CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	Clean Combustion Technology Showdown Phase 2
Emissions Reduction Scope/Description:	Methane in waste vent gas
Applicant (Organization):	Saskatchewan Research Council
Project Completion Date:	March 2023

2. EXECUTIVE SUMMARY:

The Saskatchewan Research Council (SRC) completed a showdown of enclosed combustors installed in difficult methane mitigation applications. SRC visited three sites with existing enclosed combustors treating low-pressure, intermittent, tank and pneumatic vents, measured process parameters into and out of the units, determined their methane destruction efficiencies, and collected qualitative information on the installations. Enclosed combustors mitigate waste methane sources from the oil and gas industry. They help to achieve carbon reduction goals at existing and new, remote upstream oil and gas sites. Low pressure, intermittent, fluctuating sources such as atmospheric tank and pneumatic equipment vents are especially challenging to mitigate. Field testing demonstrates that enclosed combustors are effective at mitigating these sources of methane. Methane destruction efficiencies were calculated from field-testing measurements at three enclosed combustor installations and found to be well above 95% (measured destruction efficiencies were 98 to 100%). Economic analysis indicates that enclosed combustors are an appealing methane abatement option.

3. KEY WORDS

Enclosed combustor, tank venting, pneumatic venting, methane mitigation

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4. APPLICANT INFORMATION:

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5. LEAD CONTRIBUTING PARTNER INFORMATION:

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Title:	

6. PROJECT PARTNERS

Funding for this project is made possible through PTAC's CanERIC program, funded by Alberta Innovates and NRCan, and by the Saskatchewan Ministry of Energy and Resources, and Innovation Saskatchewan. In-kind contributions are provided by Bonavista Energy, Tourmaline Oil through NGIF ETC Program, Westbrick Energy, Clear Rush Co., Emission Rx/ EnviroVault, and the Saskatchewan Research Council (SRC).

SRC gratefully acknowledges the help and in-kind contributions, coordination and field support provided by Bonavista Energy, Tourmaline Oil, Westbrick Energy, Clear Rush Co., and Emission Rx/Envirovault during testing.

A. INTRODUCTION

In April 2022, SRC completed a scoping study for a possible demonstration of combustion technology (CanERIC Combustor Scoping, available online at https://www.cerinprojects.ca/report). This study found that although enclosed combustors and incinerators do not eliminate greenhouse gas emissions, they provide an option of reducing methane, especially for existing sites. Also, with higher methane destruction efficiency and fewer flame-outs, enclosed combustors and incinerators are possibly more effective at mitigating methane than flare stacks. The flames in enclosed combustors and incinerators devices are hidden, reducing nuisances for nearby stakeholders. Other advantages, described in the scoping study, are that enclosed combustors and incinerators lower volatile organic carbon (VOC) and hydrogen sulphide (H_2S) emissions, have low installed costs, have reduced footprints, and mitigate cycling waste gas streams. As well, enclosed combustors and incinerators can be installed alongside other treatment options, as a secondary means of treating methane emissions at both new and existing sites. Enclosed combustors in particular have versatile designs, as it is easy to change out burners, move the units from site to site, or install several units in parallel.

In addition, the scoping study concluded that a technology showdown project would help to close gaps which are inhibiting deployment of enclosed combustors and incinerators. There are knowledge gaps on the design features and carbon abatement costs of difficult waste gas applications such as low-pressure, intermittent, tank and pneumatic vents. Currently, there are many enclosed combustors and incinerators treating larger vent streams at upstream oil and gas sites such as waste casing gas from oil wells. It is more difficult to treat low-pressure and intermittent flowrates from tank and pneumatic vents, and there are fewer enclosed combustors for these applications.

As recommended by the scoping study, this project conducted a combustion technology showdown, where three existing enclosed combustor installations were field-tested. Each installation is at a separate site, owned and operated by different producers, for the purpose of mitigating methane. In alphabetical order, the producers that volunteered sites are Bonavista Energy, Tourmaline Oil, and Westbrick Energy. All three units are installed on difficult methane mitigation applications, treating pneumatic and/or tank vents.

B. METHODOLOGY

Two SRC technologists traveled to the sites of three existing enclosed combustor installations to carry out consecutive field testing, from March 6th to March 10th, 2023. Prior to testing, Clear Rush Co. and Envirovault/ Emission Rx assisted with the fabrication of stack extensions with sample ports on each device. Stack sample ports are installed at 90 degrees to each other so that velocity and stack gas composition can be measured at various points along the cross-section of the stack. Three different oil and gas producers (Bonavista Energy, Tourmaline Oil, and Westbrick Energy) volunteered their sites, as well as resources to coordinate stack extension installation and field testing. Enclosed combustor original equipment manufacturers (OEM's) Clear Rush Co. and Emission Rx/EnviroVault assisted in the showdown by contributing knowledge and expertise, providing stack extensions with sample ports, transporting the stack extensions to the field, and participating in set-up, testing, and take-down.

