PTAC
PETROLEUM TECHNOLOGY ALLIANCE CANADA

Emissions Reductions and Energy Efficiency in Crude Bitumen and Heavy Oil

Final Report
March 31, 2016

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Executive Summary

PTAC has facilitated the development and demonstration of emissions reduction and energy efficiency technologies for the past decade. The current (2016) state of the oil and gas industry continues to suffer following the 2014 economic downturn due to decreased oil prices. Tight budgets of oil and gas producers coupled with the necessity for industry to meet federal and provincial emission reduction targets by 2025, creates a strong motivation for the outcomes and the recommendations of this project. PTAC's programs search, identify, and provide financial support to applied research and technology development projects which will add value to industry through dissemination of the findings.

The initial task was a conceptual engineering study aimed at understanding the applicability, operability, cost, and potential for technologies to reduce methane venting of cold heavy oil wells and well pads. Numerous existing technologies were investigated for this methane venting study and a literature search was completed to search for new technologies. Among those examined, the Slipstream GTS unit, Hexa-Covers®, and Go Technologies blower compressors were analyzed further by Spartan Controls/REM Technology Inc., Husky Energy, and Devon Canada, respectively.

REM Technology's patent pending SlipStream GTS technology was examined for potential application to combust and destroy methane gas vented from the well casing and reduce site greenhouse gas emissions. The technology involves installing an auxiliary burner in the stack of the main burner to combust excess methane gas. The technology could be extended to also combust gas vented from the heated oil tank on site. After establishing functional performance, compliance, and market requirements for CHOPS applications, developers identified and mitigated key technical risks and then proceeded with the design of a functional prototype. Analysis of the system costs, based on the prototype design, suggested that although the application of the SlipStream GTS technology to casing gas and to vents from oil storage tanks was technically feasible, the cost of implementing the technology was too high for market acceptance. Based on this result, all future development of the SlipStream GTS technology for CHOPS applications ceased.

Devon Canada conducted a demonstration trial of the Go Technologies Blower Pilot, which took place in the Bonnyville/Lloydminster district, to determine if the blower compressors could decrease site emissions by effectively capturing vented methane, optimizing equipment fuel use, increasing oil production by drawing down casing gas pressure, and decreasing maintenance requirements of casing gas equipment. The reduced maintenance objective of the pilot was met, however, measurement of reduced vent volumes, efficient fuel use, and increased oil production was inconclusive due to gas production characteristics and limited measurement capabilities in the Lloydminster district. Following pilot completion, the recommendation was to continue to monitor the blower compressors currently in place and possibly find alternative sites that would see a greater benefit from the units.

Husky Energy completed a field demonstration to assess the energy savings and feasibility of generating carbon offsets from installing Greatario Hexa-Cover® floating tiles on tanks at heavy oil sites. Hexa-Covers® were installed in Northern Alberta on a train of tanks with a parallel

train used as a control. Both trains of tanks were equipped with separate fuel gas meters and the volume of oil and emulsion entering the tanks was also metered. Emulsion content proved to be influential regarding the outcome of this Hexa-Cover® pilot. The carbon-offset potential and fuel savings were calculated which resulted in an estimated emission reduction of 48 tCO_2e on an annualized basis. The potential offsets result from a reduction in both onsite and upstream emissions. An important element of the payback for the insulation of the Hexa-Cover® tiles is the cost savings from reduced fuel consumption. It was found that the payback period was attractive when propane is the on-site fuel, but less so when natural gas is used.

