FINAL REPORT CCITF CLEAN TECHNOLOGY COMMERCIALIZATION REPORT

CCITF PROJECT NUMBER: G2018000316
PROJECT APPLICATION TITLE: THE VENTSENTINEL® CHOPS SERIES

PRINCIPAL INVESTIGATOR: N/A
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SCHEDULED COMPLETION DATE: June 30, 2021
ACTUAL COMPLETION DATE: September 30, 2021
SUBMISSION DATE: November 1, 2021

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EXECUTIVE SUMMARY

Since 2016, the Ventbuster Group has focused on developing a unique fit-for-purpose greenhouse gas (GHG) emissions technology to measure the immeasurable. A technology able to qualify and quantify low to ultra-low flow, low pressure, continuous and intermittent methane emissions from wellhead surface casing vents. In 2019, Ventbuster Instruments (Ventbusters) succeeded in filling the technological gap with the Ventbuster®. This novel, patented technology became commercial and was introduced to the industry in late 2019. To date, there exists no other technology that can accurately and intuitively provide intrinsically safe, direct, and continuous real-time measurement, with digitally recorded venting methane flow rates and pressures to the atmosphere.

Once our metering innovation concept was revealed, industry was intrigued with the technological advancement in measurement accuracy and the incredible turndown ratio. We were asked to adapt our technology to meet the challenges around methane emissions with Cold Heavy Oil Production with Sand (CHOPS) production, relative to economic challenges from the impending Governmental Climate Leadership Plan.

As circumstance would have it, Alberta Innovates (AI) tendered the Husky CHOPS Methane Challenge, to which Ventbusters was awarded a research and development grant to adapt our technology for CHOPS solution gas monitoring. After fastidious engineering, Ventbuster Instruments successfully developed the Ventsentinel®, a patent-pending, commercial prototype of an economical solution gas metering device.

Our latest technological release of the Ventsentinel® is an adaptation of the Ventbuster® and designed initially for solution gas venting measurement around oil and gas production. Industry has identified the requirement for a technical improvement of low and ultra-low venting emissions measurement to meet the current AER Directive 17 requirements and anticipated Governmental legislation around methane emission reduction targets and carbon levies.

<u>The Ventsentinel® Key Performance Indicators:</u>

- ✓ Volumetric flow range customized for any venting scenario, even beyond that of low and ultra-low flows.
- ✓ The patented flow channel has no restrictions and essentially zero pressure drop through the meter.
- ✓ Continuous real-time monitoring, accurately recording and monitoring erratic, intermittent or constant stream flow rates over any period.
- ✓ Capable of receiving external plant power and adaptable for solar battery power.
- ✓ Communication port that can adapt from a SCADA system platform to cellular telemetry.
- ✓ Free liquids in the solution gas stream are knocked-out at the inlet of the meter.
- ✓ Weather-resistant and functions in ambient temperatures ranging from -40°C to +55°C.
- ✓ Ability to measure and record pressures as required for various applications.
- ✓ Hardware and installation are more economical than current differential pressure or positive displacement meters and data acquisition platforms.

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- ✓ Eliminate the requirement for and cost of ongoing GOR testing, plus the resultant production accounting and pro-rating overhead expenses.
- ✓ Provides real-time GOR testing, which negates over-production of solution gas and the associated penalties.
- ✓ Enables industry to efficiently and economically design solution gas recovery schemes and incineration facilities.
- ✓ Installation of the Ventsentinel® CHOPS directly to the production casing head vent continuously monitors the erratic solution gas flow rate and pressure. This facilitates an early workover intervention to mitigate the restriction of heavy oil inflow due to annular foaming effects.

The industry has since identified that our smart meter technology has applications in numerous in-line placements on well sites and production facilities to measure and monitor methane emissions in real-time. These placements would be on wellhead vents, field production and storage tank vents, relief valves, underground tank vents, compressor packing vents, instrument air compressors, fuel gas lines, flare lines, and incinerators. The Ventsentinel® design offers a unique engineering advantage since this one technology can be installed onto all venting systems.

