

Table 5. Error in the standard measurements of the Ventsentinel® in Test 3.

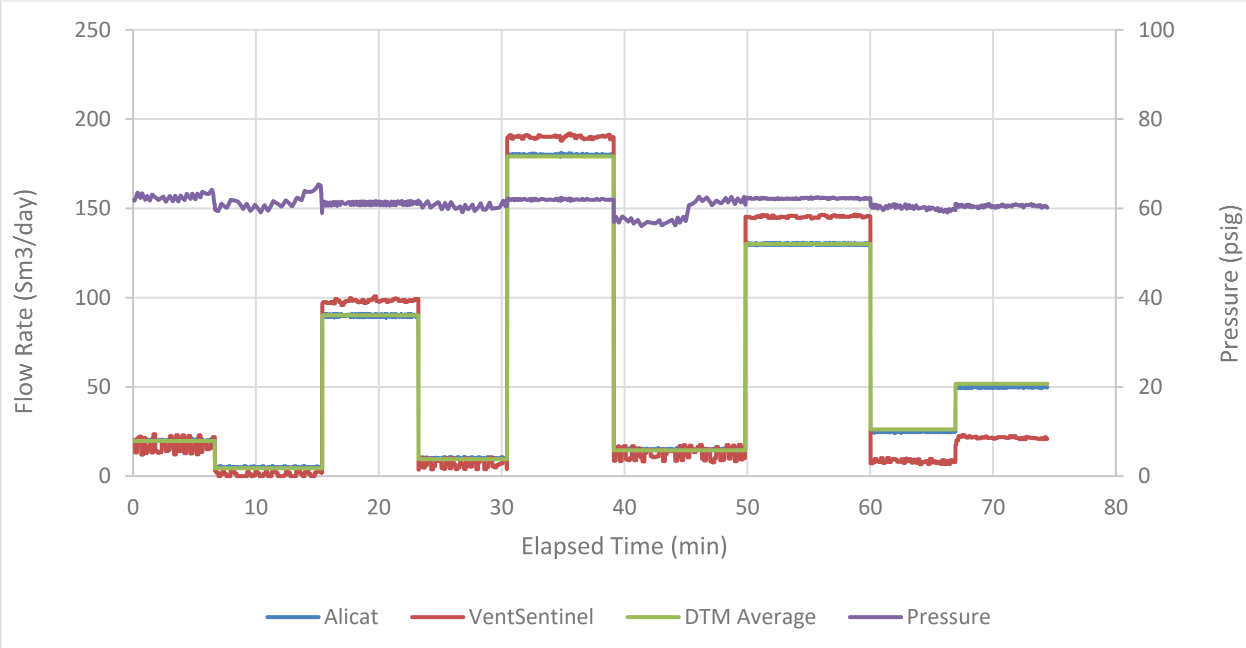

Figure 6: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 4.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-3.0	-14.7%
2	5.2	-3.8	-76.4%
3	90.0	8.2	9.1%
4	10.0	-3.0	-29.6%
5	180.0	10.0	5.6%
6	15.0	-2.4	-15.8%
7	130.0	15.4	11.8%
8	25.0	-16.7	-66.8%
9	50.0	-28.5	-57.0%

Table 6. Error in the standard measurements of the Ventsentinel® in Test 4.

