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Sandia Cooler Current Projects and Applications

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



We have five new projects for FY14 along with completion of the Demo Units



Projects funded by DOE Building Technologies Office

1. Complete 10 CPU Cooler Demonstration Units
2. Thermoelectric Cooling Device – University of Maryland/Optimized Thermal Systems
3. Condenser for Residential Refrigerator – University of Maryland
4. Heat Exchanger for HVAC systems – Oak Ridge National Lab
5. Heat Exchanger for Residential Heat Pumps – United Technology Research Center

Internally funded

6. Solid state lighting

Ten Demonstration Units will be completed by January 2014

Most components are complete and ready to assemble

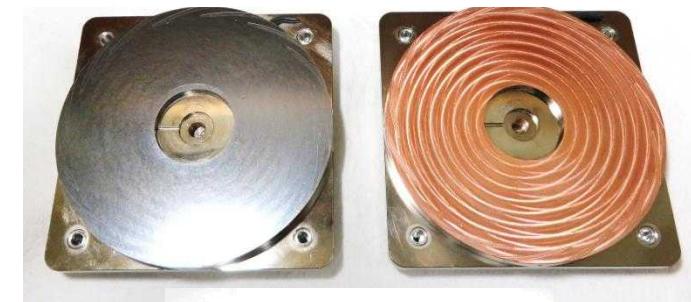
Impellers:

- **5 are complete**
 - machined, coated, motor rotor installed
- **6 more have been machined, not coated**



Vapor chamber baseplates:

- **9 are complete, 1 more in progress**
 - Machined and coated



Shafts:

- **10 are complete**



Motor Stators:

- **3 wound and ready**



HVAC Heat Exchanger - ORNL



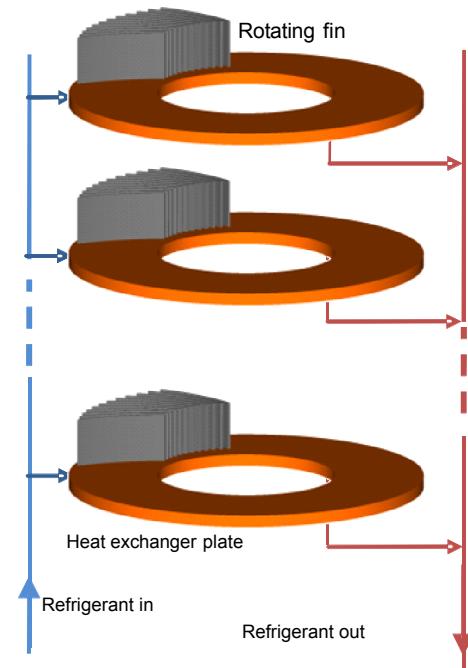
Project Goals:

- Investigate various HVAC&R applications where the Sandia Cooler would have a competitive advantage over standard HXs.
- Model, scale, design, and optimize the Sandia Cooler for a residential HVAC application including the design and integration of the refrigerant side with the Sandia Cooler base plate.
- Design and build a bench-top testing facility to evaluate the system and component performance based on the selected application.
- Instrument and test a baseline system and a prototype Sandia Cooler HX based on relevant standards.
- Perform a preliminary techno-economic evaluation using experimental performance data, typical HX duty and current market.

