ADVANCED, LOW-COST INDOOR HEAT EXCHANGER FOR GEOTHERMAL HEAT PUMPS

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MAINSTREAM ENGINEERING

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Background and Motivation

- **High initial cost is one of the largest barriers limiting market penetration of geothermal heat pumps (GHP)**
- **Need improvements in multiple areas that contribute to high cost:**
  - Ground loop
  - Site-specific engineering design
  - Interior system
- **Mainstream is developing a new heat exchanger for GHP systems**
  - Reduce indoor mechanical costs
  - Reduce pressure drop → increase COP and reduce pumping requirements

Table 1. Geothermal Heat Pump Costs

	Ground Loop	Indoor Mechanical
Residential GHP [1]	\$15,000 - \$20,000	\$7.93/ft² - \$12.20/ft² (\$4,773/ton - \$6,116/ton)
Commercial GHP [2]	\$5/ft²	\$10/ft²
Residential AC/Furnace [3]	N/A	\$4.7/ft² - \$6.9/ft²

Proposed Heat Exchanger

- **Flat plate liquid-refrigerant heat exchanger optimized for GHP systems**
  - Reduce cost
  - Increase system performance
- **Couples heat pump and ground loop, and can serve as desuperheater**
- **Design leverages advances in air-source heat pump heat exchangers**
  - Microchannel heat transfer
  - All-aluminum construction
  - Joining with controlled-atmosphere brazing

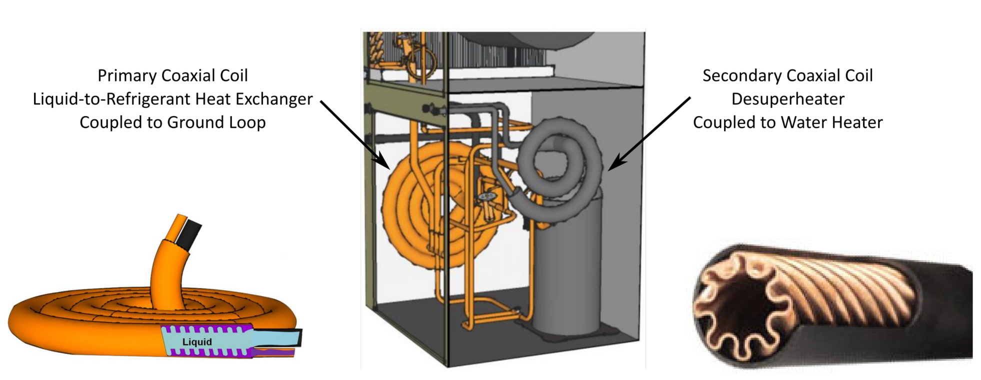

Figure 1. Coaxial coil design (left) [4], coaxial coils in typical ground-source heat pump (center) [4], and coaxial tube design (right) [5].

Figure 2. Brazed, stainless-steel and copper flat plate heat exchanger [6]

Air-Source Heat Exchanger Development

Round Copper Tube & Copper Fin ⇒ Round Copper Tube & Aluminum Fin ⇒ Round Aluminum Tube & Aluminum Fin ⇒ Microchannel Aluminum Tube & Aluminum Fin

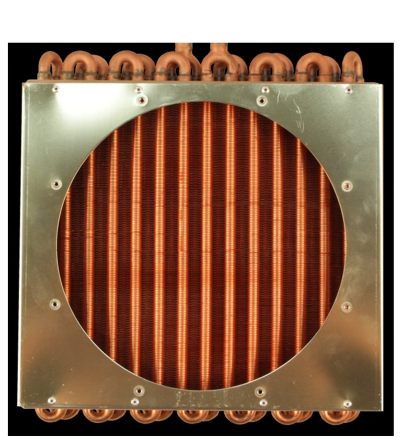

Figure 3. Copper tube-fin heat exchanger [7]

Copper Tube-Fin Heat Exchanger
- **Copper material**
- **Large diameter tubes**
- **Fewer circuits simplifies refrigerant distribution**

Microchannel Aluminum Heat Exchanger
- **Increased thermal performance**
- **Aluminum material (70% lower cost)**
- **Increased pressure capacity**
- **Lower refrigerant charge (up to 90%)**
- **Lower pressure drop**

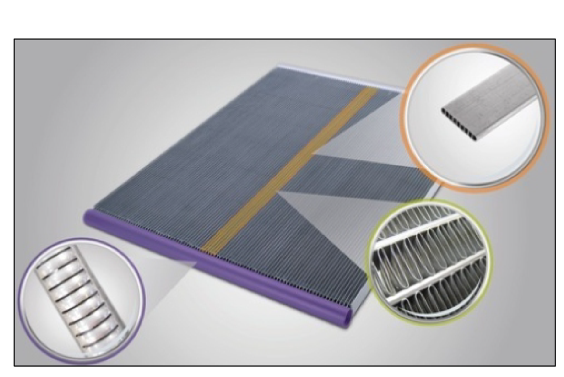

Figure 4. Aluminum microchannel heat exchanger [8]