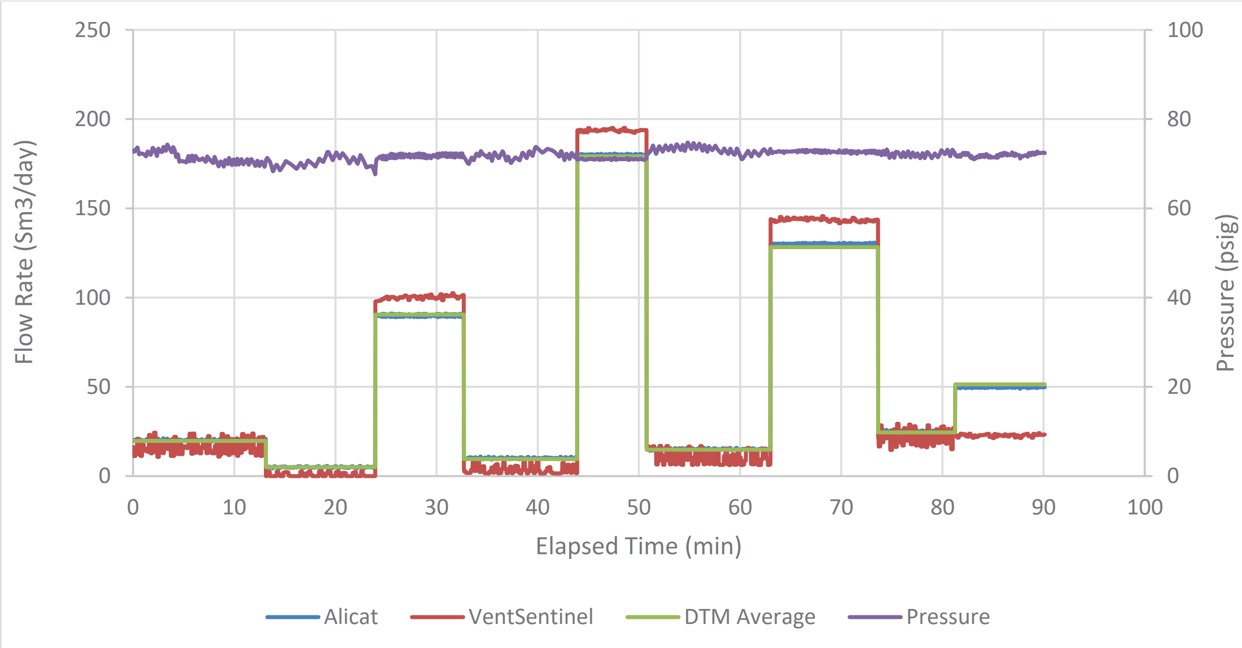

Figure 7: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 5.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-3.7	-18.3%
2	5.0	-4.2	-84.4%
3	90.0	10.1	11.3%
4	10.0	-6.5	-64.9%
5	180.0	13.7	7.6%
6	15.0	-4.3	-28.6%
7	130.0	13.5	10.4%
8	25.0	-3.0	-11.9%
9	50.0	-27.2	-54.4%

Table 7. Error in the standard measurements of the Ventsentinel® in Test 5.

