Turbo-Compression Cooling for Ultra Low Temperature Waste Heat Recovery

Contract Number: DE-EE0008325
Colorado State University (Lead); Partners: Barber Nichols Inc., Modine Mfg. Co.
Project Period: June 1, 2018 to May 31, 2021

Dr. Todd Bandhauer, Colorado State University

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Overview

Timeline

- ER Award issued June 2018
- Projected end date May 2021
- New project start

Barriers

- Utilization of low temperature waste heat (90°C to 150°C)
- Reduce system footprint
- Matching cooling demand with variable waste heat supply
- Compact low cost heat exchangers
- High efficiency turbomachinery operated over wide range of conditions

Budget

	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Project
DOE Funded	982K	455K	447K	1.88M
Cost Share	275K	148K	47K	470K

Partners

- CSU in Fort Collins, CO, leads project and is site of experimental validation
- Project partners include:
  - Barber Nichols Inc. – Specialty turbomachinery manufacturer in Arvada, CO
  - Modine Manufacturing Co. – Heat exchanger and commercial chiller manufacturer in Racine, WI

Project Objectives

Challenges in Manufacturing Environments

- AMO Strategic Goal: Improve the productivity and energy efficiency of U.S. through utilization of waste heat
- MYPP Target 12.1: Develop system designs with smaller footprints
- MYPP Target 12.3: Develop innovative, cost-effective systems to recover heat from low-temperature (<230°C) waste heat sources

Validate Turbo-Compression Cooling Concept

- Problem: efficiently convert variable low grade heat (90°C to 150°C) to cooling in manufacturing operations with a small footprint
- Relevance: co-located cooling loads and waste heat are common in many industries (e.g., food, CHP), and significant reduction in manufacturing energy possible
- Challenge: competing absorption units are sensitive to heat load variability and suffer from large footprints and other difficulties
- Solution: develop advanced turbo-compression cooling system that combines high effectiveness compact heat exchangers with highly efficient turbomachinery
- Major risks addressed in this project: (1) high turbine and compressor efficiency (>80%), (2) compressor stall at low flow (10:1 turndown), (3) high effectiveness HX with low pressure drop, (4) manufacturing system integration

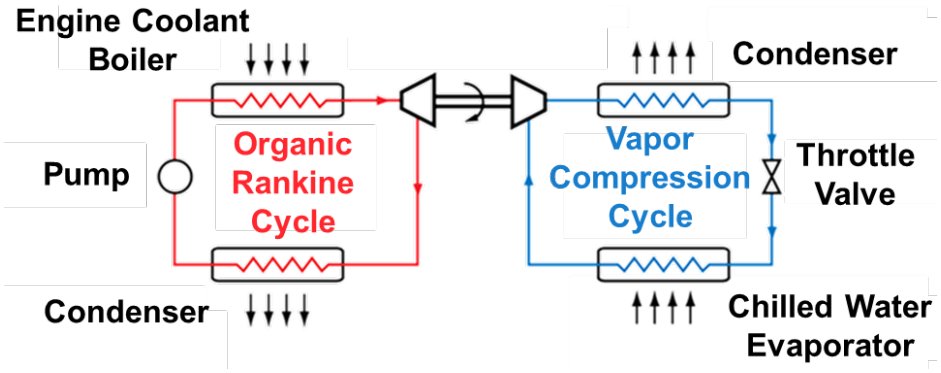
Technical Innovation

Challenges with Current Solutions – Absorption Chillers

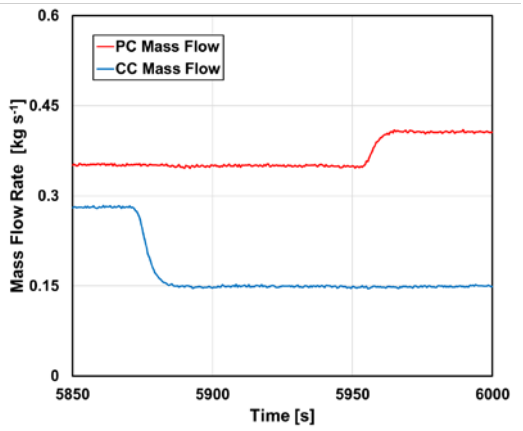
- Low refrigerant pressure require large heat exchangers
- Require steady heat input source, and chemical imbalances cause crystallization
- Corrosive fluids reduce lifespan

Proposed Solution – Turbo-Compression Cooling

- Non-corrosive, moderate pressure refrigerant: smaller, low cost heat exchangers
- Turbomachinery designed to handle transient and variable heat inputs, validated in prior efforts
- Suited for processes with variable operations with significant cooling loads (e.g., food and beverage) and potential for CHP+C (e.g., electronics manufacturing)