The project was completed with two conceptual engineering studies that were integral to the final report and project recommendations. The first was an aggregation study, which prioritized information about the geographic location of Lloydminster CHOPS fugitive emissions and provided insight on whether or not aggregating emissions from a number of well sites to a common utilization location would have better economics than capturing and utilizing on a single well basis. This study concluded that on a per well basis, it is most economic to install one enclosed vapor combustor (or other technology for utilizing vented methane) for every seven wells versus installing an enclosed vapor combustor for each venting well. It was also concluded that gas re-injection was slightly more cost effective than the combustor options, though more of a challenge to logistically gather sites into one central location. The second study focused accelerating technology development and demonstration for emissions reduction technologies in heavy oil and conventional oil and gas by performing the conceptual design and cost estimation of testing and demonstration facilities for new technologies. A fixed location facility was designed to mimic emissions from a heavy oil well site where the gas is released through the well casing and the production tank vent. A mobile facility was designed for high volume emissions from oil wells or multi-well batteries and would pre-treat the solution gas to remove contaminants such as water vapour and H_2S prior to testing technologies that would convert the gas into a more valuable commodity. The path forward for accelerating the demonstration and deployment of new technologies required to meet federal and provincial methane reduction targets will require investment in such facilities.

PTAC delivered 2 workshops on the subject of methane emissions reductions in heavy oil and in conventional oil and gas: on February 29 and March 14, 2016. The purpose of the workshops was to disseminate project results and engage industry in additional technology development opportunities that will reduce emissions of methane and other greenhouse gases.

This project encompassed a wide range of studies, and industry project partners, which covered emissions reductions in energy efficiency in crude bitumen and heavy oil. The outcome provides recommendations and conclusions on comparisons of existing technologies for methane venting reduction, results from new technology pilots, cost effective aggregation methods, and the possibility of creating future testing and demonstration facilities for emission reduction technologies.

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1. Introduction

This report provides a final account of the project Emissions Reductions and Energy Efficiency in Crude Bitumen and Heavy Oil undertaken by PTAC Petroleum Technology Alliance Canada (PTAC) in collaboration with Accurata Inc., Devon Canada, Husky Energy, REM Technology/Spartan Controls, the Saskatchewan Research Council, and Sentio Engineering. The project took place from April, 2015 to March 31, 2016.

The purpose of this project was to fill technology and knowledge gaps with practical and cost-effective early stage technologies that could reduce methane emissions and improve energy efficiency in the heavy oil and in situ oil sands industry through pre-demonstrated field trials and conceptual engineering studies. The project proceeded in five tasks, as follows:

- Task 1 – Conceptual Engineering Study of Technologies for Reducing Methane Venting in Cold Heavy Oil Production: Characterization of typical well and well pad configurations, conceptual cost and operational analysis of SlipStream GTS, T.O.P. Tank, and Hexa-Covers®, and identification of new technologies for future analysis
- Task 2 – Understanding the Performance of SlipStream GTS: Laboratory testing and analysis of prototype by REM Technology
- Task 3 – Analysis of the Field Performance of a Blower Technology by Go Technologies: Field testing and analysis of Go Technologies blower compressors by Devon Canada
- Task 4 – Analysis of the Field Performance of Hexa-Covers®: Field testing and analysis of Hexa-Covers® for improved energy efficiency by Husky Energy
- Task 5 – PTAC Workshops and Reporting: Industry workshops on project progress and findings, including conceptual engineering studies on aggregation and testing facilities

PTAC Petroleum Technology Alliance Canada (PTAC) is a not-for-profit organization that facilitates collaborative research and technology development to improve the financial, environmental and safety performance of the Canadian hydrocarbon energy industry. PTAC is facilitating this Project through its network of oil and gas operators. PTAC intends to disseminate the opportunity to the industry and facilitate the future demonstration trials that will be required in the next phase of development.

2. Background

PTAC has facilitated the development and demonstration of emissions reduction and energy efficiency technologies for the past decade. Its programs have searched, identified and provided financial support to applied research and to technology development projects and disseminated the findings to improve energy efficiency, reduce emissions of methane and flaring, and monitor fugitive emissions in the oil patch, among others. For example, the industry has saved approximately 1.2 billion m^3/year natural gas from the adoption of REM Technology products. This reduction in natural gas consumption has reduced CO_2 emission for about 14.4 million tonnes per year. At a natural gas price of $4 per gigajoule (GJ), the cost reduction potential is more than $100 million per year.