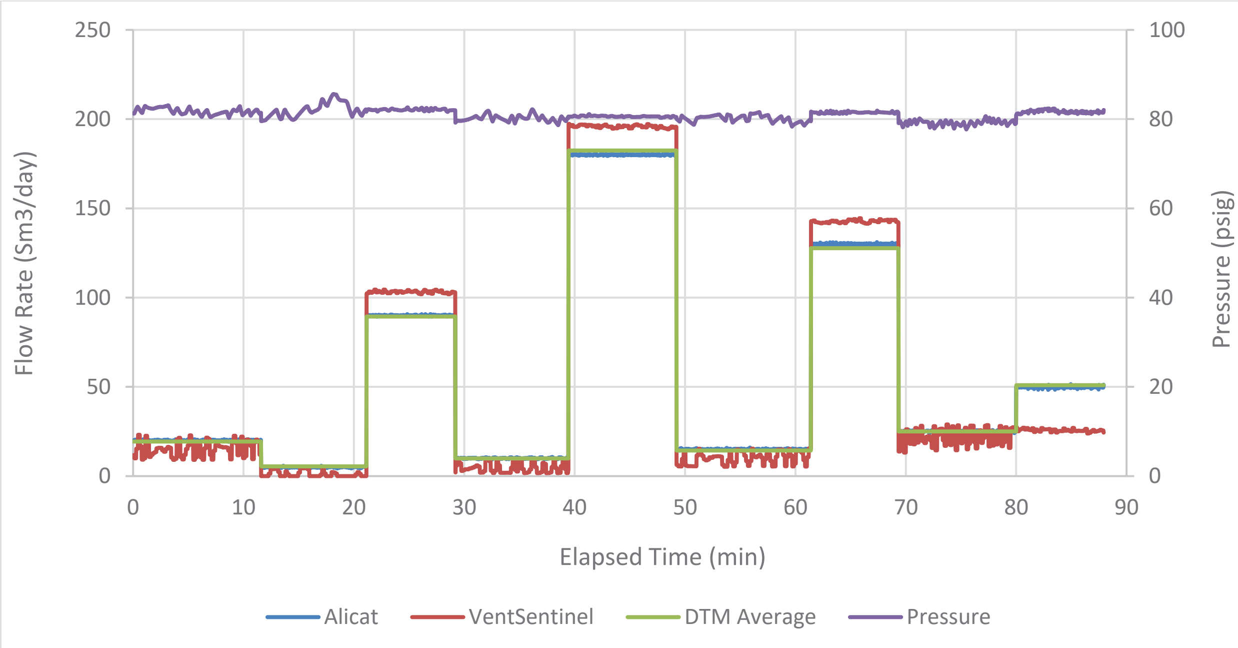

Figure 8: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 6.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-4.8	-23.7%
2	5.0	-3.9	-77.5%
3	90.0	13.2	14.7%
4	10.0	-5.5	-55.0%
5	180.0	15.9	8.8%
6	15.0	-5.0	-33.1%
7	130.0	12.7	9.8%
8	25.0	-3.2	-12.4%
9	50.0	-24.3	-48.6%

Table 8. Error in the standard measurements of the Ventsentinel® in Test 6.

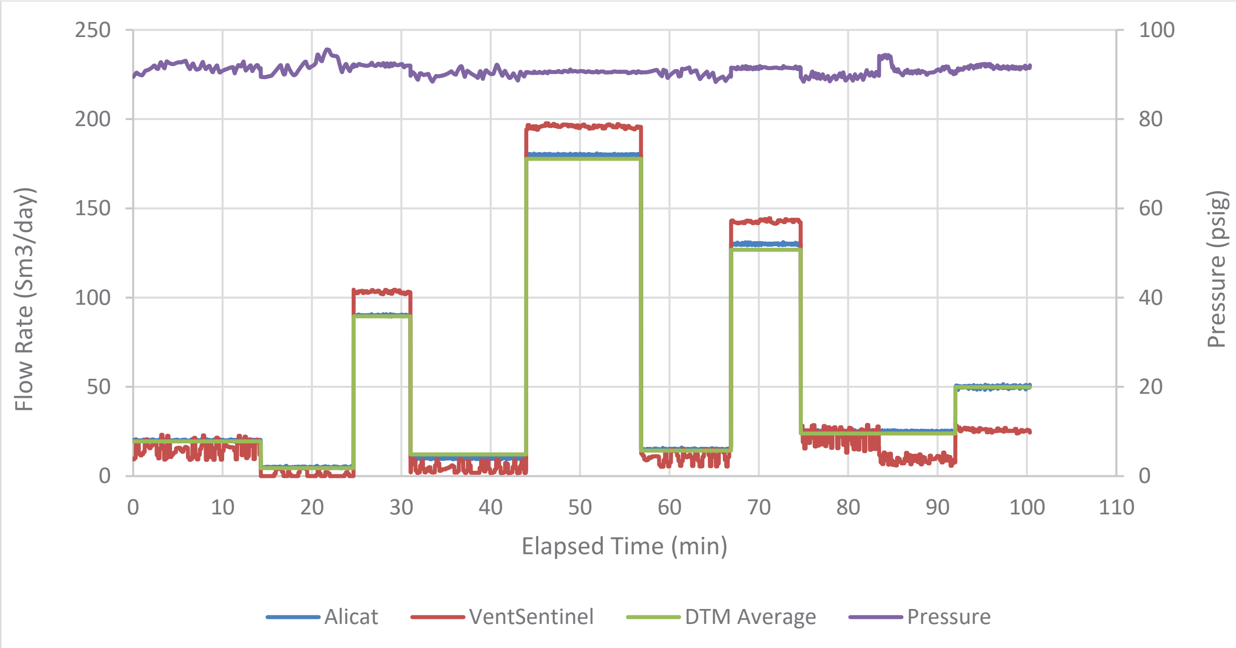

Figure 9: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 7.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	20.0	-4.6	-23.1%
2	5.0	-4.0	-79.3%
3	90.0	13.2	14.6%
4	10.0	-5.5	-55.1%
5	180.0	15.9	8.8%
6	15.0	-4.5	-29.9%
7	130.0	12.7	9.8%
8	25.0	-9.2	-36.8%
9	50.0	-24.2	-48.5%

Table 9. Error in the standard measurements of the Ventsentinel® in Test 7.