System Diagram

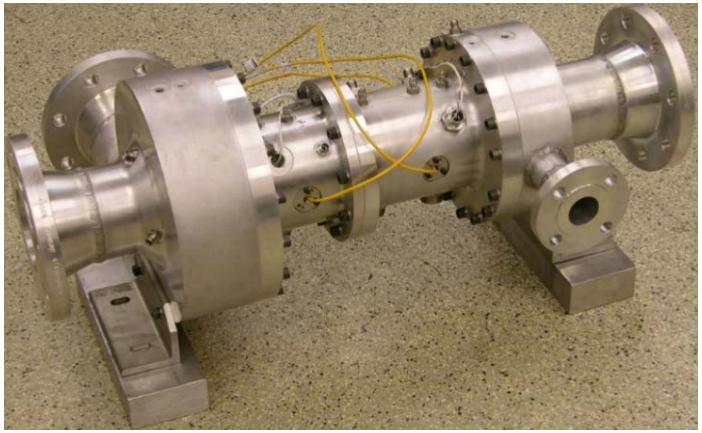


Representative Transient Operation

Technical Approach

Develop turbo-compression cooling system at industry standard conditions with high turndown and small footprint

- Turbomachinery optimized for operating conditions yields high efficiency and turndown (BNI)
- Compact, aluminum brazed heat exchangers reduce system footprint and cost (Modine)
- Advanced cycle design and integration yields viable waste heat to cooling technology with significant market penetration potential (CSU)



High Efficiency Turbomachinery

Compact Heat Exchangers

Technical Approach – Key Risks

Risk	Challenge	Mitigation	Key Milestones
Meeting Cost Target	HX Costs, Misc. Component Cost	Early discussions with Modine, compare with similar products	M1.1
Meeting COP Target	High Effectiveness HXs and High Efficiency TC	Frequent design reviews, two design concepts	M1.1-M1.4, D1 and D2
Operation at Various Loads	Compressor Stall at Low Turbine Powers	Frequent design reviews, proprietary mitigation, two design concepts	M1.1-M1.4, D1 and D2
HX Manufacturing	Large Devices	Only manufacture key components, utilize existing technologies as much as possible	M1.4
Market Uncertainty	Insufficient Waste Heat and Cooling Load, Recovery and Utilization Mismatch, Test Conditions Do Not Match Market Requirements	Early market analysis will narrow down top industrial prospects, evaluate design changes as needed, test over range of conditions	M7.1, M7.2, M6.2, M6.3

Projected Results and Accomplishments

- **Recently awarded on June 1, 2018, initial design point and market assessment complete**
- **Year 1**
  - Market Assessment
  - Finalize Design Points, Cost Assessment (M1.1 & M1.2)
  - Finalize Design Concept 1 (M1.3 & M1.4, *D1*)

Market analysis and system design

- **Year 2**
  - Heat Exchanger and Turbomachinery Fabrication (M2.1 & M2.2)
  - System Fabrication (M2.3)
  - Experimental Testing to Validate COP (M3.1)
  - Modeling of Design Concept 2 (*D2*)
  - Secure IP (M7.3)

Build system and meet first performance target

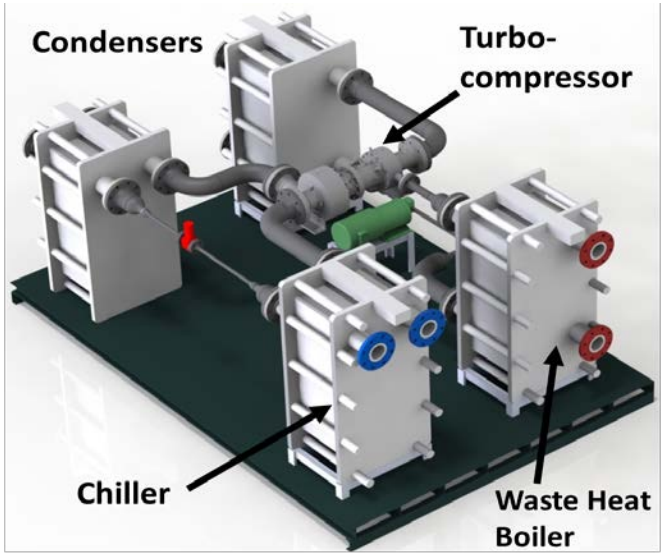
- **Year 3**
  - Finalize Design Concept 2 (M4.1)
  - Fabrication of HC, TC, and System (M5.1 – M5.3)
  - Experimental Testing to Validate COP (M6.1)
  - Experimental Testing to Validate Turndown Ratio and Varying Ambient (M6.2 & M6.3)
  - Secure IP (M7.4)
  - Final Economic and Commercial Validation (M7.5)

Modify system and meet final performance targets

Transition

Project address key technoeconomic risks and understanding likely adoption pathway for low grade waste heat to cooling systems

- Currently engaging manufacturing industries to understand adoption and integration challenges
- Some key industries could benefit from combined power and cooling (e.g., computer, electronics, and electrical equipment manufacturing)
- Successful completion of project provides industry tools to evaluate commercialization strategies, including for project partner Modine



Proposed Turbo-compression Cooling System

300 kW electrical chiller fabricated by partner Modine

Questions?