Each device was tested at its existing load condition, as found on the day of the test. The results are used to determine the methane destruction efficiency of the units. Information on the ease of operability, safety, design features, and economics are also collected.

In no particular order, are photos of each of the three test sites during field-testing:

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Fig. 1— Field-testing site, Emission Rx Unit

Fig. 2 — Field-testing site, Clear Rush Co Unit

Fig. 3 — Field-testing site, Clear Rush Co Unit

C. PROJECT RESULTS AND KEY LEARNINGS

Measured Inlet and Outlet Parameters

The enclosed combustors were tested at their existing conditions. There was minor variability in the process parameters over the duration of each field test. Flowrate to the combustors did not exhibit cycling flow. There was no evidence of the burner control systems of the combustor units shutting off the combustors during the testing. The combustors are capable of handling very low inlet pressures, and these ranged from 2.4 to 5.5 kPa_g during the field test (Table 1).

Table 1 — Inlet Gas, Ambient and Outlet Gas Conditions During Combustor Testing

Site	Inlet Gas Pressure (kPa_g)	Inlet Gas Temp. (°C)	Inlet Gas Flowrate (S m^3/d)	Ambient Temp. (°C)	Barometric Pressure (kPa_g)	Exhaust Temp. (°C)	Outlet Gas Flowrate (S m^3/d)
1	5.5	-1.8	161	-9.6	88.3	77.1	177.5
2	2.4	-9.4	30	-13	92.0	25.7	187.1
3	3.9	-10.0	248	-14.5	88.4	381.3	67.4

Methane in the waste gas streams ranged from 78.2 to 88.9% by volume. Methane in the exhaust was extremely low and ranged from 0.00022 to 0.00068 by volume % (2.2 to 6.8 ppm by volume).

Table 2 — Inlet Gas Composition During Combustor Testing

Component	Site 1 (vol%)	Site 2 (vol%)	Site 3 (vol%)
Methane	86.04	88.91	78.24
Carbon monoxide	0.00	0.00	0.00
Carbon Dioxide	0.70	0.69	0.07
Ethene	0.00	0.00	0.00
Ethane	8.06	7.13	9.88
H_2S	0.00	0.00	0.00
Propane	3.39	2.22	7.41
Propene	0.00	0.00	0.00
i-Butane	0.47	0.40	1.02
n-Butane	0.82	0.41	2.02
i-Pentane	0.26	0.12	0.66
n-Pentane	0.22	0.07	0.59
n-Hexane	0.05	0.05	0.11
Total	**100.0**	**100.0**	**100.0**

Methane Destruction Efficiency

For each enclosed combustor, conversion of methane to carbon dioxide and water vapour is nearly complete and well above 95%. Methane destruction efficiency was calculated from the inlet and outlet gas parameters to be 98 to 100% (Table 3). The units demonstrated excellent turn-down capabilities.

Table 3 — Methane Destruction Efficiency during Combustor Showdown

Site	Inlet Methane (kg/h)	Exhaust Methane (vol%)	Outlet Methane (kg/h)	Methane destruction efficiency (%)
1	3.9	0.00023	0.0067	>99
2	0.74	0.00068	0.017	98
3	6.0	0.00022	0.0026	>99

Methane Emissions

An optical gas imaging camera was used to scan for methane emission plumes in the vicinity of the waste gas feed piping and enclosed combustor units at the start of each field test. No emissions from equipment leaks nor pressure-relieving valves were detected. These results indicate that waste gas from the tank and pneumatic vents does not bypass the enclosed combustor units, and that the enclosed combustor units are not over-loaded. A very small plume was observed from the exhaust of each combustor; however, optical gas imaging cameras are poorly suited for observing and measuring methane in hot gases. As per stack testing results, there were very low methane concentrations in the exhaust gas (0.00022 to 0.00068 vol. %).

Other Emissions

Analysis was completed of BTEX components in the exhaust and the results are summarized in **Table 4**.

