Western New England University
Springfield, Massachusetts
College of Engineering
ME 439 - Professional Awareness
Advisor: Mehdi Mortazavi
Fall 2017
Project #1

Title: Enhanced heat transfer in perforated Fin Tube Radiation (baseboard)

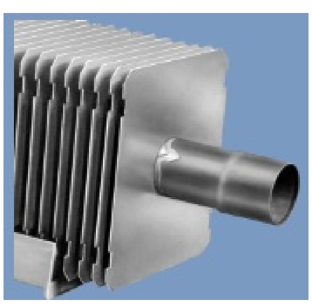
Objective: To enhance the efficiency of commercial and residential baseboards by modifying fins

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: Fin tube radiations are a common piece of equipment for heating residential and commercial spaces during heating season. They have simple structure of a tube which incorporates a number of fins in a specific length. The tube is usually from copper while fins are usually from aluminum. As a common practice, baseboard manufacturers employ a solid piece of fin without any perforation involved. However, it has been proved that convection heat transfer rate increases by employing perforated fins. The purpose of this project if to enhance heat transfer rate from commercially available baseboards by modifying fins. This can be achieved by perforating fins and testing the performance of the whole system. The ultimate goal of this project is to optimum fin geometry for an enhanced heat transfer from the baseboard to the occupied space. The big picture of this projects includes reducing fossil fuel consumption, as the primary source of energy, as well as enhancing thermal comfort in heating season. This also lowers greenhouse gas production which can be a small step in saving our planet from global warming. Figure 1 shows the a residential baseboard.

Figure 1: Exterior look of a residential baseboard

Baseboard have rather simple constructions. They are made of an enclosure and a tube with multiple fins inside. Figure below shows the internal part of a baseboard.



Procedure: This project involves both hands-on practice and running experiments and recording experimental data. The fabrication part includes applying perforation with different geometries on copper plates which will serve as fins. After test sections are fabricated, experimental setups will be installed which includes a hot water heater, hot water storage tank, a circulation pump, and the piping associated to run the system. Instrumentation should be designed and installed to measure and record information such as hot water flow rate, entering water temperature, leaving water temperature, room temperature, and temperature on fins. Also proper support needs to be designed and fabricated for hot water pot.

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Project #2

Title: PEM fuel cell ex-situ test section

Objective: To design and fabricate PEM fuel cell ex-situ test section

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: This project includes designing and fabricating an ex-situ test section of proton exchange membrane (PEM) fuel cell. PEM fuel cells are considered to be promising power sources for automotive, residential and stationary applications. They benefit from high efficiency as well as a high volumetric power density without emitting greenhouse gases as they operate. However, there are some issues that need to be solved before this type of energy system can be commercially released. One of the most challenging issues for researchers is water management in PEM fuel cells. As electrochemical reactions occur in a PEM fuel cell, hydrogen fuel is converted into useful power with water and heat as byproducts. This water needs to be removed from inside the cell for a proper operation of PEM fuel cell.

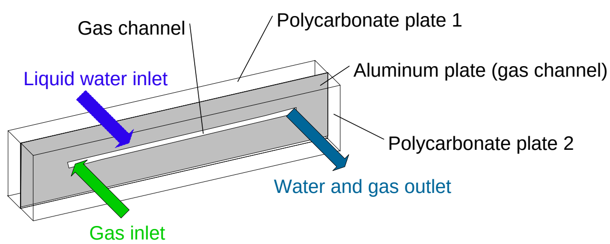

Figure 2: A test section of PEM fuel cell

The test section designed and fabricated in this senior design project will be tested in an experimental setup developed for this purpose. The intend is to measure the liquid-gas two-phase flow pressure drop along the flow channel. The flow channel is 1mm wide and 1mm deep and should be machined on a polycarbonate bar. However, alternative micro-fabrication techniques such as PDMS may be other proper approaches. The link below provides an example of PDMS technique:

`https://www.youtube.com/watch?v=KjiUUJdPGX0&t=0s`.

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Project #3

Title: Two-phase flow pressure drop measurement in PEM fuel cell

Objective: To design and fabricate an experimental setup that is capable of measuring liquid-gas two-phase flow pressure-drop in a minichannel. This project also includes conducting two-phase flow pressure drop experiments.