The project is in the context of work by PTAC and its industry and government committee to identify, demonstrate and disseminate information about new technologies to reduce methane emissions and improve energy efficiency in heavy oil and in subsurface *in situ* oil sands. Oil sands and heavy oil greenhouse gas (GHG) emissions are comprised of both combustion emissions as well as direct emissions of methane gas (the latter is at least 25 times more potent than carbon dioxide CO_2). There are significant opportunities to reduce oil sands and heavy oil GHG emissions by developing new technologies for energy efficiency and emissions reduction.

Venting of methane at crude bitumen and crude heavy oil facilities has been major source of GHG emissions assigned to oil sands production. Approximately 80% of vented volumes take place in the Bonnyville and Wainwright regions in Alberta and occurs where conservation would be prohibitively expensive using existing technologies. Solution gas vented from crude bitumen and crude oil batteries was 403 million cubic meters in 2013. Practical and economic solutions to these challenges have eluded the industry.

3. Objectives

The overall objective of the project is to determine the technical and economic feasibilities of early stage technologies that could reduce methane emissions and improve energy efficiency in heavy oil and in situ oil sands industry through pre-demonstration field trials and conceptual engineering study. This project benefits heavy oil operating companies, service and supply companies, and technology innovators, as well as governments with policy targets to achieve significant reductions in methane emissions to the atmosphere.

3.1 Objective 1 – Understand the Applicability, Operability, Cost, and Potential of Technologies and Methods Tested Researched for this Project

- The objective was to analyze various technologies and well pad configurations to determine the most efficient, cost effective, and environmentally friendly options for implementation on well sites.
- The research, development and piloting of technologies and methods concluded the following:
    - Following examination of VRUs, the Slipstream GTS, T.O.P. Tanks, Hexa-Covers®, Solution Gas Compression technologies, Combustion technologies, and other new technologies, none can be implemented easily with the exception of the Hexa-Cover® solution.
    - The cost of SlipStream GTS was too high for market acceptance.
    - The Go Technologies Blower Project successfully demonstrated a decrease in maintenance conducted on site; however, emissions reduction benefits could not be conclusively demonstrated due to the variability of vented methane volumes on site.
    - Fuel savings from Hexa-Covers® resulted in approximately 48 tCO_2e on an annualized basis. Potential offsets result from a reduction in both onsite and upstream

emissions. The economics of Hexa-Covers® will favour sites that are fueled by propane.

- On a per well basis, it is most economic to install one enclosed vapor combustor for every seven wells versus installing an enclosed vapor combustor for each venting well. Gas re-injection (i.e. collecting casing gas from multiple wells and injecting into a re-purposed well) is slightly more cost effective compared to the combustor scenarios, but also presents the challenge of gathering many sites into one central location.
- The project provided evidence to the difficulties of developing and demonstrating effective, practical, and emissions reduction technologies for meeting market acceptable cost and payback levels, and overcoming site-specific limitations. Aggregated testing facilities through a Centre for Demonstration of Emissions Reduction (C-DER) will accelerate the number of emissions reduction technologies that can be tested annually, leading to more rapid commercialization. The Centre provides a venue for access to test facilities, the ability to swiftly test a broad range of operating conditions for a specific technology, and common testing protocols that allow cross-comparison while generating essential data for technology providers, regulators, and producers, providing a path forward for investments in future research and development.

3.2 Objective 2 – Gain Industry Perspective to Shape Future Projects

- The objective was to obtain relevant feedback from industry on project deliverables.
- Two heavily attended industry workshops helped articulate and prioritize the top challenges and solutions related to methane, flaring, venting, fugitives, gas migration, and emissions reductions related to cold heavy oil production with sand (CHOPS)
- The conceptual design and cost estimation of facilities for testing and demonstrating new emissions reduction technologies provides recommendations to accelerate the development of future projects.

