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CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	**Catalytic Oxidizer Performance Test**
Alberta Innovates Project Number:	N/A
Submission Date:	March 31, 2022
Total Project Cost:	$184,584.14
Alberta Innovates Funding:	$90,929.27
AI Project Advisor:	N/A

2. APPLICANT INFORMATION:

Applicant (Organization):	**Saskatchewan Research Council**
Address:	Bay 2D, 820 51st Street East, Saskatoon
Applicant Representative Name:	Erin Powell
Title:	Manager, Process Development
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Email:	Erin.powell@src.sk.ca

3. PROJECT PARTNERS

Please provide an acknowledgement statement for project partners, if appropriate.

RESPOND BELOW

The authors would like to express their gratitude to Metan and ETTER Engineering for their technical assistance throughout the project. Financial assistance provided by PTAC, NRCan, and Alberta Innovates, via CanERIC, and by the government of Saskatchewan are also gratefully acknowledged.

A. EXECUTIVE SUMMARY

Provide a high-level description of the project, including the objective, key results, learnings, outcomes and benefits.

RESPOND BELOW

While the use of catalytic type heater pads is not new in the oil industry, the use of those catalytic pads to mitigate Surface Casing Vent Flows (SCVF) has not been tested before. This project was intended to test the robustness of this technology's ability to destruct methane and to test the durability of the design and operation of this technology on an actual SCVF.

SRC, on behalf of the CanERIC consortium, measured the destruction efficiency of a Metan catalytic methane abatement system. The project was split over two phases – the first phase consisted of lab testing to measure the methane destruction efficiency under controlled conditions. The second phase took place at a suspended well site to test methane destruction efficiency in a real-world setting.

For the first phase of this project, SRC installed a catalytic methane abatement system CMAS-1M unit at its Pipe Flow Technology CentreTM in Saskatoon. The flowrate of gas into the unit was varied across the operating range of the technology: high (10 m3/d), low (4 m3/d), and mid-range (7 m3/d). The concentration and flowrate of the exhaust gases were measured at each inlet flowrate, and the destruction efficiency of the unit calculated. Destruction efficiencies achieved in the laboratory testing ranged from 68% to 88%.

In Phase 2, SRC provided independent third-party field testing of the CMAS-1S catalytic combustor in a field setting. The field test took place at a suspended well site in Alberta. Although the unit operated at sub -30°C temperatures, due to delays installing the equipment the destruction efficiency field tests were completed in late Feb 2022 when the weather had warmed significantly. The unit was tested at a

maximum (3.4 m3/d), mid-point (2.4 m3/d), and minimum (1.4 m3/d) throughput rates. Methane destruction efficiencies during testing ranged from 78% to 94%.

B. INTRODUCTION

Please provide a narrative introducing the project using the following sub-headings.

- **Sector introduction:** Include a high-level discussion of the sector or area that the project contributes to and provide any relevant background information or context for the project.
- **Knowledge or Technology Gaps:** Explain the knowledge or technology gap that is being addressed along with the context and scope of the technical problem.

RESPOND BELOW

Some operating and suspended oil and gas wells can have surface casing vent flows (SCVF) where methane is released from the annulus between the production casing and the surface casing. While SCVFs are allowed while the wells are producing or suspended, they must be repaired at the time of abandonment, with the allowable flowrate dependent on the jurisdiction of operation. Methane is at least 25 times more potent as a greenhouse gas than CO2 on a 100-year timeframe. This proposed project was to see if SCVF methane could be converted into CO2 to lessen the impact of the greenhouse gas potential of SCVFs and to explore this solution (of converting methane to CO2) as an acceptable mitigation method for large SCVFs that are above the jurisdiction maximum SCVF threshold.