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: Liquid-gas two phase flow is a common type of flow in many industrial applications such as heat exchangers, condensers, chemical processing plants, air conditioners, and fuel cells. Two phase flow occurs in different patterns depending on the liquid to gas ratio, the superficial velocity of each phase, the surface characteristics of the channel, and the channel geometry. An accurate study of the two-phase flow can only be accomplished by assorting flows based on their channel size. Dr. Kandlikar from RIT has proposed a channel classification that can be used both for single phase and two-phase flows. The proposed classification is based on the channel hydraulic diameter and spans from sub-microns to millimeters. According to the classification proposed, channels with hydraulic diameters greater than 3 mm are referred to as conventional channels. Fuel cell gas channels are categorized as minichannels with hydraulic diameters between 200 μm and 3 mm. The classification considers channels with hydraulic diameters between 10 m and 200 μm as microchannels. However, microchannels fall below the length scale of PEM fuel cell gas channels.

The experimental setup will be something like figure below

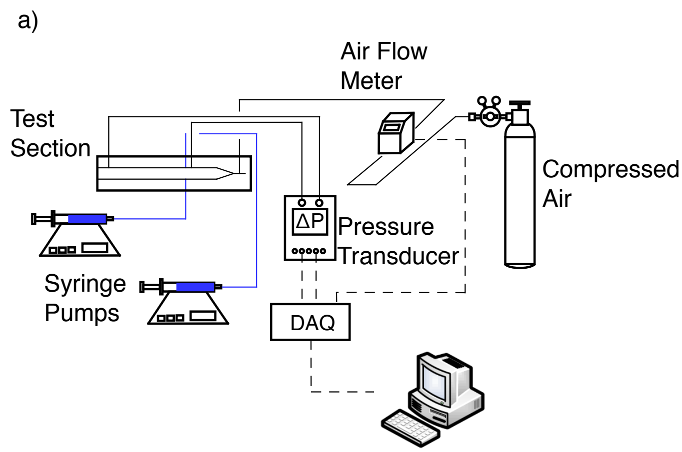

Figure 3: Experimental setup to measure liquid-gas two-phase flow pressure drop in minichannels

The second phase of this project is to run research experiments and gather liquid-gas two-phase flow pressure drops. It is expected that statistical analysis be performed on experimentally gathered data.

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Project #4

Title: Design and fabrication of flow boiling microchannel

Objective: To design and fabricate a test section that will be used in flow boiling experimental setup

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: Two-phase microchannel heat sinks are extensively used for high-heat-flux dissipation using flow boiling of a liquid coolant through parallel channels. Such channels usually have hydraulic diameter between 10 and 1000 μm. The small flow passage area and flow boiling yield very high heat transfer coefficients with minimal flow rate. Deployment of two-phase microchannel technology requires a comprehensive fundamental understanding of virtually both hydrodynamic and thermal aspects of phase change in small channels. The ability to accurately predict pressure drop and flow boiling heat transfer for a given microchannel geometry is of great importance for design and performance assessment of a microchannel heat sink.

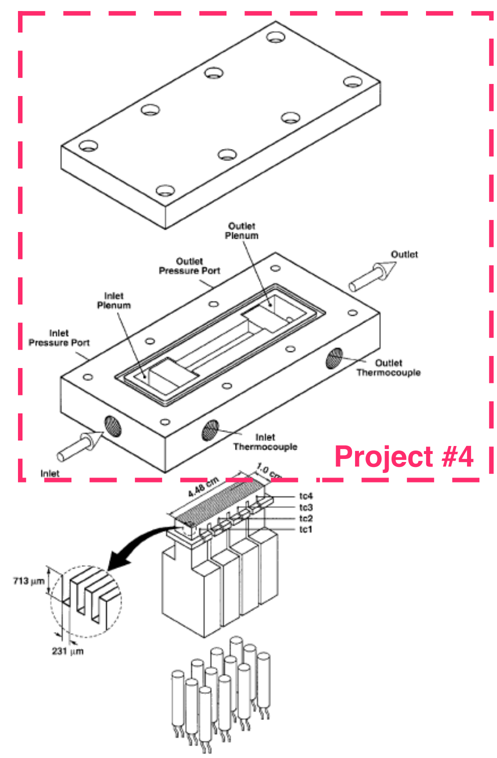

Figure 4: Schematic of test section to study flow boiling for high-heat-flux dissipation

The intend of this project is to design an appropriate test section that can be utilized in another experimental setup to study flow boiling in microchannels. This project is an integrated project with projects #5 and #6. The outcome of these projects will explore the flow boiling heat transfer characteristics of water in microchannel heat sinks. The primary objective of these three projects is to conduct a thorough experimental investigation of the heat transfer characteristics.

