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ORC Technology for Reducing Methane Emissions

What California industries have large volumes of ultra-low (1,600Âº F) waste heat? California has many forms of waste heat from industrial processes, power generation via combined heat and power systems, biogas systems, flared natural gas and biogas, biomass systems, etc. ElectraTherm is focused on several opportunities in California, with a specific focus on waste heat recovery from natural gas compression stations (see attachment)

What research is needed on advanced technologies or materials (including coatings) for recovering waste heat cost effectively in ultra-low heat or ultra-high temperatures? Demonstrations are required to show waste heat to power applications are viable and low risk. Also any opportunities for cost reduction must be pursued to reduce installed costs.
Should research focus primarily on the ultra-low or ultra-high temperature waste heat or, if not, what other temperature ranges? Waste heat is typically not high grade as in high value â€" ultra high temperatures can be used to create steam and run a typical Rankine cycle, or the high grade waste heat can be used elsewhere in the process. Also, there is more of an abundance of ultra-low temperature sources and the cost of capturing the waste heat is less when dealing with lower temperatures.
What advanced heat recovery technology improvements are needed to increase wide spread deployment by industry? The largest hurdle for waste heat to power acceptance is cost â€" the technology is proven and waste heat opportunities exist, as shown with solar and wind as volume of systems increase costs can come down. Successful demonstrations and education that waste heat to power is technically feasible, low risk and has good ROI is a must.
What are the cost and technical targets that must to be met to drive customer adoption (such as minimum rate of return or minimum percent heat recovery)? Costs need to be less than $2000/kW installed, and minimum paybacks need to be 3 years or less in California.
What complementary technologies and approaches can be combined to increase the value proposition of waste heat recovery systems? By smartly combining other equipment â€" such as biomass boilers, reciprocating engines and process heaters with waste heat to power equipment â€" system costs can be reduced.

Additional submitted attachment is included below.

A Novel Organic Rankine Cycle Retrofit Technology for Reducing Methane Emissions

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Background

Thousands of miles of pipeline are used to transport natural gas in California and throughout the U.S. The recent surge in natural gas production from shale gas reserves has been successfully driven by the existence of this pipeline network. The movement of natural gas through this pipeline in California alone is accomplished by hundreds of natural gas compression stations, because compression stations are required every 25-50 miles to maintain stable natural gas flow in the pipeline. Most of the compressors in these stations are driven by reciprocating engines, which are effectively very large automobile engines. These engines are fueled by natural gas from the pipeline. The engine's primary purpose is to supply mechanical horsepower (HP) to the compressor. However, about 5% to 7% of the engine's HP is used for parasitic power for cooling of the engine and the hot compressed natural gas.

The conventional reciprocating engine-based compressor unit is shown in Figure 1. Engine HP is transferred to the compressor by means of the common shaft connecting this equipment. The engine provides the HP for the parasitic load for the cooling system via a power takeoff (PTO) from the engine. This cooling system typically has multiple cooling circuits servicing the engine cooling water, oil cooler and inter-stage coolers for the gas compressor. Our plan is to use a novel Organic Rankine Cycle (ORC) system to convert the waste heat into power to drive the cooling system for compression stations.

