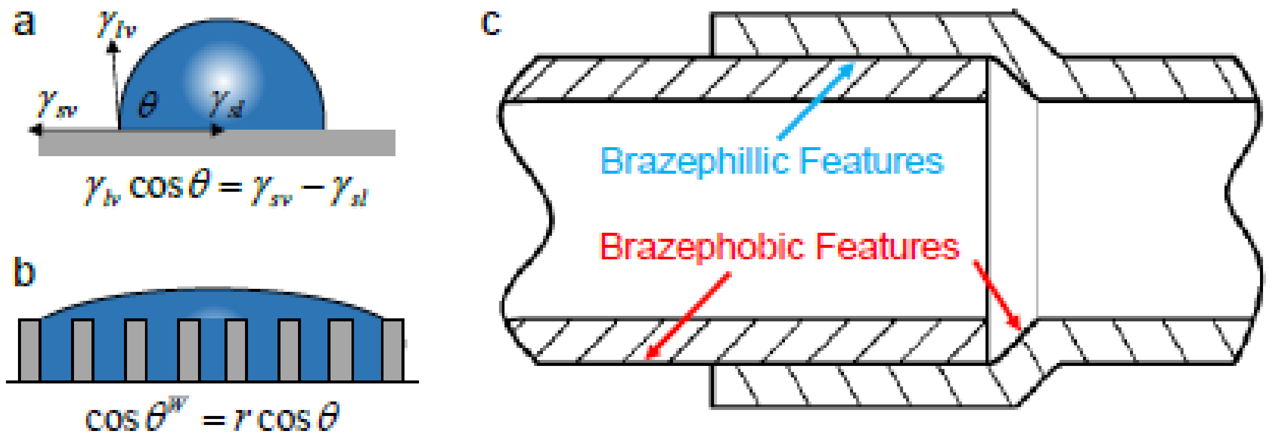
Improved Braze Joint Quality Through use of Enhanced Surface Technologies

2017 Building Technologies Office Peer Review



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: **10/3/2016**

Planned end date: 11/30/2018

Key Milestones

1. Milestone 1; 1/27/17 – Rationale for selection
2. Milestone 2; 2/21/17 – Potential landscape geometries

Budget:

Total Project $ to Date:

- DOE: $1534
- Cost Share: $313

Total Project $:

- DOE: $414,210
- Cost Share: $82,832

Key Partners:

University of Illinois at Champaign/Urbana

Project Outcome:

Maintenance of life cycle HVAC equipment efficiency by refrigerant retention through use of enhanced surface braze joints to reduce refrigerant leakage. Ultimate goal of reduction in refrigerant leaks by 25% and reduction in braze materials by 10%.

Purpose and Objectives

Problem Statement: One of the causes of reduced efficiency during the life cycle of commercial and residential HVAC products is loss of refrigerant charge, which is typically a result of leakage through commonly used braze joints

Target Market and Audience: Commercial and residential HVAC industries will benefit from the technology development to reduce refrigerant leaks. This $50+B market's energy consumption increase due to refrigerant leakage can be as high as 30 TBtu over a 10 year span for a single market segment.

Impact of Project:
Project Output: Life cycle improvements in HVAC&R equipment energy consumption through reduction in braze joint refrigerant leaks.
Near-term outcomes: Surface enhancement identification that enhances braze joint strength and thermal/pressure cycling capability. Investigation and validation of manufacturing processes.
Intermediate outcomes: Implementation of use in round tube plate fin coil manufacturing processes
Long-term outcomes: Use of surface enhancements throughout commercial, residential HVAC, transport refrigeration and other industry brazing processes on all types of braze joints to minimize refrigerant leakage

Approach

Approach: Engineered surface structures will be used to wick braze alloy and flux to brazing joint areas to create stronger and more robust braze joints. These surfaces for brazing would be braze alloy/flux phobic or philic to help direct the brazing materials.