Heat Pump Heat Exchanger - UTRC

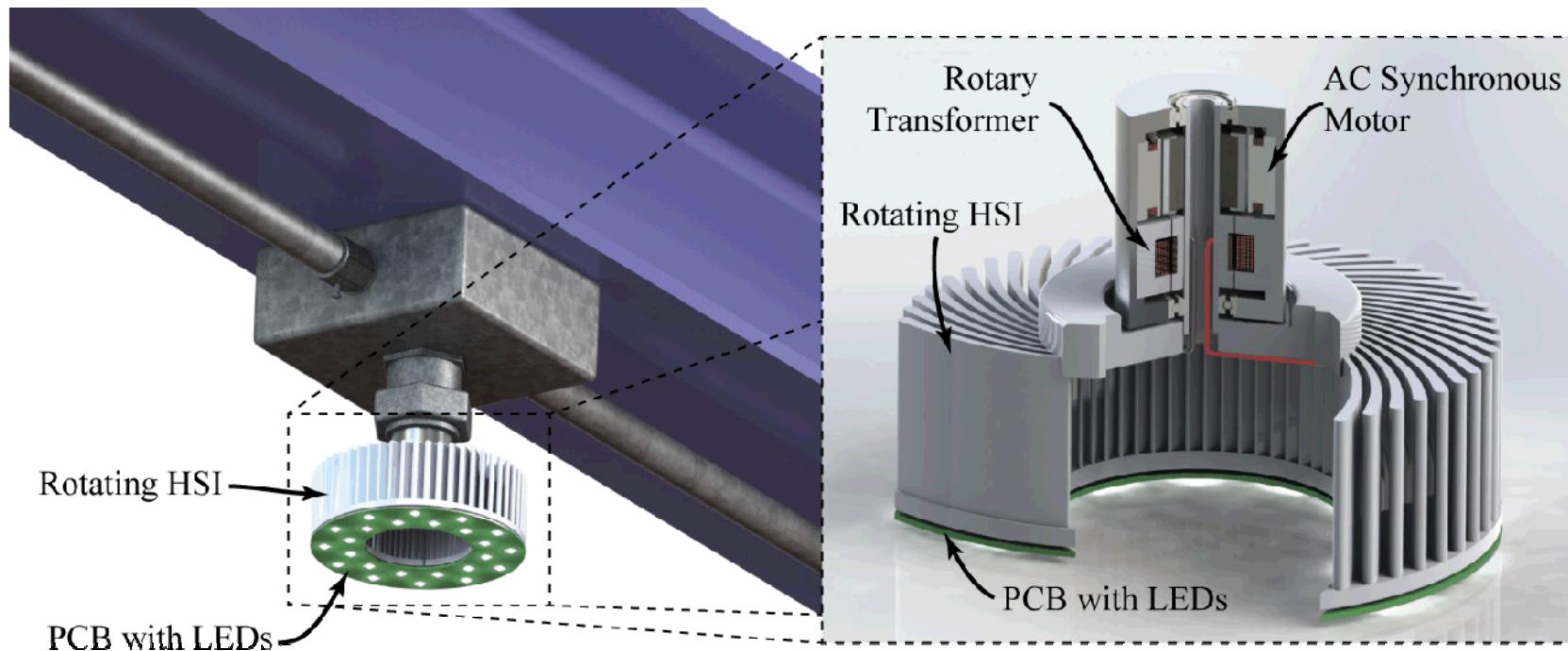
Project Goals:

- Model, scale, design, and optimize the Sandia Cooler for a residential HVAC application
- Build and test a 1 kW heat exchanger/fan subsystem based on the optimized Sandia Cooler design at relevant HVAC condenser and evaporator conditions
- Demonstrate through testing approximately 30% reduction in heat exchanger overall thermal resistance compared to conventional technology given comparable fan power and volume
- Demonstrate through system-level modeling approximately 10% increase in system efficiency with little or no increase in cost or volume relative to a 13 SEER baseline system.



Rotary-Cooled Solid-State Lighting

- A new variation of the Sandia Cooler tailored to solid-state lighting:
 - LEDs mounted directly to rotating heat-sink-impeller
 - No air bearing or associated air gap thermal resistance
 - Electrical power delivered to LEDs via a high-efficiency rotary transformer



Thermoelectric Cooler – UMD/OTS



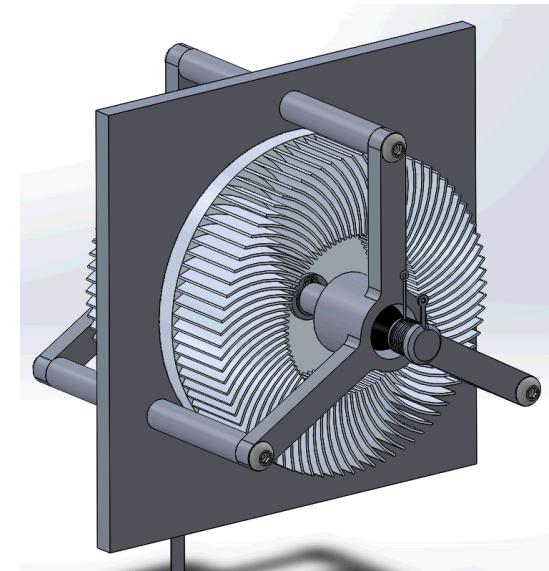
Project Goals:

- Assess existing thermoelectric cooler applications to determine an appropriate target market
- Perform a teardown analysis of a commercial device to measure the performance
- Develop an optimized design utilizing Sandia Coolers and a custom TE module
- Fabricate, assemble and test a prototype device to demonstrate enhanced performance and/or energy efficiency compared to the commercial system

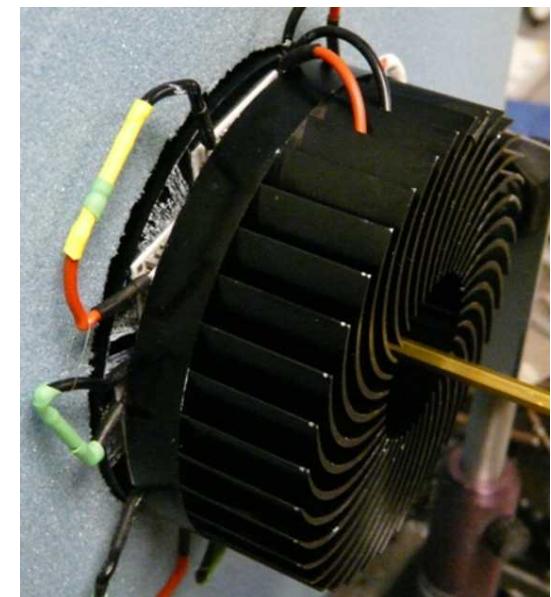
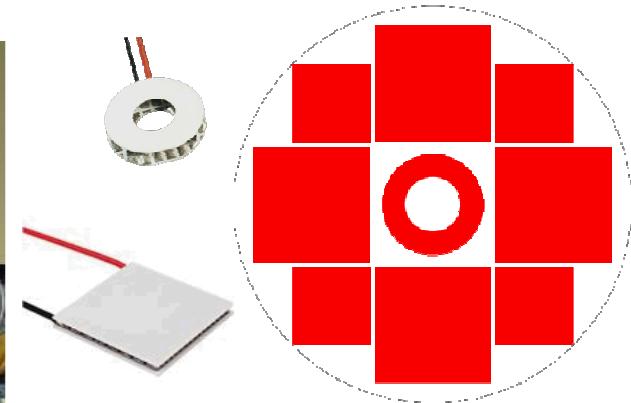
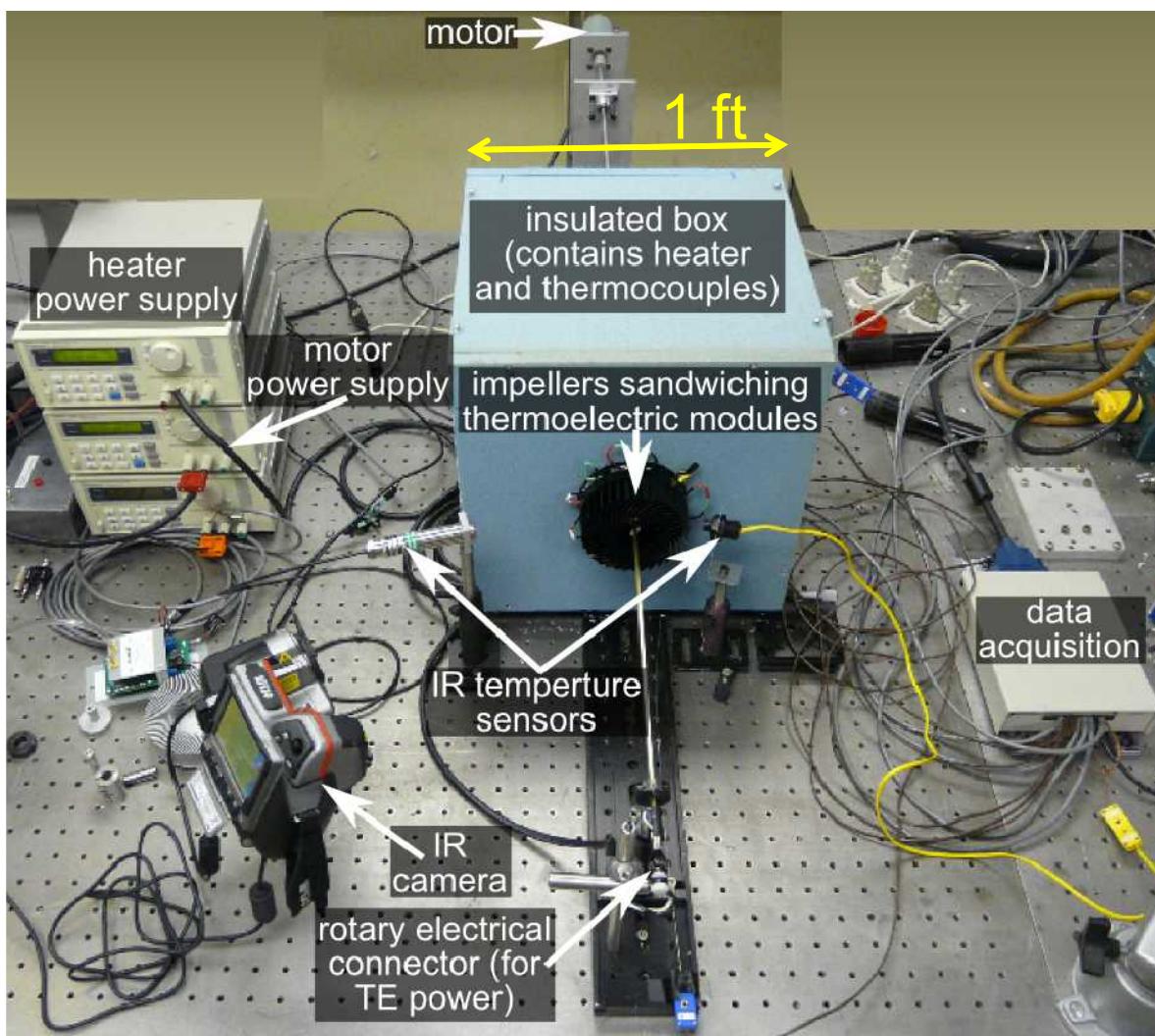
Wine Cooler A/C Unit



