PROJECT SUMMARY AND OUTCOMES

ENGINE MODERNIZATION FOR GHG REDUCTION

Ember Resources in collaboration with Waukesha, Ironline Compression and five other project partners collaborated to convert an older engine series to the latest version with a lower carbon footprint.

Prepared by Ember Resources as part of the Methane Consortia Program

Table of Contents

Introduction

PTAC is working with Alberta Environment and Parks to collaborate on the formation of consortia with industry to reduce emissions of methane and promote innovation in reduction mechanisms within the Alberta oil and gas sector. As part of this program, Ember Resources worked with Ironline Compression to modernize a Waukesha Engine. This consisted of an upgrade/ conversion of a Waukesha 7042GL (Series 2) to the latest technology available from the Original Equipment Manufacturer (OEM), the Waukesha Series 5.

The Waukesha Series 5 consists of redesigned engine components, control systems, and catalyst technology designed to achieve substantial GHG reductions. The application of this technology reduces the carbon footprint, increase reliability, and lowers operating and maintenance costs by increasing the maintenance interval and the equipment life cycle.

Project Summary

Waukesha engines are well-known in the Canadian oil and gas industry. Decades of experience have provided the opportunity to improve engine design to increase efficiency, reliability and emission reductions capability. The Waukesha Series 5 upgrade consists of the following additions:

- Cylinder heads with improved cooling:
- Pistons with smaller crevice volumes to reduce unburned hydrocarbons and methane slip;
- A new camshaft profile to change intake valve timing;
- New turbochargers to help increase engine efficiency;
- New controls to maintain a strict air-fuel ratio.

The resulting combination of these additions leads to lower emissions and fuel consumption rates.

Ember Resources has worked with Ironline Compression in this project. Ironline was the key partner in implementation of the engine modernization. The experienced partnership led to the successful roll of the upgrade. Ironline is experienced with engine overhauls, and retrofits, and has a good working relationship with Waukesha. Below is the list of the other partners involved in this project:

- 24/7 Compression ~Red Deer
- Tiger Machining ~Edmonton
- Connelly Insulation ~Red Deer
- SOL Thermal ~Edmonton
- Spartan Controls ~Calgary

Purchase and Installation Process

Vendor selection was made through a systematic bid process. Component lists based off engine serial number were supplied by Waukesha and distributed to OEM parts and labour suppliers. Vendors then provided detailed scope of work and costs submitted back to Ember. Submissions were scrutinized, discussed, and awarded based on the information provided.

Project Schedule

Monday June 22nd, 2020
Installed OEM supplied Empact catalyst housing and wiring harness tray.

Tuesday June 23rd, 2020
Repaired tin cladding and exhaust pipe insulation around catalyst install.

Wednesday June 24th to Friday June 26th, 2020
Organized parts and deliver to site. Prepared parts to be distributed for conversion.

Monday June 29th, 2020
Started disassembly of engine and prepared for engine block machining.

Tuesday June 30th to Wednesday July 1st, 2020
Machined the engine block and installed the new lower liner fits.

Thursday July 2nd to Thursday July 9th, 2020
Reassembled the engine with the new mechanical components.

Tuesday July 7th to Thursday July 9th, 2020
Installed the new engine wiring harnesses, computer modules, and monitoring and control systems.

Wednesday July 8th, 2020
Installed the catalyst insulation cover.

Friday July 10th, 2020
Re-programed the control panel to integrate with new engine systems. Started-up the engine successfully.

Emissions Profile

Summary of GHG Mitigated Due to the Project

The project reduced unburned methane in the engine exhaust from 50 g CH_4 per m^3 of fuel input to 1.5 g CH_4 per m^3. This resulted in an emissions intensity reduction of 48.5 g of CH_4 per m^3 of fuel input, a 97% reduction from the baseline. The Series 5 technology accomplishes this reduction by being more fuel-efficient while still maintaining stoichiometric combustion. The outcome is minimizing methane slip. Methane slip is the unburned fuel that would have been released to the atmosphere in the exhaust as pure methane (CH_4). Minimizing unburnt fuel is crucial to reducing GHGs since 1 gram of CH_4 is 25 times more impactful to GHG emissions than 1 gram of CO_2. This reduction is based on component design and control technology. A significant contributor is the piston design that reduces unburned hydrocarbons by reducing areas that trap fuel.