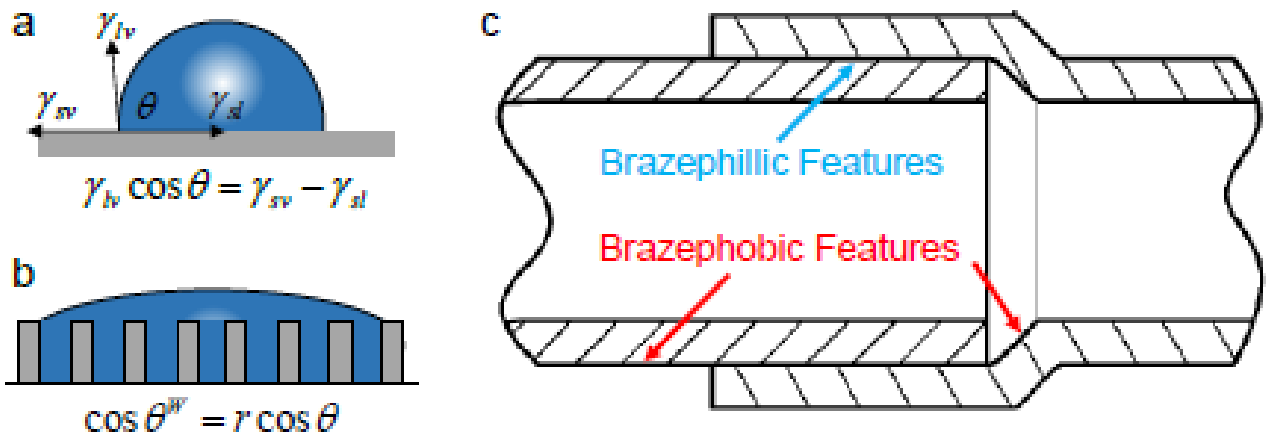
Key Issues:

1. Surface topology identification through wicking capability and strength improvements
2. Cost of Surface Application
3. Ease of Manufacturability

Distinctive Characteristics: Attacks issues within a mature manufacturing process methodology through use of new surface topologies

Approach

Use of brazephilic and brazephobic surface features to move braze alloy to areas needed to improve braze joint strength and reliability



- Improve braze joint hydrostatic burst strength
- Improve braze joint thermal/pressure cycling capability
- Meet or exceed braze penetration internal requirements
- Reduce internal U-bend leak rates while maintaining or lessening cost per U-bend joint

