NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Compact, Light-Weight, Single-Phase, Liquid-Cooled Cold Plate

2011 DOE Vehicle Technologies Program Review

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May 10, 2011

Project ID: APE039

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Overview

Timeline

- Project start date: FY11
- Project end date: FY12
- Percent complete: 20%

Budget

- Total project funding
  - DOE share: $700K
- FY11 Funding: $700K

Barriers addressed

- Cost
- Weight
- Performance

Targets addressed

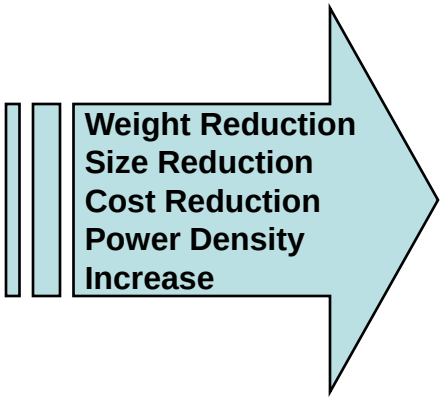
- Cost
- Specific Power
- Power Density

Partners

- Interactions & Collaborations
  - UQM, Wolverine Tube, Inc., Plastics supplier
- Project lead: NREL

Relevance/Objectives

- Advanced thermal control technologies are critical to enabling higher power densities and lower system cost.



Credit: Sreekant Narumanchi, NREL

Relevance/Objectives

- Overall Objective
  - Develop and demonstrate inverter plastic heat exchanger based on forced convective single-phase jets in conjunction with enhanced surfaces.
- Addresses Targets
  - Through thermal management, directly addresses the 2015 power electronics power density (12 kW/liter), specific power (12 kW/kg), and cost ($5/kW) goals.
  - Enables use of high-temperature glycol-water coolant for power electronics cooling (single engine coolant loop).
- Uniqueness and Impacts
  - Novel use of impinging jets in conjunction with microdeformation-based enhanced surfaces in an inverter heat exchanger.
  - Light-weight plastic used for bulk of inverter heat exchanger.
  - Demonstration within an automotive supplier's (UQM) inverter.

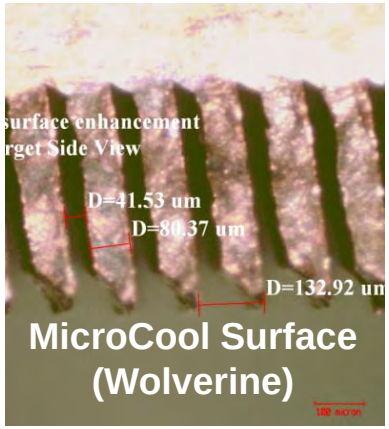
Milestones

Month / Year	Milestone or Go / No-Go Decision Point
January 2011	• Acquired power modules from UQM and initiated design of heat exchanger based on jet impingement in conjunction with microdeformation-based enhanced surfaces. • Identified light-weight plastic material suppliers (DuPont, Cool Polymers, Quadrant).
June 2011	• Obtain functioning inverter from UQM. • Complete finite element analysis (FEA) and computational fluid dynamics (CFD) analysis of baseline channel flow-based heat exchanger and jet impingement-based heat exchanger. • Complete design review with UQM and Wolverine Tube, Inc. ➢ Go/No-go decision point: Whether to proceed with fabrication of jet impingement-based heat exchanger.
November 2011	• Complete heat exchanger fabrication and perform experiments (steady-state and dynamometer) with glycol-water coolant (at 105°C) to characterize thermal performance of baseline channel flow and jet impingement-based heat exchanger. • Characterize reliability of impinging jets in conjunction with enhanced surfaces.