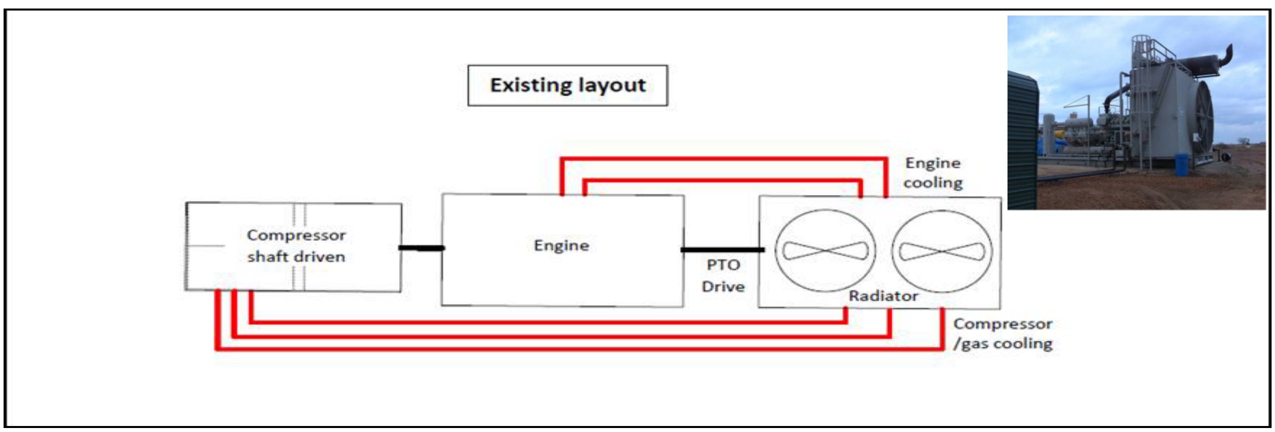

Figure 1 – A Typical Reciprocating Engine Natural Gas Compressor

An organic Rankine cycle (ORC) uses the same physics as a Rankine steam cycle except that the working fluid is not water/steam, but a fluid with a boiling point below room temperature. Waste heat is used to convert this liquid into a high-pressure vapor that is expanded to spin an electric generator and produce power. After spinning the expander, the vapor is condensed back into liquid through a liquid loop radiator integrated with the ORC's condenser. The effective "fuel" for this power is waste heat. Because the driving energy for this process is waste heat, the power generated does not consume any additional fuel or generate any additional emissions.

Proposed Technology

Although utilization of the full waste heat load generated by the engine and compressor with an ORC system would generate the most overall benefit, this approach would be difficult to deploy for the compression stations that are supporting our existing natural gas pipeline infrastructure. Full utilization would require extensive site construction which will include the design and installation of multiple new heat exchangers for the engine exhaust and compressed natural gas. Instead, we will focus on utilization of the waste heat from the engine's cooling water system. This will minimize site construction to disconnecting the existing PTO from the station's cooling system, installation of ElectraTherm's POWER+ GENERATOR ORC system, and installation of a small electric motor to drive the compression station's existing cooling system. The engine's cooling water (typically in the 195-230°F range) drives ElectraTherm's POWER+ GENERATOR ORC system producing power to drive the compression station's cooling system providing "free cooling" for the compressor station. The proposed ORC process integration is shown in Figure 2.

ElectraTherm is a global leader in the industry in low-temperature ORC technology with over 70 machines in the field in 10 countries. Their proven technology has more than 1,200,000 hours of commercial fleet operating time. In 2016, ElectraTherm was acquired by BITZER, the world's largest independent manufacturer of refrigeration compressors and is now utilizing BITZER's expander technology in the ElectraTherm POWER+ GENERATORS.