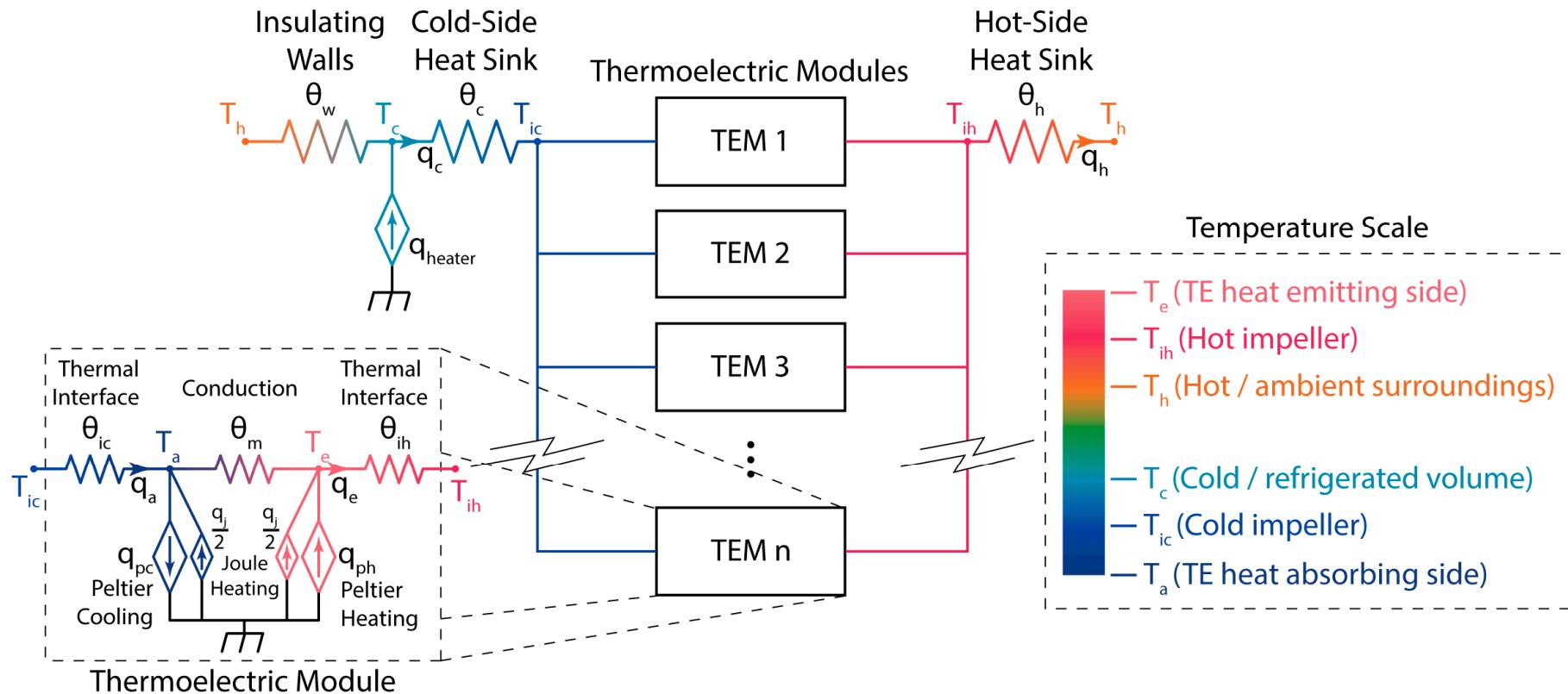
Sandia Cooler concept



A Sandia cooler-thermoelectric assembly has been evaluated using off-the-shelf components