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Project #5

Title: Design and fabrication of flow boiling test section holder

Objective: To design and fabricate an assembly that can hold microchannel test section in flow boiling experimental setup

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: Two-phase microchannel heat sinks are extensively used for high-heat-flux dissipation using flow boiling of a liquid coolant through parallel channels. Such channels usually have hydraulic diameter between 10 and 1000 μm. The small flow passage area and flow boiling yield very high heat transfer coefficients with minimal flow rate. Deployment of two-phase microchannel technology requires a comprehensive fundamental understanding of virtually both hydrodynamic and thermal aspects of phase change in small channels. The ability to accurately predict pressure drop and flow boiling heat transfer for a given microchannel geometry is of great importance for design and performance assessment of a microchannel heat sink.

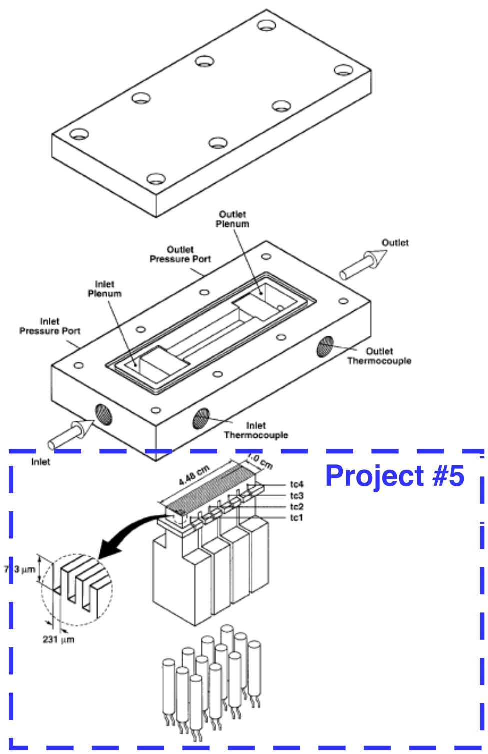

Figure 5: Schematic of test section to study flow boiling for high-heat-flux dissipation

The intend of this project is to design an appropriate assembly that can support the flow boiling minichannel in experimental setup of project #6. This project is an integrated project with projects #4 and #6. The outcome of these three projects will explore the flow boiling heat transfer characteristics of water in microchannel heat sinks. The primary objective of these three projects is to conduct a thorough experimental investigation of the heat transfer characteristics.

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Project #6

Title: Flow boiling experimental setup

Objective: To design and fabricate an assembly that can hold microchannel test section in flow boiling experimental setup

Sponsor: Western New England University, Department of Mechanical Engineering

Project Description: Two-phase microchannel heat sinks are extensively used for high-heat-flux dissipation using flow boiling of a liquid coolant through parallel channels. Such channels usually have hydraulic diameter between 10 and 1000 μm. The small flow passage area and flow boiling yield very high heat transfer coefficients with minimal flow rate. Deployment of two-phase microchannel technology requires a comprehensive fundamental understanding of virtually both hydrodynamic and thermal aspects of phase change in small channels. The ability to accurately predict pressure drop and flow boiling heat transfer for a given microchannel geometry is of great importance for design and performance assessment of a microchannel heat sink.