When SCVFs are present, the amount of methane flowing is typically lower than production casing gas flow. As such, the flowrates in SCVF are usually not high enough for those vents to be tied into typical methane destruction devices such as flares, combustors, or methane internal combustion engines. Metan, in conjunction with ETTER Engineering, have developed a catalytic oxidizer system, which is meant to handle methane flowrates as low as 1.4 m3/day up to 25 m3/day. The units are scalable to handle larger flow volumes by adding more modular units to satisfy the demand. It is similar to a catalytic heater pad, such as platinum catalyst pad, used to convert methane into CO2 at low temperatures (~200°C). The catalytic heater is rated for Class 1 Div. 1 operation and the unit has been mounted in a weatherproof enclosure. The unit operates in the same manner as a typical catalytic heater in that electric heat is applied (via a 12-volt truck battery or portable generator) to the unit during the startup sequence to preheat the catalyst. Once the catalyst has been heated for a minimum of 15 minutes, gas is introduced, and the catalyst retains enough heat to sustain the oxidization process without an external electrical heat source.

While the use of catalytic type heater pads is not new in the oil industry, the use of those catalytic pads to mitigate SCVF has not been tested before. This project was intended to test the robustness of this technology's ability to destruct methane and to test the durability of the design and operation of this technology on an actual SCVF.

SRC, on behalf of the CanERIC consortium, measured the destruction efficiency of a Catalytic Methane Abatement System (CMAS). The project was split over two phases – the first phase consisted of lab testing to measure the methane destruction efficiency under controlled conditions. The second phase took place at a suspended well site to test methane destruction efficiency in a real-world setting.

Please provide a narrative describing the project using the following sub-headings.

- **Knowledge or Technology Description:** Include a discussion of the project objectives.
- **Updates to Project Objectives:** Describe any changes that have occurred compared to the original objectives of the project.
- **Performance Metrics:** Discuss the project specific metrics that will be used to measure the success of the project.

RESPOND BELOW

C. PROJECT DESCRIPTION

1. PROJECT DESCRIPTION:

In Phase 1, SRC installed a catalytic methane abatement system CMAS-1M unit at its Pipe Flow Technology Centre™ in Saskatoon. The flowrate of gas into the unit was varied across the operating range of the technology: high, low, and mid-range. The concentration and flowrate of the exhaust gases were measured at each inlet flowrate, and the destruction efficiency of the unit calculated.

In Phase 2, SRC provided independent third-party field testing of the CMAS-1S catalytic oxidizer in a field setting. The field test took place at a suspended well site in Alberta. Although the field validation was originally planned to test the unit at sub -20°C temperatures, a series of setbacks pushed the field test into late Feb 2022 when the weather had warmed significantly.

2. PROJECT OBJECTIVES

The originally proposed objectives of this project were to test the methane destruction efficiency and cold-weather performance of Metan/ETTER's catalytic oxidizing technology. With the rapidly warming temperatures experienced while preparing for the field test, the second objective was modified to test the destruction efficiency and operability of the unit in a real-world field installation.

3. PERFORMANCE METRICS:

Accurate destruction efficiency calculation requires both gas flowrate and composition. The parameters measured at each flowrate, and required instrumentation are listed below.

- Inlet gas flowrate – measured by diaphragm gas flowmeter
- Exhaust gas flowrate – measured by anemometer
- Inlet gas composition – gases sampled and measured by gas chromatography (GC)
- Exhaust gas composition – gases sampled and measured by GC
- Exhaust gas moisture content – measured separately, as the GC requires dry gas
- Inlet gas temperature – measured by thermocouple
- Inlet gas pressure – measured by 0-7-inch water column pressure gauge
- Exhaust gas temperature - measured by thermocouple
- Atmospheric pressure – as reported by weather monitoring station

D. METHODOLOGY

Please provide a narrative describing the methodology and facilities that were used to execute and complete the project. Use subheadings as appropriate.

RESPOND BELOW

4. PHASE 1:

SRC installed a catalytic methane abatement system CMAS-1M unit at its Pipe Flow Technology Centre™ in Saskatoon. Catalytic heaters were already installed in a section of the facility rated for handling volatile materials, the Shook-Gillies High Pressure High Temperature Facility. A natural gas line from one of these existing units was diverted to the CMAS-1M test unit. Required instrumentation was installed upstream. The instrumentation required (valve, volumetric gas meter, thermocouple, pressure gauge, sample port) was installed upstream of the oxidizer orifice of the CMAS unit. See diagram in Figure 1.