System-level model developed in Matlab for design; validated with experiments



$$V = IR_m + \alpha_m \Delta T$$

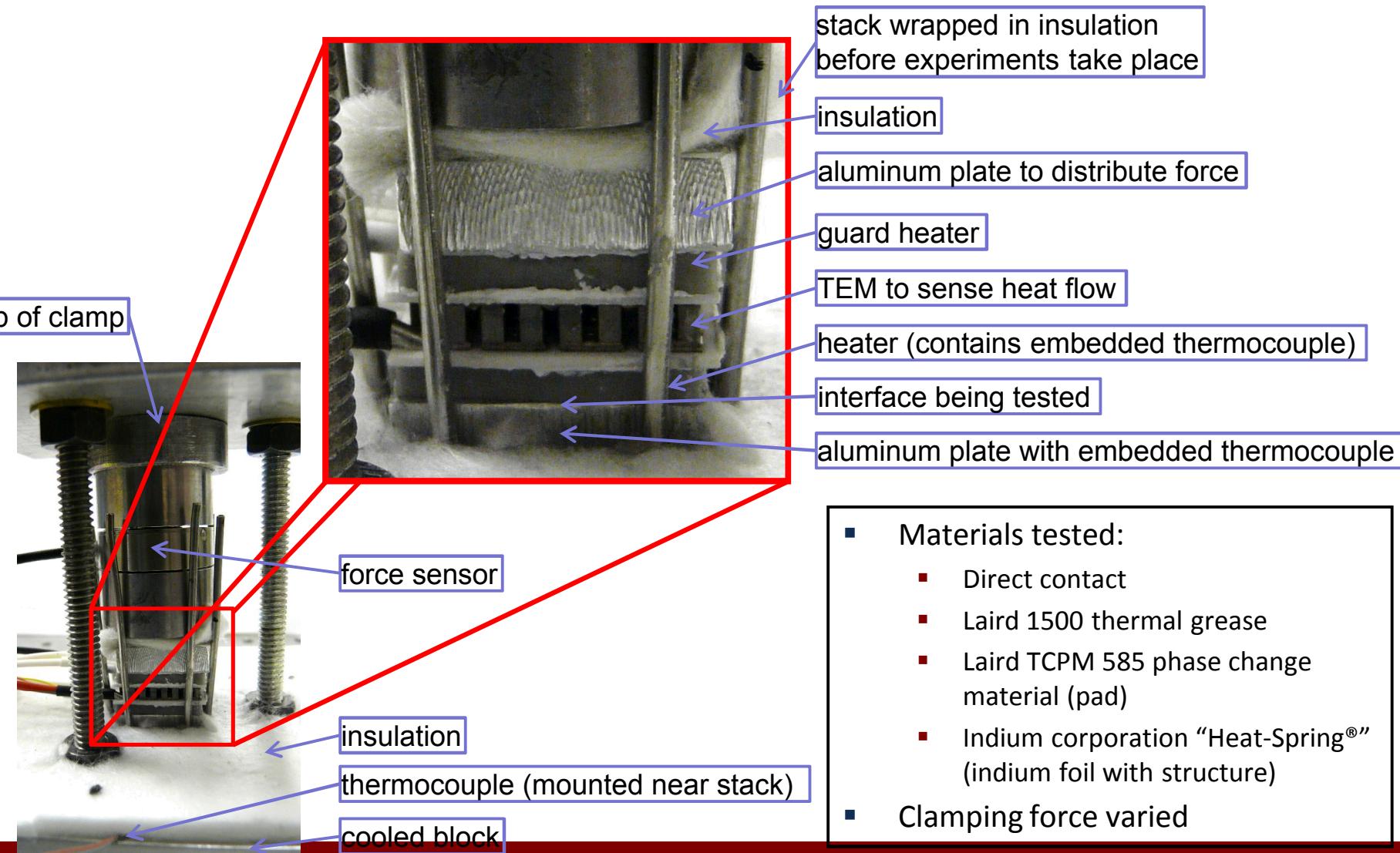
Thermoelectric
Equations

$$q_e - \alpha_m T_e I = -\frac{T_e - T_a}{\theta_m} + \frac{I^2 R_m}{2}$$

$$q_a - \alpha_m T_a I = -\frac{T_e - T_a}{\theta_m} - \frac{I^2 R_m}{2}$$

Thermoelectric equations, energy balances, and heat transfer rate equations are solved simultaneously.

An experiment was designed to evaluate different interface materials



Investigation of Performance Potential of Sandia Cooler in Refrigerator Applications

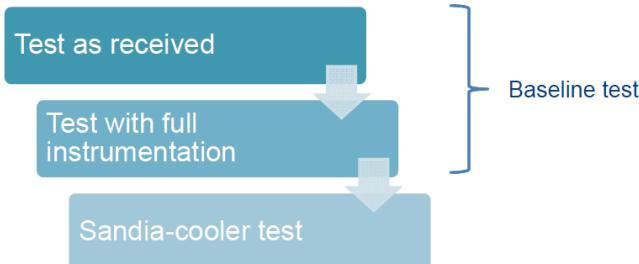


Project Goals:

- Design and fabricate a refrigerator condenser based on the Sandia Cooler
- Select, obtain, and characterize the performance of a residential refrigerator before and after installation of the new condenser
 - The refrigeration circuit and refrigerant charge shall be tuned to achieve optimum performance with the new device.