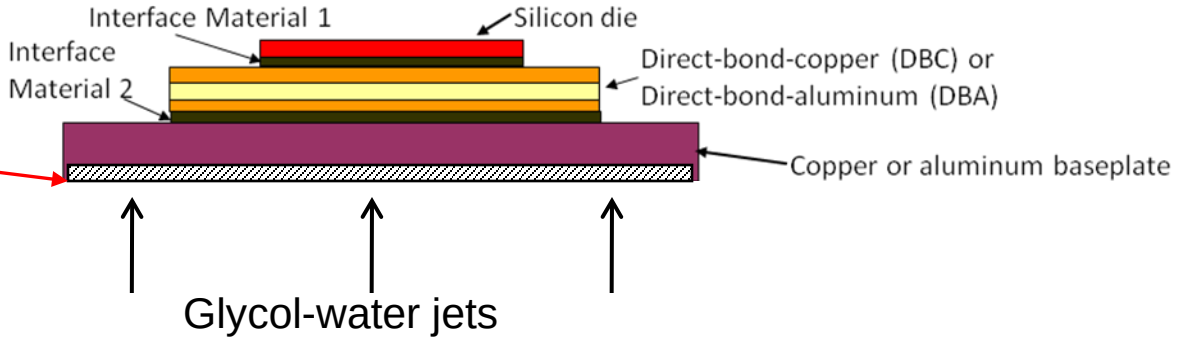
Approach

Heat exchanger

Credit: Sreekant Narumanchi, NREL



Credit: Mark Mihalic, NREL

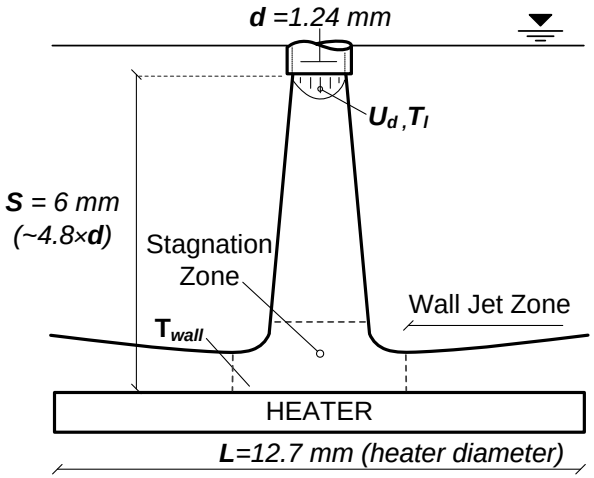


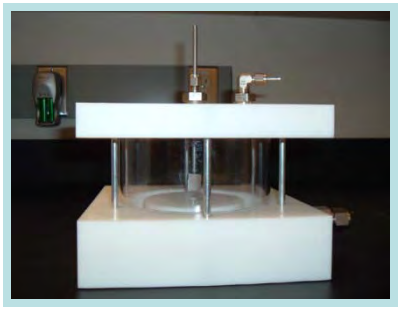
- Reduce thermal resistance, increase heat transfer rates through impingement on enhanced surfaces, and use light-weight material.
- Characterize thermal performance based on steady-state and transient/realistic loading conditions.

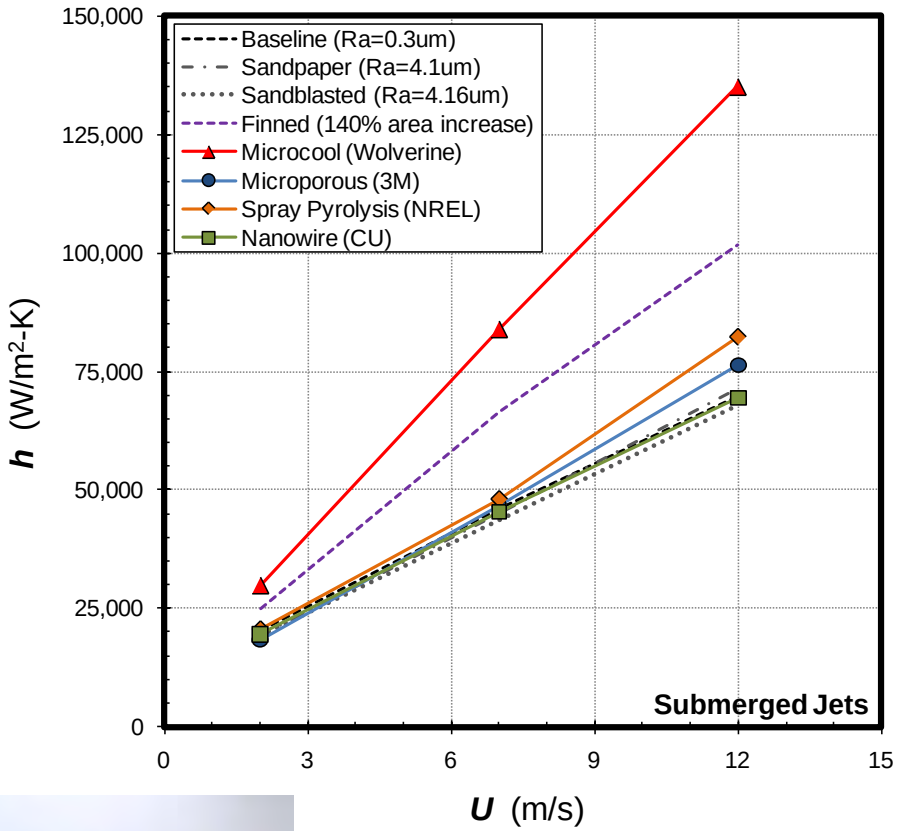
Accomplishments – Results for Impinging Jets in Conjunction with Enhanced Surface