Table 4— Exhaust Gas BTEX Components

Component	Site 1 (ppb v)	Site 2 (ppb v)	Site 3 (ppb v)
Benzene	6.3	4.6	3.1
Ethylbenzene	0.09	0.29	0.39
m, p-Xylene	0.45	1.2	1.61
o-Xylene	0.19	0.37	0.66
Toluene	2.2	5.5	1.6

Combustion Technology

Table 5 compares the field testing results to other recent CanERIC field testing of units which can combust waste methane at upstream oil and gas sites. The electrical generators included a Stirling Engine, several combined heat and power units, an internal combustion engine, and a microturbine. Oil and gas sites with higher waste gas flows could consider both enclosed combustors and electrical generators in parallel. Sites with lower waste gas flows could consider catalytic combustors in addition to enclosed combustors or electrical generators.

Table 5 — Comparison of Enclosed Combustors to other Combustion Solutions

Technology	Application	Test Runs/unit[1]	Rated Gas Feed rate (S m^3/d)	Methane destruction efficiency (%)	CanERIC Project (footnote reference)
Enclosed combustor	Vents from pneumatic equipment (1st site)	1	1000	>99	Current study
Enclosed combustor	Vents from pneumatic equipment (2nd site)	1	1000	98	Current study
Enclosed combustor	Tank vent	1	500	>99	Current study
Enclosed combustor	Compressor dry gas seal primary vent	2	1000	>99	2
Enclosed combustor	Vents of pneumatically actuated valves	4	500	>99	2
Catalytic Combustor	Surface casing vent flow	3 at field conditions	1.4 to 51	78.39 to 93.74	3
Electrical generators	Temporarily installed for technology testing	2	14 to 449	Over 97% on average	4

D. PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	$139,000 cash; $31,000 in-kind	$40,000 to $50,000
Technology Readiness Level (Start / End):	9	9
GHG Emissions Reduction (kt CH4/yr):	Up to 0.204 kt/yr/combustor	up to 0.204 kt/yr/combustor
Estimated GHG abatement cost ($/kt CH4)	$175,000 to $530,000	$63,000 to $190,000
Jobs created or maintained:		

[1]The unit is tested at a different flowrate in each test run.
[2]Enclosed Combustor Testing at TC Energy, March, 2022, Erin Powell, SRC. www.cerinprojects.ca/projects.
[3]Catalytic Oxidizer Performance Test, March, 2022, Erin Powell, SRC. www.cerinprojects.ca/projects.
[4]Electrical Generation Technology Showdown, June, 2022, Erin Powell, SRC. www.cerinprojects.ca/projects.

E. RECOMMENDATIONS AND NEXT STEPS

The key findings are as follows:

1. Enclosed combustors are commercially-ready option for widespread deployment for difficult methane abatement applications such as low-pressure, intermittent tank and pneumatic vents.

2. Methane destruction efficiencies were calculated from field-testing measurements at three enclosed combustor installations and found to be 98 to 100%.

3. During each combustor test there was minor variability in flowrate, temperature and pressure. There was no evidence of the units cycling on and off.

4. Enclosed combustors are capable of significant turndown and exhibit high methane destruction efficiencies (greater than 95%) even at low flowrates.

5. Enclosed combustor installations should consider including a signal from the burner control panel to a SCADA system to indicate whether the unit is operating.

6. There was no evidence of methane emissions from leaks in the inlet waste gas nor waste gas bypassing the combustor units.

7. At the three field test sites, enclosed combustors were installed to mitigate methane from pneumatic and tank vents, and none of the installations required boosting the vent gas pressure to the combustors. Feed pressures ranged from 2.4 to 5.5 kPa_g (0.35 to 0.80 psi_g).

8. Enclosed combustors have a great deal of design versatility, as they are quick and easy to deploy, they can be moved from site to site, they are available in different sizes, their burner/orifice sizes can be changed, and they can be installed in parallel. Long-term variations in load to the combustor may require system modifications.

9. The units are simple and straightforward to operate, and re-start quickly.

10. Enclosed combustor units and their installations include features for reducing health and safety risks: flame arrestors on the air intake, setback distances from other oil and gas equipment, burner control system with temperature, pressure indication and pressure valves for shutting down the combustor, liquid knockout, and high-pressure protection on feed piping. These features were in place at the three sites of the technology demonstration.

11. Enclosed combustors may be installed along with other methane mitigation options, including electrical generators and catalytic combustors.

12. Enclosed combustors are a relatively inexpensive methane mitigation option. The marginal cost of abatement is expected to be $63,000 to $190,000/kt methane. Pilot gas ignition increases carbon dioxide emissions by a small amount and is expected to increase the marginal cost of abatement by an increment of $125 to 1250/kt methane.

13. Where carbon offsets are available or methane mitigation needs to be quantified, an attractive feature of enclosed combustor installations is that the entire waste gas stream can be fed to the unit, metered, and totalized accurately.