4. Project Results

The following provides a short summary of the objectives, methodology and results for each of the major elements of the project. A full report is available for major elements and these reports will be published on the PTAC website.

4.1 Methodology

The project approach involved several major steps:

(1) Examination of VRUs, SlipStream GTS, T.O.P. Tanks, Hexa-Covers®, Solution Gas Compression, Combustion, new technologies via literature search, and analysis of key equipment

components, piping control requirements, process schematics, operational challenges, safety concerns, and cost.

(2) Conceptual evaluation, design, fabrication, and evaluation of a pre-production SlipStream GTS prototype, and assembly, installation, and testing of the prototype.

(3) Installation and pilot operation through measurement of methane vent volumes, fuel usage, well site production, and maintenance conducted for 2 Go Technologies blowers at different locations.

(4) Identification of the baseline condition for on-site source emissions and comparison of fuel rate savings for the baseline condition (without Hexa-Covers®) versus operations with Hexa-Covers®.

(5) Identification of geographical locations and densities of CHOPS wells operating and venting casing gas in Alberta and Saskatchewan and cost analysis of economically viable methods for combustion of these emissions, particularly comparing individual well combustions to grouped wells with one large combustor.

(6) Site selection, conceptual design, assessment of budgetary capital and operating costs, and determination of access terms, funding, and collaboration for facilities within a Centre for emissions reduction testing.

4.2 Technology for Emissions Reductions

With support from oil and gas producers, this project identified viable solutions and insight into various technologies for different types of operation sites. The study provides an expert opinion and statistical information to aid producers when choosing future technologies to invest in and implement. Thus, through dissemination to industry, this study improves knowledge on existing and new technologies currently available and informs on the selection of technologies for specific sites or geographical locations.

The full report is available at: **http://bit.ly/2EyO44J**

4.3 SlipStream GTS – CHOPS Development Project

A number of technical challenges were encountered based on the functional and performance requirements for the SlipStream GTS system and each of them were addressed prior to design work. Casing vent gas flow variability, stack temperature limitations, valve train hardware sizing and selection, site power limitations, heat recovery, and stack design support were among those challenges. Although the cost evaluation for this unit lead to the determination of the system not being cost effective for CHOPS applications, the project findings can be applied to future prototypes for improvements.

The full report is available at: **http://bit.ly/2EZr3ph**

4.4 Go Technologies Blower Pilot

The results from this pilot operation show potential that the blower will create casing gas efficiencies at future locations and Devon Canada plans to seek out alternative sites that would

see greater benefit from the blower units. This pilot also highlighted that compressor evaluation is seriously limited by the gas measurement techniques currently employed in Bonnyville and Lloydminster and that casing gas venting reduction technologies would greatly benefit from advancement in gas measurement technology in CHOPS fields. Thus, this study identified a technology gap in the industry while validating the performance of the Go Technologies blowers.

The full report is available at: **http://bit.ly/2snLE47**

4.5 Hexa-Cover® Pilot Project

Overall, this pilot determined the most cost effective sites for Hexa-Cover® implementation. Focus for potential future pilots could utilize the knowledge gained from the Husky pilot to consider other strategies, such as implementation of Hexa-Cover® tiles at propane fuelled sites with a minimum in 10% reduction in fuel use.

The full report is available at: **http://bit.ly/2Cfe93H**

4.6 Study of CHOPS Emissions Aggregation

Knowledge from this study shows where opportunities exist to reduce venting volumes at CHOPS sites in Alberta and Saskatchewan and specifically investigated cost variance between the installations of enclosed vapor combustors for each well versus for every few wells. This information will provide CHOPS producers with the knowledge to make informed decisions when considering casing gas conservation methods for their CHOPS sites.