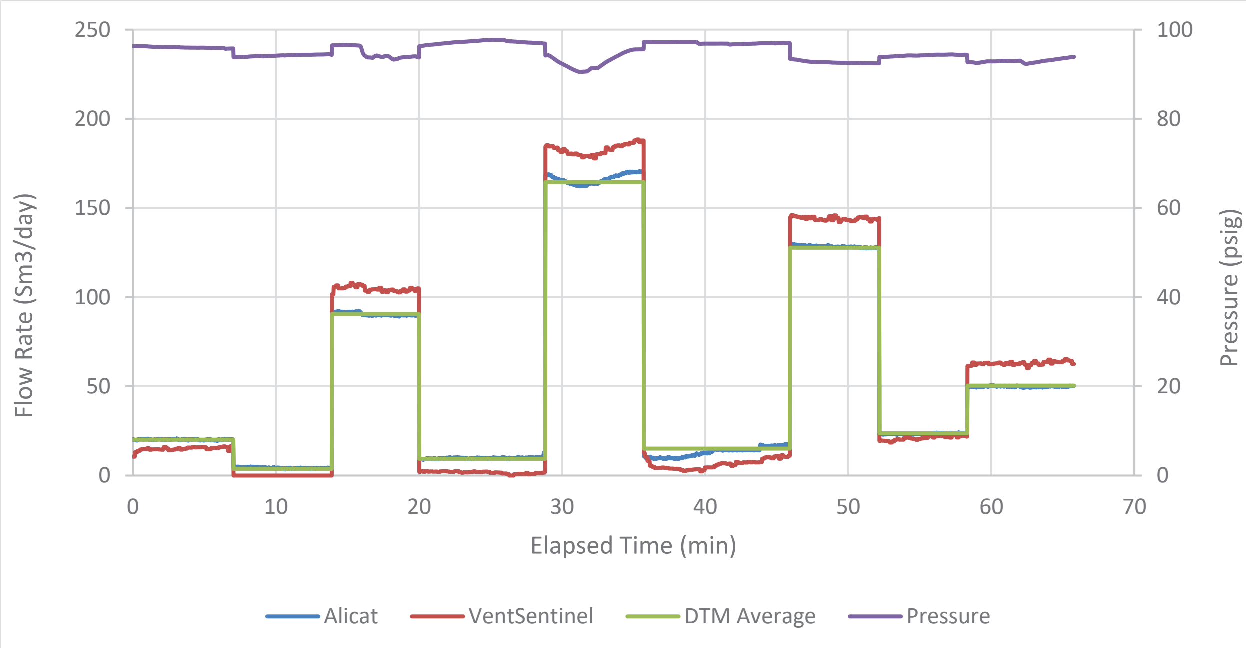

Figure 10: Standard air flow rate (Alicat, Ventsentinel®, DTM) and line pressure measurements in Test 8.

Step	Flow Rate Alicat (Sm^3/day)	Error VS-Alicat (+/- Sm^3/day)	Rel. Error VS-Alicat (%)
1	-5.1	-5.1	-25.4%
2	-4.3	-4.3	-100.0%
3	14.2	14.2	15.6%
4	-8.1	-8.1	-82.6%
5	16.5	16.5	9.9%
6	-6.8	-6.8	-52.9%
7	15.7	15.7	12.2%
8	-2.5	-2.5	-10.5%
9	13.1	13.1	26.2%

Table 10. Error in the standard measurements of the Ventsentinel® in Test 8.

4.0 CONCLUSIONS

The objective of this project phase was to evaluate the accuracy and utility of the Ventsentinel® prototype system in measuring compressed air at various flow rates and pressures. This also allowed the meter supplier and designers an opportunity to generate diagnostics data during the tests and adjust the design if desired. From this study, the following conclusions were made:

- On average, the Ventsentinel® prototype meter demonstrates reasonably good performance where the measurement error is typically within +/- 10 Sm^3/d

- The Ventsentinel® prototype meter shows excellent performance in compensating for changes in line pressure as the average error remains within +/- 3.6 Sm^3/d as the pressure increases to 95 psig.