References

[1] Battocletti, E.C. and W.E. Glassley, *Measuring the Costs and Benefits of Nationwide Geothermal Heat Pump Deployment*. 2013, Bob Lawrence & Associates and the California Geothermal Energy Collaborative.
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[8] Sapa. Microchannel Heat Exchangers. [cited 2017 January 17]; Available from: http://www.sapagroup.com/en/precision-tubing/hvacr/applications/micro-channel-heat-exchangers/.
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Plate Optimization

- **High performance flat plate heat exchanger design requires optimizing plate design**
  - Maximize heat transfer coefficients
  - Minimize pressure drop
  - Standard GHP fluid combinations (e.g., R-410A and 20-80 PG-H_2O)
- **Pressure drop in ground loop determines pump size requirements and parasitic pump power**

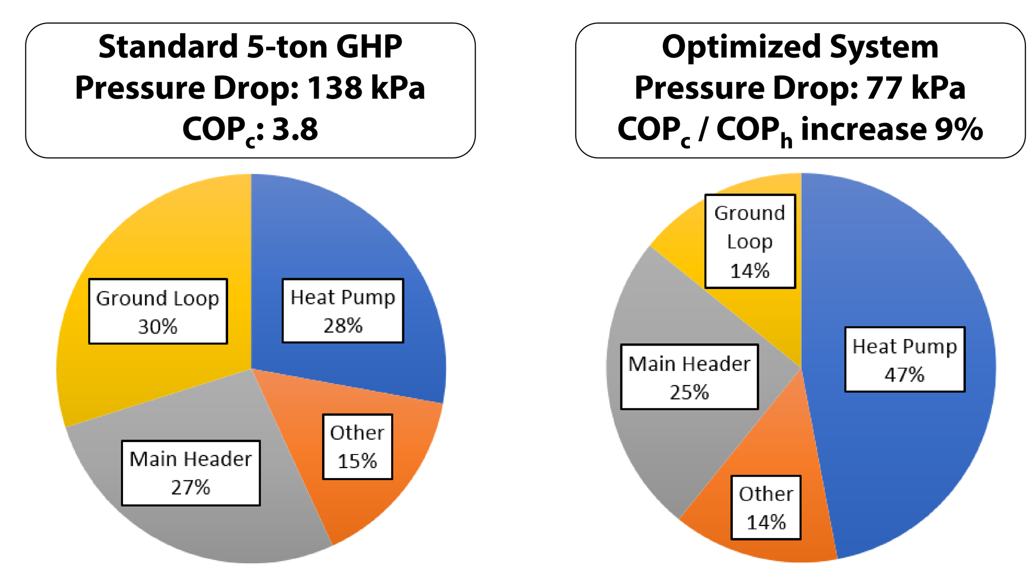

Figure 5. Ground loop pressure drop breakdown of (left) example 5-ton GHP and (right) GHP system with optimized piping and header configuration (adapted from [9])

Refrigerant Distribution

- **Coaxial coils have a single fluid flow path**
- **Proposed heat exchanger has multiple parallel flow passages**
- **Cooling mode → condenser**
  - All vapor inlet with even distribution
- **Heating mode → evaporator**
  - Two-phase inlet (quality 0.1-0.4)
  - Gravitational and inertial forces result in poor fluid distribution and performance degradation

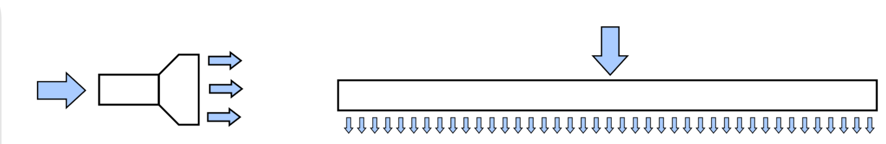

Figure 6. Fluid distribution in tube-fin coil and microchannel heat exchanger

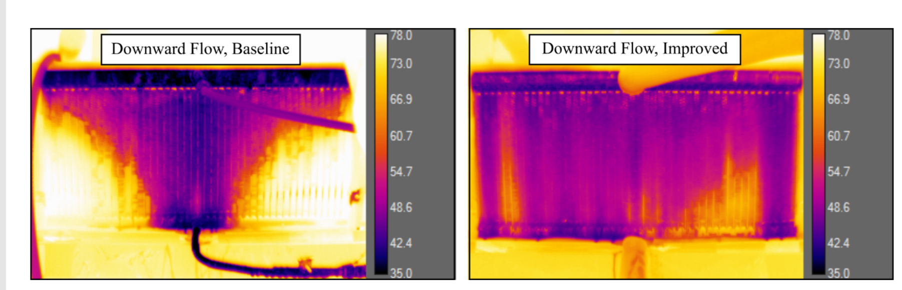

Figure 7. Infrared image of distribution enhancement in microchannel evaporator. Technology developed in ongoing Navy SBIR program (Contract #N00014-15-C-0134).

Fabrication

- **Brazed with controlled atmosphere brazing (CAB) furnace**
  - Low cost
  - High reliability
- **Standard fabrication technique for automotive radiators and air-source heat pump outdoor coils**

Figure 8. Mainstream's brazing facility

Future Work

- **Currently one month into Phase I program**
- **Phase I plan includes designing, fabricating, and testing a subscale prototype heat exchanger**

Acknowledgements

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