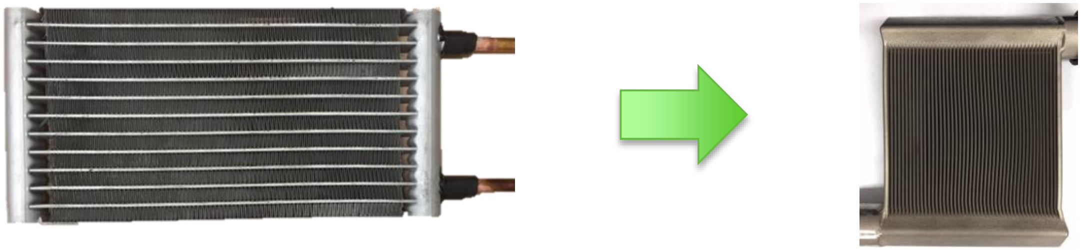
Design and Manufacturing of High Performance, Reduced Charge Heat Exchangers (HPRC-HX)



University of Maryland

Prof. Reinhard Radermacher (PI); Dr. Vikrant C. Aute (Co-PI),

raderm@umd.edu; vikrant@umd.edu

Project Summary

Timeline:

Start date: March, 2018

Planned end date: March, 2021

Key Milestones

1. Non-round tube optimization and manufacturability investigation; Mar 2019
2. Develop, fabricate and test prototype HXs; March 2020/2021

Budget:

Total Project $ to Date:

- DOE: $1,575,000
- Cost Share: $1,750,000

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Key Partners:

ORNL (Funded)	Arconic
HTT (Funded)	Daikin/Goodman
Wieland	JCI
Burr Oak	ICA
Luvata/Modine	Brazeway
3D Systems	Guentner

Project Outcome:

- Development of a comprehensive HX optimization framework
- Accelerate R&D of novel HX designs promoting 25% reduction in size and weight while maintaining structural integrity & thermal performance
- Facilitate closure of the technology-to-market gap for non-round tube HXs

Team

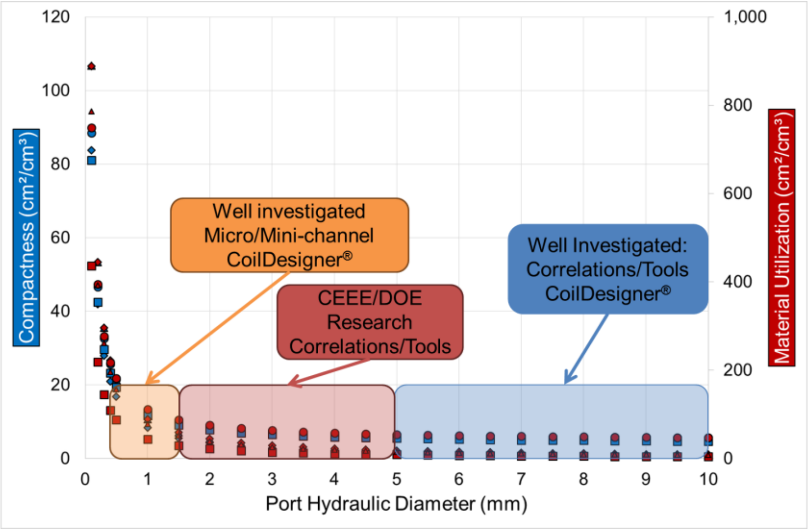
- **University of Maryland, College Park (UMCP, Performer & Lead)**
  - *Reinhard Radermacher* (PI); *Vikrant Aute* (Co-PI), *Yunho Hwang* (Co-PI), Jiazhen Ling, Jan Muehlbauer; *Graduate Research Assistants: Ellery Klein*, James Tancabel
  - *Expertise*: 30+ years of experience in R&D of heat pumps, refrigerant, HVAC&R components and systems, modeling and optimization software development; system and component test facilities; funded by industry and government
- **Oak Ridge National Laboratory (ORNL, Performer)**
  - *Patrick J. Geoghegan, Co-PI, R&D Staff; Researchers: Ayyoub Mehdizadeh Momen,* Mingkan Zhang
  - *Expertise: Computational heat transfer, additive manufacturing, testing*
- **Heat Transfer Technologies (HTT, Performer)**
  - *Yoram Shabtay*, Co-PI; President; John Black, VP, Market Development
  - Expertise: 20+ years of experience in design and mfg. of heat exchangers for pre-production evaluation; development of innovative joining techniques for small diameter tubes and manifolds
- **Industry Partners**
  - *9 Industry partners, including tube manufacturers and HVAC OEMs.*