As a result of AI, Climate Change Innovation and Technology Framework (CCITF) Clean Technology Commercialization – Husky CHOPS Methane Challenge, the “prototype” Ventsentinel® CHOPS Unit is now in commercial field trials in the Lloydminster area.

PROJECT DESCRIPTION

In March 2018, The AI Clean Technology Commercialization Program: The AI – Husky CHOPS Methane Challenge was announced.

The CHOPS Methane Challenge encompassed two distinct but complementary technology streams. We felt our technology addressed the first stream, specifically targeting the technological gap of accurate and quantifiable measurement of produced solution gas from CHOPS wells. Measurement was primarily focused on vented casing gas, secondarily on tank vapour volumes. The solution needed to be economical, inflict a minimal footprint, be fully functional below -35°C, communicate with existing SCADA systems, handle free-liquids entrained in the solution gas stream, provide relevant real-time data collection and analysis, and measure volumetric flow rates over a range of at least 160 – 500 m3/day.

Our Ventsentinel® CHOPS Series technology has a unique direct flow channel with no restrictions and zero pressure-drop, which can be custom manufactured for any flow range. It is a smart meter that continuously measures and monitors low, erratic, intermittent, and or constant flow streams in real-time. It measures flow pressure, flow temperature and stamps date and time on the data. It is designed to be mounted in-line with any hydrocarbon venting assembly with a water knock-out system at the meter's inlet if required. Power can be adapted from an external plant source to a solar rechargeable system. Communications are adaptable from customer SCADA systems to a cellular package with data collected on our IoT platform and viewed via our web portal.

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Ventbusters engaged Tangent Design Engineering to assist with the design modifications required to transition our sophisticated SCVF remediation product, the Ventbuster®, towards the more “simplistic," cost-conscious iteration of the Ventsentinel®.

The objectives of the project are to transition the Ventsentinel® CHOPS product to TRL 9 by completing the following:

1. Re-designing the beta-prototype body/enclosure as an in-line metering device with optimized installation flexibility
2. Update the internal power source and onboard firmware for extended long-life operation if external power sources are not available or practical
3. Obtain Hazardous Area certification for this product architecture
4. Qualify the accuracy and repeatability of the product under a variety of applications and weather conditions
5. Finalize the means to knock-out free liquids entrained in the solution gas at the inlet of the Ventsentinel® while considering maintenance requirements

The Scope of work overview for the project was:

Task 1) Concept Development
Task 2) Alpha Detailed Design
Task 3) Alpha Prototype Fab, Assembly & Test
Task 4) Beta Prototype Design Updates, Fab, Assembly, & Test
Task 5) Design Transfer including Product Regulatory Certification
Task 6) Production Manufacturing with Contract Manufacturer

OUTCOMES AND LEARNINGS

At the end of this project, we produced two commercial Ventsentinel® prototypes, a 1" unit and a 2” unit designed per Husky Oil Operations Limited's requests to have plant power capabilities and SCADA communications.

One of the primary objectives of the project was to obtain Hazardous Area Certification for the Ventsentinel®. Learnings from certifying our Ventbuster® product told us that this could be an extended process; it took almost 18 months to certify the Ventbuster®. We purposely incorporated electronic components consistent with our Ventbuster® to help with Intertek certification testing on the Ventsentinel®.

The certification testing process took from mid-March 2020 until the end of June 2020. A three-and-a-half-month timeframe. We were happy that our difficult learnings from the Ventbuster® project transferred into a much smoother certification for the Ventsentinel®.

We received our Hazardous certification in July 2020 for:

1. VS200 Sentinel Unit: US: Class I Zone 0 Aex ia IIB T3 Ga / Canada: Ex ia IIB T3 Ga / -40°C < Tamb < 55°C
2. VS100 SCADA Unit: US: [AEx ia Ga] IIB / Canada: [Ex ia Ga] IIB / -40°C < Tamb < 55°C / Um = 30VDC.