Another way to describe this outcome is that the engine modernization resulted in a reduction from 10 g CH_4/Bhp-hr to 0.5 g CH_4/Bhp-hr. Operating the engine at 1000 Bhp and 8760 hrs per year will result in an emissions reduction of 83.22 tonnes of CH_4 per year, which translates to a reduction in CO2e emissions of 2080 tonnes per year assuming a 25x global warming potential for methane. At the full load of 1480 Bhp, the same reduction from 10 to 0.5 g CH_4 /Bhp-hr and 8760 operating hours per year equals to an emissions reduction of 123 tonnes of CH_4 per year (3079 tonnes of CO2 per year).

This reduction was proven through four similar projects by Ember Resources where Waukesha engines were modernized to the Series 5 level. These 2019 projects were supported by the Energy Efficiency Alberta Custom Energy Solutions program. They included pre- and post-emission testing to prove the emissions reductions claims of the technology. Table 1 shows the pre-conversion audit of emissions for one of these projects. It is shown that CH_4 emissions ranged from 44 to 58 g/m^3. Table 2 shows the post conversion audit of the same engine; it is noted that CH_4 emissions are now between 1.1 and 1.2 g/m^3. Fuel flow measurements were used to calculate BSFC, and exhaust stack gas analysis testing was used to measure CH_4, NOx, CO, CO_2 reductions.

Table 1. Pre-conversion audit of emissions of the Waukesha L7042 engine at the 7-11-30-25W4 facility

Engine Speed (RPM)	Engine Load (BHP)	NOx (g/bhp-hr)	NOx (g/m^3)	CH_4 (g/bhp-hr)	CH_4 (g/m^3)	CO_2* (g/m^3)	CO_2e (g/m^3)	CO_2e (tonnes/yr)	CO_2e (tonnes/hr)	BSFC (Btu/BHP-hr)
1075	982	2.63	12.14	9.95	45.87	1864.47	3065.51	5715.45	0.65	6941.45
1075	946	2.49	11.44	9.65	44.34	1864.47	3024.03	5449.25	0.62	6964.51
1075	921	2.44	11.38	9.88	46.02	1864.47	3065.94	5303.94	0.61	6867.44
1050	922	2.22	10.48	10.40	49.02	1864.47	3136.75	5371.57	0.61	6790.94
1050	891	2.58	11.98	9.72	45.13	1864.47	3046.15	5119.03	0.58	6895.49
1000	820	2.59	12.29	10.26	48.73	1864.47	3137.75	4742.71	0.54	6739.77
950	825	1.26	6.12	12.10	58.86	1864.47	3299.49	4707.81	0.54	6576.13
950	806	1.23	5.99	11.65	56.65	1864.47	3307.61	4796.47	0.55	6577.98
950	788	1.30	6.30	11.64	56.27	1864.47	3363.38	4990.81	0.57	6620.75

*CO_2 determined via carbon mass balance.

Source: AER Source Test Report for Ember Resources, 7-11-30-25W4 Facility, Alberta, Engine: Waukesha L7042GL, SN: C-14667/1; Prepared By: Oasis Emission Consultants, Inc., August 20, 2019

Table 2. Post-conversion audit of emissions of the Waukesha L7042 engine at the 7-11-30-25W4 facility