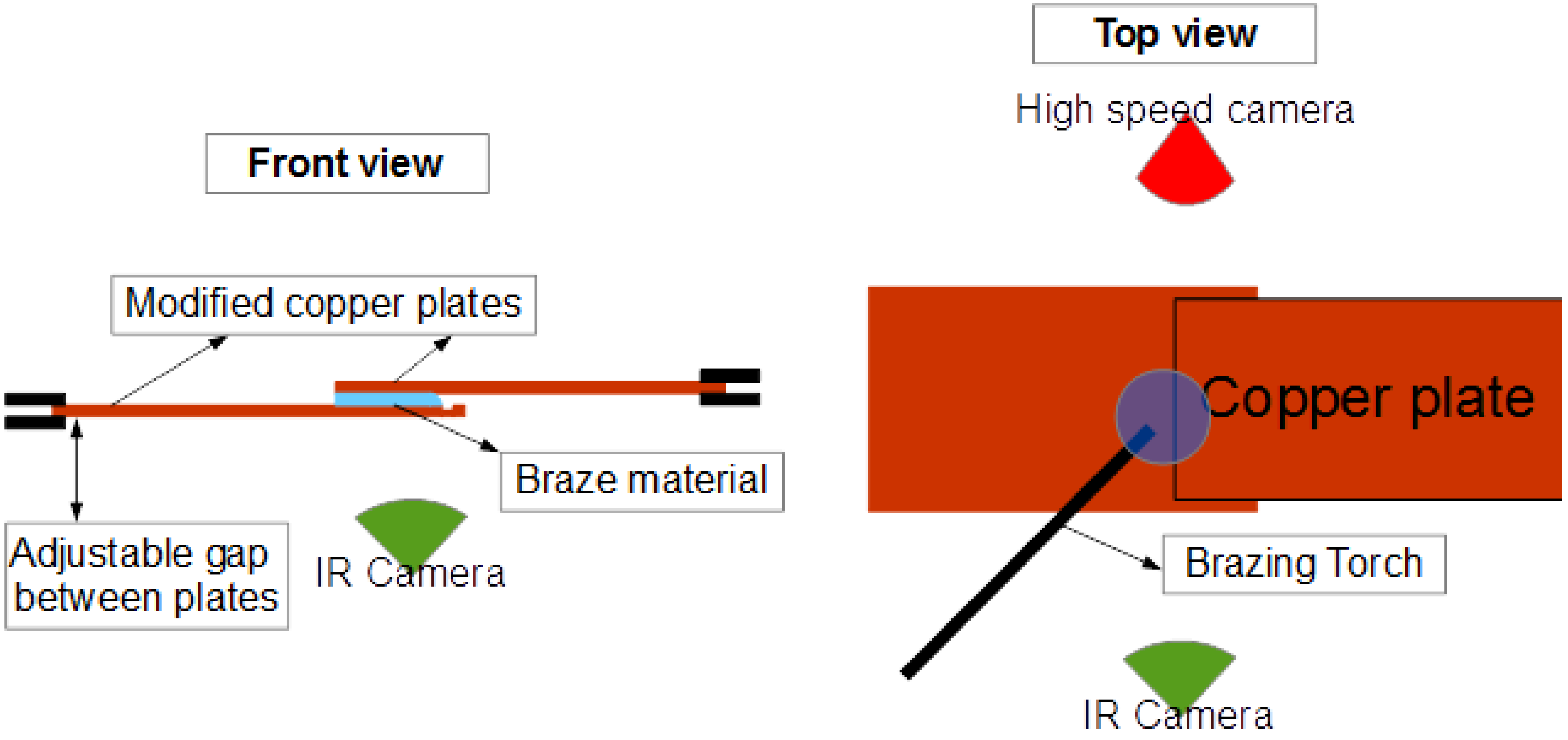
Progress and Accomplishments

Accomplishments:
- Braze training completed for UIUC researchers to understand existing process
- Braze materials and surface material determination