We also received a working pressure certification of 4960 kPa (720 psi).

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During the initial field site visit and subsequent conversations, Husky personnel requested design specifications for flow of up 1500 m3/day for the 1” unit and 3500 m3/day for the 2” unit with the ability to withstand a pressure of 4960 kPa.

These rates are more indicative of process flow as opposed to typical CHOPS casing head vent flow volumes.

Computational fluid dynamics (CFD) were performed to understand the flow conditioning requirements and the exact directional placement of the sensor in the flow channel. It was found that flow measurements are sensitive to upstream piping and elbow arrangements and that an inclined sensor provided more consistent results for a variety of input flow conditions.

The available calibration equipment can test flow to 500 m3/day. Higher flow calibration would require new equipment to be purchased or specialized laboratory space to be sourced.

After much testing and discussion, the 1500 and 3500 m3/day flow designs were put on hold. These high flow volumes were not in the initial project challenge, and additional funds were not available to continue those specific design evaluations. Through the CFD analysis, we learned that it would be possible to produce a unit that could measure the volumes and withstand the 4960 kPa pressures. Design changes would be required to incorporate flow conditioning hardware to maintain accuracy at the higher flow levels.

The extensive CFD analysis also provided the flow conditioning requirements for the CHOPS expected project volumetric flow ranges of 160 – 500 m3/day.

The Ventsentinel® calibrations were performed using a seamless or “smooth” pipe, 18" on the inlet and a 6” on the outlet. This was the minimum lengths required to retain accuracy.

The ranges, using air, that the Ventsentinel® units have been calibrated to are:

- 1” calibrated 0.6 m3/day (500 std cm3/min) (500 ml/min) – 720 m3/day (500 std L/min)
- 1” upper limit projected is 1200 m3/day (830 std L/min)

- 2” calibrated 7.2 m3/day (5000 std cm3/min) (5000 ml/min) – 720 m3/day (500 std L/min)
- 2” upper limit projected is 6000 m3/day (4170 std L/min)

We are equipment limited for calibrating the higher ranges at this time, but as indicated above, we anticipate obtaining a much higher upper flow limit.

One of the riskiest experimental portions of the Ventsentinel® design was finding the proper encapsulant for the electronics that could meet the conditions outlined in the Standard for Requirements for Process Sealing Between Electrical Systems and Flammable or Combustible Process Fluids, UL122701, while also providing a pressure seal for 4960 kPa. Multiple samples were trialed before a specific Key Polymer Tough Seal encapsulant was chosen to withstand a full 150 thermal and pressure cycles of Tangent testing. Intertek performed further extreme testing before issuing the UL 122701:2017Ed.3 certification.

In mid-June of 2021, our first 1" Ventsentinel® unit was installed on a Legacy Husky site near Lloydminster, Alberta. Disappointingly, the well then had some issues with broken rods. Once a rig was able to fix the well, the equipment was reinstalled, and our first data was received in mid-August.

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The field trial involved the installation of a Calscan Hawk 9000 (the Hawk 9000) upstream of our Ventsentinel® as a control unit.

In the first data report from Husky, on August 16, 2021, they noticed a difference in flow rates, “the Ventsentinel® is reading roughly 0.970 e3m3/day, and the Hawk 9000 is reading around 0.650 e3m3/day.” We are thrilled to see how well the data is tracking from these two very different meters for a flow volume above our calibrated range in our commercial prototype unit.

The 0.32e3m3/day flow difference can likely be explained by the technology that is intrinsically different to both meters. The Hawk 9000 is a differential pressure (DP) meter. With all positive displacement (PD) or DP gas meters, a gas stream must have a sufficient volume and be under sufficient pressure to overcome the mechanical resistance of these metering devices. As a result, the first indication of flow does not occur until the mechanical resistance can be overcome with enough velocity generated within the gas stream. Thus, there is never an accurate measurement of first induced flow, rather an empirical estimation of what that may be before the meter can read the flow rate.