- As the flow rate increases from 5 to 180 Sm3/d, the Ventsentinel® prototype meter follows a trend of under-predicting to over-predicting the compressed air flow rate. Therefore, it is anticipated that the accuracy of the system can be improved through simple re-calibrations.

- At the last flow test condition (50 Sm3/d) on some tests (3,5,6,7), the Ventsentinel® systems encounters technical issue which may be addressed with further development of the prototype.

- Overall, and taking into consideration the Phase 1 test results, the Ventsentinel® prototype meter demonstrates encouraging potential for both field site GHG emission and instrument air flow measurement applications.

		Line Pressure (psig)									
		0	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**95**	**Avg.**
Air Flow Rate (Sm3/d)	**5**	-0.6	-1.5	-2.1	-3.1	-3.8	-4.2	-3.9	-4.0	-4.3	**-3.0**
	10	-0.6	-1.6	-2.0	-4.2	-3.0	-6.5	-5.5	-5.5	-8.1	**-4.1**
	15	-0.7	-1.7	-2.2	-2.0	-2.4	-4.3	-5.0	-4.5	-6.8	**-3.3**
	20	-0.3	-1.5	-1.8	-1.8	-3.0	-3.7	-4.8	-4.6	-5.1	**-2.9**
	25	0.2	-1.0	-1.2	-2.2	-16.7	-3.0	-3.2	-9.2	-2.5	**-4.3**
	50	2.7	5.5	5.3	-29.8	-28.5	-27.2	-24.3	-24.2	13.1	**-11.9**
	90	3.5	6.9	6.7	7.4	8.2	10.1	13.2	13.2	14.2	**9.3**
	130	4.2	7.7	7.1	8.7	15.4	13.5	12.7	12.7	15.7	**10.9**
	180	20.0	7.8	7.5	10.4	10.0	13.7	15.9	15.9	16.5	**13.1**
	Avg.	**3.2**	**2.3**	**1.9**	**-1.8**	**-2.6**	**-1.3**	**-0.5**	**-1.1**	**3.6**	

Table 11. Summary of error (Sm3/d) in the standard measurements of the Ventsentinel® for all 8 tests.

	Line Pressure (psig)

		0	30	40	50	60	70	80	90	95	Avg
Air Flow Rate (Sm3/d)	**5**	-11.3%	-28.8%	-41.6%	-61.9%	-76.4%	-84.4%	-77.5%	-79.3%	-100%	**-62.3%**
	10	-5.7%	-16.4%	-19.9%	-41.4%	-29.6%	-64.9%	-55.0%	-55.1%	-82.6%	**-41.2%**
	15	-4.5%	-12.3%	-14.4%	-12.8%	-15.8%	-28.6%	-33.1%	-29.9%	-52.9%	**-22.7%**
	20	-1.3%	-7.5%	-8.7%	-8.8%	-14.7%	-18.3%	-23.7%	-23.1%	-25.4%	**-14.6%**
	25	0.9%	-3.8%	-4.8%	-8.7%	-66.8%	-11.9%	-12.4%	-36.8%	-10.5%	**-17.2%**
	50	5.4%	11.0%	10.5%	-59.6%	-57.0%	-54.4%	-48.6%	-48.5%	26.2%	**-23.9%**
	90	3.9%	7.6%	7.4%	8.2%	9.1%	11.3%	14.7%	14.6%	15.6%	**10.3%**
	130	3.2%	5.9%	5.4%	6.7%	11.8%	10.4%	9.8%	9.8%	12.2%	**8.4%**
	180	11.1%	4.3%	4.2%	5.8%	5.6%	7.6%	8.8%	8.8%	9.9%	**7.3%**
	Avg	**0.2%**	**-4.4%**	**-6.9%**	**-19.2%**	**-26.0%**	**-25.9%**	**-24.1%**	**-26.6%**	**-23.0%**	

Table 12. Summary of relative error (%) in the standard measurements of the Ventsentinel® for all 8 tests.