4.7 Conceptual Study of Facilities for Emissions Reduction and Energy Efficiency in Crude Bitumen, Heavy Oil, and Other Oil and Gas Operations

The projected benefit of creating a Centre for Demonstration of Emissions Reduction with testing facilities for emissions reduction technologies would enable rapid demonstration and validation of prototypes ready for commercial deployment. Awareness of this idea among industry may help to create excitement and increase involvement in its potential development, shaping the end result to fit with industry needs.

5. Project Achievements

5.1 Achievement 1 – SlipStream GTS Testing Learnings

Promising design options were identified during prototype testing that can be used for further experimental assessment which could create new opportunities for product development in this space.

5.2 Achievement 2 – Hexa-Cover® Pilot Learnings

Hexa-Cover® installations at reasonably priced propane fuelled sites are more economic, without offsets, than installations on sites which use natural gas. Moving forward, Husky and other heavy oil operators will take these findings into account when implementing Hexa-Covers® at additional sites.

5.3 Achievement 3 – GO Technologies Pilot Learnings

The pilot resulted in reduced maintenance requirements for casing gas equipment and was declared successful by Devon Canada in demonstrating decreased methane vent volumes post blower compressor installation, increased fuel consumption by each site while eliminating propane use, and increased oil production by eliminating casing gas back pressure. Moving forward, there is potential that the blower compressors will create casing gas efficiencies at locations other than those piloted.

5.4 Achievement 4 – Casing Gas Conservation Methods for Lloydminster CHOPS Wells

Collecting casing gas from multiple wells and injecting into re-purposed wells was considered the only viable option for casing gas conservation. Cost comparisons between installing enclosed vapour combustor units for every five or seven wells versus installing one unit for each individual venting well showed that the most economical option is to install one unit for every seven wells. These conclusions are valuable to industry with CHOPS operations.

5.5 Achievement 5 – Facilities for Testing and Demonstration of New Emissions Reduction Technologies

A fixed and a mobile facility for testing and demonstrating new emissions reduction technologies were designed and cost estimated at the conceptual level. This information forms the basis for recommendations in future research and development investments.

6. Project Outcomes

6.1 Emissions Reduction Novel Technology Trials and Conceptual Studies

Cost effective emissions reduction options are vital in today's industry due to newly administered government targets for the year 2025. Field trials and pilots for testing new equipment are an important part of innovation and both the successes and failures can lead to improvements of existing emissions reduction technologies. Dissemination of conceptual studies will raise awareness among industry, which will promote better practices based on the most current information available.

Testing and researching technologies such as SlipStream GTS, Hexa-Cover tiles, and Go Technologies blowers for this project has provided direction for future studies to reduce wellsite emissions, helped decipher the best areas of application for each technology in order to achieve the most effective results, raised awareness among industry stakeholders about what technologies are available and applicable to their sites, and improved the technology providers' understanding of strengths and weaknesses of current prototypes, which can be applied to future designs.

A summary of project outcomes is below:

- Following examination of VRUs, the Slipstream GTS, T.O.P. Tanks, Hexa-Covers®, Solution Gas Compression technologies, Combustion technologies, and other new technologies, none can be implemented easily with the exception of the Hexa-Cover® solution.
- Fuel savings from the Husky Hexa-Cover® pilot project resulted in an estimated emission reduction of 48 tCO_2e on an annualized basis. Implementation of Hexa-Covers® at sites fueled by propane was found to be more economic than at sites using natural gas as fuel.
- The Go Technologies blowers offered the benefit of reduced site maintenance and will continue to be monitored by Devon Canada to identify additional information. REM Technology's Slipstream GTS was not able to progress to the 'fabrication of prototype' stage, but the work completed can be applied to future studies.
- An overall cost evaluation of CHOPS well aggregation showed that installation of 3" HDPE piping with the casing gas of seven wells being aggregated to one common combustor is the most economic option.
- Facilities for accelerating the demonstration and deployment of novel emissions reduction technologies were designed and cost estimated at the conceptual level, providing a blueprint for future investments in emissions reduction research and development.