The Ventsentinel® is based on thermal mass technology with a surface sensor that can measure true zero flow and precisely detect and measure the actual first flow. The units are designed to flow through 1" or 2 " diameter with virtually no backpressure. As such, the Ventsentinel® often measures higher volumes of gas than conventional gas meters. Future impartial third-party testing by InnoTech should provide a good examination and explanation of the difference in flow measurements we are seeing.

The trial was to run both units for a couple of months and then remove the Hawk 9000 to see if it was causing any turbulence to the flow for the Ventsentinel®. As of this report, both units are still installed.

** PLEASE SEE THE ATTACHED PICTURES (FIGURES 1-4) AND DATA GRAPH, IN THE ATTACHED APPENDIX.*

GREENHOUSE GAS AND NON-GHG IMPACTS

In Alberta, Regulators estimate that 15.0 MMTCO2e annually are vented to the atmosphere from the oil and gas industry. Of that amount, 12.0 MMTCO2e annually have been attributed to heavy oil production. Our technology provides continuous, real-time quantification of venting methane to establish a baseline of actual GHG emissions. The Ventsentinel® empowers the industry with the tool to meet existing and future regulatory requirements around reducing GHG emissions. Because the Ventsentinel® can quantify emissions, it can enable industry producers to generate emission offset credits and provide an economic incentive to reduce emissions and lead to clean technology projects that otherwise would not occur. The Ventsentinel® – CHOPS Series gas meter offers increased profitability and operational excellence with its analytics for a better understanding and optimization of solution gas recovery, to help reduce up to 12.0 MMTCO2e emissions annually and streamline regulatory compliance.

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OVERALL CONCLUSIONS

We received some constructive feedback from an independent third party, Justin Engel, Senior Programmer with Blade Automation.

Husky hired Justin to deal with an issue with the Scadapack (controller) connected to the Ventsentinel® at the CHOPS well site. “The function block that manages the flow of data to (not from) the Ventsentinel® had lost its configuration and needed to be rebuilt. This issue had nothing to do with the Ventsentinel® and was purely a logic issue on the Scadapack.”

His feedback continued with, "As a side note, I feel you have a great product that could be a great success with a better User Interface (UI) and some lipstick on the physical meter itself.
With respect to my thoughts on the product, please see below.

1. Meter units are in m3/day, and it would be beneficial to adjust that and have the default units in dekatherm/day.
2. The meter configuration uses a Bluetooth interface, and it would be nice to see the addition of a hardwired configuration port and a better UI (tailored to the Ventsentinel®) to make the configuration changes regardless of Bluetooth or hardwired."

The basic design for the CHOPS project works. We still have work to do to bring the calibration process into mass manufacturing cost-effectiveness. We feel that this is the biggest hurdle to overcome in getting the product to the commercial market.

SCIENTIFIC ACHIEVEMENTS

There is a US patent pending on the Ventsentinel® technology. During this project, the Ventsentinel® name acquired Registered status in both Canada and the United States.

NEXT STEPS

There has been an incredible amount of interest in the Ventsentinel® technology.

In-depth conversations with Spartan Controls resulted in their commissioning of 10 Ventsentinel® units; 5 - 1" units and 5 – 2" units. With their help, we have negotiated a field trial project with PTAC and CanERIC. Through the CanERIC trials, third-party testing will be undertaken by Innotech Alberta in Edmonton and CMC Research Institute field facility in Brooks. Cenovus Energy and Bonavista Energy will provide facilities for storage tank measurements, and Cenovus has a compressor seal testing project to begin in October. Field testing will be undertaken by GreenPath Energy and overseen by Spartan Controls. Results from the CHOPS field trial will also be included in the CanERIC trials.