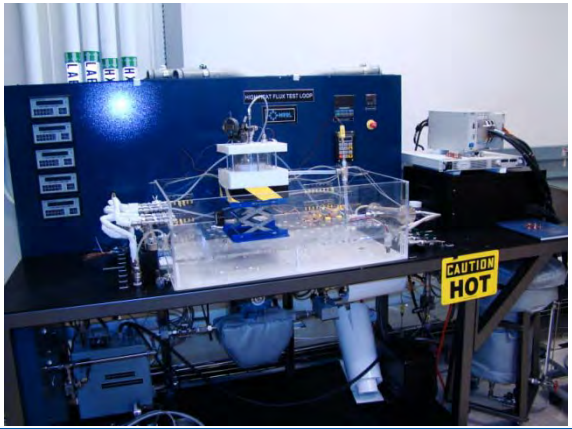
Work presented previously

- Wolverine MicroCool† surface produced highest heat transfer enhancement (~100%).





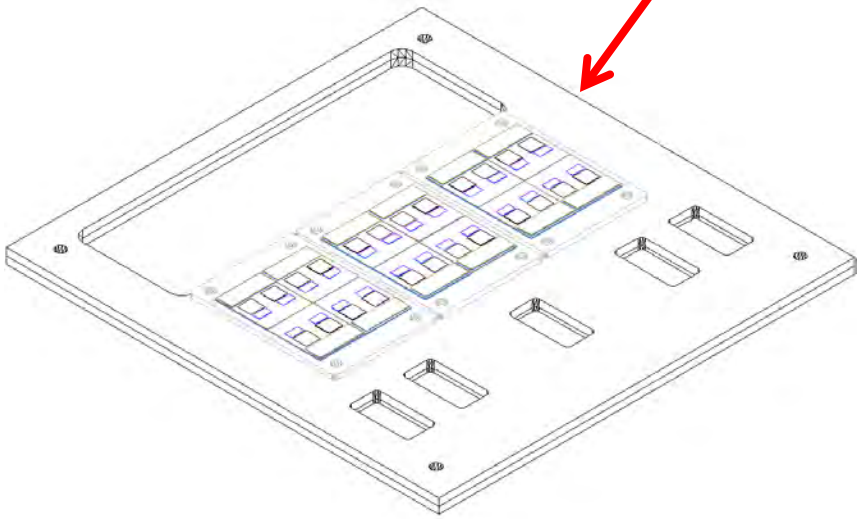




Credit: Sreekant Narumanchi, NREL (all photos)

Accomplishments – Inverter Acquisition and Design of Heat Exchanger

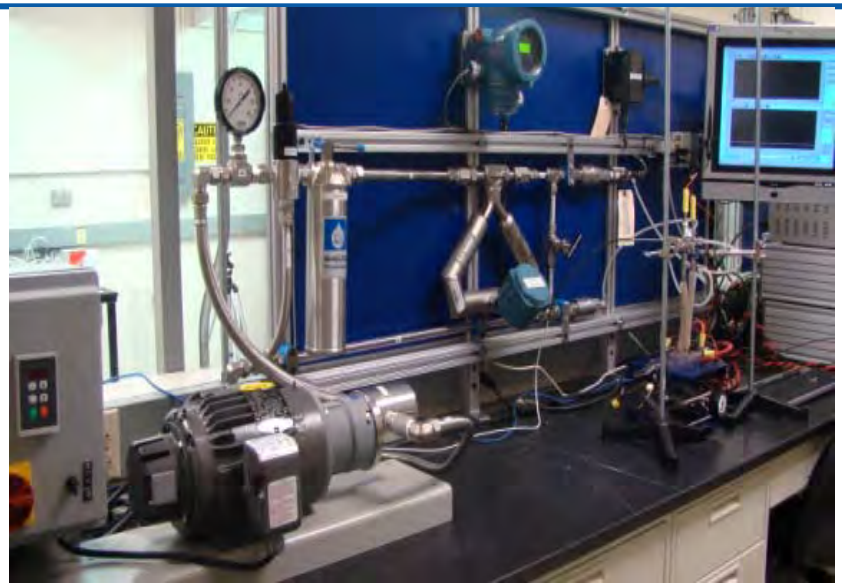
- Power modules and functioning inverter acquired from UQM
- Contacts established with suppliers of plastic materials (e.g., DuPont, Cool Polymers, Quadrant)
- Design of jet impingement-based heat exchanger in progress
  - Impingement on the base plate
  - Base plate to have Wolverine MicroCool® surface enhancement (microdeformed surface)
  - FEA and CFD analyses initiated



Credit: Sreekant Narumanchi, NREL (all photos)

Accomplishments – Glycol-water and Reliability Loops

- Glycol-water loop established
- Loop established to study long term reliability of impinging jets on promising enhanced surfaces (e.g., Wolverine MicroCool® surface)
  - Tests initiated with glycol-water impinging on MicroCool® surface (on 12.5-mm-diameter copper target surface)