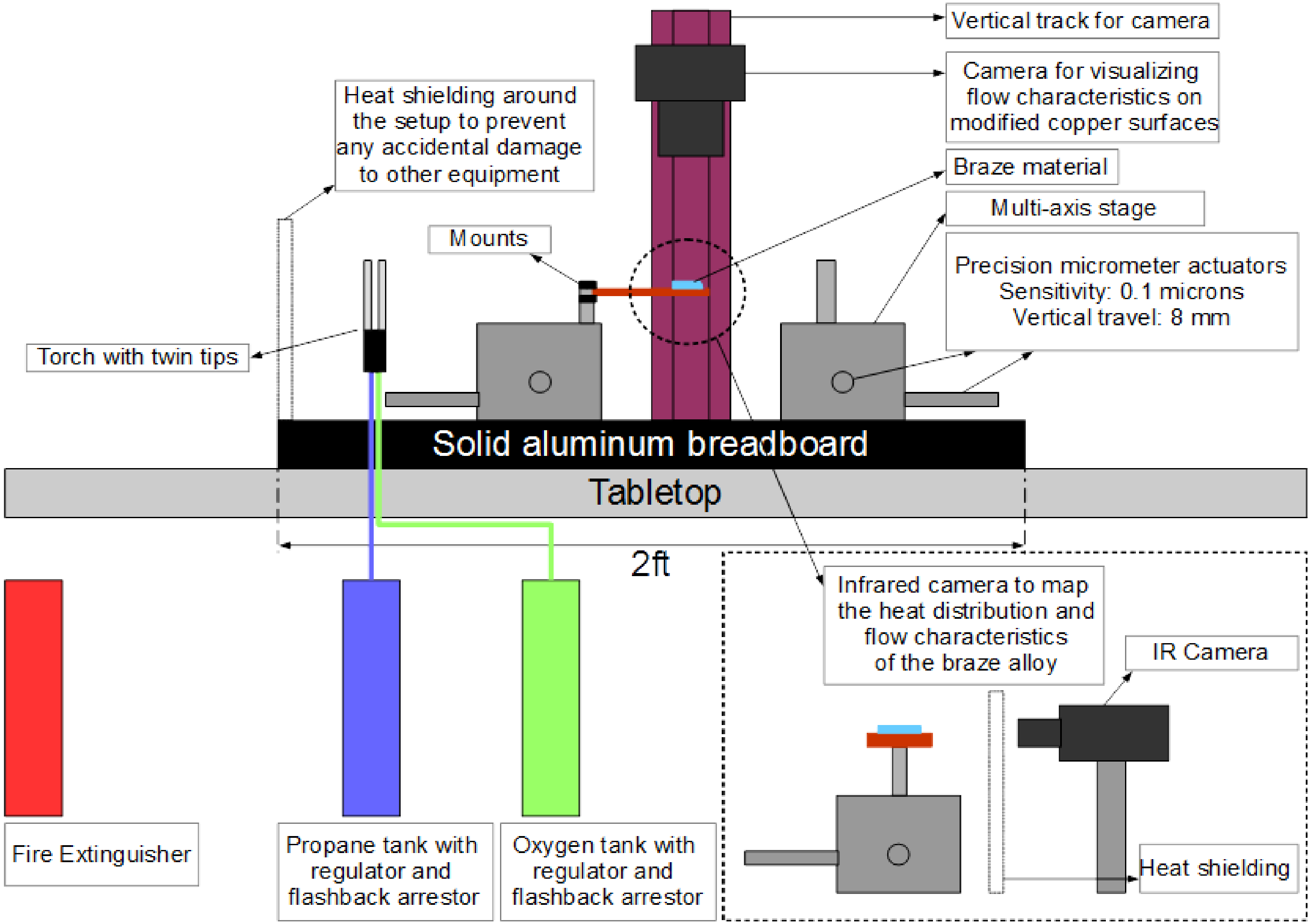
Progress and Accomplishments

Accomplishments:

- Experimental test rig determined and designed to observe the interaction between the braze material and modified copper surface. Test rig will help with repeatability of measurements with regards to wicking and capillary action based on surface enhancement.