Engine Speed (RPM)	Engine Load (BHP)	NOx (g/bhp-hr)	NOx (g/m^3)	CH_4 (g/bhp-hr)	CH_4 (g/m^3)	CO_2* (g/m^3)	CO_2e (g/m^3)	CO_2e (tonnes/yr)	CO_2e (tonnes/hr)	BSFC (Btu/BHP-h
1152	838	0.24	1.10	0.32	1.45	1863.72	1904.86	3058.63	0.35	7127.17
1152	796	0.23	1.04	0.25	1.12	1863.72	1896.31	2992.04	0.34	7372.98
1151	775	0.25	1.08	0.31	1.32	1863.72	1901.50	2991.43	0.34	7550.57
1050	752	0.24	1.04	0.27	1.19	1863.72	1898.17	2836.90	0.32	7392.45
1050	731	0.26	1.13	0.32	1.42	1863.72	1904.16	2777.23	0.32	7421.47
1048	697	0.27	1.20	0.44	1.93	1863.72	1917.20	2685.10	0.31	7474.10
947	671	0.29	1.29	0.40	1.79	1863.72	1914.12	2508.24	0.29	7263.99
947	647	0.23	1.00	0.27	1.20	1863.72	1898.12	2430.54	0.28	7361.63
947	636	0.22	0.97	0.24	1.06	1863.72	1894.63	2415.48	0.28	7456.24

*CO_2 determined via carbon mass balance.

Source: AER Source Test Report for Ember Resources, 7-11-30-25W4 Facility, Alberta, Engine: Waukesha L7042GL, SN: C-14667/1; Prepared By: Oasis Emission Consultants, Inc., October 16, 2019

The actual results tested from engine conversions Ember completed in 2019 were normalized and led to the conclusion that the Series 5 technology reduced unburned methane in the engine exhaust from ~50 g CH_4 per m^3 of fuel input to ~1.5 g CH_4 per m^3, an emissions intensity reduction of 48.5 g of CH_4 per m^3 of fuel input and a 97% reduction from the baseline.

Abatement Cost

Pre project abatement cost is $247.50 per tonne of CO2e per engine. These abatement costs were assumed using OEM models of pre conversion and post conversion BSFC, and exhaust stack emissions values.

The calculated abatement cost at project completion is roughly $178 per tonne of CO2e. This is based on the above referenced testing conducted in 2019 on a similar conversion for four different engines. Actual testing from 2019 proved to result in better than anticipated GHG and fuel consumption reduction results. Based on this knowledge, it is assumed actual reduction results could be higher than indicated above.

The project lifetime is estimated to be 10 years. For this project period, abatement costs are estimated at 21.5$/t CO2e (for a reduction of 2,080 tonnes of CO2e/year).

Conclusion

Project learnings

Based on historical conversions, organization and pre-planning was of high importance to ensure the project was successful in its implementation. Every detail to be completed was discussed and plotted in a shared timeline. Parts were removed from packaging and organized in an order that was needed throughout the job timeline prior to job commencement. Appropriate personnel were only on site at the required times throughout project implementation. A lot of learnings from the 2020 retrofit of the engine were focused on efficiency within project execution and alignment. The project team hopes to build off these learnings and create efficient frameworks to implement within future engine modernization projects.

The suppliers and partners mentioned above were directly associated with this project, but many other services were seen to benefit indirectly from the implementation of this project. Shipping and transport, materials provided for manufacturing, warehousing and distribution, tool, and consumables suppliers, as well as OH&S aspects of this project are indirect contributions. This type of project is seen to reduce Alberta's carbon footprint, but also distributes positive income throughout many levels of the economy.

Technology learnings

As mentioned within the technology summary, the Waukesha series 5 has undergone substantial development to increase its efficiency, reliability, and impact in reducing GHG emissions. The newly developed piston as part of this upgrade has resulted in significant reduction of methane slips. The overall upgrade of the engine was successful and will result in significant yearly reductions in GHG over the lifetime of its implementation.

This project was a huge learning curve for the entire project team. The resilience from all parties involved to push through any challenges encountered was commendable. Due to the workload and parts required for these conversions, the cost could be considered as quite high in comparison to standard or status quo life cycle costs. Fortunately, programs such as the MCP provide the means necessary to subsidize these costs and in turn reduce GHG emissions to fight climate change while keeping budgets manageable and in alignment with day-to-day operating costs.