

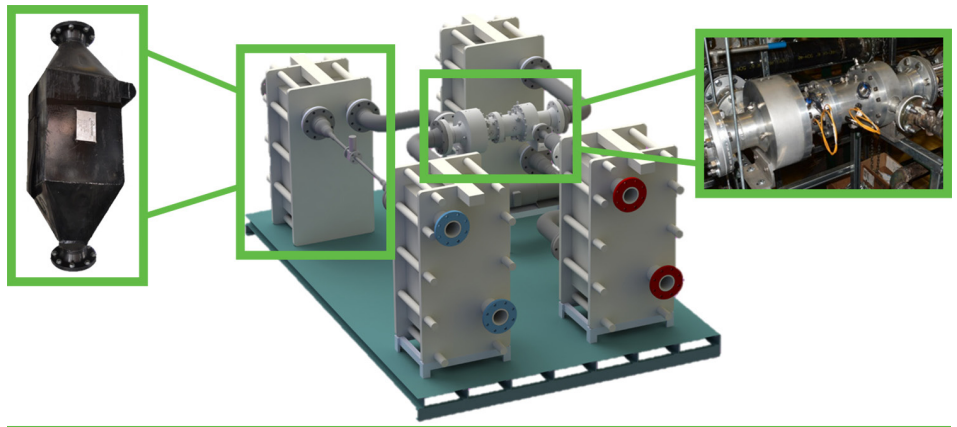
Turbo-Compression Cooling for Ultra-Low Temperature Waste Heat Recovery

Developing a cost-effective cooling system that utilizes low-quality waste heat from cooling water used in diesel generators

Utilizing waste heat from industrial processes presents a significant opportunity to improve energy efficiency at manufacturing facilities. In particular, low-temperature waste heat from industrial processes and systems, such as jacket cooling water in engines and waste heat from steam boilers, offers a largely untapped energy source. What has limited the ability of industrial facilities to utilize such low-temperature waste heat is the lack of cost effective technologies to capture the energy for a useful purpose.

At many industrial facilities, one potential use for the waste heat is to convert it to process cooling. The thermally activated cooling technologies currently in the market have not, however, seen widespread adoption due to high cost, large system size, limited turndown capability, and/or a low coefficient of performance (COP).

To overcome these challenges with thermally activated technologies, this project seeks to develop a novel, low-cost turbo-compression cooling (TCC) system that utilizes low temperature waste heat available in industrial processes. The TCC system absorbs heat from the engine coolant of a diesel generator and consists of two different cycles that are coupled by a high efficiency turbo-compressor.



The turbo-compression cooling system being developed utilizes high efficiency turbomachinery and a new type of liquid-coupled aluminum heat exchanger that provides a large amount of surface area at a low cost. *Photo credit Modine Manufacturing Company.*

The project goal is for the system to achieve a competitive COP and cost while maintaining operation at a 10:1 turndown ratio.

- Utilization of non-corrosive, non-toxic, and non-flammable refrigerants that can be operated at reasonable pressures.

Benefits for Our Industry and Our Nation

The TCC system being developed can significantly increase the amount of waste heat captured at industrial and manufacturing facilities. A 2011 study by Georgia Tech estimated that manufacturing and industrial processes rejected approximately 77 trillion Btu of waste heat into engine coolant in 2006. Based on this value, thermally activated cooling technology with a COP of 0.6, such as the TCC system being developed, would have the potential to provide around 46 trillion Btu of usable heat for onsite cooling to increase the efficiency of manufacturing operations.

When compared to current thermally activated technologies available in the market, the TCC offers several advantages, including:

- Short payback period; if project goals for efficiency and system cost are met, payback period is expected to be two years or less assuming diesel fuel prices of approximately \$2.50 per gallon.
- Suitable for applications with heat load variability.
- Use of low-cost materials, which contributes to the low overall system cost.

Applications in Our Nation's Industry

This low-cost, high-efficiency thermally activated technology could potentially be utilized by numerous industrial and manufacturing facilities that use liquid-cooled systems, such as stationary engines and steam boilers. The TCC system allows these facilities to utilize the low-temperature waste heat that is usually uneconomic to capture. The developed system can be used to offset a number of cooling loads at these industrial facilities, including process cooling and refrigeration.

Project Description

The project seeks to develop a turbo-compression cooling (TCC) system that is powered by ultra-low temperature waste heat from engine coolant in diesel generators. The effort builds on prior and ongoing work on a thermally activated cooling system that utilizes low-grade waste heat from the combustion exhaust gases of power plants. The TCC system consists of two different cycles—power fluid and cooling fluid cycles—that are coupled by a high efficiency turbo-compressor. The project objective is to validate that the system can achieve a COP of 0.6 at a 300 kilowatt-thermal (kW_{th}) cooling load while meeting the cost target. The system's performance at partial load conditions will also be validated.

Barriers

- Development of highly efficient power and cooling loops that operate very close to theoretical Carnot limits.
- Turbomachinery needs to provide high efficiency operation at turndown ratios as low as 10:1.
- Achieving the targeted high COP at a low cost.
- Ability to match cooling demand with variable waste heat supply.

Pathways

The project focuses on two primary technical innovations that enable the TCC system's high performance at a low cost: high-efficiency turbomachinery and low-cost, highly effective heat exchangers.

The project team will conduct component and system modeling and analysis to identify the most suitable and highly efficient turbo-compressor configuration for the system. One of the project team members has extensive experience in designing and fabricating high-efficiency turbomachinery for a wide range of applications.

Heat exchangers used in industrial applications—such as gasketed plate and frame heat exchangers and shell and tube devices—are typically made of stainless steel or other relatively expensive materials. This project utilizes a new type of liquid-coupled aluminum heat exchanger that provides a large amount of surface area at a low cost.

Based on the modeling and analysis work, a first design concept of the TCC system will be fabricated and tested. If this concept meets established performance goals, a second design concept will be fabricated to validate that it can meet the performance and cost targets.

Milestones

This three-year project began in 2018.

- System and component modeling, analysis, and design for first design concept (2019).
- Fabrication and testing of first design concept with COP target of 0.5 at the cost target (2019).
- Detailed market analysis for the TCC system (2019).
- System and component modeling, analysis, and design for second design concept (2020).
- Fabrication and testing of final design concept with COP target of 0.6 at the cost target (2021).

Technology Transition

The project goal is to demonstrate a TCC system in a relevant environment. If the effort is successful and the developed system meets the performance and cost goals, the project team will be in an excellent position to attract additional funding to further develop and commercialize the technology. To advance the technology towards the market, Colorado State University may spin out a company that can seek grants or investor funding, or the technology can be licensed to a company for commercialization.

Globally, the absorption technology market is expected to reach \$1 billion by 2023. The diesel generator market is projected to see strong growth, especially in developing countries where electric grid infrastructure is poor. As a result, there appears to be a significant market opportunity for a low-cost thermally activated cooling technology such as the TCC system.

Project Partners

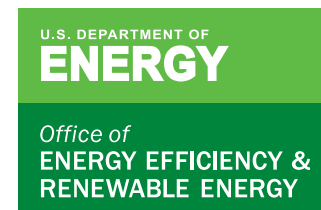
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