- Compare volume, weight and power consumption of the original condenser–fan assembly against the new condenser
- Compare overall refrigerator performance with the new condenser installed to show improved COP and/or increased available cabinet space

Performance will be measured before and after installation of Sandia Cooler condenser

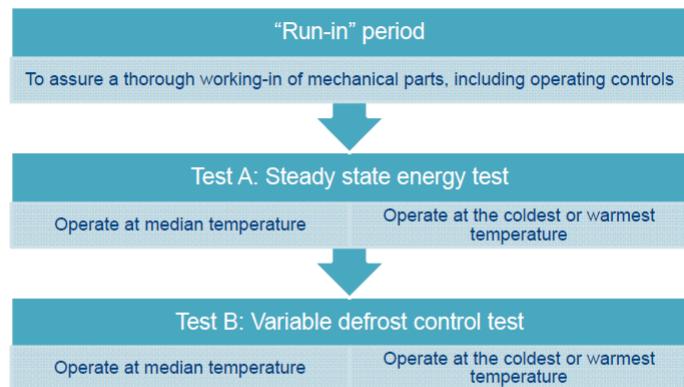
Experiment



Expected Test Results

| Data expected | Total refrigerator power |
|---------------------------------|--|
| Compressor Power | |
| Cabinet temperatures | |
| Cycle temperatures | Compressor discharge temperature, condenser inlet, condenser outlet, evaporator inlet, evaporator outlet, compressor suction |
| Cycle pressure | Compressor discharge, suction pressure |
| Refrigerant mass flow rate | |
| Evaporator pressure drop | |
| Condenser pressure drop | |
| Total yearly energy consumption | |