Experimental Test Rig



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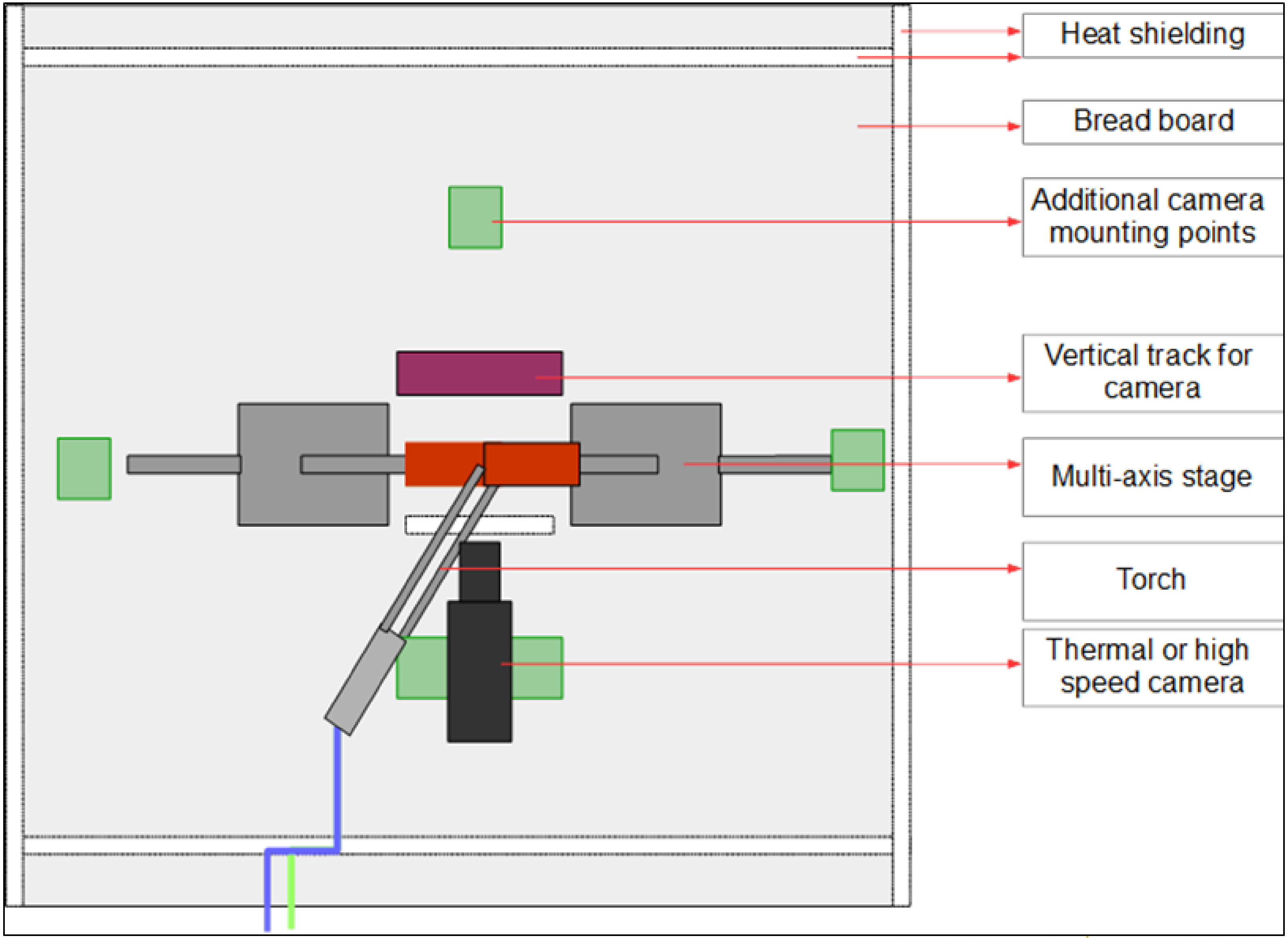
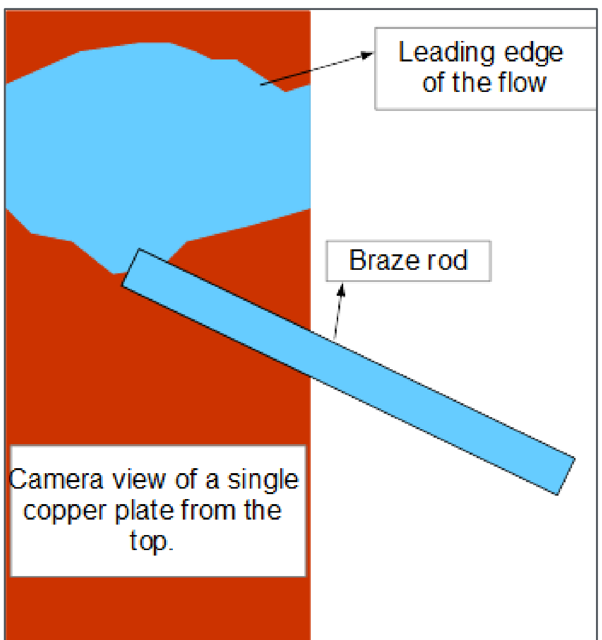
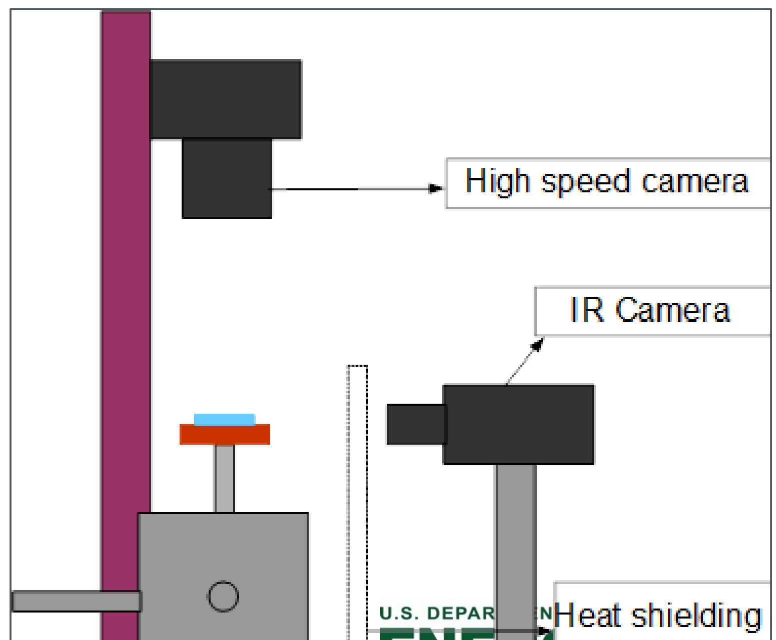
Top View of Experimental Test Rig