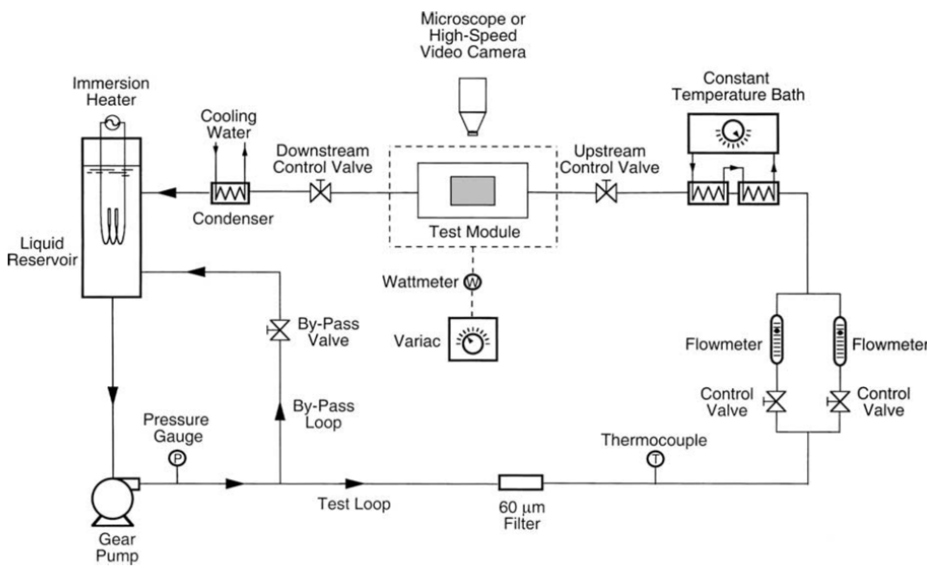

Figure 6: Schematic of flow boiling experimental setup

The intend of this project is to design and fabricate an experimental setup to conduct research experiments of flow boiling in microchannels. This project is an integrated project with projects #4 and #5. The outcome of these three projects will explore the flow boiling heat transfer characteristics of water in microchannel heat sinks. The primary objective of these three projects is to conduct a thorough experimental investigation of the heat transfer characteristics. The test section fabricated in projects 4 and 5 will be installed in the experimental setup of this project (#6).

ME 440-Senior Design Projects

Multiscale Thermal Fluids Laboratory
Departent of Mechanical Engineering
Western New England University
Springfield, MA
AY 2017-18

Advisor: Mehdi Mortazavi

Objective

Research approaches (in general):

- Experimental
- Computational (numerical)
- Analytical (theoretical)

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Research approaches (in general):

- Experimental
- Computational (numerical)
- Analytical (theoretical)

Research steps (experimental approach):

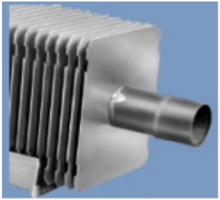
$\boxed{\text{1. Literature review}} \rightarrow \boxed{\text{2. identifying } \textit{"gaps"}} \rightarrow$
$\boxed{\text{3. designing experimental setup and test section}} \rightarrow$
$\boxed{\textbf{4. fabricating setup and test section and troubleshooting}} \rightarrow$
$\boxed{\text{5. conducting research experiments}} \rightarrow \boxed{\text{6. analyzing data}} \rightarrow$
$\boxed{\text{7. drawing conclusion and reporting to community}}$

Project #1 Enhanced heat transfer in perforated Fin Tube Radiation (baseboard)

Area: Heat Transfer SolidWorks: 10%, Coordination: 30%, Analysis 10%, Hands-on: 50%

Objective:

- study the effect of perforated fin on heat transfer from baseboard
- Different patterns will be tested
- Different water flow rates will be tested

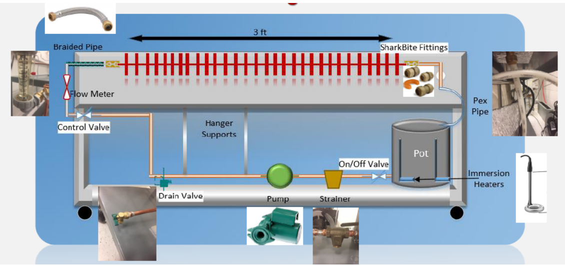


Project #2 Design and fabrication of perforated fin experimental setup

Area: Heat Transfer | SolidWorks: 10%, Coordination: 30%, Analysis 10%, Hands-on: 50%

Objective:

- Improve the existing experimental setup
- Design and fabricate a separate structure to hold water tank
- Connect thermocouples to different test sections