Micro Motion, a corporation under Emerson, is currently testing a 1" and 2” unit in their Colorado facility. They do not have technology in their portfolio with the turndown ratio that the Ventsentinel® product has. Spartan Controls tested both a 1" and 2" Ventsentinel® unit in their Edmonton facility. They tested each unit against three coriolis meters for accuracy and still could not reach the low-end flow volumes that the Ventsentinel® can measure. The incredible turndown ratio and accuracy are what has Spartan Controls and Micro Motion very interested in getting this technology to market.

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Vertex, TC Energy, Tundra Process Solutions, Reliance Oil Field Services, and Radicle Balance are some of the other big names that are waiting for testing to be completed and the product brought to market.

We are working with IRAP to undertake a mass calibration project. Currently, it takes over 24-hours to calibrate a unit. We believe that this process can be streamlined and will develop a viable system for fully calibrating Ventsentinel® units in anticipation of volume manufacturing. The Ventsentinel® product will be price-sensitive, and current calibration methods are not cost-effective.

As field testing progresses and we receive feedback, commercial manufacturing plans will be developed. We feel that our core technology is unique, and there is an urgency to get it to market both for our business growth and for the industry to have a product available so they can be compliant with impending regulations.

COMMUNICATION PLAN

We have not done any communication about the project. We hope that our company will receive recognition for being the successful applicant to the AI CCITF Clean Technology Commercialization – Husky CHOPS Methane Challenge, and we would like to promote and celebrate the completion of this project.

We have developed a technical spec sheet for the Ventsentinel® product, which is only being distributed to interested parties at this time. Once field trials have been successful and we move towards manufacturing, we will develop a product section on our current website, www.ventbusters.com, and allow access to download the tech sheet.

We will make announcements on LinkedIn as the product nears market availability. We also have plans of joining with our bigger customers to make announcements as we reach distribution agreements. Communication will also proceed with the help of CanERIC and PTAC once further trials are completed.

CONFIDENTIAL INFORMATION

Please see attached documents in Appendix.