Observation Techniques

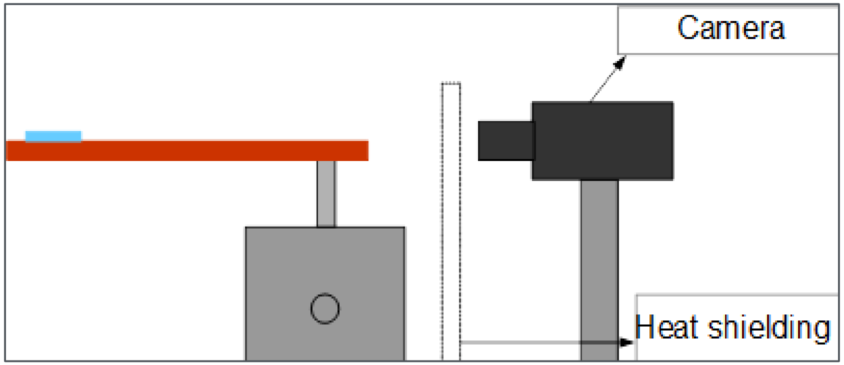
- The interaction between the braze material and the modified copper surface will be explored using various observation techniques.
- Top and side views of a single plate with heat source on the bottom.
  - Characterize viscous flow over a porous media.
  - Measure propagation speed.
  - Measure spreading parameters with respect to time.
  - Thermal camera can monitor temperature profiles of the flow.

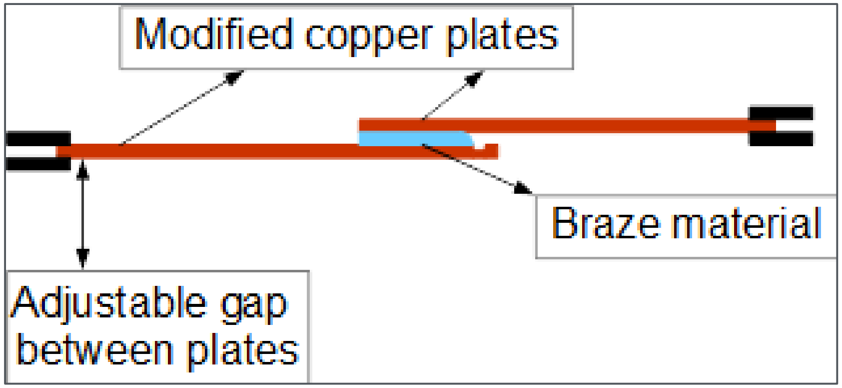




Observation Techniques

- Front view of a single plate with heat source on the bottom.
  - Measure spreading parameters with respect to time.
  - Thermal camera can monitor temperature profiles of the flow.
- Front and side views of sandwiched plates with heat source on top and bottom.
  - Observe and quantify capillarity effect.
  - Observe flow spreading and propagation.
  - Introduce combination of brazephillic and brazephobic surfaces.

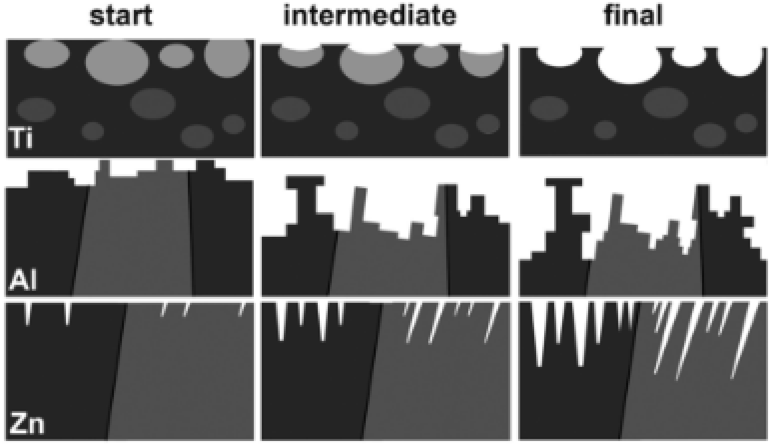




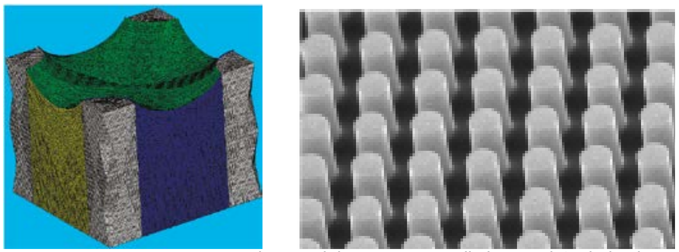
Progress and Accomplishments

Accomplishments:

- Initiation of landscaping of surface structures and creation techniques
  - Examining different techniques for creation of surfaces and surface topology itself
    - Creation of surfaces through mechanical techniques
    - Non-mechanical surface creation
- Initiation of modeling of liquid braze alloy propagation
  - Models to predict liquid propagation rates in capillary tubes that balances capillary pressure with viscous resistance.
  - Tools for prediction of capillary pressure.
  - Find the viscous resistance of pillar arrays by idealizing them as infinitely long cylinders
  - Semianalytical model to predict liquid propagation rates based on the diameter, height and period of the micropillars