Test Procedure

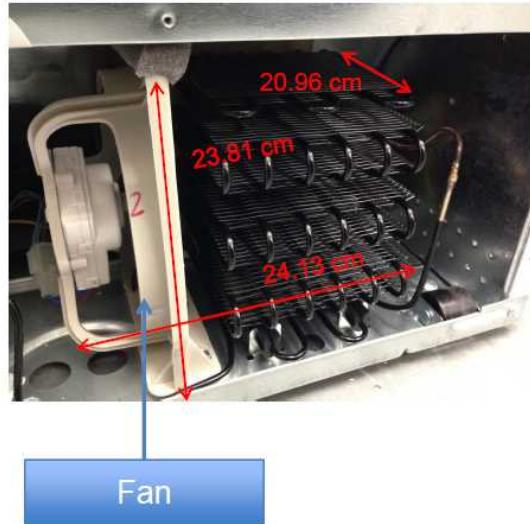
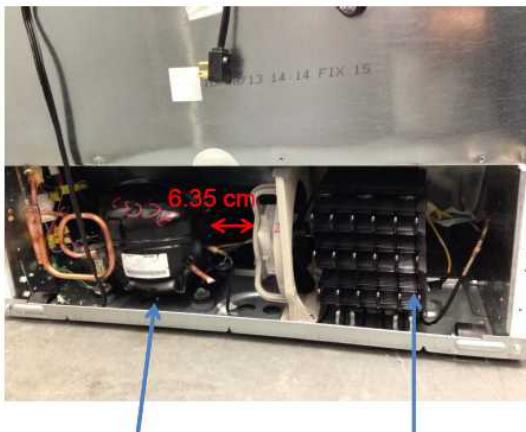


Standard:

- DOE, 2012, *Uniform test method for measuring the energy consumption of electric refrigerators and electric refrigerator-freezers*
- AHAM HRF-1-2007



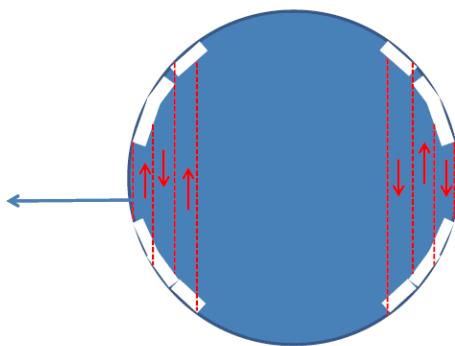
Test unit currently being installed in UMD environmental chamber



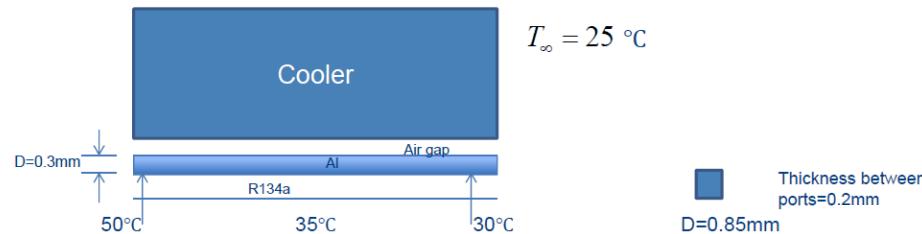
| Company | Frigidaire |
|--------------------------------|------------|
| Product No. | FFHT1826LW |
| Total capacity (cu. ft) | 18.2 |
| Refrigerator capacity (cu. ft) | 14.13 |
| Freezer capacity (cu. ft) | 4.07 |
| Width (in) | 29.6 |
| Height (in) | 66 |
| Depth (in) | 29 |
| Estimated mass flow rate(g/s) | 0.72 |

Design work underway for integrated baseplate/refrigerant condenser

Heat transfer and pressure drop analysis being carried out assuming a micro channel design

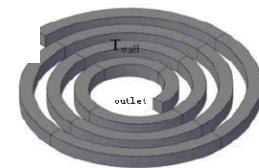


Assumption:



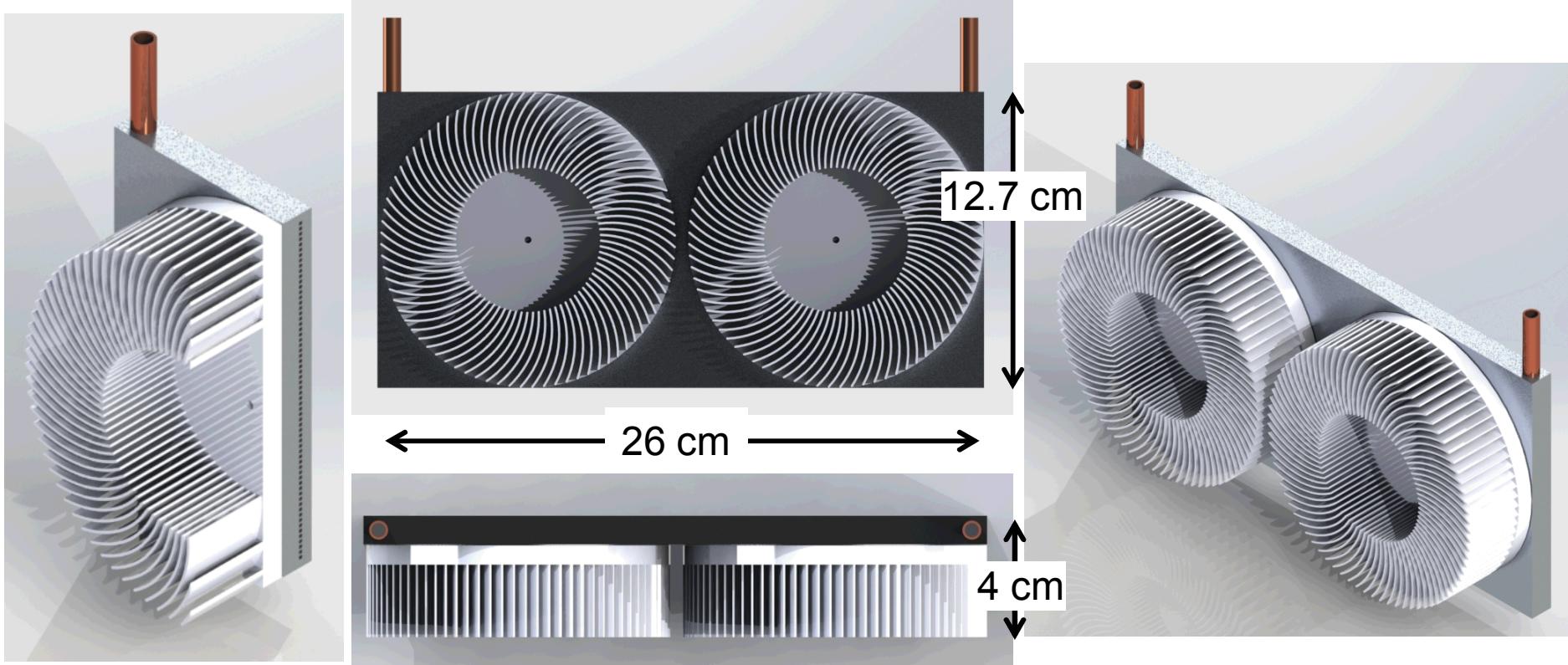
Spiral configuration enables even distribution of vapor and liquid and simplifies manifold

Assumption: 2.2mm (inner diameter)
0.4mm (shell thickness)
0.72g/s (mass flow rate)
serial



| Items | Unit | Vapor | Two-phase | Liquid | Total |
|-----------------|------------------------|--------------|-----------|--------|-------|
| Mass flux | kg/(m ² *s) | 189.4 | 189.4 | 189.4 | |
| Re | - | 32796 | | 2350 | |
| Nu | - | 88.98 | 86.24 | 16.88 | |
| H | W/(m ² *K) | 650.7 | 3121 | 610.8 | |
| A_{ref} ratio | - | 0.0839 | 0.8235 | 0.0926 | 1 |
| Area needed | | 2.60*A_plate | | | |
| Length | m | 0.60 | 5.88 | 0.66 | 7.14 |
| Pressure drop | kPa | 1.75 | 21.27 | 0.080 | 23.1 |

A conceptual design for the condenser is being developed



- Various impeller configurations are being tested for optimum heat transfer and air flow management
- Enclosure design will be developed to separate and direct inlet and exit flow