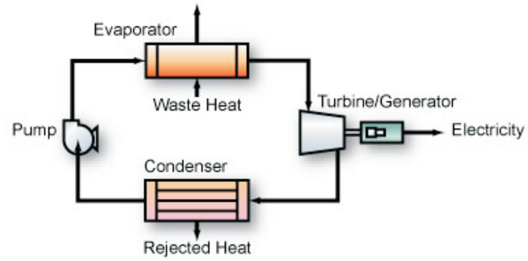
Modifications and Optimization of the Organic Rankine Cycle

Improved Recovery of Waste Heat in Industrial Processes



Innovations
- Direct evaporator eliminates need for secondary heat transfer loop

Feasibility
- Based on an existing GE conceptual design

Applications
- Initial application into reciprocating engines and gas turbines.
- Long-term application of tapping industrial waste heat

Concept schematic of direct evaporator for Organic Rankine Cycle

Illustration courtesy of Idaho National Laboratory.

Introduction

Waste heat from turbines and engines used in industrial applications along with waste heat from industrial processes are exceptionally abundant sources of energy. If even a fraction of this waste heat could be economically converted to useful electricity, it would have a tangible and very positive impact on the economic health, energy consumption, and carbon emissions in the U.S. manufacturing sector. The current waste heat recovery technologies, including Organic Rankine Cycles (ORCs) and thermoelectrics, are technically feasible but economically unattractive. This limits their current use to a small number of niche applications.

ORCs operate by transferring heat from the source through an evaporator to boil a fluid and create vapor that is expanded across a turbine or other work extraction device. This creates shaft power that can be easily turned into electrical power through a generator. Current limitations in ORCs have led to inefficient systems that offer only marginal economic benefits. These limitations stem from the use of a secondary heat transfer loop in most commercial systems to offset safety risks. This secondary loop creates additional costs for each unit, increases the opportunity for component failure, and reduces the conversion efficiency of the system.

To address these problems, researchers are working to develop advanced and cost-effective ORCs. The research team will leverage previous research in advanced ORCs to develop a new direct evaporator technological solution that will reduce the ORC cost by up to 15%, enabling the rapid adoption of ORCs for industrial engines and turbines.

Benefits for Our Industry and Our Nation

GE has more than 1,800 simple cycle gas turbines installed in North America and Europe that cumulatively generate more than 60 GW of electrical power. If 20% of this installed base were retrofitted with the proposed ORC technology, 3 GW of additional electrical power could be produced, which would effectively utilize 90 trillion Btu of waste heat per year. These energy savings represent CO_2 emission savings of 4.8 million metric tons, and economic savings of $630 million. An anticipated additional economic benefit of this research effort is a reduction in the costs of ORC technology, which will provide greater returns on investment than previous ORC systems.

Applications in Our Nation's Industry

This technology will be initially retrofitted for waste heat recovery in engines and turbines. ORCs can be used in waste heat recovery applications for a broad range of industries, including metals and minerals manufacturing, refineries, chemical processing plants, concrete plants, iron smelters and a vast array of other industrial processes.

Project Description

This project will optimize the ORC for the conversion of low-temperature waste heat from gas turbine or reciprocating engine exhaust to electricity. The work entails detailed design and modeling of a direct evaporator concept that improves efficiency by eliminating the usual secondary heat exchanger loop. Thermal decomposition and flammability analyses of the organic working fluid will be performed to maximize performance and minimize risk of the system. A prototype test facility will be designed and constructed to evaluate the operation of the direct evaporator. The result of these efforts will be a safe, economically feasible direct evaporator design manufactured with the gas turbine or reciprocating engine as a single package that is easy for customers to install and operate.

Barriers

- Most commercial ORCs use a flammable hydrocarbon working fluid. If the evaporator were to develop a leak, the flammable working fluid would leak into the hot exhaust stream and create a potential fire hazard. Additionally, an evaporator placed directly in the exhaust stream poses the risk of heating up the working fluid to the point that it rapidly decomposes, forming decomposition byproducts. This can reduce cycle efficiency and cause potential fouling of the heat exchanger tubing.
- It is common for ORCs to cost $2500/kW and above. At this cost, most of the available waste heat recovery opportunities are not economically viable.

Pathways

To eliminate the limitations caused by the secondary heat transfer loop, researchers will develop advanced ORCs by using advances in direct evaporators, based on conceptual designs that have been developed by GE. This research effort will accelerate the development of the technology through research in flammability, two-phase heat transfer, and experimental validation.

Milestones

This project started in December 2008.

- Detailed design and modeling of evaporator
- Design and construction of partial prototype test facility
- Working fluid decomposition chemical analyses
- Test-bed heat transfer evaluation
- Design, build, and test prototype evaporator in ORC cycle

Commercialization

GE will initially focus on pairing its ORC technology with direct evaporator, with existing GE turbines and engines; specifically the small-frame gas turbines offered by GE Oil and Gas operations, and the natural gas reciprocating engines offered by its Jenbacher operations.

After GE has evaluated and proven the reliability of its ORC cycle in a sizable installed base of GE engines and gas turbines, it will then be able to adapt this ORC technology to a broader range of applications, especially industrial sources of heat.

Project Partners

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