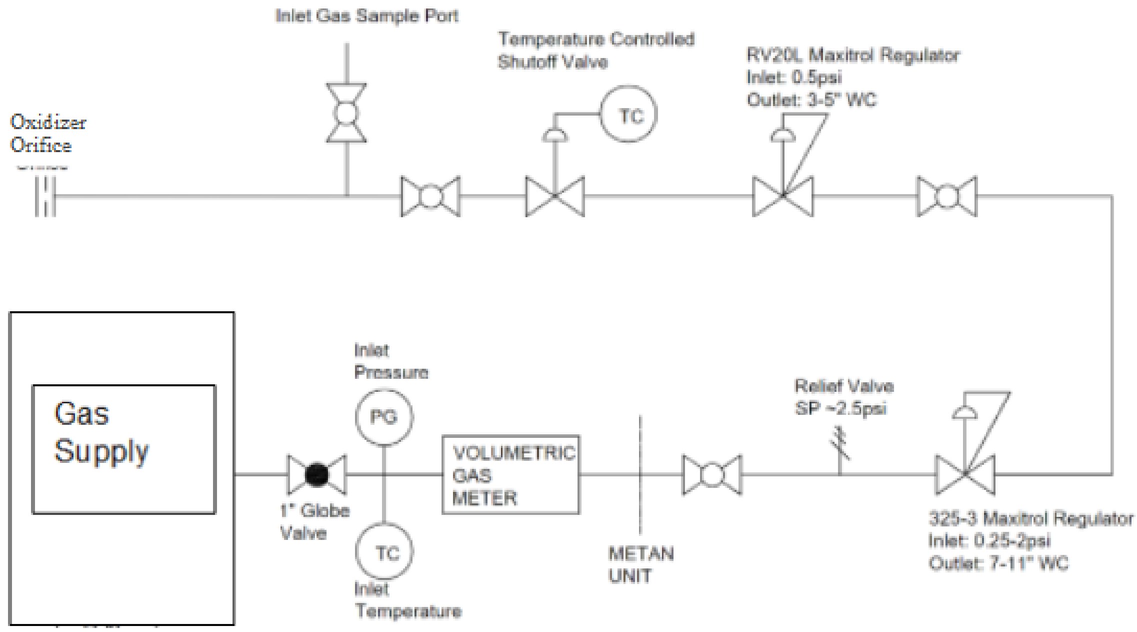

Figure 1: Original Equipment Configuration (runs 1-3)

Following the first series of experiments, some changes were made to the apparatus. Specifically, the natural gas source was replaced with a cylinder of high-pressure laboratory grade methane and regulated down to 15 psi. See diagram in Figure 2.