APPENDIX

1. FIGURES

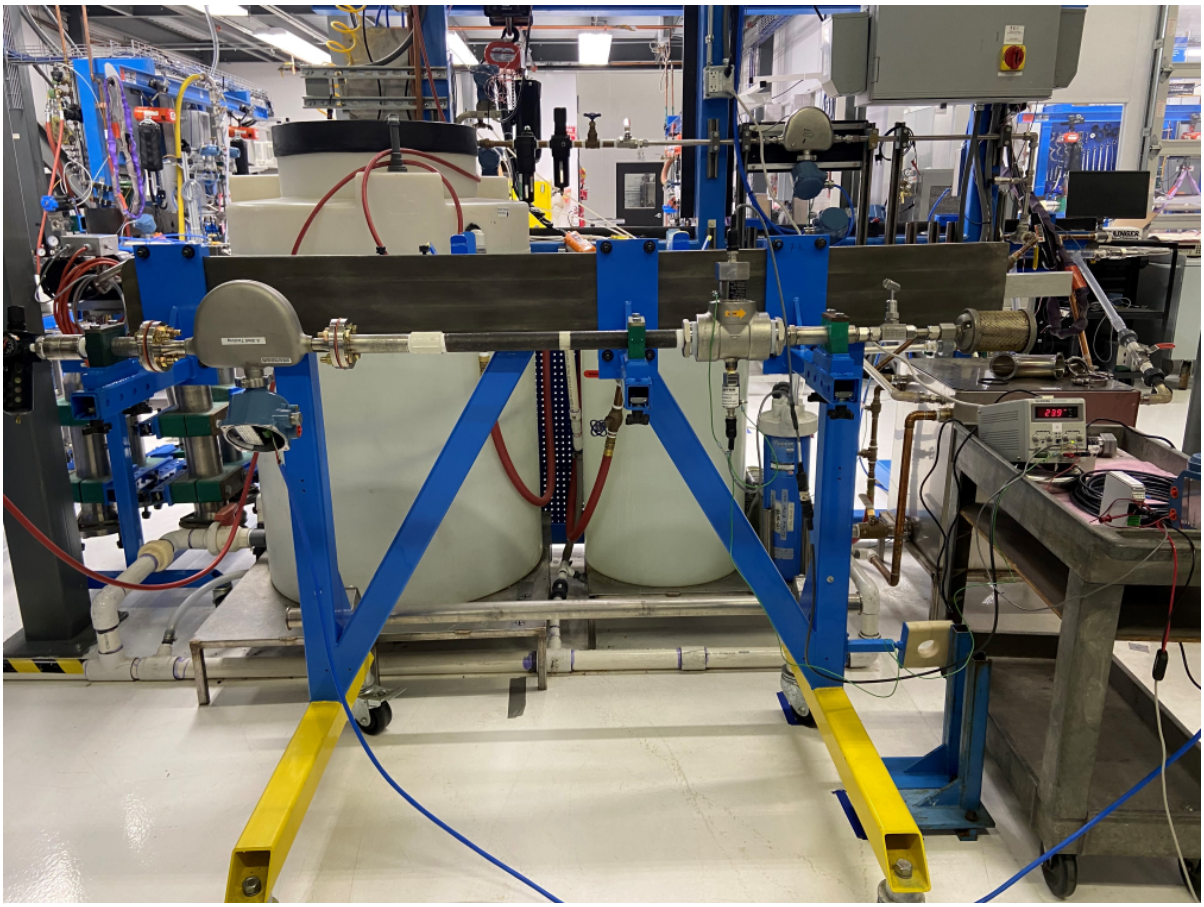

Figure 1. Prototype testing, in shop environment.

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Figure 2. Ventsentinel® unit, field trials.

Figure 3. SCADA Pack, attached to wellsite power source, field trials.

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Figure 4. Ventsentinel® unit, field trails, close-up on the unit attachment to line.

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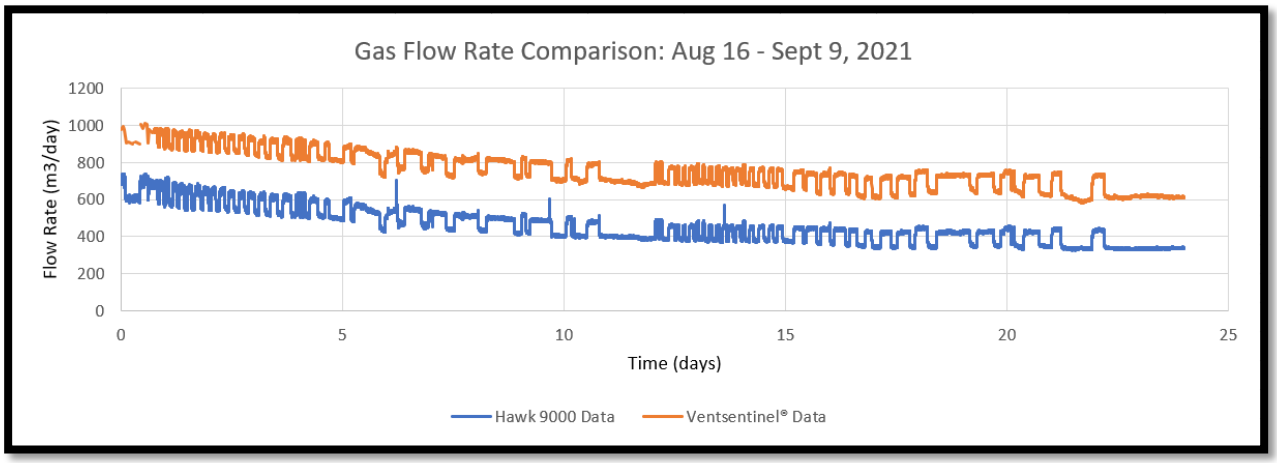
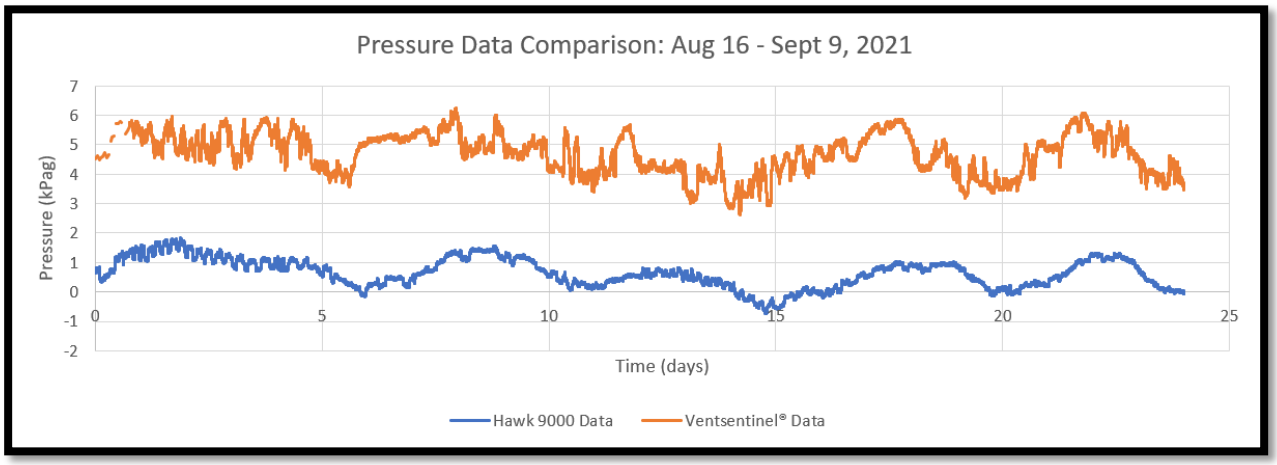
2. GRAPHS