These findings result in step towards achieving the new emissions reduction targets set by the Federal and Alberta Governments.

7. Description of Benefits

7.1 Benefit 1 - Stakeholders

The field testing activities in the project allowed the Canadian developers of the three prototype technologies (Slipstream GTS, Go Technologies, and Hexa-Covers®) to encourage their deployment in the oil sands and heavy oil industry. The project also provided critical feedback to the developers of these technologies, which gives them the opportunity to improve the technology and correct any weaknesses following field trials and bring them closer to commercialization. Cost analysis and efficiencies were also taken into account for each stage of this project. The ultimate medium to long term benefit is a substantial reduction of methane venting in crude bitumen and heavy oil production in conventional oil and gas operations in Canada and international jurisdictions. The technology companies developing these innovations may see growth opportunities for their manufacturing operations regionally and through export opportunities.

7.2 Benefit 2 - Canada

The project is important as it further develops Canada's capabilities to address a major source of GHG emissions in oil sands production: the venting of methane at crude bitumen and crude heavy oil facilities. Methane is a greenhouse gas estimated to be at least 25 times more potent than carbon dioxide. The issue of methane venting while critical in crude bitumen and heavy oil

operations is ubiquitous in the oil and gas industry. Canada would be able to produce hydrocarbon products from oil sands and heavy oil sources to address the global market needs while mitigating impacts to the environment.

8. Conclusion

The focus of this project was to determine the technical and economic feasibilities of early stage technologies for emission reduction and energy efficiency purposes in heavy oil and in situ oil sands industry through field trials and conceptual engineering studies.

The conceptual engineering studies investigated technologies, cost effective layout scenarios for CHOPS sites, and potential future endeavors that may assist in technology development. These studies helped to conclude the best choices for pilot projects, the most cost effective method of methane aggregation from CHOPS wells, and addressed barriers delaying the development of new technologies.

The results of the REMVue SlipStream GTS CHOPS Development Project concluded that the cost of implementing the technology is too high for market acceptance, and therefore all future development of the technology stopped. The initial scope definition, conceptual evaluation, and prototype design were completed and findings from these stages are to be used to improve future technologies. Therefore the technology readiness level did not progress for this particular prototype, but the findings have provided valuable information to take into account for future design.

The Go Technologies pilot project saw that one of the key performance indicators, reduced site maintenance post blower installation, was met. However, limited measurement capabilities in the pilot locations and variable gas production characteristics caused measurement of reduced vent volumes and fuel use efficiency to be inconclusive. Based on project findings, Devon Canada will continue to monitor the blower compressors currently in place and seek out sites that would see a greater benefit from the units. The technology readiness level of the Go Technologies Blower progressed from TRL 6 to 7.

The Hexa-Cover® pilot saw variance in the daily fuel savings throughout its duration and it was concluded that these savings do not justify an investment in future Hexa-Cover® projects when the site is fuelled with natural gas given current low prices for natural gas. As stated throughout this report, the economics of installing Hexa-Covers® become more favourable when installed on reasonably priced propane fuelled sites.

The aggregation study sought to improve the economics of technology deployments by aggregating vented methane volumes from more than one site to a single utilization site, thereby spreading capital and operating costs of one piece of utilization equipment over more than one wellsite. The study demonstrated that this approach is both practical and economic.

The project encountered challenges in the timely and effective testing and demonstration of new emissions reduction technologies. The cost of field demonstration is high when performed at an actual operating site. Furthermore, operating sites suffer from variable and sometimes unpredictable gas volume and instrumentation issues which may impair the quality of test results.

Therefore, the construction and operation of dedicated facilities for the testing of future emissions reduction technologies would prove beneficial in reducing these barriers and accelerating the time to widespread industry deployment. As part of its final reporting, the project performed the conceptual design and cost estimation of such facilities, which provide a blueprint for future investments in research and development.