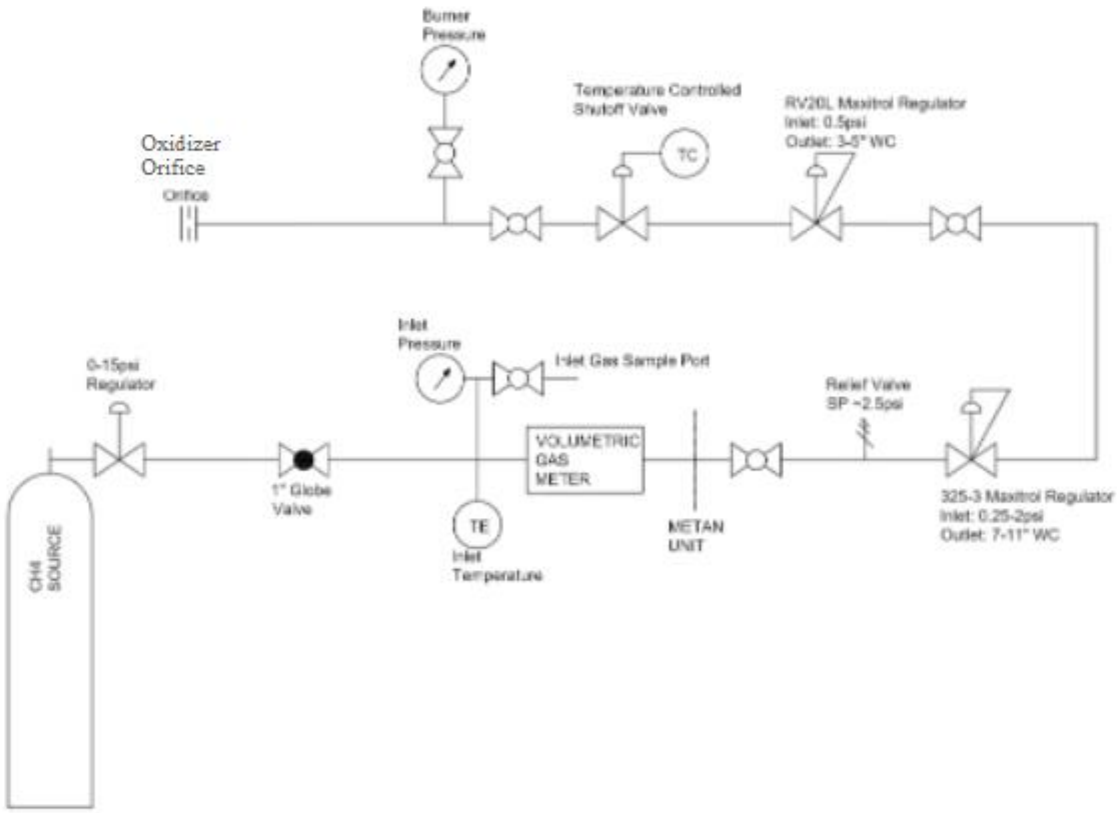

Figure 2: Configuration during runs 4-6

5. PHASE 2:

An industry partner provided a site for the required field work. It had the following characteristics:

- The flow of associated gas at the site was >3.4 m3/day
- The CMAS-1S was installed on site prior to SRC arrival.
- Power was not available on this site. Instead, SRC provided a generator to power the required instrumentation.

Figure 3: Metan CMAS-1S Catalytic Combustor at the Field Test Site

E. PROJECT RESULTS

Please provide a narrative describing the key results using the project's milestones as sub-headings.

- Describe the importance of the key results.
- Include a discussion of the project specific metrics and variances between expected and actual performance.

RESPOND BELOW

6. PHASE 1 RESULTS:

A project kick-off meeting was held Sept 24, 2020. In October, SRC received the CMAS-1M catalytic methane abatement unit from Metan and installed it at their Pipe Flow Technology Centre™ in Saskatoon. A natural gas supply line was diverted from an existing catalytic heater to the CMAS-1M test unit.

The first set of experiments, runs 1-3, were conducted in November 2020. Flowrate was varied by adjusting the pressure drop across a globe valve and measured by the meter. Inlet and exhaust gasses were sampled using an Iron Lung and stored in Tedlar bags for analysis by gas chromatography at SRC's Petroleum Analytical Laboratory. Results from the Phase 1 tests are summarized in Table 1:

Table 1: Methane Destruction Efficiency for Runs 1-3

		Run 1		Run 2		Run 3	
Methane Balance	Units	In	Out	In	Out	In	Out
Flowrate	m^3/h	0.41	129.94	0.33	122.73	0.16	85.46
Composition	vol %	92.21	0.08	92.48	0.054	93.38	0.054
Flowrate methane	m^3/h	0.38	0.10	0.31	0.066	0.15	0.05
Density methane	kg/m^3	0.6649	0.5268	0.6694	0.5340	0.6745	0.5945
Mass Flowrate methane	g/h	249.35	52.58	204.67	35.30	100.70	27.23
Destruction Efficiency	%	78.92		82.75		72.96	

Regulatory requirements for destruction efficiency vary by jurisdiction, but in Alberta the requirement is >95%. Although the catalytic oxidizer used in the Metan CMAS-1M unit had achieved >95% destruction efficiency in earlier laboratory testing with ETTER, it only achieved results of 73-83% during the first phase of testing at SRC. In consultation with Metan and ETTER, the authors postulated that the lower-than-expected efficiency may have been caused by the low inlet pressure to the unit. The addition of a valve, meter, and instrumentation caused significant pressure drop on the gas pipeline, and the resulting inlet pressure was well below the required 0.25 psi.