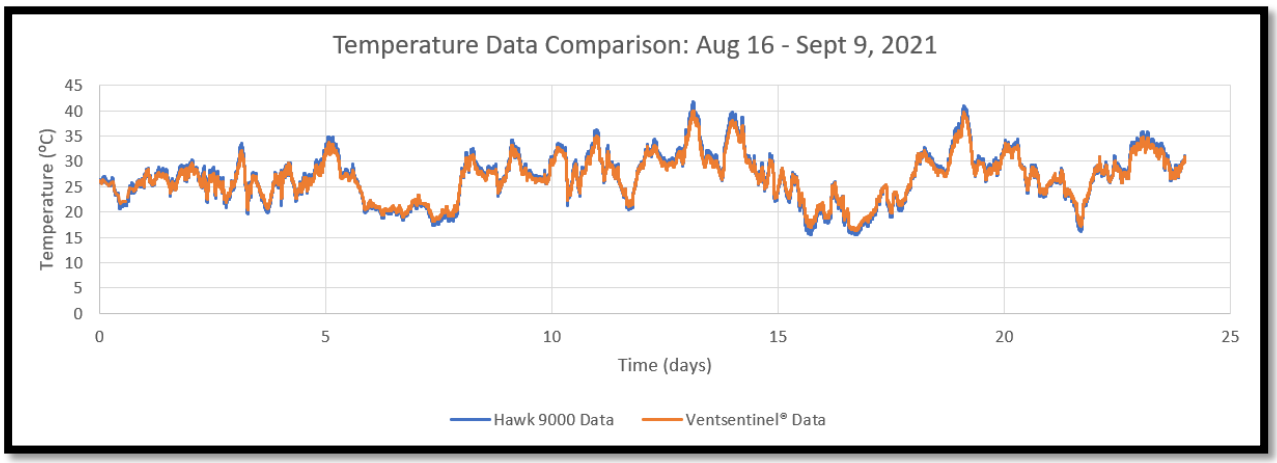
1" Ventsentinel® CHOPS Unit Prototype Field Trial

Legacy Husky Site: LSD 04-31-048-04W4M

Ventsentinel® Solution Gas measurement Data in comparison with HAWK 9000







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