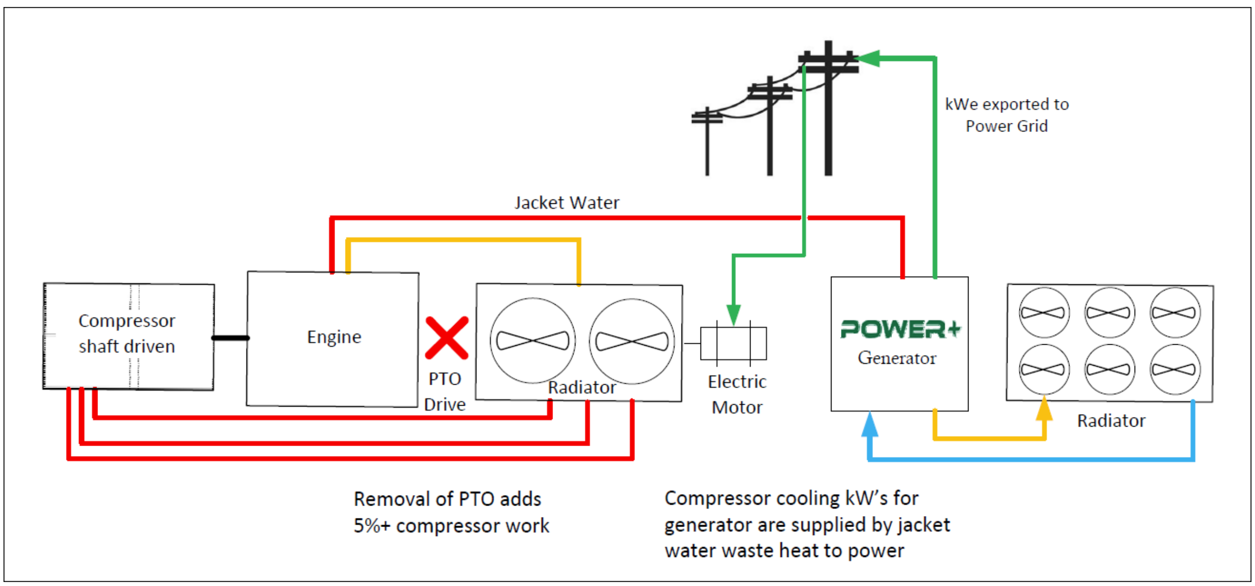

Figure 2 – Waste Heat Recovery in Gas Compression

Our proposed retrofit approach has the following advantages:

- Reduced natural gas consumption by 11 to 14 MMSCF per year,
- Increased compression capacity with existing compressor, and
- Increased natural gas throughput within existing infrastructure

The increased compression capacity will allow increased throughput of natural gas by up to 5% through the existing natural gas pipeline infrastructure. The increased cooling capacity will reduce the number of days when, due to high ambient temperatures (hot summer days), insufficient cooling capacity is available, and the engine can provide less natural gas compression because of engine de-rating. Both advantages increase the effectiveness of the compression stations to maintain maximum performance of the natural gas pipeline infrastructure. In addition to the direct reduction of natural gas consumption through increased efficiency, the benefits to the natural gas pipeline infrastructure should also reduce flaring, because, with additional capacity, the pipeline should not be the limiting factor forcing flaring rather than exporting the natural gas.

The focus of this project would be 100% conversion of the engine's cooling water thermal energy into power. The R&D effort will optimize waste heat recovery from the engine's cooling water. We will investigate the new CFC-free (climate friendly with low global warming potential) refrigerants coming on the market and potential for blends of refrigerants to identify a working fluid with optimal performance for the operating temperature of the engine's cooling water. There are many new refrigerants that have higher energy at lower temperatures (that may match very well with the cooling water temperature ranges) that have not been tested in ORCs but that have the potential to really expand the waste heat to power market effectively and significantly increasing utilization of all the lower grade waste heat sources in the U.S. for generating power and increasing efficiency of waste heat to power conversion and reducing fuel consumption. ElectraTherm has extensive facilities to develop and test various refrigerants and ORC designs in its facility in Flowery Branch, GA. In addition to this R&D effort, engineering efforts will include ORC sizing of expander, ORC main components such as heat exchangers and pumps to optimize effectiveness of ElectraTherm's ORC systems for this application.

The project will focus on design and optimization of ORC for utilization of natural gas compression station's engine cooling water, alternate refrigerant testing, site design, construction, installation, commissioning and one year of operation with proper measurement and verification of benefits of the new ORC system. The activities will address the technical risks associated with integration of an ORC into existing compression stations which include: reliability of the ORC to provide electric power for the motor driving the compression station's cooling system, achieving zero process interruptions due to the new equipment and its operation, maintenance requirements for the ORC for remote operation at existing compression stations, and ability to tune working fluid to optimize ability to extract maximum power from the waste heat available at typical operating and ambient conditions of existing compression stations.