A second round of lab experiments were conducted in January 2021 using a high-pressure cylinder to supply methane gas. Flow was controlled using the RV20L regulator built into the Metan unit and measured using the same diaphragm meter described previously. The results are summarized in Table 2:

Table 2: Destruction Efficiency for Experiments 4-6

		Run 4		Run 5		Run 6	
Methane Balance	Units	In	Out	In	Out	In	Out
Flowrate	m3/h	0.42	134.05	0.29	119.43	0.17	94.52
Composition	vol %	99.94	0.11	99.94	0.099	99.94	0.029
Flowrate methane	m3/h CH4	0.42	0.14	0.29	0.118	0.17	0.03
Density methane	kg/m3	0.7504	0.5257	0.7345	0.5606	0.7603	0.5937
Mass Flowrate methane	g/h CH4	316.98	75.95	210.83	66.11	129.55	16.15
Destruction Efficiency	%	76.04		68.64		87.53	

Results for the second set of experiments were similar to those achieved in the first round of lab testing. The measured methane destruction efficiency was still below that required by Alberta regulators, i.e., 95%.

Following the lab test, the CMAS-1M unit was returned to Metan/ETTER Engineering for inspection. It was found to be free from damage that could have impacted performance. The project team made the decision to continue to pursue field testing (Phase 2) with a smaller unit, the CMAS-1S.

7. PHASE 2 RESULTS:

The Metan CMAS-1S catalytic methane abatement unit was installed on the casing gas vent of a suspended well in the Bonnyville area. SRC travelled to the field test site the week of Feb 28-March 4 with their Centre for the Demonstration of Emissions Reduction (CeDER) trailer to perform methane destruction efficiency testing. During testing, the CMAS-1S unit's throughput was varied by altering the flowrate of associated gas into the unit, using the built in RV20L regulator. Samples of the inlet and exhaust gases were taken, and process variables recorded at each flowrate. The summarized results of these tests are provided in the following tables.

Table 3: Field Test Destruction Efficiency

		Run F1		**Run F2**		**Run F3**	
Methane Balance	Units	In	Out	In	Out	In	Out
Flowrate	m^3/h	0.12	56.62	0.078	70.27	0.046	48.01
Composition	vol %	96.43	0.0236	96.71	0.0078	96.71	0.0224
Flowrate methane	m^3/h	0.12	0.0134	0.075	0.00549	0.044	0.0108
Density methane	kg/m^3	0.71462	0.59817	0.73859	0.63296	0.75106	0.66524
Mass Flowrate methane	g/h	83.82	7.99	55.52	3.48	33.13	7.16
Destruction Efficiency	%	**90.47**		**93.74**		**78.39**	

The exhaust compositions for run F-1 (3.4 m3/d) and Run F-3 (3.4 m3/d) are very similar, while the methane % is lower and the flowrate higher for Run F-2 (2.4 m3/d). There was a fair bit of wind during the second day of testing, which increases both the excess air passing through the unit and the flowrate measured by the anemometer. By the time of run F-3, the technologist had set-up a wind break by the exhaust port to reduce interference from the wind.

The CMAS-1S unit achieved methane destruction efficiencies between 78% and 94% over its operating range during the field test. Results achieved in Phase 2 were similar to those recorded during Phase 1, lab testing. The measured methane destruction efficiency was still below that required by Alberta regulators, i.e., 95%, but at a level reasonable for applications in both Saskatchewan, which regulates combustors based on minimum exit temperature and minimum heating value, and BC, which regulates based on overall site emissions.

Additional samples of the inlet and exhaust gas for each run were sent to Innotech Alberta for VOC analysis. The results are presented in Table 4.

Table 4: Field Test VOC Levels

	Benzene	Ethylbenzene	m,p-Xylene	o-Xylene	Toluene
Run	ppbv	ppbv	ppbv	ppbv	ppbv
F-1- Inlet	50.9	7.43	5.78	1.92	9.64
F-1- Exhaust	0.43	0.13	0.23	0.16	0.17
F-1- Exhaust	0.51	0.22	0.33	0.21	0.24
F-2- Inlet	49.1	7.61	5.10	1.71	9.96
F-2- Exhaust	0.36	0.18	0.28	0.18	0.17
F-2- Exhaust	0.32	0.17	0.29	0.19	0.28
F-3- Inlet	49.3	6.95	4.53	1.64	9.25
F-3- Exhaust	0.34	0.18	0.14	0.06	0.15
F-3- Exhaust	0.19	0.12	0.22	0.15	0.17

VOC content of the inlet gas remained steady during the test period. Exhaust samples during each test were performed in duplicate to provide redundancy. Exhausted VOCs were below 1 ppb in all cases.