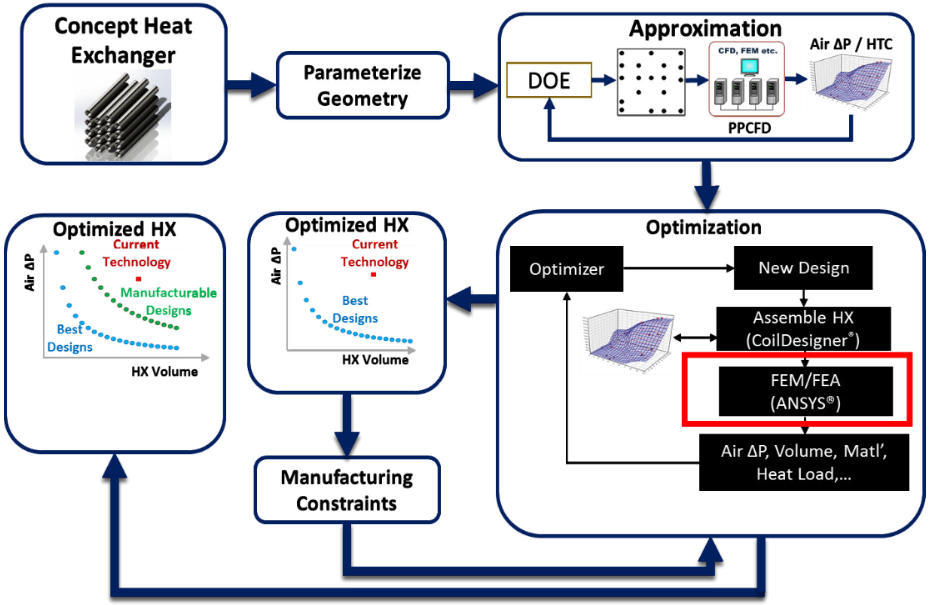
Need & Challenges

- **Heat Exchangers (HX) are a key component in HVAC&R systems**
  - Hold refrigerant charge; Impact on system efficiency
- **Improved heat exchangers lead to:**
  - 30% less refrigerant amount
  - 25% less weight; 25% more compact
  - Lower energy consumption, lower emissions
  - Lower costs
- **Challenges in bringing new HX Technology to market**
  - Novel designs, need to be at least 20% better
  - Novel tools that leverage developments in computing, fluid and structures analyses
  - Lack of basic heat transfer and flow fundamentals and correlations
  - Availability of components
  - Joining/manufacturing techniques
  - Flow maldistribution
  - Fouling and wetting
  - Noise and vibration

Approach

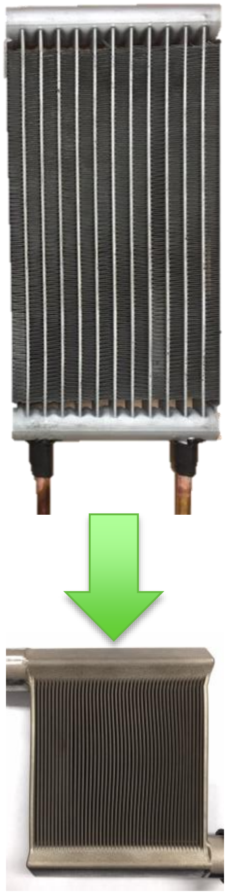
- **Novel Optimization Framework**
  - Small hydraulic diameter HX
  - Shape optimized tubes
  - Potential finless designs
  - Minimize charge and weight, while maintaining thermal and structural performance
- **Focus on manufacturing**
  - Investigate manufacturing of non-round tubes and related joining methods
- **Focus on field performance**
  - Wetting, fouling
- **Active industry involvement**
  - New prototypes to be tested by industry partners; at their labs, with their systems
  - Immediate feedback on commercial viability and design modifications





Impact

- **Impact**
  - New HX designs are expected to have 30% reduced charge and at least 25% reduced weight for the same performance
  - 30% reduction in refrigerant charge has the potential to reduce 35MT of CO2 emission*
  - HX design framework applicable to other HXs in HVAC&R industry
    - HX design independent of refrigerant choice and can be optimized for new refrigerants/blends
  - Size/weight reduction can lead to savings in material and logistics costs
  - Non-round tube manufacturing and joining methods will help reduce barrier to entry for potential OEMs and accelerate commercial use
  - Industry involvement in developing and testing of new designs with immediate and iterative feedback on commercial viability and tech to market