Potential Demonstration Partners

Critical success criteria for this project would be the deployment of this technology to a demonstration site with a natural gas industry partner to prove out the proposed benefits. ElectraTherm has many ongoing relationships with oil and gas companies and has also garnered interest via its flare demonstration project with Hess. It is known in the U.S. that the oil and gas industry is one of the largest potential markets for waste heat to power. Through our relationship with the Houston Advanced Research Center (HARC) and the Environmentally Friendly Drilling Program such companies as Markwest, Tallgrass, Conoco Phillips, ExxonMobil, Anadarko, etc. would all be target companies to support a field demonstration.

In addition to experimental R&D work, we will perform a comprehensive techno-economic analysis (TEA) to develop estimates for capex and opex for the proposed system, with emphasis on the payback period for installing the proposed ORC system in a compressor station.

The target level of performance for this project would be to effectively use ElectraTherm's ORC system to recover sufficient power to fully supply all of a compression station's parasitic load for the cooling system. The benefits of this novel ORC integration into existing compression stations will significantly increase the performance of these compression stations and the overall natural gas pipeline infrastructure by reducing methane consumption by each compression stations and increasing the natural gas throughput of a compression station by about 5% without increasing natural gas consumption, emissions, or additional equipment other than the ORC system, and expanding the compression station's existing cooling capacity limiting derating compression capacity during hot summer days.

Although the oil and gas industry has exploited waste heat to power technology for large compressor turbines and therefore know of the potential value of this technology. We are not aware of any waste heat to power systems for the reciprocating compressors, which are the workhorse for the natural gas industry. Discussions of applying ElectraTherm's ORC technology at natural gas compression stations has elicited industrial interest, but the demonstration data collected in this project are anticipated to result in rapid and significant deployment of the technology. Because of the wide range of operating and ambient conditions associated with the compression stations, knowledge and effectively demonstrated performance of new working fluids can be effectively leveraged for more comprehensive power recovery from all waste heat sources in California.

Project Team - ElectraTherm is a leader in small ORC technology with a product range of 45kW-120kW and with BITZER as its parent, is continuing to advance ORC technology with system and expander R&D. ElectraTherm developed its foundational Series 4000 unit with support from a DOE grant from 2011 through 2014 to demonstrate micro-geothermal for co-produced fluids from oil and gas fields and ElectraTherm is now working on an EERE funded cooperative agreement to develop advanced engine + ORC combinations. A Series 4000 POWER+ GENERATOR is shown in Figure 3. ElectraTherm also, through several Department of Defense contracts with the Navy has demonstrated radiator replacement with a POWER+ GENERATOR for a reciprocating engine – and in doing so also demonstrated up to 10% fuel efficiency improvements. ElectraTherm partnered with the Department of Defense to build the first fully integrated stationary engine and waste heat to power generator. The testing began at ElectraTherm in Reno, Nevada in 2015. ElectraTherm's POWER+ GENERATOR was integrated with a Cummins KTA-50 1.1-MW engine for increased engine efficiency and engine cooling benefits, while replacing the engine's radiator entirely. ElectraTherm is very motivated to break the paradigm of gas compression plants today and show where waste heat to power can have a significant impact on the California natural gas infrastructure and methane emissions reductions.

Resources

Flared gas from wastewater treatment plants and oil and gas production – see brief 1 minute video here: https://youtu.be/YbxkKizyFXA or https://www.dropbox.com/s/igi9gmtusii33er/WWTanimationvideo.mp4?dl=0

Reciprocating Engine exhaust and jacket water such as distributed combined heat and power (CHP) systems and biogas systems – see brief video here:

https://youtu.be/fca0faX8R84 OR https://electratherm.com/radiator-with-a-payback-video/

1.

Distributed biomass systems as one developed in concert with CEC – see brief video here:

https://youtu.be/6TIVCrwh6P8 OR https://electratherm.com/biomass-casestudy/