Baytekin-Gerngross et al., Nanoscale Horiz., 2016,1,467



Xiao, Enright, Wang, "Prediction and Optimization of Liquid Propagation in Micropillar Arrays

Progress and Accomplishments

Market Impact:

- Too early in in project at this stage (Budget Period 1) to quantify impact on products
- Cost analysis will be conducted in Budget Period 2

Awards/Recognition:

- Prof. Nenad Miljkovic – ONR 2017 Young Investigator Award Recipient

Lessons Learned:

- Removal of manual brazing inconsistencies key to achieving valid selection of surface enhancement
- Business development agreements need to hammered out very early in the application process to allow for immediate commencement of work

Project Integration and Collaboration

Project Integration: Trane and UIUC teams are meeting biweekly to ensure that progress is well understood, communication flows and that potential solutions are viable from a manufacturing process perspective

Partners, Subcontractors, and Collaborators:
UIUC (Prof. Nenad Miljkovic) is the primary subcontractor for identification of enhanced surface topologies

Communications:
None – Project initiated fall 2016

Next Steps and Future Plans

Next Steps and Future Plans:

- Determination of surface geometry enhancements to compare
- Surface Geometry Candidate Comparison – April to December 2017
  - Comparison of surface geometries in flat plate braze test apparatus
  - Comparison of surface geometries in round tube braze test
  - Initial manufacturing cost analysis
  - Selection of surface geometry for manufacturing maturation
- Surface Geometry Maturation – January 2018 to November 2018
  - Soft tooling determination and acquisition
  - Manufacturing of large sample size for testing and analysis
  - Reliability testing
  - Manufacturing cost analysis

REFERENCE SLIDES

Project Budget

Project Budget: Started with proposal budget and slowly ramping up with subaward agreement
Variances: Spend to ramp up in next quarter with subcontractor expenses
Cost to Date: $1,534
Additional Funding: None

Budget History					
10/1/16 – FY 2016 (past)		FY 2017 (current)		FY 2018 – 11/30/18 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,534	$313	$209,237	$54,418	$89,688	$18,525

Project Plan and Schedule

Task Name	Start	Finish
A- Completion of IP Management Plan	Thu 9/1/16	Thu 9/1/16
1A-IPMP signed by representative parties and approved by DOE	Fri 9/2/16	Fri 9/2/16
B1-Define SoA brazing processes	Mon 9/5/16	Fri 11/18/16
Milestone B1- SoA brazing process	Thu 12/1/16	Tue 2/21/17
B2- Training of Members	Tue 11/1/16	Fri 12/2/16
B3- Background Determination of alloys and fluxes	Mon 12/5/16	Thu 12/8/16
B4- Landscape Potential Geometries	Wed 2/1/17	Tue 2/28/17
B4- Dissemilation of potential landscape geometries to DOE	Wed 2/1/17	Wed 3/1/17
C- Selection process for microstructure geometry determination	**Mon 5/1/17**	**Thu 12/7/17**
C1- Create different surface geometries thru sanding and	Mon 5/1/17	Fri 5/19/17
C2- Braze tube geometries with different geometries	Mon 5/22/17	Wed 5/31/17
C2- Review of generated surfaces	Mon 5/22/17	Wed 5/31/17
C3- Section and analyze braze joints	Thu 6/1/17	Fri 6/30/17
C4- Burst test braze joints	Thu 6/1/17	Fri 6/30/17
C5- Brazing samples autobrazer	Wed 7/5/17	Thu 7/27/17
C6- Iterate design gemetries for improvements	Thu 8/24/17	Mon 8/28/17
C6- Review of generated surfaces, and manual and auto braze	Thu 8/24/17	Mon 8/28/17
C7- Create different surface geometries for sanding and	Fri 9/15/17	Tue 9/19/17
C8 - Braze tube geometries with different geometries	Fri 9/29/17	Tue 10/3/17
C9- Section and analyze joints	Sat 10/21/17	Tue 11/14/17
C10- Burst Test braze Joints- Meet or exceed SoA requirements	Sat 11/11/17	Tue 11/14/17
C11- IR Braze samples autobrazer	Fri 12/1/17	Thu 12/7/17
C12-Initial Manufacturing Cost Study	Sat 11/4/17	Tue 11/28/17