- **Target Market**
  - Residential and commercial air conditioners and heat pumps
  - New construction and retrofit applications

Progress

- **Project started in Feb 2018**
- **Hosted initial kick off meeting**
  - Scheduled follow on brainstorming session
- **Investigating manufacturing options for various materials: Copper and Aluminum**
- **Designed first version of extrusion dies for aluminum**
  - In collaboration with industry partner
  - Conducted CFD analysis to assess impact of manufacturing variations
  - Strength/structural analysis is in progress
- **Conducted literature review on latest prototyping methods and air-to-refrigerant heat exchanger designs**
  - Two publications in progress; one of them to be presented at the upcoming Intl. Air Conditioning and Refrigeration Conference at Purdue, July 2018, Purdue.
- **Scheduling machine shop time with industry partners for Q1'2019**

Stakeholder Engagement

- **Project Started in February 2018**

- **Key players in the entire supply chain (from tube manufacturer to HVAC OEM) involved in the project**
  - Immediate feedback on key design and manufacturing decisions
  - Investigation and development of tooling and joining processes required for mass production
- **New prototypes will be independently tested by at least 3 US manufacturers for performance validation**
  - Component tests
  - System tests
  - Reliability tests (specifics TBD)

Remaining Project Work

Year	Tasks	Description
1	Intellectual Property Management Plan	Develop and deliver IPMP
	Finalize non-round tube designs & establish manufacturing approach	1. Develop HX optimization framework which includes FEA/FEM analysis along with traditional air-side heat transfer and pressure drop analysis 2. Obtain a set of non-round, small diameter tube HX designs achieving desired weight reduction, heat transfer enhancement, pressure drop reduction, and charge reduction at the tube level. 3. Investigate non-round tube extrusion and tube/header integration techniques along with industry partners
	Go / No-Go Decision Point #1	1. Deliver set of optimal non-round tube HXs that are 25% lighter, 25% more compact, and reduce charge by 30% compared to baseline. 2. Report non-round tube manufacturing options and HX assembly methods that passed pressure tests.
2	Design, fabricate, & test prototype non-round tube HXs	Design, prototype, and test 3 to 5 kW range air-to-refrigerant HXs using small diameter, non-round tubes.
	Go / No-Go Decision Point #2	Deliver set of in-house validated HX prototypes to three US manufacturers for independent validations.
3	Design, fabricate, & test 3-Ton system non-round tube HXs & validate system level performance and system charge reduction	1. Review manufacturing / industry feedback regarding Year 2 prototype HXs. 2. Integrate feedback to improve, scale up, and fabricate Year 2 HXs for 3-Ton systems 3. Validate system level performance and system level charge reductions 4. Submit final project report to DOE

Thank You

University of Maryland, Oak Ridge National Laboratory, Heat Transfer Technologies LLC.
Reinhard Radermacher, PI, raderm@umd.edu
Vikrant C. Aute, Co-PI, vikrant@umd.edu

REFERENCE SLIDES

Project Budget

Project Budget: Outline the project budget and history.
Variances: Describe any variances from original planned budget and identify if/how the project plan was modified.
Cost to Date: Identify what portion of the project budget has been expended to date.
Additional Funding: Note, if any, other funding sources.

Budget History					
Insert Start Date – FY 2017 (past)		FY 2018 (current)		FY 2019 – Insert End Date (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share

Project Plan and Schedule

Describe the project plan including:

- Project original initiation date & Project planned completion date
- Schedule and Milestones
- Explanation for slipped milestones and slips in schedule
- Go/no-go decision points
- Current and future work

Project Schedule		
Project Start: Insert Start Date		Completed Work
Projected End: Insert End Date		Active Task (in progress work)
		Milestone/Deliverable (Originally Planned) use for missed
		Milestone/Deliverable (Actual) use when met on time
Task		Q4 (Jul-Sep)
Past Work		
Q1 Milestone: Exa		
Q2 Milestone: Exa		
Q3 Milestone: Exa		
Q4 Milestone: Exa		
Q1 Milestone: Example 5		
Current/Future Work		
Q3 Milestone: Example 6		
Q4 Milestone: Example 7		

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If you have a better visual to put in place for this schedule template, please feel free to do so.