F. KEY LEARNINGS

Please provide a narrative that discusses the key learnings from the project.

- Describe the project learnings and importance of those learnings within the project scope. Use milestones as headings, if appropriate.
- Discuss the broader impacts of the learnings to the industry and beyond; this may include changes to regulations, policies, and approval and permitting processes

RESPOND BELOW

8. LEARNINGS FROM THE FIELD SETUP:

- When mating the Metan unit to a surface casing vent, surface casing flow may need to be held back via a pressure regulator to ensure the Metan unit has sufficient gas flow once in operation. As we saw in the initial configuration, piping pressure went to zero once the Metan unit was started up, possibly causing the Metan unit to shut down on low inlet gas pressure
- While the Metan unit is meant to be very basic in nature as most of these well sites do not have electricity at them, the Metan unit does not have an indication on it to show whether it is operating. During the field testing, the field operator was using a temperature gun to check whether hot gases

were coming out of the exhaust to know whether the unit was running. It was suggested to Metan that they add an exhaust temperature gauge on the exhaust outlet and perhaps a water column pressure gauge between the Baso valve (thermocouple valve) and the catalytic oxidizer pad to know whether gas is flowing into the unit.

- The electric cables that were supplied with the unit were very short and would not meet the requirements for Class 1 Div 1 service based on their length. During the test, a gas tester was used to ensure methane concentrations were below the lower explosive limits prior to startup. It is recommended that electric start up cables need to be longer to meet Class 1 Div 1 requirements.
- The threaded connections on the thermocouple were loose (likely from shipping), which may have not allowed the Baso valve to stay open. It is recommended to either add a locking nut or thread locker to ensure that the nuts do not loosen off.
- The legs of the Metan unit are equipped with mounting bracket holes to allow for the unit to be mounted to structures. It is recommended that the installation, operation, and maintenance manual mention that the bottom of the unit must be free of any obstructions due to the air intake and be mounted to either a structure or additional legs to ensure no obstruction such as snow.

G. RECOMMENDATIONS AND NEXT STEPS

Please provide a narrative outlining the next steps and recommendations for further development of the technology developed or knowledge generated from this project. If appropriate, include a description of potential follow-up projects. Please consider the following in the narrative:

- Describe the long-term plan for commercialization of the technology developed or implementation of the knowledge generated.
- Based on the project learnings, describe the related actions to be undertaken over the next two years to continue advancing the innovation.
- Describe the potential partnerships being developed to advance the development and learnings from this project.

RESPOND BELOW

9. RECOMMENDATIONS:

- The electric cables that were supplied with the unit were very short and would not meet the requirements for Class 1 Div 1 service based on their length. During the test, a gas tester was used to ensure methane concentrations were below the lower explosive limits prior to startup. It is recommended that electric start up cables be lengthened to meet Class 1 Div 1 requirements.

- The threaded connections on the thermocouple were loose (likely from shipping), which may have not allowed the Baso valve to stay open. It is recommended to either add a locking nut or thread locker to ensure that the nuts do not loosen off.
- The legs of the Metan unit are equipped with mounting bracket holes to allow for the unit to be mounted to structures. It is recommended that the installation, operation, and maintenance manual mention that the bottom of the unit must be free of any obstructions due to the air intake and be mounted to either a structure or additional legs to ensure no obstruction such as snow.
- The unit does not have any indicators of whether it is operating. It is recommended that either an exhaust temperature gauge or water column gauge (between the Baso valve and the catalytic pad) are installed to allow for some sort of indication.

10. COMMENTS FROM METAN & ETTER

ETTER is working with the field test unit installers and operators to gather further feedback for design enhancements and include installation, startup, and ease of operations.

ETTER is continuing work on further testing lab units and enhanced catalyst technology to improve the destruction efficiency of methane and expand the technology further.