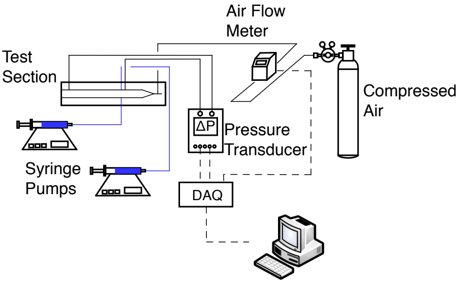
Project #3 Two-phase flow pressure drop measurement in PEM fuel cell

Area: Fluid Mechanics | Coordination: 30%, Analysis 20%, Hands-on: 50%

Objective:

- Measure liquid-gas two-phase flow pressure drop in PEM fuel cell flow channels (diameter $\simeq$ 1mm)
- Develop pressure drop corealation by analyzing experimentally measured pressure drops

a)

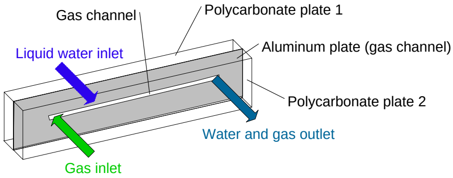


Project #4 PEM fuel cell ex-situ test section

Area: Fluid Mechanics | SolidWorks: 40%, Coordination: 25%, Analysis 15%, Hands-on: 20%

Objective (in addition to objectives of project #2):

- The goal is to study pressure drop over the bends of flow channels
- Pressure drop in test sections with flow channels of different dimensions will be measure
- The experimentally measured pressure drops will be utilized to proposed a two-phase flow pressure drop model



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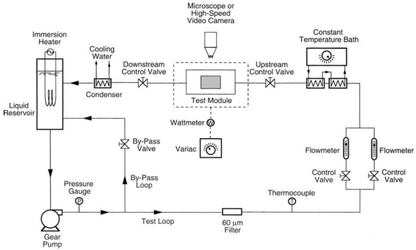
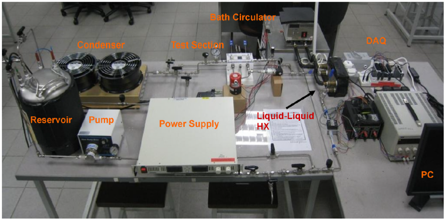
Project #5 Flow boiling experimental setup

Area: Thermodynamics, Heat Transfer | Hands-on: 60%, Coordination: 30%, Analysis 10%

Objective:

- Design and fabricate experimental setup for flow boiling in microchannel experiments
- This is an *integrated* project with projects #6 and #7
- The goal is to study high-heat-flux dissipation through coolant phase change along microchannels (diameter < 1mm)



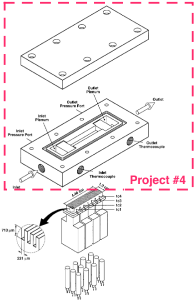


Project #6 Design and fabrication of flow boiling microchannel

Area: Thermodynamics, Heat Transfer Hands-on: 20%, SolidWorks 40%, Coordination: 30%, Analysis 10%

Objective:

- Design and fabricate test section holder that also includes cartridge heaters
- This is an *integrated* project with projects #5 and #7

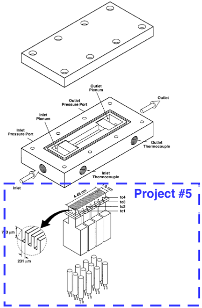


Project #7 Design and fabrication of flow boiling test section holder

Area: Thermodynamics, Heat Transfer | Hands-on: 20%, SolidWorks 40%, Coordination: 30%, Analysis 10%

Objective:

- Design and fabricate test section to conduct flow boiling experiments
- Apply novel techniques to enhance heat transfer
- This is an *integrated* project with projects #5 and #6



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Project #8 Drainage phase diagram of PEM fuel cell porous layer

Area: Fluid Mechanics | Hands-on: 60%, Coordination: 30%, Analysis 10%

Objective:

- Evaluate water transport in the plane of porous layer (similar to paper) at different compression
- Design and fabricate Hele-Shaw cell and experimental setup