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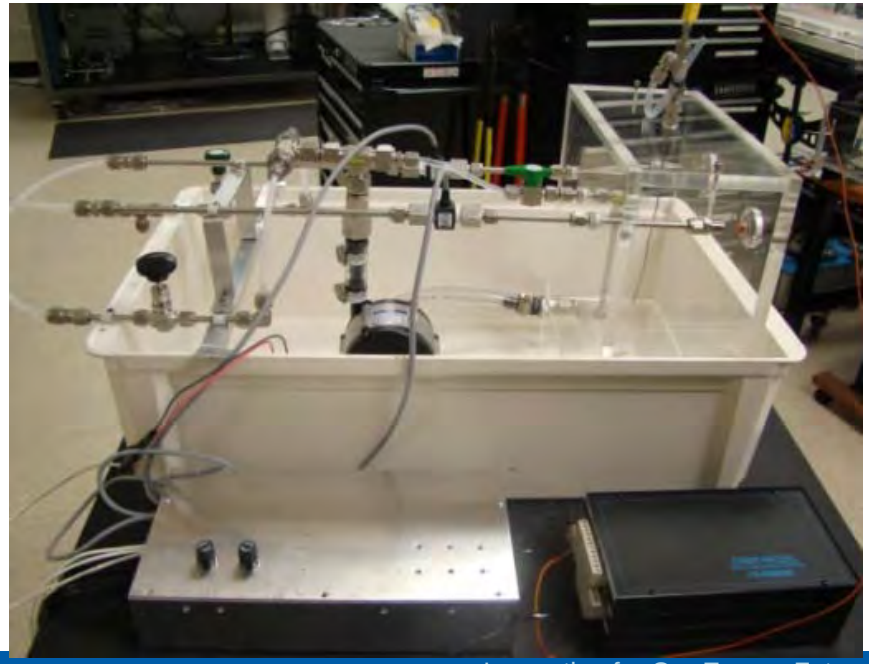

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[1]Credit: Sreekant Narumanchi, NREL

[2]Credit: Gilbert Moreno, NREL

Collaborations

Collaborator	Type of Interaction / Collaboration
Electrical & Electronics Technical Team	• Technical guidance
UQM	• Provider of inverter and power modules • Source for dynamometer testing of the inverter
Wolverine Tube, Inc.	• Source for generating microdeformation-based enhanced surface on copper base plate
DuPont, Quadrant, Cool Polymers	• Source for appropriate plastic for bulk of the inverter jet-based heat exchanger

Future Work (1/2)

Remainder of FY11

- Complete design of jet impingement plate.
- Complete FEA and CFD analyses.
- After design review with UQM and Wolverine, fabricate the heat exchanger
  - Synthesis of Wolverine MicroCool® surface (microdeformation technology) on the copper base plate.
  - Acquire suitable plastic material (e.g., from DuPont, Cool Polymers, or Quadrant) for the bulk of heat exchanger.
- Initiate tests on the heat exchanger
  - Power module tests using a transient thermal tester
  - Dynamometer testing
- Initiate long-term reliability testing of impinging jets on MicroCool® surface.

Future Work (2/2)

FY12

- Complete experimental testing of the heat exchanger.
- Complete long-term reliability testing of impinging jets on MicroCool surface.
- In conjunction with UQM, reduce footprint of the inverter to reduce cost, weight, and volume
  - Demonstration tests similar to FY11.

Summary (1/2)

DOE Mission Support

- Through thermal management, enable 2015 power electronics goals of power density (12 kW/liter), specific power (12 kW/kg) and cost ($5/kW).
- Enable use of glycol-water coolant at 105°C (i.e., single coolant loop).

Approach

- Jet impingement on base plate with MicroCool® surface enhancement (microdeformed surface).
- Light-weight, low-cost plastic for rest of the heat exchanger.
- Demonstration of reliability.

Accomplishments

- Acquired power modules and inverter from UQM.
- Initiated design of jet impingement plate.
- Initiated FEA and CFD analyses.
- Established glycol-water loop and jet-impingement reliability loop.
- Initiated reliability tests for jets in conjunction with MicroCool® surface.

Summary (2/2)

Future work

- Complete FEA and CFD analyses.
- Fabricate heat exchanger based on jets in conjunction with Wolverine MicroCool® surface.
- Complete experimental testing of heat exchanger.
- Complete reliability assessment/testing of impinging jet on MicroCool® surface.
- In collaboration with UQM reduce footprint of inverter.

Collaborations

- Electrical & Electronics Technical Team
- UQM
- Wolverine Tube, Inc.
- DuPont, Quadrant, Cool Polymers

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Acknowledgements:

Susan Rogers, U.S. Department of Energy

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